

Constantine Stephanidis
Margherita Antona (Eds.)

Universal Access in Human-Computer Interaction

Design Methods, Tools,
and Interaction Techniques for eInclusion

7th International Conference, UAHCI 2013
Held as Part of HCI International 2013
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7th International Conference, UAHCI 2013
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Las Vegas, NV, USA, July 21-26, 2013
Proceedings, Part I



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Foreword

The 15th International Conference on Human–Computer Interaction, HCI International 2013, was held in Las Vegas, Nevada, USA, 21–26 July 2013, incorporating 12 conferences / thematic areas:

Thematic areas:

- Human–Computer Interaction
- Human Interface and the Management of Information

Affiliated conferences:

- 10th International Conference on Engineering Psychology and Cognitive Ergonomics
- 7th International Conference on Universal Access in Human–Computer Interaction
- 5th International Conference on Virtual, Augmented and Mixed Reality
- 5th International Conference on Cross-Cultural Design
- 5th International Conference on Online Communities and Social Computing
- 7th International Conference on Augmented Cognition
- 4th International Conference on Digital Human Modeling and Applications in Health, Safety, Ergonomics and Risk Management
- 2nd International Conference on Design, User Experience and Usability
- 1st International Conference on Distributed, Ambient and Pervasive Interactions
- 1st International Conference on Human Aspects of Information Security, Privacy and Trust

A total of 5210 individuals from academia, research institutes, industry and governmental agencies from 70 countries submitted contributions, and 1666 papers and 303 posters were included in the program. These papers address the latest research and development efforts and highlight the human aspects of design and use of computing systems. The papers accepted for presentation thoroughly cover the entire field of Human–Computer Interaction, addressing major advances in knowledge and effective use of computers in a variety of application areas.

This volume, edited by Constantine Stephanidis and Margherita Antona, contains papers focusing on the thematic area of Universal Access in Human–Computer Interaction, and addressing the following major topics:

- Design for All Methods, Techniques and Tools
- eInclusion Practice
- Universal Access to the Built Environment
- Multi-sensory and Multimodal Interfaces
- Brain–Computer Interfaces

The remaining volumes of the HCI International 2013 proceedings are:

- Volume 1, LNCS 8004, Human–Computer Interaction: Human-Centred Design Approaches, Methods, Tools and Environments (Part I), edited by Masaaki Kurosu
- Volume 2, LNCS 8005, Human–Computer Interaction: Applications and Services (Part II), edited by Masaaki Kurosu
- Volume 3, LNCS 8006, Human–Computer Interaction: Users and Contexts of Use (Part III), edited by Masaaki Kurosu
- Volume 4, LNCS 8007, Human–Computer Interaction: Interaction Modalities and Techniques (Part IV), edited by Masaaki Kurosu
- Volume 5, LNCS 8008, Human–Computer Interaction: Towards Intelligent and Implicit Interaction (Part V), edited by Masaaki Kurosu
- Volume 7, LNCS 8010, Universal Access in Human–Computer Interaction: User and Context Diversity (Part II), edited by Constantine Stephanidis and Margherita Antona
- Volume 8, LNCS 8011, Universal Access in Human–Computer Interaction: Applications and Services for Quality of Life (Part III), edited by Constantine Stephanidis and Margherita Antona
- Volume 9, LNCS 8012, Design, User Experience, and Usability: Design Philosophy, Methods and Tools (Part I), edited by Aaron Marcus
- Volume 10, LNCS 8013, Design, User Experience, and Usability: Health, Learning, Playing, Cultural, and Cross-Cultural User Experience (Part II), edited by Aaron Marcus
- Volume 11, LNCS 8014, Design, User Experience, and Usability: User Experience in Novel Technological Environments (Part III), edited by Aaron Marcus
- Volume 12, LNCS 8015, Design, User Experience, and Usability: Web, Mobile and Product Design (Part IV), edited by Aaron Marcus
- Volume 13, LNCS 8016, Human Interface and the Management of Information: Information and Interaction Design (Part I), edited by Sakae Yamamoto
- Volume 14, LNCS 8017, Human Interface and the Management of Information: Information and Interaction for Health, Safety, Mobility and Complex Environments (Part II), edited by Sakae Yamamoto
- Volume 15, LNCS 8018, Human Interface and the Management of Information: Information and Interaction for Learning, Culture, Collaboration and Business (Part III), edited by Sakae Yamamoto
- Volume 16, LNAI 8019, Engineering Psychology and Cognitive Ergonomics: Understanding Human Cognition (Part I), edited by Don Harris
- Volume 17, LNAI 8020, Engineering Psychology and Cognitive Ergonomics: Applications and Services (Part II), edited by Don Harris
- Volume 18, LNCS 8021, Virtual, Augmented and Mixed Reality: Designing and Developing Augmented and Virtual Environments (Part I), edited by Randall Shumaker
- Volume 19, LNCS 8022, Virtual, Augmented and Mixed Reality: Systems and Applications (Part II), edited by Randall Shumaker

- Volume 20, LNCS 8023, Cross-Cultural Design: Methods, Practice and Case Studies (Part I), edited by P.L. Patrick Rau
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- Volume 25, LNCS 8028, Distributed, Ambient and Pervasive Interactions, edited by Norbert Streitz and Constantine Stephanidis
- Volume 26, LNCS 8029, Online Communities and Social Computing, edited by A. Ant Ozok and Panayiotis Zaphiris
- Volume 27, LNCS 8030, Human Aspects of Information Security, Privacy and Trust, edited by Louis Marinos and Ioannis Askoxylakis
- Volume 28, CCIS 373, HCI International 2013 Posters Proceedings (Part I), edited by Constantine Stephanidis
- Volume 29, CCIS 374, HCI International 2013 Posters Proceedings (Part II), edited by Constantine Stephanidis

I would like to thank the Program Chairs and the members of the Program Boards of all affiliated conferences and thematic areas, listed below, for their contribution to the highest scientific quality and the overall success of the HCI International 2013 conference.

This conference could not have been possible without the continuous support and advice of the Founding Chair and Conference Scientific Advisor, Prof. Gavriel Salvendy, as well as the dedicated work and outstanding efforts of the Communications Chair and Editor of HCI International News, Abbas Moallem.

I would also like to thank for their contribution towards the smooth organization of the HCI International 2013 Conference the members of the Human-Computer Interaction Laboratory of ICS-FORTH, and in particular George Paparoulis, Maria Pitsoulaki, Stavroula Ntoa, Maria Bouhli and George Kapnas.

May 2013

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HCI International 2014

The 16th International Conference on Human–Computer Interaction, HCI International 2014, will be held jointly with the affiliated conferences in the summer of 2014. It will cover a broad spectrum of themes related to Human–Computer Interaction, including theoretical issues, methods, tools, processes and case studies in HCI design, as well as novel interaction techniques, interfaces and applications. The proceedings will be published by Springer. More information about the topics, as well as the venue and dates of the conference, will be announced through the HCI International Conference series website: <http://www.hci-international.org/>

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Part I
**Design for All Methods, Techniques
and Tools**

Designing Ethnographic Encounters for Enriched HCI

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Abstract. This paper presents three case studies of design research in HCI that has utilized an ethnographic approach to understand user needs. All of the projects were undertaken at the Helen Hamlyn Centre for Design (HHCD), based at the Royal College of Art. The HHCD specialises in an inclusive design philosophy, which seeks to directly involve users in the design process. Two of the projects were undertaken as Research Council United Kingdom (RCUK) funded initiatives, and one was commissioned by a major technology company. They highlight how a design ethnography approach can be both rigorous for academic design research within HCI, and dynamic for the needs of the commercial sector.

Keywords: ethnography, inclusive design, design research methods, user engagement.

1 Introduction

The philosophy of inclusive design focuses on the direct engagement with people as the end users of design. In particular, engagement has been sought with ‘expert users’ [1], whose first hand experience of ageing, impairment and/or their immediate community can highlight the challenges people face in their encounters with poorly designed products, environments and/or services. Working with users whilst engaging a range of ethnographic methods can provide a deeper level of data for designers to explore and innovate from.

Millen [2] has noted that the incorporation of ethnographic methods has become increasingly popular within the practice of human-computer interaction. Yet, Millen also indicates that ‘there has been a common misunderstanding among HCI professionals about the analytical nature of ethnographic research’ [2]. This paper aims to address this concern by introducing three case studies of ethnographic design research that explores HCI, and highlights how the ethnographic method provided in-depth data for the design researchers to analyse as well as a robust engagement methodology for the participants in the inclusive design research process.

2 Ethnography

Ethnography is a qualitative research process that principally involves fieldwork amongst a chosen group of people. Undertaking an ethnographic study is the key

method within the discipline of social and cultural anthropology [3], and its level of detail and in-depth analysis has resulted in the practice receiving wide consideration within design research, with many design consultancies and research groups actively including anthropologists within research teams [4].

Traditional ethnographic encounters often take place over many months (in the case of Social Anthropology PhD research up to a year), and analysis can take equally as long. It is therefore a time intensive method that has required a considerable amount of editing to be suitable for both the time demands of the commercial design sector and the swift design responses in artifact development. Hence a 'rapid ethnography' [2] has been developed in which short focused field studies are undertaken to gain a wider understanding of the context of use for the intended design output. Under a rapid ethnographic method, participant observation, in which researchers directly interact with informants, may take place over a few days instead of many months. Open-ended interviews are condensed into a focused interview that directly explores the issue at hand. Such rapid response requires a certain focus in preliminary research before the ethnographic process begins. For example the key activities should be identified so that research questions can be focused directly on addressing these. Key informants should be identified and recruited to the project and interactive techniques should be developed to draw out specific user behavior [2].

Millen uses photographic analogies to define the difference between traditional and rapid ethnographic methods. The traditional method is considered 'a very wide angle research lens' in which the breadth of data collected may not present initial insights for a time poor design team. In contrast, a rapid ethnographic approach is viewed as a telephoto lens in which the research team identify the key question to be addressed and knows where to aim the lens [2].

Wasson notes that ethnography has been associated more with data collection than analysis, and that consideration should be given to the level of knowledge that anthropological training brings to the analysis of the resulting data. This includes the interpretation of ethnographic material based on deeper cultural understandings, a narrative that focuses on the world of user-product/ environment/ service interactions, and insight on how the focus of the study may be incorporated into daily activities, and carry symbolic meanings. Without a deeper understanding gained in data analysis, ethnographic studies especially undertaken under the rapid methodology, can run the risk of becoming 'a pale shadow of itself', and therefore should not be considered as such if merely undertaken by a 'designer with a camera' [4].

This paper will present three case studies that have employed ethnographic techniques within their design research methodology. The studies highlight how the use of ethnography (both rapid and more in-depth) has provided rich qualitative data which has not only informed greater understanding of people's interactions with environments, products and services, but also produced innovative design solutions, especially with regards to people's encounters with technology.

3 The Great British Public Toilet Map (Jo-Anne Bichard, Gail Ramster and Catherine Greene)

The Great British Public Toilet Map was developed as the key deliverable for the TACT3 (Tackling Ageing Continence through Theory Tools & Technology) research project. TACT3 was a multidisciplinary collaboration that ran between 2008-2011, between Brunel University, the Universities of Sheffield, the West of England and Manchester, the Dalarna Research Institute and the Bristol Urological Institute and the Royal College of Art. TACT3 was funded by the New Dynamics of Ageing (NDA) Research programme <http://www.newdynamics.group.shef.ac.uk/> 'a seven year multidisciplinary research initiative with the ultimate aim of improving quality of life for older people'. The NDA, which was funded by all of the UK's research councils, has been considered 'the most ambitious research programme on ageing ever mounted in the UK'.

Working under the title 'Challenging Environmental Barriers to Continence' the researchers undertook a series of interviews with two key stakeholder groups, namely members of the public as users of publicly accessible toilets and members of professional bodies involved with the service delivery of publicly accessible toilets. This second group included architects who specialise in the siting, design and planning of provision, managers of provision from local authorities, department stores and transport terminals, and community groups interested in promoting local provision. In total 101 interviews were conducted with users (covering the age ranges of the needs of a new born child to Nonagenarian's), in which their experiences of toilet use and provision were explored. Previous research has noted that in the design and management of public toilet provision there is often conflict between what users require for toileting in comfort and dignity, and what providers can manage. This has often resulted in design decisions that take on an 'access versus fortress' [5] agenda in which designing out elements of anti-social behaviour take precedence in the design brief to the detriment of wider user inclusion and access.

3.1 Rapid Ethnography through Participatory Design Games

Whilst the interview process yielded strong data on preferences and avoidances, deeper engagement was required. Given the highly personal nature of the research subject, a traditional ethnographic approach such as participant observation could not be incorporated. To overcome this issue, the design researchers developed participatory design game that was able to explore this sensitive area in more depth. The game involved participants working together using a set of picture associated cards to design their ideal public toilet. By matching normally diametric opposite needs together such as that of an older man and younger woman (figure 1), or an able bodied man with a women who uses a wheelchair, the game provided participants with tools to work together and identify shared needs. The data gathered from the 'game' method revealed that all the participants agreed on the need for facilities to be clean, and for the design of items such as locks and hand dryers to be easy to understand and effective. The game also highlighted the need for publicly accessible toilets to meet individual user needs, and that these are varied and complex. Better

information about provision would improve the service for users, giving them the ability to find a toilet that meets their personal needs.

Here the researchers found a direct correlation with the data gathered through focused interviews with providers, in which the management of information on service provision emerged as a problematic area that needed to be addressed.

Based on the issue of information management raised by both user groups, the research refocused from critiquing physical space to exploring the opportunities of digital space to deliver a framework for improved service delivery. Initially, and based on their inclusive philosophical perspective, the researchers explored crowd sourcing as a method of data capture on current toilet provision. However an analysis of crowd-sourced data highlighted how crowd-sourced information alone is insufficient as it can be inaccurate and become quickly obsolete [6].



Fig. 1. Participatory Design Game for Publicly Accessible Toilets

3.2 Digital Research Tools, Digital Data and Digital Resource

Reframing the research into digital space also expanded the inclusive community engagement to include those with interests in the UK's open data movement. Community members were contacted and communicated with using Twitter and the development by Ramster of the blog 'Public Toilets and...' <http://gailknight.wordpress.com/>. These resources were actively used as data gathering tools as well as to feedback findings and question data collection barriers encountered during the research process [7].

Currently, there is no centrally collated information, database or inventory of UK publicly accessible toilets. Coupled with the UK government's call for more open data to be released especially in relation to public services, the research focused on delivering a resource that explored how open data is gathered and then used.

The development of The Great British Public Toilet Map <http://greatbritishpublictoiletmap.rca.ac.uk/> aimed to do this through its public participation features in which it not only retrieves released open data on public toilet provision but also provides a platform for members of the public to request that such data is made available to populate the map.

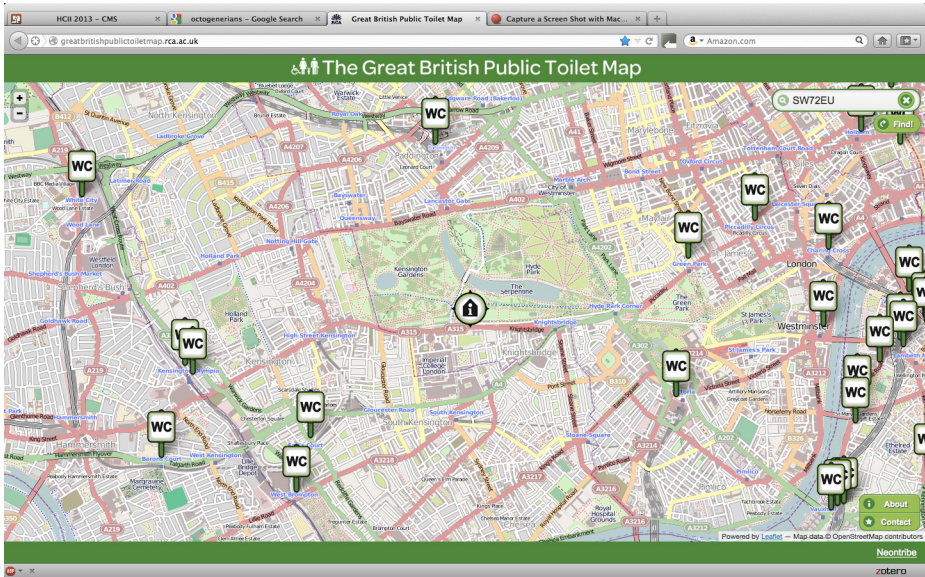


Fig. 2. The Great British Public Toilet Map

4 Mobile Working Lives (Tom Staples and Catherine Greene)

The current selection of information technologies (IT's) such as laptops, smartphones and tablets provide a degree of greater flexibility and mobility to working life, especially those whose work can be considered traditionally 'mobile' such as plumbers, salesmen, paramedics and builders. For example – whereas once a plumber would have a series of locations to visit including visiting the client and ordering required parts. Much of this can be done remotely whilst 'on the job'.

Mobile Working Lives was a pan European project in partnership with Samsung Design Europe. It incorporated focused ethnographic interviews with mobile workers in four countries, and four languages. The diversity of language in this project required the researchers to develop a specific tool for the ethnographic encounter that could transcend language barriers. This tool comprised a mapping exercise to act as a conversational prompt during ethnographic interviews. Interviews were conducted after a morning of shadowing the mobile worker, an echo of the traditional participant observation method.

A total of 32 people participated in the study, their ages ranged from 21-62 and they represented 29 different professions. The variety of professions revealed surprising uses of new social technologies for example, a TV Crew in Oslo used Facebook for workplace banter as silence was often required in their workplace, the TV set. In London, a roof thatcher whilst appreciating how smartphones had helped him manage his business felt that he should keep it hidden when meeting clients as such technology did not fit with wider social models of a craftsman. The thatcher felt that being seen with his smartphone may damage a sense of trust held by clients towards him.

4.1 Rapid Ethnography through Interactive Activity Mapping

The mapping process began by asking the participant to think of a recent busy day, to recall where they went (for work or non-work reasons). Each location was written on a specific sticker and placed on a sheet of paper with a line drawn between the places indicating the journeys and the order in which they were made (figure 3).

The participant was then asked what professional and social activities took place at each location. Each activity was then written on a specific sticker and attached to the location where it took place (figure 4).

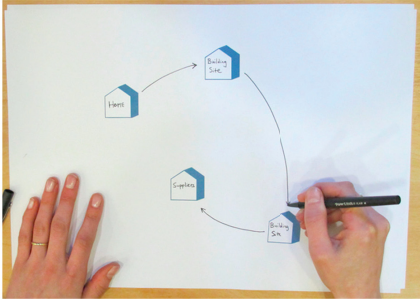


Fig. 3. Journey map

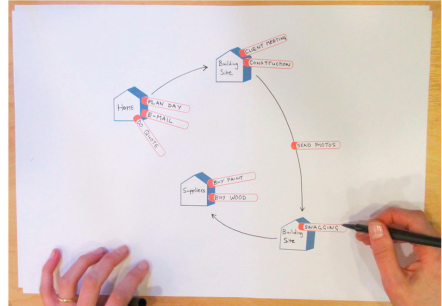


Fig. 4. Activities map

At this stage a sheet of tracing paper was laid on top of the locations and activities sheet and used to capture a new layer of data focused on the interactions the participant had that day. Specific stickers were then used to map where these interactions took place, with whom and the nature (face to face, mobile phone call, SMS, VOIP call or email) of the interaction (figure 5).

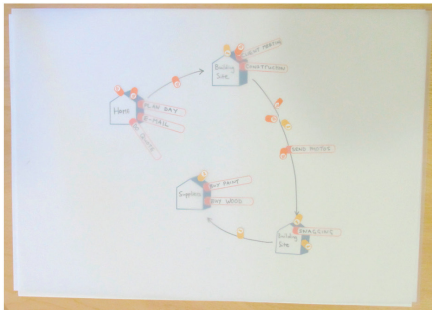


Fig. 5. Interactions map

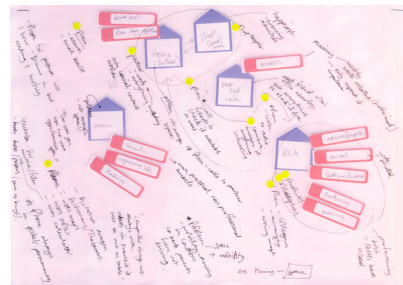


Fig. 6. Integration map

Once all the factors of the day were mapped out, it was then possible to ask questions like: 'Where did you feel your skills were best used in the day', and also, 'where were you happiest', 'what problems did you have in the day', and how did you solve those problems'? This final stage was also used to prompt subjects such as how much the participant values what they do, who their support networks are, and how

self-reliant they are. By mapping the answers this way it was possible to see patterns of working, areas of high and low activity and which skills are used where. It was also possible to see the areas of work and non-work activities, where they overlapped and what the role of technology was in each of these activities (figure 6).

4.2 Findings

The research delivered five key findings that described mobile workers interaction with information technologies. These were:

- **Work/life.** There now exists the potential to work near constantly, with mobile devices giving access to contacts and working tools anywhere. While this is liberating to many people it can also make managing ones time more difficult.
- **Transitions.** Being able to adapt and be flexible in how you work is key to mobile working. Journey times serve as a break between jobs giving people time to adapt or ‘change clothes’ between one task and the next.
- **Learning.** Mobile technologies are providing mobile workers with new routes to information. While opening up new processes for learning and sharing information, these technologies also pose a barrier to others who struggle to keep up with them and the increasing demands they bring.
- **Channels.** Mobile workers receive information in lots of different formats, printed, as a PDF on a phone, or as an excel file on a computer. The problem is that while a person receives something in one format it may be more useful to them in another format and they end up processing it into a different format so that they can use it in the way they want. In the process information is often lost or miscommunicated.
- **Networks.** More likely to work on their own and therefore lack the support of a close work community, mobile workers often rely on their own personal networks to act as this support. Therefore having a wide personal network can be really beneficial and is important but maintaining these contacts takes time.

5 Creative Citizens (Gail Ramster and Catherine Greene)

The Creative Citizen project is a three-year study (May 2012-October 2014) funded by the Arts and Humanities Research Council (AHRC) and Engineering and Physical Sciences Research Council (EPSRC) Connected Communities and Digital Economy Programme. The multi-disciplinary research is in collaboration between Cardiff University, University of Birmingham, Birmingham City University, the Open University, the University of the West of England and The Royal College of Art. The RCA and the Open University are leading on a strand of the research called ‘Community Led Design’ that is exploring how social media and web tools could offer new opportunities for communities to come together to redesign spaces and/or services within their neighbourhoods.

5.1 Introducing Rapid Ethnography Techniques to Students

The researchers are working directly with community groups to understand the medias they have employed to engage wider members of the community and if new

technologies may help. Currently there is very little research to show how such technologies are used. As part of the project the researchers designed a cross-disciplinary student engagement event with twenty students at the Royal College of Art. This event aimed to introduce student designers to rapid ethnographic techniques for community design focused research. Divided into Four teams, the students worked with three London based community projects. Each community group set a challenge for the students to respond to in order to kick-start ideas for their specific project.

5.2 The Community Projects

Streets Ahead is a neighbourhood group in the London Borough of Stockwell. Their objective is the greening of their local urban spaces to create safe places for children to play and neighbours to meet. Their project ‘Grass Routes’ has led to a local street, once a space for parking cars, being transformed into a shared space with flower beds, trees and children’s play equipment. The challenge for the students was to look at how residents could connect their local stories past, present and future to the physical spaces of the local area.

Tate South Lambeth library is a small, local library in Vauxhall South West London, and situated in a beautiful Victorian building. Once threatened with closure, it now offers film nights, language classes, gardening groups, and other events, as well as having a traditional library service. The challenge for the students was to look at how the library could attract, and be attractive to, more local people.

The Mill, was once a local library, but was closed by the local authority in 2007. Local residents gained access in 2011 and begin to transform the venue into a neighbourhood centre. With NGO support it is now home to a poetry group, knitting club, film society, social innovation start-ups, community breakfasts, and a mentoring service amongst others. It has managed to reach most groups in the area except the age group 16 to 24 year olds. Due to the London riots in 2011 the Mill is very conscious that this very important group must be included within their neighbourhood services. The challenge to students was ‘What new services, spaces, events could attract teenagers?’

5.3 Rapid Ethnography as Multi-disciplinary Technique

With only three days to respond to them. The multi-disciplinary teams, comprising RCA students from visual communications, service design, innovation design engineering, animation, design products, information experience design, design interactions, photography and history of design, spent time with local residents and community participants as well as those hard to reach groups identified by both the library and the Mill. Data gathering methods included focused interviews and participant observation. Based on these ethnographic encounters they developed ideas in direct co-operation with users and received immediate feedback from the community. In one case a team prototyped their idea on day 2 by running a games event with young people at the Mill. These experiences and ideas were then presented on the third day to both the communities and RCA staff and students for open discussion and feedback.

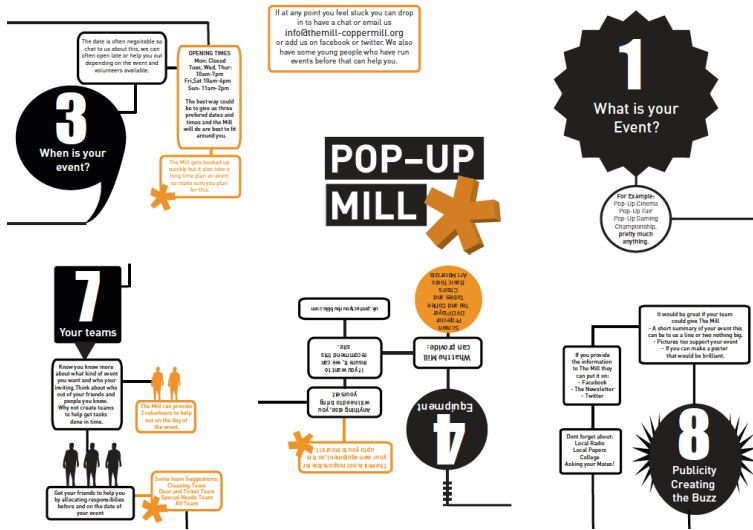


Fig. 7. Process chart for community pop-up event

5.4 Rapid Ethnographic Reflections

At the start of the three days the students had been asked to consider the role of technology in meeting their challenge, whether this was communication technologies or more interactive digital interventions. Initially for the students a technology based intervention seemed almost ‘obvious’. However, during the final presentations it was interesting to see that after the ethnographic encounter, (being on-site, listening to those involved and understanding the needs of the respective projects), each team chose to respond with proposals that relied predominantly on small media and face-to-face



Fig. 8. Small media initiatives

initiatives, this included; noticeboards, flyers, events, that were only supplemented by a simple online presence. Collectively the teams identified the need for media(s) to be universally accessible (not necessarily HCI based), hyperlocal, cheaply reproducible, and reliant on resources readily available such, as an A4 colour printer.

6 Conclusions

This paper has presented case studies of design research that has incorporated a technology (HCI) perspective. The case studies focus on an inclusive design philosophy in which users as experts in their own lives participate in the design process. Rapid ethnography offers a methodology to facilitate this inclusion, but may also require input from designers to address certain needs such as sensitivity of a subject as in the case of toileting or crossing language barriers as in the case of mobile working lives. Traditional ethnographic techniques might have afforded time for deeper interviews and sensitive environmental observations (toileting), or for researchers learning language skills (or even being employed with such skills), yet in the mobile working lives project, the researchers were designers employed for design skills not linguistic ability, hence an innovative mapping tool was developed that could be used across cultures of language and profession. Similarly, a participative design game was constructed for users to talk across social groups about highly personal and intimate concerns with regards to toileting.

Engaging students in rapid ethnographic techniques provided them a tentative insight into reflexivity, a valued aspect of ethnographic encounter for the ethnographer themselves. Aull-Davis suggests that a reflexive approach incorporates an attention to multiple perspectives in which peoples separate social realities become valid objects of knowledge and therefore valid and valuable research fields [3].

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Heuristic Methods Aiding Ergonomic Design

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Abstract. The increasing complexity of the world of technology and the technical components surrounding humans increases the need for ergonomic measures. However, these activities often have only a corrective character, and therefore, despite (or perhaps because of) the possibility of computer support, their results are not satisfactory. When solving problems, very often it is difficult to give up the well-worn strategies or hypotheses, even though they turn out to be ineffective. During the design process a specific attitude is formed towards a certain kind of conduct, which certainly makes it difficult to adopt new and effective strategies, which in turn inhibits creativity. Moreover, it appears that in many cases a functional solution is not determined by a systematic evaluation of all possible solutions, and the initially adopted concept's primary reasons often have been removed. Therefore, in this article, it was decided to take on the subject of the possibility of using heuristic methods in ergonomic design. In the article, described is the use of specific methods and design situations requiring a new approach. Also presented are the limitations of heuristic methods for ergonomic design and the possibility of their fusion in typical design processes.

Keywords: ergonomic design, heuristic methods, design, ergonomics.

1 Introduction

Ergonomic design has become a very broad concept. It encompasses all of the areas of human functioning, from complex megasystems consisting of networks of interconnected human-technical systems [4] to simple hand tools [5]. In addition to its initial application in the development of working conditions, ergonomic design is very widely used in designing an environment suitable for people with disabilities [5]. The need to take into account human needs in creating technical objects was mentioned for the first time in the mid-twentieth century, and following that for the first time used was the term ergonomic design, a new kind of design that takes into account the so-called "human factor" [21]. It was at this time noted that in order to solve problems related to human activity it is not enough to have intuition, experience, and "common sense," as was thought thus far, and one should rely on scientific principles, as in the case of machine design [1]. However, the search for ergonomic solutions that will meet the criterion of an important and deliberate change according to the primary functions of the design process [3] is a complicated process, and thus far not one that

can be fully described by a computer algorithm. In addition, in viewing the design process as a creation of a suitable system designed to meet a specific need or to fulfill a specific function [17], assigning quantitative characteristics to technical objects seems too shallow of an approach to the design process.

Also, it is worth noting that studies show that the human factor criteria are effectively incorporated into the design process in the early stages, i.e. until the end of the preliminary design, or at all stages prior to the preparation of system documentation. This is due to the fact that it is during the early stages of design that determined are the issues essential for the functioning of the system, such as the type of applied technologies or the level of automation and robotization of processes [12, pp. 38-39]. Subsequent design decisions, for example those taken at the detailed design stage and at later stages can correct the earlier shortcomings in the area of ergonomic criteria only to a small degree, and the extent of possible changes in the project is determined by the previously undertaken decisions of strategic importance [22;12, pp. 38-39]. Therefore heuristic procedures, being one of the first stages of design, are able to have a much greater effect on the ergonomic quality of products than the following structured design activities.

2 The Search for Solutions as the Primary Function of Design Processes

The unchanging stages in the design process are analysis, synthesis, and evaluation, which simplified, can be defined as: breaking down the problem into parts, assembling the parts in a new way, and studying the consequences of introducing the new system into practice [13, p. 82]. Such described design processes require a very complex testing apparatus, which will allow a broad approach especially to the disintegration of the problem into its components and then a new approach to them.

In almost all cases, the appropriate formulation of the design problem allows one to transition to a group of optimal solutions, whereas an inadequate or unreliable approach will cause the design solution to be characterized by a greater or lesser error. However, only the following stages of designing involving the search for solutions that will meet a need described in the design process allow one to attain solutions of the described quality.

The search for solutions should therefore meet the following requirements in order to achieve an optimal ergonomic solution [on the basis of 11, p. 324]:

- solutions which arose before the full formulation of the problem may be defective – not fully analyzed parameters describing the problem,
- analyze all of the possible solutions, because then there is a greater probability of finding better solutions,
- at the beginning do not specify the abilities and limitations in terms of achieving ideal solutions because the limitations may turn out to be only illusory
- regardless of how many solutions have already been invented, one can always find one that is newer and better – search for it as long as time permits,

- do not be limited to search for solutions in various areas of information, the designer should rely on his or her own ingenuity,
- the greater the amount of knowledge, the greater the chance for a successful generation of solutions to the problem,
- the belief “this is how it must be” is the enemy of creativity, while a sense of security and persistent love to stick with what has survived years confines the ring of ideas,
- increase to a maximum the number of unique solutions which will be analyzed,
- expand to a maximum the boundaries of the possible solutions by eliminating the illusory limitations,
- before determining the group of sought solutions one should not describe the problem in detail, because it can turn out to be an obstacle that discredits the optimal solution,
- do not prematurely eliminate solutions even if they seem ridiculous, useless, or wasteful, because it may be only an illusory feature,
- gather all possible solutions from all available sources – from literature, patents, and other technical fields or beyond, because
- combine the ability to use the resource of known solutions with the ability to create one’s own original ideas, because often the best solutions are beyond the knowledge of textbooks or traditional practice,
- focus attention on the methodology of finding solutions because the "hit and miss" approach is a method characterized by the unnecessary return to similar solutions, with low effectiveness,
- do not look for a new solution by modifying the existing solution, rather search for an option that differs substantially from it; the evolution of a design results in an unnecessary duplication of errors from previous solutions,
- do not continuously use the same way of solving a problem, a habit will lead to the narrowing and stiffening of the ways of thinking, it becomes an obstacle to innovative thinking,
- when searching for new solutions one should rely on his or her own imagination, but simultaneously the designer should not allow emotional involvement in his or her solutions, since other much better competing solutions may exist.

In particular, the last of the rules show that the right approach to the design problem will result in obtaining a suitably wide perspective, which gives one the chance to obtain a solution with a much higher ergonomic quality. Such an approach, however, requires methods that do not restrict, but expand, the number of possible solutions. Hence, the interest in heuristic methods.

3 Methods Applied in Ergonomic Design

Although industry and academia agree that the human aspect is very important for the success of a product, and also for the safety of its functioning, there are few methods and tools that help designers with such factors during the synthesis stage of the design

process [20]. This assumption is true, of course, not taking into account a number of executive programs, such as CATIA, which function only as a tool to support the process of ergonomic design in the automotive industry [24]. One of the few available examples is the “behavioral design approach” (BDA), which integrates user behavior with product data as design work. By defined behavioral tasks to be done by the user and product, a set of solutions could be considered before choosing a final solution. Similar in terms of the approach method is discovering the ergonomic needs of users through observation and analysis of the ways of product usage by different user groups [9]. However, this approach does not meet the adopted criterion of the design process – the possibility of a broad search for possible solutions, based on the accepted needs of the user [20].

Certainly, one of the most promising methods that can be used in the design processes is Reverse Engineering, which allows for the duplication of an already existing product. Its main feature is the mapping of existing objects through virtual points located in space [19]. This allows for easy transfer of existing objects into the virtual space, and hence one can not only copy technical objects, but also biological objects, yielding a reproduction of objects such as designed handles. This method works well in the design of simple design solutions for a fixed group of recipients, but is not applicable to the design of more complex solutions.

During further seeking of methods supporting ergonomic design mentioned should be a wide group of simulation solutions, whose task is to assess the ergonomic solutions prior to implementation. As an example of this approach provided is a simulator of assembly and maintenance operations under a constrained environment, which determines the accessibility and the other ergonomic issues, such as muscle effort and its related fatigue. Based on a single objective optimization method, trajectory planning for different operators could be generated automatically [14].

However, the presented methods do not meet the adopted design criterion, the broad search for solutions. Hence the interest in heuristic methods that can be used to solve ergonomic problems.

4 Heuristic Methods Finding Application in Ergonomic Design

Without a doubt, there are a number of universal heuristic methods, which can be used in any properly conducted design method. It is worth to recall what they are used for and what these heuristic methods consist of. Heuristics is the science of methods of detection of new facts and the relationships between them (from the Greek *heurisko* – to find) [21]. In most cases, heuristic methods are used to overcome the limitations of thought and to open the designer to new areas that were previously overlooked [21].

The most frequently quoted and at the same time applied inventive heuristic is Brain Storming. Its creation is attributed to Alex Osborne in the 40’s of the last century, but historians have found its prototypes even a thousand years before our era in Asia. The idea is to stimulate the brainstorming session participants (meeting) to freely report a large number of possible ideas. This approach is based on the assumption that a large number of ideas will include at least a few that are good [3; 18]. It is true

that the effectiveness of this method is challenged [3], however, in its defense it can be given that it is an excellent opportunity to get to know the opinion of the other people on the problem, which is almost always a necessary step in the design procedure. An example of the application of this technique may be the method cited in "Sociotechnical design for a sustainable world," which consists of three stages [7]:

- matrix that cross-matches basic needs and the available forms of waste and thereby induces, by brainstorming, the development of design opportunities,
- four matrices for identifying the ergonomic demands of the three human users (the primary, the intermediate, and end users) and the environment, and
- matrix that evaluates the design alternatives in terms of sustainability, quality, and cost.

A method similar in structure to the brainstorm is Synectics, whose name is derived from Greek and means to connect into one piece parts or elements different from each other and which seemingly have nothing in common. The method was developed by William J. Gordon and involves the taming of strangeness and the transformation from the ordinary to the bizarre, which enables the achievement of the five mental states necessary to respond in a creative way: engagement and detachment, rejection of premature solutions, speculation, object autonomy, and hedonic response [3, p. 99]. For design processes with a focus on human needs this method seems to be particularly useful at the very early stages of designing a specific solution.

In terms of chaotic methods, which also bring tangible results, mentioned should be SCAMPER and functional analysis. While it is difficult to measure the ergonomic effects of the application of both of these methods it is due to the much greater emphasis in the functional analysis method on the analysis of the problem that gives a better understanding of the complex relationship between the human – technical object [6]. The SCAMPER method is used for solving ergonomic problems, where the methodological approach to the design problem does not give the expected results, and in order to find the solution one needs to mentally "test" the range of solutions. SCAMPER is an acronym derived from the first letters of the names of the steps you can take towards creating a concept of a new solution in terms of a product (substitute, combine, adopt, modify/distort, put to other purpose, eliminate, rearrange/reverse) [3, pp. 97].

Functional analysis (also known as Zwicky morphology) gives more opportunities to perceive previously not considered combinations by simulating a combination of different parameter values. The application of this method in ergonomic design is found particularly in the case of simple and not very complicated systems, where the number of individual variations allows one to analyze the problem. In the case of a larger number of parameters of a given object the multiplied number of variants precludes their consideration, without limitation of the aspects under consideration.

The downside to all the previously mentioned methods is their high flexibility, but this is due to the need to elicit an accordingly broad view. However, there are many more scientific approaches used in design, of a heuristic approach, as exemplified by the ant colony optimization algorithm, which in combination with ergonomic requirements allowed for the development of new ergonomic solutions in the field of keyboards [23].

One of the more formal, but with a heuristic nature, methods is TRIZ. This method is rarely used in relation to ergonomic design – only 8 appearances in the SCOPUS database – which seems to be particularly surprising because of the very useful tool called: Altshuller invention patterns, which allow to synthetically consider the possibilities, depending on your problem. The aim of TRIZ methods is to direct the search for solutions in order to minimize the unnecessary effort of searching by designating a vector for the search. This method is applicable, despite the significant passage of time since its invention, in significantly reducing the time to seek a solution by eliminating the “hit or miss” method [3, p. 66]. Contemporary applications include, among others, the design of ergonomic hand tools [15].

5 Heuristic Rules for Ergonomic Design

Basing on one’s own experiences as well as from interviews with designers, and the review of design methods, one can conclude that ergonomics is an object of interest in the later stages of the design process, when one cannot get a significant improvement in the quality of ergonomic solutions. It is therefore necessary to create a model of conduct that will allow to respond reasonably early to questions about the ergonomic cost of solutions. It is extremely difficult because at this stage the measures to meet specific needs which will determine the mode of action of the product on the user are not defined.

To avoid the effects described above one should be guided by the following principles during the initial, heuristically supported, stages of the design process:

- particularly in the early stages of design when choosing the general concept of a solution the participation of persons involved in ergonomics should be sought,
- for each considered solution the ergonomic costs should be considered, taking into account the most detrimental effects of the applied solution and the probability of their occurrence and to take into further consideration those which provide a suitably low ergonomic risk,
- heuristic thinking should be applied not only to the technical solution of a specified problem, but also to the interface between the solution and the user,
- new solutions require a thorough rethinking of the whole construction in terms of ergonomic functions, it may indeed be proven that the described solutions resulted from circumstances which no longer exist,
- one should look for solutions similar to the original ways of functioning of man; nature had millions of years to prepare humankind for the conditions under which we lived until recently, while we have done it for just a few millennia,
- one should notice the human co-existence at all of the life stages of the proposed solutions, as well as after their completion.

These rules do not cover all of the sound design practices and also are an addition to universal design or concurrent design methods [2]. In addition, ergonomic design requires a number of organizational changes within the company performing them. One of the changes is an alteration of organizational culture and acceptance of participation of employees in designing and implementing new solutions. [16]. In the end all design methods need to enable an optimal choice of product parameters by decreasing product sensitivity to the occurrence of disturbances in a manufacturing process, and to achieve the lowest quality loss while keeping planned production costs [8].

6 Conclusion

It should be noted that low ergonomic quality also causes reduced product quality, and to improve the ergonomic quality one should proactively consider ergonomic requirements already in early design phases of new product and assembly concepts [10]. The ever increasing interest in the evolution of ergonomic and safe products, and thus, among others, the working conditions associated with working with them, is due to the possibility of obtaining the desired economic benefits [10].

It is also worth noting additionally that the very idea of taking into account ergonomic requirements may seem contrary to heuristic concepts, which require an appropriately wide approach to the design process and accomplishing a very wide search of all possible solutions, including those that would be at first rejected. However, one should keep in mind that the discovery methods based on heuristic mechanisms such as TRIZ, rely on positive directing [3, p. 66] and in such a sense the directing of the search to favorable areas in terms of ergonomics will bring considerably better results in the final solutions for the operating or servicing them human.

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Universal Access to Interaction as Revealed by UAHCI Words

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Abstract. The analysis of publications created over time as journal articles and other media is important to emphasize the interests, identity and culture in a certain research area. This paper proposes an analysis on the content of the Universal Access in Human-Computer Interaction (UAHCI) conferences since 2007, based on information from the article titles. We were especially interested in knowing about changes in recent years related to user categories, the technologies used, and the processes associated with the systems engineering or with the human-computer interaction practices. Discussions are situated from the creation and observation of *tagclouds* formed with the data. As a contribution, we found what the words reveal about main trends of the area, the profile and the differences between the various editions of the conference, and also the gaps and potential for future research work toward accessibility and design for all.

Keywords: Universal Design, User and Context Diversity, Applications.

1 Introduction

Besides important to emphasize the interests, identity and culture in a certain research area over time [1], the analysis of institutional archives, as journal articles and other media, is important for readers, authors, publishers and advertisers to better and more objectively understand their field of interest. Moreover this kind of analysis may provide a glimpse of trends, modes of thought and the potential future for the area.

Accessibility has been considered a major concern of the Computing field, supposedly the most effective discipline for adapting the user interfaces to the varied needs of users, including those that are challenged to interact with computing systems despite their disadvantage physical condition [2].

The design of accessible software applications is considered very hard to achieve, due to several reasons: there is a proliferation of platforms through which people may interact with computer-based services and applications; modalities of interaction are being extended from the keyboard to include speech, gesture, touchscreen, etc.; the users also represent a wide diversity in their abilities usually not known to developers. Thus, it is difficult to anticipate every mode of interaction different people may use, providing accessibility to every platform and application. Moreover, as discussed by

Cerf [2], although general purpose tools to cope with specific human condition, such as screen readers for blind users or automatic caption for deaf users may be useful, no automatic adapting tool will make a poorly designed interface accessible.

Given the complexity of the problem, this work investigates the subject by getting a picture of the field, based on an analysis of the content of the Universal Access in Human-Computer Interaction (UAHCI) conferences since 2007. A set of 834 papers was published during this period: 246 in 2011, 248 in 2009, and 340 in 2007. Discussions are situated from the creation and observation of *tagclouds* formed with the article titles. We were especially interested in knowing about changes in recent years related to user categories, the technologies used, and the processes associated with the engineering of systems or with the human-computer interaction practices.

Therefore, this paper aims at providing a roadmap on work in the field, pointing out its trends, and showing the origin of major authors. This information may be helpful for researchers and practitioners who are starting work in the field, and even for experts who want to build on it. The paper is organized with a section situating the context of this research, followed by a description of the systematic review process; a section on the findings is followed by a categorization of results, analysis and discussion to finally conclude.

2 The Study Context, Representation and Method

The International Conference on Universal Access in Human-Computer Interaction is currently in its 7th edition, and has been part of the biannual HCI International, the International Conference on Human-Computer Interaction (now in its 15th edition). The HCII gathers other 9 related conferences addressing the thematic areas of Human-Computer Interaction, and Human Interface and the Management of Information. Thus, it represents a wide audience from academia, research institutes, industry and governmental agencies, and comprehensive content in the field, judged to be of high scientific quality. These papers address the latest research and development efforts and highlight the human aspects of design and use of computing systems.

The volumes analyzed in this work [6-8], correspond to the 4th, 5th and 6th editions of UAHCI, and contain papers in the thematic area of Universal Access in Human-Computer Interaction, addressing the following major topics: Diversity (116 papers in 2007, 77 in 2009 and 117 in 2011), Applications and Services (109 papers in 2007, 86 in 2009 and 72 in 2011), and Interaction, Design for All and eInclusion (115 papers in 2007, 85 papers in 2009 and 57 papers in 2011).

2.1 Data Representation

For an overview of the themes present in the conferences analyzed, we use the expressive power of representations known as *tagclouds* (tag clouds). A *tagcloud* is a visual representation of a set of words, typically tags (labels), which gained notoriety when it was used in social software sites such as "del.icio.us[®]" or "flicker[®]". Each

word is highlighted within the cloud according to its importance within the set of words, and gain enhancement through manipulation of visual characteristics, such as font size, color, weight, etc. [3]. For Rivadeneira et. al. [4], this format is useful for quickly providing the most prominent terms and relative importance of a specific word within the analyzed set. Also, it provides a general impression of the whole words set and the "essence" of the data represented. For example, in social software sites, the *tagclouds* can provide an impression about interests or expertise of a person.

Depending on the context in which they are used, Rivadeneira et. al. [4] suggest four different tasks that can be performed with *tagclouds*: search, navigation, impression formation or gisting, recognition or correspondence. Although *tagclouds* are less accurate and efficient in some specific cases than other forms of visualization, such as tables and wordlist, the *tagclouds* are advantageous to capture the essence of large amounts of descriptive information by presenting it succinctly [5]. This scenario of success motivated by the need of a summarized analysis of a large amount of data is one of the reasons for our choice of *tagclouds* as a representation in this work. For further analysis, tables and graphs were used (e.g. to show the relative frequency of words that stood out in a particular conference).

2.2 The Review Process

The review process is composed by 5 steps as briefly described. In the first step, all the papers published in all the conference editions were considered. A general-specific strategy was adopted to generate visualizations for the whole set of papers (general level) as well as for specific sub-topics (specific level). In the second step, the conferences were analyzed in isolation, starting from an overview and detailing their respective sections. In a similar way, an analysis was conducted to identify the most active authors in the field during the period, and the origin of the different contributions. In the fourth step, terms were organized into categories of interests: user profiles, technologies, and methods. In order to identify trends, we computed the frequency of appearance for some pre-defined terms. The result was organized by years, sections, and overall (considering the three conferences). Finally in the fifth step, all the information produced in the previous steps were crossed and analyzed. The analysis was supported by a tool that allows, among other things, to identify all papers that have some term of interest in their titles; the tool indicates the amount of papers that satisfy the query and the percentage that such amount represents of the total. An example of this search can be seen in Figure 1.

Observing the number of papers that use the term *Design* in their titles in Figure 1, the percentage remains almost constant in 2007 and 2009 with 15.88% and 14.92%, respectively, and increases in 2011 reaching 21.54%, suggesting an still increasing focus of interest.

3.1 Analysis by Topics

Treating Diversity. Diversity is in the realm of the universal access considerations regarding people's interaction with technology. The topic has been treated in the UAHCI in every edition of the conference: *Coping with Diversity* (in 2007), *Addressing Diversity* (in 2009), and *User and Context Diversities* (in 2011), with 116, 77 and 117 papers published, respectively.



Fig. 3. Tagclouds of terms used in the Diversity topic papers for 2007, 2009 and 2011

The tagclouds in Figure 3 reveal that the most salient word in this topic, in all the editions of the conference, is *Design* representing 30.17%, 24.68% and 27.35% respectively of the total of words (see also Figure 2). It is much more present than the word *Evaluation*, which represents respectively 4.3% in 2007, 5.19% in 2009 and 2.56% in 2011, suggesting more contributions towards design issues than to evaluation issues. Regarding other words reflecting stages of products lifecycle, *Development* appears in 6.90%, 1.30% and 5.13% respectively in 2007, 2009 and 2011, following the same pattern of the word *Evaluation*; while *Analysis* represents 3.45%, 0% and 3.42% respectively, and *Modeling* represents 0.83%, 2.60% and 0.85% of the words occurrences.

Regarding the user categories and human references addressed, the most salient words are: *User*, *Elderly*, *Older*, *Adults* (in 2007), *Cognitive*, *Elderly*, *Older* (in 2009) and *Older*, *User*, *People*, *Adults* (in 2011). The generic term *User* is still dominant, representing 19.83%, 20.78% and 17.95% of the words in 2007, 2009 and 2011 respectively, while the specific terms individually represent between 5 and 8%. Taking together, the *Older* and *Elderly* seem to be the most salient category of users addressed, representing 16.38%, 14.28% and 16.24% of the words. This category is followed by the *Adult*, with 5.17%, 1.30% and 6.84% of words occurrences in 2007, 2009 and 2011 respectively. It is worth mentioning the low occurrence of the words *Children* and *Child*, the last one represented by 1.72%, 1.30% and 0.85% of the words in each edition of the Conference: 2007, 2009, 2011, while the words *Teen* and *Teenager* appear only in 2011, representing 0.85% of the words. The generic term *Disabled* represents 3.45%, 1.30% and 1.71% respectively in the 2007, 2009 and 2011 editions, similarly to the more salient specific disabilities: *Blind* appears in 3.45%, 0% and 1.71% in 2007, 2009 and 2011 respectively, while *Deaf* appears 0%, 2.60%, 0%.

Still regarding the target users' considerations, it seems to have a smooth change in focuses along the editions of the Conference, reflected in the appearance and disappearing of some specific words. The focus seems to go from *biometric* (3.45%,

0%, 0.85%) and *authentication* (5.17%, 0%, 0%) technologies for the blind and disabled in 2007, to *cognitive* (5.7%, 11.69%, 2.56%), *mental* (2.59%, 5.19, 1.71%) impairments (e.g. *dementia* 0%, 5.19%, 0%) in 2009, to aspects related to *affective* experience (0%, 0%, 4,27%), and *culture-specific* (0%, 1.30%, 3.42%) issues in 2011.

Regarding context diversity, from the generic *Home* (5.17%, 1.30%, 1.71%), specific domestic environments start to appear along the Conference editions, e.g. *Living* (0%, 2,60%, 4,27%) and *Kitchen* (0%, 0%, 1.71%).

Applications. *Applications and Services* is the topic maintained in the three editions of the Conference, with 109, 86 and 72 contribution papers, respectively.



Fig. 4. Tagclouds in the Applications and Services topic papers for 2007, 2009 and 2011

The tagclouds of Figure 4 reveal that *Accessibility* and *Web* are the two most frequent words in 2007 and 2009 contributions, showing a decrease in 2011: *Accessibility* represents 20.18%, 17.44%, and 6.94% of the words in this topic, respectively, while *Web* represents 14.68%, 20.93% and 6.94%. The most frequent word in the third edition of the Conference is *System*, growing from 9.17% in 2007 to 13.95% in 2009 and 18.06 in 2011. It is worth noting that the *Usability* classical word present in the titles of contributions represents 3.67%, 3.49% in 2007, 2009 respectively and disappeared (0%) in 2011.

Learning and Education seem to be the main focuses of applications and services in all considered editions of the Conference. *Learning* and *Education*, taken jointly represent 23.86%, 12.8% and 20.83% of the words in the contribution titles of this topic in 2007, 2009 and 2011 respectively. Nevertheless, *e-Learning* has shown a decrease represented by 11.01% of appearance in 2007, to 3.49% in 2009 and 1.39% in 2011. *Management* has also shown a place, except for 2009, with 5.50% and 6.94% of the words in 2007 and in 2009.

The *Web* seems to be the main platform addressed, besides being one of the two most frequent words, representing 14.68%, 20.93% and 6.94% of the words. Nevertheless, other words suggest trends such as *Mobile*, with increasing appearance: 0.92%, 3.49% and 4.17% in 2007, 2009 and 2011 respectively, although the word *Phone* does not appear at all.

Regarding the Design-Evaluation balance, the data show more salience for *Evaluation* in 2007 (11.01% of the words), decreasing in the last two editions: 3.49% in 2009 and 5.56% in 2011, while *Design* remains constant around 10% of the words

(10.09%, 10.47% and 9.72% in 2007, 2009 and 2011 respectively). Also, studies seem to be the predominant type of contributions in this topic, with *Study* appearing in 2.75% , 9.30% and 8.33% of the words in 2007, 2009 and 2011, respectively.

Interaction, Design for All, eInclusion. In this work we are analysing Interaction-related words as they appear in the following topics of the three last editions of the Conference: *Ambient Interaction* in the 2007 edition, *Intelligent and Ubiquitous Interaction Environments* in the 2009 edition and *Design for All and eInclusion* in the 2011 edition. The tagclouds for these topics are illustrated in Figure 5.



Fig. 5. Tagclouds in the Interaction, Design for All and eInclusion topic for 2007, 2009, 2011

The 2007 and 2009 tagclouds are quite similar in the words they salient, changing place between the first and second most frequent words. *Ambient*, *Environment*, *Mobile*, *Interface* and *Interaction* are around 10% and 19% of the words in both editions of the Conference and are less explicit in the 2011 edition, ranging from zero presence, e.g. for *Mobile*, to 1.75% for *Ambient* and 5.26% for *Environment* and *Interaction*, respectively, to 12.28% for *Interface*.

Words representing categories of interaction in the 2007, 2009 and 2011 editions are represented by *Adaptive* (4.35%, 4.71% and 8.77% respectively), *Intelligent* (4.35%, 4.71%, 1.75% respectively), *Visual* (4.35%, 2.35%, 8.77% respectively), *Multimodal* (6.09%, 2.35%, 7.02% respectively), among the most recurrent.

Except for the word *Interface*, which maintain a high salience in the three editions of the Conference, the 2011 edition topic data suggest a shift in focus from the environment/ambient interaction to the higher level concepts of Design for All and eInclusion, adding to some words in common (e.g. *Adaptive*, *Visual*, *Multimodal*), issues such as [user] *experience* (0% in 2007 to 5.26% in 2011), [public] *policy* (0% in 2007 and 2009 to 3.51 % in 2011), and *cultural* issues (0.87% in 2007 to 3.51% in 2011), as well as other devices (e.g. *TV* from 0% in 2007 and 2009 to 3.51% in 2011) suggesting demands for new ways of interacting.

3.2 The UAHCI Worldwide Extent

In this work, we extracted the full list of authors of papers from 2007 to 2011. This list included a total of 2024 authors and then we did the data analysis including only those authors who published two or more papers, so we were left with a total of 340 authors. For each of these, we established the country and institution that they represent. We found that those authors come from 30 countries, 200 institutions and 834 papers contributed to the themes of UAHCI from 2007-2011. This information is resumed as follows.

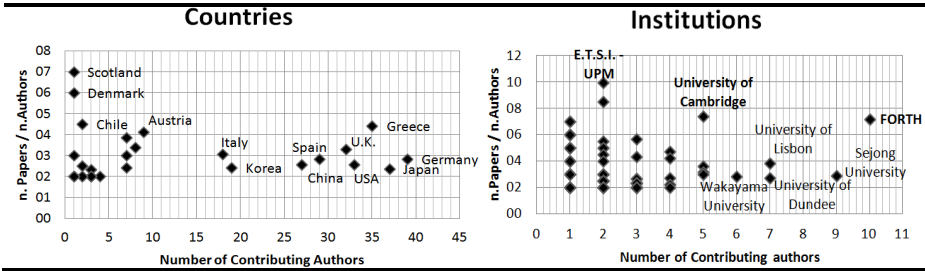


Fig. 6. Countries and Institutions with respect to the number of authors and papers/authors

The three countries with the largest numbers of authors are: Germany, Japan, and Greece, with 39, 37 and 35 authors, respectively. Among the 30 countries involved, those with the largest numbers of papers associated are: Greece, with a total of 154 papers, followed by Germany with 110 and the United Kingdom with 105. Considering the average production of papers of each considered country, we have a distribution as illustrated by Figure 6.

Considering the average production of papers by author of each country, an interpretation that can be made is that Greece, United Kingdom and Italy have the highest average production by author among countries with more than 15 authors; their averages are 4.4, 3.3, and 3.1, respectively. Also, countries such as Scotland, Denmark and Chile have average paper's production by author greater than each of the other countries considered with 7.0, 6.0, and 4.5, respectively.

Analysing the institutions associated, Figure 6 highlights “Life Supporting Technologies E.T.S.I. Telecomunicacion. UPM” (20 papers and 2 authors) with the highest average papers per author, although the *Foundation for Research and Technology - Hellas (FORTH)* is the institution with the largest number of contributions (72 papers and 10 authors).

3.3 Synthesis and Discussion

Looking at the general data of all topics and editions of the Conference, some aspects deserve attention. Regarding conceptual approaches to the research problem, Accessibility is the most emphasized word, (8.27% or 69 papers address it in their titles), followed by Universal (4.32% or 36 papers), suggesting the natural path from the former to the later. Usability still appears (2.88% or 24 papers), and Participatory and Participation are still rare (0.12% or 1 paper and 0.24% or 2 papers) suggesting the traditional approaches to the user involvement. Design is more emphasized (17.27% or 144 papers) than Evaluation (5.40% or 45 papers), and is more addressed in the Diversity topic, while Evaluation is more salient in the Applications topic.

The general data clearly show an aging-centered focus for the human considerations and needs (Older and Elderly together represent 8.28% or 69 papers), with less stress for specific disabilities (Blind and Deaf together represent 3.3% or 28 papers). This result may suggest a trend to blur the frontier between normality and deficiency towards the design for all.

Devices and platforms still appear in generic terms: *Mobile* represents 6.59% or 55 papers (more salient in the Interaction topic), and *Web* represents 8.15% or 68 papers (more salient in the Applications topic). Application domains have a clear focus on *Education* and *Learning*, which together represent 8.39% or 70 papers; the *Health* domain is still present in 2.16% or 18 papers, with an important growth in 2011.

The general results also show that the social aspects of system design and use, typical of the contemporary Web applications, although experiencing a growth in the last edition of the Conference, are not still so prominent (*Social* is present in 1.80% or 15 papers). Moreover, the trends of the HCI domain for future towards elements of affective, emotional, motivational issues, as discussed by [9] are poorly addressed (*Affective* appears in 0.6% or 5 papers, *Emotional* and *Motivation* appear in 0.24% or 2 papers, each), representing open opportunities in the field. Also, It is worth noting the timid appearance of *Value* (0.24% or 2 papers), and *Aesthetics*, which is not present.

The worldwide distribution of the authors and their institutions show a predominance of contributions coming from Europe. This fact might suggest the data is reflecting, in some way, the European scenario of needs regarding access to technology. This also leads us to wonder how different the data could be whether situated in different scenarios, as for example of developing countries, where other challenges have to be faced regarding eInclusion, for example illiteracy and social barriers.

4 Conclusion

The design of software applications considering the varied needs of users, including those that are challenged to interact with computing systems despite their physical, psychological or social conditions is considered very hard to achieve. The HCI field has accumulated knowledge to cope with the challenges of designing interactive devices. Getting an overview of the main issues that have been addressed in recent years in the field is a way to identify lacking issues and new research opportunities.

This paper shed light on the main focuses of research addressed by the last three editions of the UAHCI Conference and the origin of the contributions. Results show the wide extent of the Conference, having contributions from 2014 authors coming from 30 countries, 200 institutions. Nevertheless, European countries lead the highest average production by author among countries with more than 15 authors. Roughly, *Design* is the most frequent word in the contributions, the *Older*, *Elderly* and *Adult* are the most addressed categories of target users, the *Mobile* and the *Web* are the most present platforms for interaction, although as generic references. There is few allusion to the social issues typical of contemporary Web applications, such as those associated to social software and the related concepts such as values, aesthetics, collaboration, participation, signaling important subjects still open to research in the field.

The analysis used *tagclouds* as a way to get the accentuation of subjects being discussed in the different topics of the Conference. The results obtained also indicate that the use of *tagclouds* provided a quick and simultaneously comprehensive overview of the data, considering the volume analyzed. Although paper titles usually are representative of their content, a possible refinement in the study could incorporate keywords and the abstracts, for further analysis. The tool developed for supporting this work also enables further work, to analyze specific classes of contributions.

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Implementing Disability Accommodations in a Widely Distributed Web Based Visualization and Analysis Platform – Weave

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Abstract. Visualization tools give authors the ability to present large amounts of data in a way that allows the viewer to gain understanding of the data with just a glance. This strategy, while useful to the sighted population, presents obvious barriers for blind or visually impaired individuals. A solution to this problem has become more vital, as ever more publicly funded agencies turn to data visualization as a tool for conveying information to the public. In this paper we present a solution based on previous research that allows a system to do automatic analysis of a line chart visualization to extract and then present it's intended message. Previous advancements in this area, an implemented prototype of the proposed solution and a description of the platform in which it was built are presented, as well as a discussion of the implications of this research and future work.

Keywords: Weave, visualization, accessibility, blind, screen reader, disability, universal design, vision, access.

1 Introduction

Type the term “visualization” into a web-based search engine, and it is not surprising that more than fifty million results are returned. Clearly, visualization is a huge component of this golden age in multimedia. There are tremendous visualization tools available. These tools are colorful, aesthetically pleasing, even glamorous - but most importantly, they are informative. Visualization tools give authors the ability to present huge amounts of data in a way that allows the user to gain understanding with just a glance, and provides an appealing solution to a worsening problem known as information overload. Information visualizations are increasingly becoming adopted as a solution for large data dissemination. Though information visualization as a method for information dissemination is incredibly useful for individuals with the necessary visual faculties, this method presents obvious barriers to understanding for individuals who are blind or visually impaired. This problem, a lack of accessibility by this population to the presented information, is often ignored by organizations and website developers. Recent legal action by groups advocating for comprehensive

website accessibility has many organizations, particularly those who receive public funding, scrambling to provide accessibility [1] that meets the WCAG 2.0 guidelines, which are currently the gold standard [3].

In this paper, we present a description of a novel user interface prototype, for the creation and manipulation of accessibility features directly within a visualization and analysis system. This work is implemented within Weave, which is an open-source web-based analytic and visualization platform. Weave is an ideal candidate to receive accessibility tools of this sort because it is open source, freely available, and is currently deployed and widely used by a diversity of organizations (many of which are publicly funded). The users of the sites of many of these organizations are also potentially individuals who currently do not have access to the information being provided using Weave [4]. The work described here is meant to be employed by website administrators as a way to advance a website towards realization of WCAG 2.0 guidelines.

This user interface provides the administrator with tools to both manipulate and access either system -or user- generated textual descriptions of visualizations within Weave. Access to these descriptions must be practical and cost effective. Users cannot be expected to spend any more time or money than a typical user would have to, to obtain the same information. The resulting information is therefore designed to be accessible by technology that is already widely adopted by the target population; screen reading software, particularly JAWS [13]. However, because of the nature of the implementation, this work is compatible with all types of screen reading software.

The user interface can be used to create visualizations and Weave overview descriptions using a manual method, an automatic method, or a combination of these. The basic case provides a novel method for allowing the user to create and adjust manual description components. The advanced case allows the inclusion of automatically generated description components. This system prototype is loosely based on the message category and recognition work done by Greenbacker et al [5][6]. Once a message is identified, it is made available via the systems graphical user interface as an option for inclusion in the final description. More detailed descriptions of these functionalities and the theory behind them follow in section 4. We will discuss how the chosen software platform extends the usefulness and functionality of related work, and creates new research possibilities in section 5.

2 Related Work

There are many approaches to providing alternative methods for accessing graphics, both practically and in recent research. On the internet, current standards call for website designers to provide a short description in a graphic's alt tag [17], but this detail is often ignored and it does not take an internet user long to stumble upon a website where this detail is absent. Manual creation of descriptions, although a great start, may be inaccurate and clearly does not scale. The automatic components we propose in this paper addressed these issues.

Researchers involved in the SIGHT project [2] have a well-developed system for line and bar charts providing high-level summaries of these graphs when they are encountered in documents, with additional details on demand. This research is ground

breaking, but is implemented only for static images, thus missing out on the potential to provide users with a better awareness of a visualization that has interaction or animation. It is also focused on providing a graph summary after the visualization has been created as an image, thus missing out on the potential benefits that our system may offer to a visualization designer, particularly one with a specific goal in mind. This is also implemented as a browser extension, thus requiring the user to download and install additional software, contrary to the system prototype presented in this paper. Other graph summarization methods have been researched, however these are either too granular [10] or too general [11] for practical use with a screen reader.

In the SAGE [14] system, an automatic caption generator for charts was implemented. The communicative goal of the graphics is gained by given data points. SAGE differs from SIGHT in that the communicative goal is deduced by reasoning about the communicative signals in the graphic [16].

The iSonic system, a sonification system for data exploration that was built for blind users, allows the user to explore geo-referenced statistical data [12]. This approach takes into account interaction but not animation, is limited to geographical data, and is more of a data exploration tool rather than a high-level summarization tool.

3 Implementation Platform

3.1 Weave

Weave is a visualization and analysis platform that is web-based and open source. It was developed by a team of researchers and developers at UMass Lowell in collaboration with the Open Indicators Consortium, a diverse team of public and nonprofit organizations from across the United States. The size and diversity of the Open Indicators Consortium as a group of system stakeholders has resulted in a system that performs well for a multitude of different purposes. This has aided progress toward realization of the Weave mission: to enable anyone to visualize any available data for any purpose.

Progress toward this goal however has been directed at the 85% of the population that is not permanently disabled. This focus on the able-bodied potential user population is also the case for most software development projects [7], however by ignoring the 15% of the population that is permanently disabled; the Weave project not only loses out on a large potential user population, but also fails to achieve its mission.

Weave is built as a windowing system in much the same way as Microsoft Windows. In any instance of Weave there can be as many or as few visualizations and data sets as the user wants or requires. Users can add, delete, resize, and minimize windows. Windows usually contain visualizations or visualization components but may also contain explanatory user-generated text or more complicated functionality such as statistical tools. As an open-source system with a diverse set of stakeholders and users, it is necessary for site administrators to have the ability to configure the level of complexity available to the end users.

Thus, Weave can be as simple or as complicated as necessary, depending on the use case which ranges from basic visualization for display/presentation purposes, with

all or almost all complicated functionality disabled, to data exploration and analysis, with functions such as interactive probing, window configuration, data import/export/subsetting and statistical tools, in addition to much more available to the user. Weave instances can be viewed either as an independent web page, or they can be embedded into webpages as just one of many components.

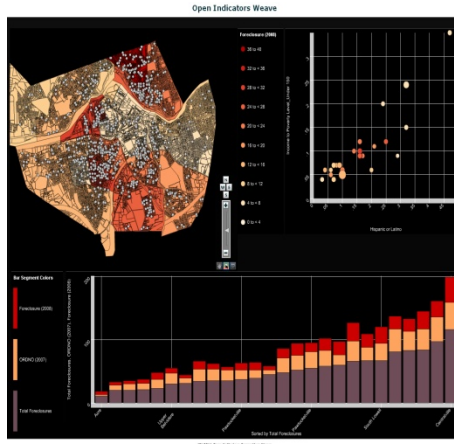


Fig. 1. Foreclosures in Lowell, MA, *Weave*

3.2 Weave's Users

Weave was brought to fruition with the support of the Open Indicators Consortium (OIC) [4]. The OIC has funded and guided most of the development of the Weave platform by participating in an agile development process. Due to the diversity of individuals and organizations within the OIC, Weave has been developed to suit the needs of a wide range of users. As a result, Weave can be suitable for users ranging from a random internet-browsing individual who happens to land on a web page that is running Weave, to an academic researcher using Weave to analyze complicated heterogeneous data. Three types of Weave users are defined an accompanying description of how the user interface will uniquely benefit this type of user.

Use Case: Typical Internet User. The simplest case we present here is when a citizen with average computer skills visits the website of a publicly funded entity, such as a city or town website. In this case it is reasonable to assume that the user is visiting the site to retrieve information or to perform an action that they know this site provides. This person may encounter an instance of Weave embedded into the HTML of this page. Regardless of the complexity of each instance of Weave embedded within any website, the visualization(s) within it have likely been placed there to convey a message, probably a message pertaining to the relative data and mission of that organization. In this case, the system described in this paper will aid the user who is accessing this page with screen reading software that retrieves the intended message of each instance of Weave within that page - extending the reach of that website to include

internet users with impaired vision. It also assists the user who does not have the necessary visual literacy to interpret a particular visualization or group of visualizations.

Use Case: Data Analyst. This use case is “advanced” in that the user is exploring a dataset to try to uncover meaning, and in doing so, she or he will probably make use of Weave’s more advanced statistical features and visualizations. Exploration of data sets (visual or otherwise) is a cognitively taxing and complex task. In fact, system design and methods that aid in the task of knowledge discovery and data analysis are a major research area and are being approached from many angles. The system described in this paper is uniquely beneficial to this type of user as well. As a visual analyst explores a data set, s/he is constantly changing and refining the visualization with which s/he is working. The automated component of the system described produces dynamically generated message components that adjust to reflect changes made to the visualization. This may support the data analyst by providing a textual interpretation of the visual scene.

Use Case: Website Author or Administrator. In this case the user may be charged with the responsibility of creating or maintaining the website of a publicly-funded entity such as that of a city or state government or a government agency such as the Department of Education. This user will be using Weave as a website component in order to tell a story or to provide a constituent with information, and this person may also find it absolutely crucial to ensure that the information or story being provided visually using Weave is also available in a more accessible form. This can be achieved by providing the information within the HTML of the webpage, however; design considerations may prohibit this. Here, the system being presented allows this user the freedom to make use of both manual and automatic components in order to provide the website viewer with a description or story that matches exactly with her or his goals. This description, once created, may have some, all, or none of its components be automatically generated by the system and therefore dynamically changing. Once the description is satisfactory, the website administrator can access it as a string variable, using it to populate any textually based part of a webpage, including regular text areas, popup text, or as the “alt” and “longdesc” tags associated with that instance of Weave. Automatically generated components of that description will propagate through Weave, updating the variable, thus being reflected in the webpage wherever that variable is being used.

4 Theory and Implementation

4.1 Screen Reader Compatibility

A first step in this work was to implement a framework enabling a webpage with an embedded instance of Weave to access information contained within Weave. This mechanism uses the Weave Javascript API [8] to access a special type of variable called a sessioned variable. A sessioned variable is simply any run-time variable within Weave that is to be stored in session state. We created two variables of this sessioned

type, one to represent a short description (basic description, explained in section 4.2) and one to represent a long compound description. A test webpage was set up to test the functionality of this framework, confirming that these string variables are indeed accessible outside of the instance of Weave itself from the webpage using common HTML elements. This test webpage was then accessed using the Jaws screen reading software as well as the Mac built in screen-reading software, VoiceOver [15], to confirm that screen reading software can indeed gain access to the text and properly utilize it.

4.2 User-Generated Descriptions

A basic graphical user interface tool was built to facilitate the creation of user generated textual descriptions. This functionality is provided both for the creation of Weave instance summarizations, within the main Weave preferences, and for the creation of individual visualization summarizations, within each individual tool's preferences. This GUI allows the user to manually type in descriptions of visualizations or the entire instance of Weave that is accessible from outside of Weave.

A Weave instance summarization, or an overview summarization, is considered in this interface to be a basic description and is referred to as such. This description is expected to have the least amount of detail as it may describe a complicated Weave instance with multiple visualizations and is restricted in length to fifty or fewer characters. An example of a basic description is: "Three visualizations showing BMI data for Boston".

An individual visualization (or tool) description is referred to as a manual visualization long description component. A manual visualization long description component may be more detailed than a basic Weave description because it is only representative of, at most, one visualization and thus is expected to summarize potentially fewer details. A manual visualization long description component is also restricted to fifty or fewer characters. An example of a manual description is: "Line chart showing skyrocketing obesity." This type of manual description may be desirable for the interjection of the author's domain knowledge, to emphasize specifics, or set a tone.

4.3 Automatically Generated Descriptions

The Weave architecture is based on the concept of session states. All actions made within the system, including visual parameter settings, tool properties and user interactions are recorded and this "snapshot of history" is stored as a session state [9]. The session state contains all of the information required to restore a given Weave visualization, or instance, to the screen. To create a visualization that is accessible to visually impaired individuals, it can be used to generate a description of the visualization.

The session history feature of Weave allows the programmatic creation of specific descriptions of visualizations on the fly, even as they are being modified or animated since the parameters in the session state change when the visualization changes. To do this we use the session history to automatically detect certain features of the visualization such as data change and columns replacement. This data information is then sent to the R statistical package using a plug-in to the Weave architecture which then

computes and sends back to Weave statistical information that is used to determine and construct messages about that visualization, a process inspired by and partially based on the work of Demir et al [2]. To date we have slope information computed statistically. Currently this process has been implemented for simple instances of line charts for the messages of increasing, decreasing, and stable trends as message categories defined in the work of Greenbacker et al [5]. An example of an automatic visualization long description component produced by our prototype system is: “This line chart has an overall increasing trend from 1995 to 2010.”

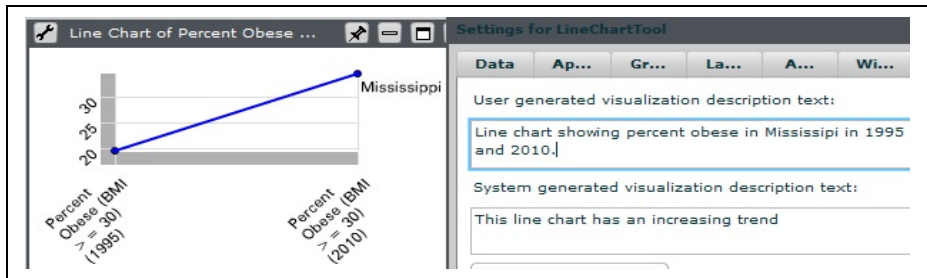


Fig. 2. A simple line chart with user generated & system generated descriptions, *Weave*

4.4 Compound Extended Descriptions

Long descriptions are a user-determined combination of the basic description, manual visualization long description components, and automatic visualization long description components. For each component that is defined using the interface, a control is dynamically created within the long description (aka compound description) interface. These controls are in the form of radio buttons that only appear in the interface once that particular description component is defined by the user or generated by the system. These are designed to allow manipulation of the final long description text by toggling the individual description components into or out of the long description.

The order of the components in the long description is determined by the order in which they are added or subtracted using the GUI. The end result is a series of sentences appended together, which may or may not contain the overview sentence or any of the individual tool description (manual or automatic) sentences, according to the user’s choice. An example of a long description that has a basic description, a manual visualization tool description, and an automatic visualization tool description included may be: “Three visualizations showing BMI data for Boston. Line chart showing skyrocketing obesity. This line chart has an overall increasing trend from 1995 to 2010.”

In addition to the GUI, the long description is also manually editable. This allows the user to adjust the flow of the long description once the necessary elements have been edited. This allows complete control over the final long description without forcing the user to re-type or remember each of the components. An example of how this may be used would be to edit the example long description sentence above to read “Three visualizations showing BMI data for Boston. Line chart showing skyrocketing obesity, an overall increasing trend from 1995 to 2010.”

5 Conclusions and Future Work

In section two of this paper we presented a comprehensive review of screen reading software, sonification, and graph summarization, and explained how these works differed from and contributed to the work presented in this paper. Section three described the software platform in which this work was implemented, presenting three different use cases and explaining how the work presented in this paper is useful in each of those three cases. In section four we described the implementation and theory behind this work and gave examples of the output produced by each part.

The work presented in this paper describes one of the first graphical user interfaces ever implemented within a visualization and analytic system. It was designed specifically to work with the tools available and already being used by visually impaired individuals, specifically screen-reading software.

However, there are several areas to explore as future work. First, the work will be extended for advanced line charts which need more message categories for description. This work provides the user with the ability to both manually and automatically adjust a description of a visualization, but the implications of this hybridization of content contribution has not yet been studied. Since this system automatically generates message text, it may also have interesting implications and applications in report generation. Because the Weave software platform was built using a session state based architecture, this work has access to both the visualization parameters in addition to the raw data. In the future, this may allow in the future for us to adjust our methods to compute messages about both the visualization and the data, possibly allowing the viewer to make comparisons between the two and to gain insight into the truthfulness and accuracy of the visualization being presented. [18]. We also intend to study the effect that the availability of a dynamically changing high-level message has on a visualization designer, by presenting designers with a basic goal and observing the design process to see if it is affected by an accurately changing message.

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Interviewer Agent for Cognitive Task Analysis

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Abstract. A chat-based interviewer agent (IA) for cognitive task analysis was developed. This agent automatically generates questions for and responses to the answers from the human interviewee. The automated response process is based on shallow intelligence incorporating an interview technique for cognitive task analysis. We also considered the knowledge awareness (KA) effect and designed the interview as a fake group interview, with one agent interviewer, one agent interviewee, and a human interviewee. We conducted test interviews with 14 subjects to evaluate the new functions of the IA. The results show that KA and the fake group interview were effective and that the performance was better than that of the previous version, which used a one-on-one interview without considering KA.

Keywords: interviewer agent, cognitive task analysis, knowledge awareness, group interview effect.

1 Introduction

An interview is an effective method to elicit knowledge and opinions from other people because of its interactivity and flexibility. It is, therefore, often used in many domains for various purposes. For example, in the human factors and ergonomics (HF/E) domain, interviews are often used as a major knowledge elicitation method in cognitive task analysis (CTA) (Crandall et al., 2006), in which the cognitive processes in areas such as problem solving and decision making are examined. This type of interview is also applicable to and is often used for the assessment of the usability and accessibility of human-computer interactions (Polson et al. 1992). The interview is, however, time consuming in terms of preparation, implementation, and data analysis. Also, the quality of the data obtained from an interview depends more or less on the techniques and skills of the interviewer. There is also a limitation in that it is difficult to conduct interviews many times with many people. To solve this problem, we have been developing a chat-based conversational agent that conducts CTA interviews by generating questions for and responses to the answers from a human interviewee, and by managing the entire interview process. In this paper, we introduce the basic mechanism and several new features of this interviewer agent, and show how the agent works by presenting some interview results obtained by the agent.

In the next section, a short review of the related studies on conversational agents is presented, and the common problems of the past approaches are discussed. In Section 3, the new approach adopted for the design of our interviewer agent, i.e. CTA and the

group interview, is introduced and its implementation is explained in Section 4. Some test interviews were carried out for verification and the results are presented in Section 5, which is followed by discussion and the conclusions in Section 6.

2 Related Studies on Conversational Agents

There is a long history behind the development of the dialogue system or conversational agent (CA) (Weizenbaum 1966), and many related studies have been conducted to date. One of the main categories of the CA is the chat-agent or chat-bot, whose purpose is simply to chat and have fun (Wallace, Mauldin et al. 1994, Augello et al. 2008). Another major category is the interactive information provision system or a navigation agent through dialogue. This kind of system or agent tries to search a database and provide appropriate information or to help achieve a task such as ticket purchase through a dialogue with a human user (Kiyota et al. 2003, Watabe et al. 1986, Misu et al. 2007). However, no comparable development effort has been made in another CA category: the CA that is used to elicit information from a human user, i.e. an interviewer agent (IA). Several trials of interviewer agents have been conducted (Torizawa 2007, Ito et al. 2007); however, none of these CAs work effectively, judging by the excerpts of the conversation logs shown in the articles.

One of the main reasons for this is that they did not consider the specific features of interview conversations sufficiently. For example, an interview is a goal-oriented conversation, and is usually semi-structured. The previous IAs, however, do not contain such well-designed interview models, and simply have some key questions to present according to normal conversational rules. Also, there are many special techniques that can be used to promote interview conversations, like laddering or showing sympathy. In most cases, however, they consider only the laddering technique while ignoring the others. It is better to consider these techniques as much as possible to enable the CAs to better imitate the natural flow of an interview conversation.

Another major problem, which is common to all kinds of CAs, is that because the CAs do not understand the meaning or intention of the sentence entered as an answer by a human user, they provide unsuitable responses. It is therefore necessary to implement new techniques to reduce unsuitable responses, i.e., to deceive the human interviewee.

3 Our Approaches

To overcome the above limitations of the previous IAs, the critical decision method (Klein et al., 1989), which is one of the major CTA methods used in HF/E study, is adopted as a framework to manage the interview process and to offer a well-designed semi-structured interview. We also designed our interviewer agent as fake group interview software, consisting of two CAs and one human interviewee. One CA plays the interviewer and the other performs as a fake interviewee. For the human interviewee, therefore, it seems like a group interview where there is another interviewee, which is actually one of the CAs.

3.1 Critical Decision Method

The critical decision method (CDM) is a semi-structured interview technique that uses specific questions as so-called CDM probes to investigate the decision processes invoked by people during major or significant incidents. The CDM probes are applied according to the timeline of the important events in such incidents. We use a set of CDM probes like those presented in Table 1 to automatically generate key questions for the interview.

Table 1. Examples of CDM Probes

Category	Example
Uncertainty	Was there any uncertainty about that?
Prediction	Did any unpredictable events occur?
Timing	What kind of information was required at that time?
Attention	In that situation, where was your attention required?
Purpose	What is the purpose of that?
Alternatives	Did you have any alternative?
Obstacles, Difficulties	What were the difficulties in that situation?

3.2 Group Interview and Knowledge Awareness

We adopted a group interview style for the IA conversation. One of the reasons for this approach is that it would be easier for a human interviewee to understand the intent of a question after reading the answer provided by the CA interviewee to the same question, particularly when the question is vague or difficult to understand. Another reason is to add depth to the question by using the effects of knowledge awareness. Knowledge awareness (KA) is a concept that was proposed from the results of a collaborative learning study (Ogata et al., 1996), which helps a person to be aware of his/her own knowledge by presentation of another person's knowledge or story. In our IA, we use questions like those listed in Table 2 as KA questions, with the intent of making a human interviewee aware of his/her own knowledge and opinions and to help elicit that knowledge.

Table 2. Examples of KA questions

Item	Example
Reason	Why do you think he/she took that kind of action?
Information	What do you think was the most important information that prompted him/her to take that action?
Alternatives	If you were in the same situation, what other options would there be for actions that you could take?
Comparison	Did you take the same action as he/she did?
Reason	Why didn't you take that action?

4 System Design and Implementations

The system architecture and the mechanism used to generate the series of questions are explained in this section. This IA was designed and implemented for the Japanese language only.

4.1 System Architecture

The architecture of the IA system is illustrated in Fig. 1. The IA has a chat-type user interface shown on the right. The interview conversations are presented in the main window and the human interviewee enters his/her answer through the text window at the bottom. The database stores an interview guide, a phrase dictionary, and the conversation log. The interview guide is referred to for management of the whole interview process and is used to control the context of the interview by selecting the next appropriate question. The phrase dictionary is used at the query generation stage and provides a suitable phrase and expression for the query. The conversation log is used to create fake answers from the CA interviewee.

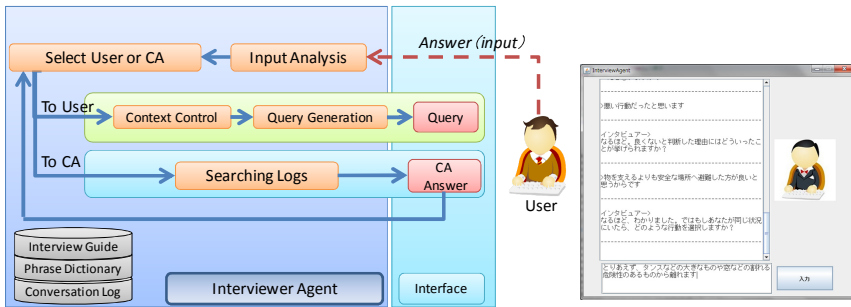


Fig. 1. System architecture

Interview Guide. The interview guide consists of a set of CDM probes and the conversational topics to be asked about with the probe questions. The topic can be defined hierarchically, which allows the structure of the interview to be determined. Fig. 3 shows an example of a question provided by the IA. In this example question, “To gather information” and “cellular phone” are the topics of the probe, where the former is placed in a higher category, and “are there any difficulties when you” is a phrase used for the probe question. The interview guide is editable for the purpose of an interview. An interview guide determines the overall flow of an interview shown in Fig.3.

情報収集の際に 携帯電話に関して、何か困ったことはありましたか？		
With regard to the <i>cellular phone</i> , are there any difficulties <i>when you gather information</i> ?		
(subtopic)	(CDM probe)	(topic)

Fig. 2. An example question (Upper: original Japanese, Lower: English translation)

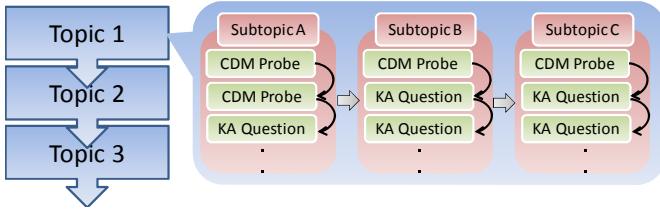


Fig. 3. Overall flow of an interview

Phrase Dictionary. Each questioning phrase in an interview conversation has a specific function, e.g., starting the conversation, exploring a subject in more depth, changing topics, or closing the conversation. The CDM probe and the KA question are also types of functions. We classified and implemented 40 different functions for the IA. We prepared several typical expressions and question templates, corresponding to each of the functions in the phrase dictionary. These expressions and the templates for the CDM probes and the KA are also stored in this dictionary. The IA selects an appropriate function based on the basic questioning graph, which is explained in section 4.2.1, in response to the previous input from the interviewee, and then picks up another expression or template at random and generates the next new question.

Conversation Log. Because this IA is a chat-type software, it is easy to record all the conversation data automatically. This record contains pairs of a question and its answer in relation to subject including its function, the target of the probe, and the input time and duration. This log is also used to generate fake responses from the CA interviewee by searching for the same function and target.

4.2 How to Form a Question

An interview starts with the IA introducing itself and asking the interviewee’s name. Then, IA generates the first question according to the interview guide and selects the first interviewee to be questioned. When the human interviewee is selected and the answer is entered, it is parsed and analyzed using natural language processing techniques to identify which cognitive process the answer refers to, from the four main cognitive processes: “information acquisition”, “situation awareness”, “decision-making”, and “action execution”. The IA then selects the next interviewee to be questioned; if the human interviewee is selected, the next question is generated according to the content of the previous answer and the basic flow of questioning. If, however, the CA interviewee is selected, the CA is provided with a similar question and then searches for an appropriate answer to the question from the database, and presents it as if the answer was given by another interviewee.

The Questioning Sequence Graph. While the overall flow of the interview is determined by the content of the interview guide, the local pattern is determined by a directed graph of the 40 questioning functions, which describe the possible sequences of questions. This graph is not a complete or a random graph, because each connection is

restricted by the meaning of the previous question, and it is sometimes conditional. We have carefully designed and implemented the graph with due consideration of such meanings and conditions, and with reference to actual human-human interviews.

5 Test Interview

We carried out an experiment to assess several functions of the IA, and compared the results with those obtained by a previous version of the IA, which has the same architecture and database, but lacks several functions that are present in the current IA. A sample interview log is presented in the Appendix. The entire interview has 102 turns; however, only 47 turns are listed because of space limitations.

5.1 Experiment

The test subjects were 14 people, 10 males and 4 females, with ages ranging from 18 to 30. The interview theme was about the experience of traveling home on March 11th 2011 during the Great East Japan Earthquake. The subjects were given an explanation of the interview with the IA and its theme. They were told to answer the questions posed by the IA with their experiences. They were also told that this was a group interview. It took about 5 min to give these instructions. Each interview lasted approximately 30 min. All interview conversations were automatically recorded and were analyzed in more depth after the interview. Subjects were asked to evaluate the quality of the IA dialogue from the 7 aspects listed in Table 3 with ratings on a 0-4 scale after the interview.

Table 3. Evaluation questions

No	Question
1	Is the overall flow of the interview natural?
2	Are the questions easy to understand?
3	Is the use of words natural?
4	Is there duplication of questions during the interview?
5	Is the conversation interactive?
6	Is the allocated time appropriate?
7	Do you want to use the IA again?

5.2 Results

Subjective Evaluation. Fig. 4 shows the results of the subjective evaluation and the differences between the current IA and the previous IA. The horizontal axis corresponds to the questions in Table 7, and the vertical axis represents the average scores of the subjective ratings. The previous IA adopted a one-on-one interview method and did not consider KA. The results for the previous IA were obtained with 9 different subjects under the same experimental conditions. The results showed that in all aspects other than No. 4, the current IA was superior to the previous IA; the most significant difference was found in the time allocation aspect (No. 6).

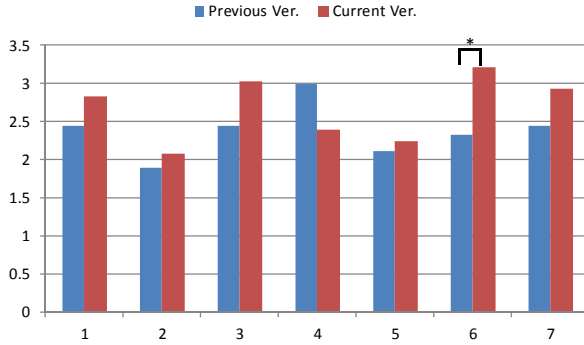


Fig. 4. Subjective evaluation of the quality of dialogue

Efficiency of Knowledge Elicitation. We analyzed the conversation logs by using a qualitative content analysis method and counted the new knowledge data and opinions that were obtained through the interview. Fig. 5 shows the results of this analysis. The bar graph on the right shows the knowledge elicitation ratio, which is the average number of new knowledge data and opinions obtained by one question. It shows that the current version was slightly better than the previous one, but was almost the same on average. We divided the logs of the test interviews into three segments and conducted the same analysis. The graph on the left shows this result; the first segment is the average ratio for the first one-third of the participants, while the second segment is the second one-third, and the third segment is the remainder. The results show that, while the efficiency decreased as we repeated interviews with the previous version, the current version maintained the efficiency over the final segments. This is not surprising because, as we repeat interviews, it will become increasingly difficult to obtain new knowledge and opinions because of the likelihood that the earlier interviewees provided them. However, the current version can provide more chances for the later interviewees to offer new information by using the KA questions with reference to the previous answers with their new knowledge and opinions. By detailed analysis, we found that it was actually this effect that improved the efficiency over the last one-third.

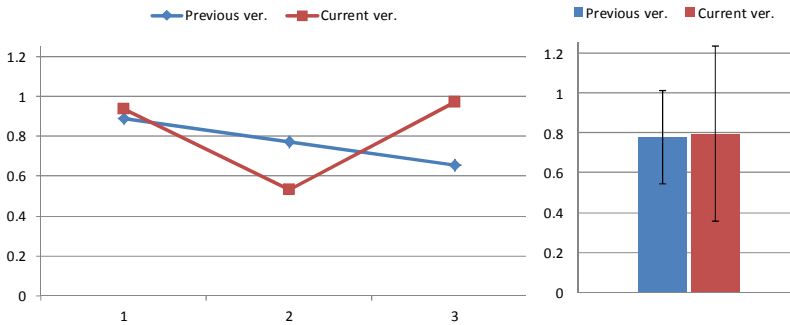


Fig. 5. Efficiency of knowledge elicitation

6 Conclusion

An IA incorporating the CDM, which is one of the major cognitive task analysis techniques, was developed. KA, which helps to elicit tacit knowledge with reference to other peoples' knowledge and opinions, was also implemented in this IA. In implementing the KA questions, we designed the interview as a fake group interview consisting of an interviewer agent, an interviewee agent, and a human interviewee. Test interviews with human subjects were conducted to assess the IA performance. The results show that the performance was slightly better in terms of both subjective evaluation and knowledge elicitation efficiency than that of the previous version, which used a one-on-one interview without considering KA. This suggests that a group interview with IA is possible and that the conversation quality does not deteriorate with the introduction of a fake interviewee agent, even though the group interview conversation became more complicated than the one-on-one interview. The results also show that KA was effective in maintaining high knowledge elicitation efficiency.

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Appendix

1	IA	はじめにお名前を教えてください/Please tell me your name.
2	U	[被験者]/[User]
3	IA	初めまして[被験者]さん,[CA]さん.インタビューさせていただき[IA]と申します.本日はよろしくお祈りします/ Nice to meet you [User] and [CA]. My name is [IA] and I am today's interviewer.
4	IA	[CA] さんに質問します.地震直後の安全の確保に関して,印象に残っていることを教えてください/I'd like to ask you [CA] about the most memorable thing when you secured your own safety after the earthquake.
5	CA	地震発生時は家にいたのですが,棚の上のものが落ちないように支えていました./I was at home at that time, and was holding a shelf so that the objects on it would not fall off.
6	IA	なるほど,わかりました.少し話は変わりますが,今までいろんな方が物の落下について話されたのですが, [CA]さんも印象に残っていますか/Hmmm, I understand. By the way, many people have mentioned falling objects. Did you also experience this [CA]?
7	CA	はい.全てのものは支えきれず,いくつか物が落下しました/Yes. I couldn't hold everything and some objects fell.
8	IA	なるほど.そのとき,利用した知識は正確なものだったと思いますか/Well, was your knowledge useful at the time?
9	CA	本当は物を支えるのではなく物の落下のないところに避難するべきだったと思います/Instead of holding the shelf, I think it would have been better to move to a safe place where things were not falling down.
10	IA	なるほど,わかりました.そのとき,優先的に収集した情報は何でしょうか/I understand. What kind of infor- mation did you preferentially gather at that time?
11	CA	地震の発生場所と規模です/The epicenter and its scale.
12	IA	参考になりました.ありがとうございます/That was very useful, thank you.
13	IA	[被験者] さんに質問です.[CA]さんが述べた物の落下に関する行動ですが,[被験者名]さんは「良い」行 動だったと思いますか?それとも「悪い」行動だったと思いますか/Now I'd like to ask [User] some ques- tions. With regard to [CA]'s reaction to the falling objects, do you think his reaction was good or bad?
14	U	悪い行動だったと思います/I think it was bad.
15	IA	なるほど.既に述べられていること以外で,どのようなことがこの行動を取る原因になったと思いますか/In that case, what else do you think was his reason for taking that action?
16	U	地震を甘く見てしまったことが原因だったと思います/I guess he underestimated the danger of the earth- quake.
17	IA	わかりました.ではもしあなたが同じ状況にいたら,どのような行動を選択しますか/Well, if you were in the same situation, what other options would you take?
18	U	とにかく避難経路を確保して,机の下などにもぐります/ I would maintain an escape route in any case, and hide under the desk.
19	IA	なるほど.どういった理由でその行動を選択したのでしょうか/Hmmm. Why would you take those actions?
20	U	身の安全の確保を最優先すべきだと思うからです/Because I thought that securing my own safety was the first priority.
21	IA	わかりました.ありがとうございます/I understand. Thank you.
22	IA	地震直後の安全の確保に関して[CA]さんに質問したいのですが,そのことについて印象に残っていること を教えてくださいいただけますか?/I'd like to ask you [CA] about securing your own safety after the earthquake. Could you tell me what you remember about that?
23	CA	周りに倒れてくるものがないか確認しました/I confirmed whether or not there was anything falling down.
24	IA	わかりました.それはどうしてですか/Well, what was the reason for that?

25	CA	怪我をしたくないからです/Because I did not want to get hurt.
26	IA	怪我をしたくないからです/I understand.
27	IA	続いて[被験者]さんにお伺いします。地震直後の安全の確保に関して、他に印象に残っていることや苦労したことにはどんなことがありますか/Next, I will ask you [User]. With regard to securing your own safety after the earthquake, could you tell me what else was important or troublesome?
28	U	料理の途中だったので、すぐに火を消しました/I was cooking at that time, so I turned off the burner.
29	IA	なるほど、それでどうされたんでしょうか/Well then, what did you do next?
30	U	その他に火事の原因になるものが無いことを確認しました/I checked whether or not there were any other sources of fire.
31	IA	わかりました。ありがとうございます/I understand. Thank you.
32	IA	他に地震直後の安全の確保について[被験者]さんからお話しただけのことはありませんか/Do you [User] have anything else to tell us about securing your own safety after the earthquake?
33	U	ありません/No.
34	IA	このあたりで次の「安否や被災情報の収集」の話題に移らせていただきます/I would now like to move on to the next topic, which is gathering information about the disaster and the safety of other people.
35	IA	安否や被災情報の収集に関して[CA]さんに質問したいのですが、そのことについて印象に残っていることを教えていただけますか/I'd like to ask you [CA] about gathering information on the disaster and the safety of other people. Do you have something important to tell us about that?
36	CA	私は携帯からネットを使って調べました/I got information through the Internet by using my cellular phone.
37	IA	うーん、なるほど、どんなことがあったか、覚えてる範囲でかまいませんので教えて頂けますか/Oh. Please tell me what happened as you remember it.
38	CA	ダメもとでネットに接続してみたら使えたので地震速報のサイトで情報を集めたり、交通機関を調べたりしました/I thought it was worth a try and found that the service was available, so I collected information from a news website and searched for information about public transportation.
39	IA	わかりました。ありがとうございます/I understand, thank you.
40	IA	[被験者]さんに質問です。[被験者]さんは被災情報の収集に関して、[CA]さんと同じような行動を取りましたか/I will now ask you [User]. Did you take similar action to that of [CA] to get information about the disaster?
41	U	私はパソコンの電源を付けていたので、インターネットで情報収集しました/I was using a PC, so I gathered information from the Internet.
42	IA	そうだったんですか。[被験者]さんはどういった理由でその行動を選択しましたか/That is interesting. What was the reason for selecting that action?
43	U	パソコンの方が情報が見やすいし、携帯よりもつながりやすいと思ったからです/I thought it would be easier to see the information on the PC and would be easier to get connected.
44	IA	なるほど。同じ状況の時、選択する可能性がある行動にはどのようなものがありましたか/Yes. Did you have any other possible options in that situation?
45	U	“CA”さんと同様に携帯を使うことです/Using a cellular phone like “CA” did.
46	IA	わかりました。その行動はどういった理由で選択肢のひとつとして挙がったのでしょうか/I understand. Why do you think that this was one of the options?
47	U	情報収集として普段一番使っているツールだからです/Because we usually use cellular phones to search for information.

A Method to Evaluate Disabled User Interaction: A Case Study with Down Syndrome Children

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Abstract. Testing products with representative users is a key factor for user-centered design. When such representative users are disabled children the user testing process becomes a challenge and in this case evaluation methods based on heuristics and inspection could not attend the final user needs. The major purpose of our research is to provide an evaluation method that could measure disabled children interaction. This work first discusses the development of the coding scheme based on the detailed video analysis method which was adapted to observe interaction of children with Down syndrome. After that we demonstrate the method reliability by applying the Cohen's kappa coefficient and the any-two agreement measure. Finally we discuss how this method could be used to evaluate usability and fun problems.

Keywords: Usability game evaluation, children interaction, down-syndrome.

1 Introduction

Recently the concern with the development of people with special needs and their inclusion in society has grown. The first step to make this possible is to provide children with special needs ways of stimulus that are pleasant and efficient at the same time. One way to combine these two features is through digital games that stimulate most of the speech, comprehension, attention, perception and other factors needed for a good social life.

The learning process of children with Down syndrome occurs at a slower rate compared to other children of the same age, for this reason they take longer to learn how to read, write, do math, among other tasks. [5] Moreover, these children are more likely to have more interaction problems that must be taken into account when someone proposes to develop some kind of software for this specific audience. In this case, evaluation methods of interaction based on inspection and heuristics cannot meet this need since they do not involve the end user.

Due to the specific needs of children with Down syndrome, evaluators may not predict usability and fun problems and when computer games are evaluated it is important to fix both. In spite of that, there is no coding scheme of behavior that indicates these problems in computer games for children with any kind of special need. In this way, this article proposes a new coding scheme to detect usability and fun

problems in games developed for children with Down syndrome. The method is based on a list of breakdown indication types to evaluate children's computer games [2]. Nevertheless, the definitions of existing breakdown indications probably need to be changed, new breakdown indications need to be added, and some indications have to be removed. The article starts with a brief introduction to the method created by Barendregt and Bekker [2] and then immediately describes the changes made to adapt it to children with Down syndrome. After that, it will be described how user interaction was captured, application of the method and also the results that prove the reliability of the method. Finally, the article discusses the results for reliability of the method and also how this method could be combined with other in order to better study the fun criterion.

2 DEVAN

DEVAN [5] is a tool for detailed videos analysis of user test data. It makes use of a table format for representing an interaction at multiple levels of abstraction.

DEVAN method was originally designed to detect usability problems in products targeted at adults and it was adapted by Barendregt and Bekker [2] to assess usability and fun problems in games targeted at children.

2.1 DEVAN Adapted for Children

Based on the list of breakdown indications of the DEVAN method [5], Barendregt and Bekker [2] presented a new list of breakdown indications that reflects the behavior observed in children when they indicate problems of fun and usability.

Despite the fact that the DEVAN method was developed to detect usability problems in task-based products for adults, for the new method [2] it was chosen not to use explicit tasks. The goals set by the tasks may interfere with the goals provided by the game, because children feel obligated to fulfill the tasks and also to achieve the goals of the game [13].

To enable detection of fun problems, the taxonomy defined by Malone and Lepper in 1987 [12] was explored. This taxonomy consists of four main heuristics: challenge, fantasy, curiosity and control. From each heuristic the following indications were added to the list: *help*, *bored*, *impatience* and *dislike*.

Moreover, in [2] Barendregt and Bekker observed the need to include other breakdown indications. Usually, games with texts that are difficult to read or with complex verbal explanations generate attention problems, so the breakdown indication *perception problem* was added. Sometimes children remain passive when an action is expected because they don't know how to proceed. To represent these situations *passivity* was included.

Finally, the indication *wrong action* has been added to include situations in which the child does not understand how the game works properly and when asked about a particular action, the answer is not correct.

2.2 Adaptations in the Coding Scheme

In order to meet the need of evaluating digital games for children with Down syndrome, it was necessary to remove, add or redefine meanings of some information contained in the list of previous work [2].

Removed Breakdown Indications. Basically children who have Down syndrome have more difficulty expressing themselves verbally. In [2] there were breakdown indications which were only based on verbal explanations. In this work it could be difficult to observe these and probably its frequency would be very low. Because of that the following breakdown indications were removed: wrong goal, wrong explanation, recognition, ‘doubt, surprise and frustration’.

Maintained Breakdown Indications. Six breakdown indications from [2] were maintained with no changes in their definition. The indications and reasons for keeping them are presented below. *Wrong action* was kept on the list because it can be observed when a child clicks on a non-clickable area or performs an action that was not expected at that moment. The difficulty of interacting with a physical game device is characterized by the indication *execution problems*.

If the game responds slowly, or if the user fails to perform some type of command in the game, the indication *impatience* appears when the user repeatedly click on a button or make more abrupt movements in an attempt to do something work or get a faster response. Games for children with special needs should also entertain their users and propose challenges. But when the challenge proposed is very easy and does not interest the child to continue playing, certainly the indication *subgame stopped* will be noticed. When the game fails to stimulate the user's curiosity, the child begins to yawns and sighs which are a clear demonstration of the indication *bored*. The game interface should be able to drive the user in a simple and efficient way, if this does not happen, interaction problems can occur and the user can get confused, pointing the indication *puzzled*.

Modified Breakdown Indications. Five breakdown indications from [2] were maintained but had their definitions changed. As previously mentioned children with Down syndrome have difficulty to verbalize their feelings and thoughts, for this reason the need of verbalization was removed from the definition of indications: *perception problem* and *random actions*.

Difficult to achieve goals, hinder the child to proceed without the intervention of a mediator. Mediators often help children with Down syndrome when they realize that the child cannot proceed, i.e. without a verbal request, thereby avoiding serious problems. *Help* also had its definition changed, again precluding the need for verbalization. If the fantasy provided by the game is too childish or too scary the child may express *dislike*, which can be observed only through facial expressions.

If the child does not know how to perform some action he or she tends to be *passive* just staring at the computer screen. But there are other reasons that could cause the child to have that reaction, for example, he or she did not want to perform an activity because it is difficult or boring, or even by lack of stimulus.

New Breakdown Indication. During an interaction session it was observed that one child performed a wrong action just to enjoy the reaction of a character. Such behavior did not fit perfectly into *wrong action* indication, appearing then the need to insert an indication of *intentional wrong action*. In this action the child knows that it is not the correct action, but he or she is still doing it only for the purpose of fun.

3 Capturing the User Interaction

Our study case is based on the user interaction with JECRIPE – a game that has a purpose of stimulating preschool children with Down syndrome [1]. Four children with Down syndrome, aged between 6 and 12 years (mean = 9 years), joined the group of users (Figure 1). None of the children had experienced JECRIPE before and was chosen not to use explicit tasks. From the interaction session we obtained a video of approximately 20 minutes containing interactions of children with the three game scenarios (Figures 2 (b), (c) and (d)). Ethical procedures regarding the user participation in the video was also performed.



Fig. 1. Capturing the user interaction in a video recording

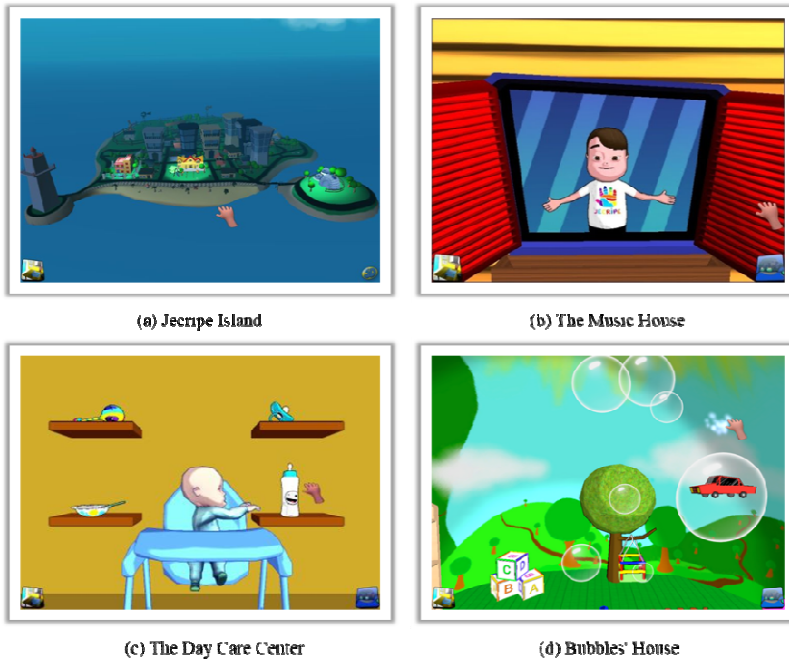


Fig. 2. JECRIPE interactive scenarios

4 Coding the User Interaction

To encode the video, we invited eleven students from the Human Computer Interface class that had little or no experience in such evaluations. They were divided into 4 groups. The training session consisted of a 30 minute presentation in which videos exemplifying the codes to be used were shown (see Appendix).

Evaluators were instructed to observe the occurrence of problems and to examine whether these problems characterized some of the indications present in the table. Each interaction problem detected and the corresponding code should be noted the instant of its occurrence. The average time for analysis and coding was approximately 43 minutes.

5 Results of the Method Reliability

It is most unlikely that different evaluators will agree exactly, by giving the identical result for all evaluation sessions. The any-two agreement method measures the extent of agreement on what problems the system contains for pairs of evaluators [3]. For each comparison the number of agreements, disagreements and single points were recorded, always considering the margin of 4 seconds to be counted as the same observation point (see Figure 3).

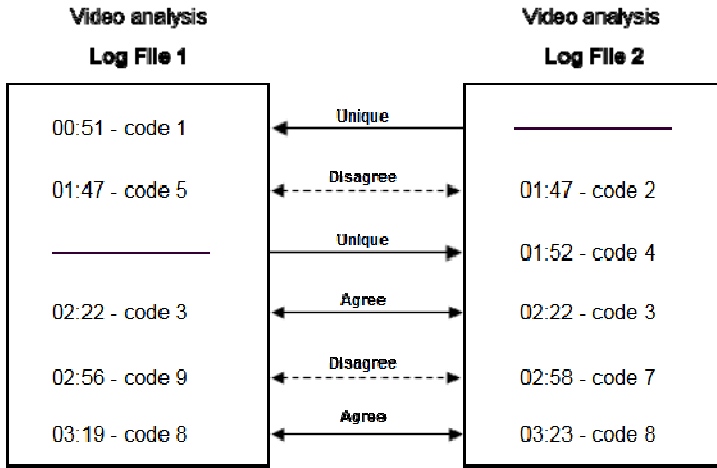


Fig. 3. Video coding analysis

The results of the comparisons for each pair of evaluations are shown in Table 1. The average score was 44%, exceeding the average of 38.5% obtained in [2]. The number of single points was the factor that affected most negatively the percentage obtained. It happened mainly due to the fact that some groups of evaluators noted long intervals while others noted small intervals for the same interaction problem observed. The points of disagreement were investigated in order to determine the indications that generated more conflicts.

The codes *wrong action* and *execution problems* were the most confusing. In the video analyzed, children often could not perform an action especially because of the difficulty in handling the mouse and on situations like that a group classified it as *wrong action* and another as *execution problems*. This divergence in classification may have occurred because the evaluators may have interpreted differently the definitions of the codes or they had different focuses on that moment. For example, while one group was more attentive to perform the sequence of actions in the game, the other watched not only the realization of the actions but also the interaction with the physical devices, in this case the mouse, the game.

Table 1. Results for each any-two comparison

Evaluation A x Evaluation B	Any-Two (%)	Agreements	Disagreements	Unique A	Unique B
Evaluation 1 x Evaluation 2	49	39	4	29	7
Evaluation 1 x Evaluation 3	47	49	7	18	31
Evaluation 1 x Evaluation 4	44	38	17	19	12
Evaluation 2 x Evaluation 3	39	36	7	6	44
Evaluation 2 x Evaluation 4	45	33	7	9	25
Evaluation 3 x Evaluation 4	41	40	16	30	12

Another index used to measure the method consistency was the Cohen's Kappa [4], for interpreting the result the following guideline was used [11]:

- Less than 40% = low agreement.
- Between 40% and 60% = average agreement.
- Between 60% and 75% = good agreement.
- More than 75% = excellent or perfect agreement.

For that purpose two new evaluators received the same training session described before and a list of observation points for which they individually had to pick a code.

This list was created by taking the list of all four groups of evaluators in the first evaluation. When at least three of the four groups of evaluators in the first experiment agreed on an observation point (but not necessarily on the code), it was included in the list of observation points, resulting in a list of 47 fixed observation points. Of all the 47 points contained in the list, 30 were also encoded in both assessments, producing a concordance of approximately 64%. Sometimes it was noted that the discrepancy occurred due to the priority order, e.g. an evaluator puts a code as the most important while the other placed it as the second.

Table 2 shows a comparison between the percentages achieved in any-two agreement and also Cohen's kappa for this work and [2]. It is important to emphasize that the evaluators considered in this study for the validation of Cohen's Kappa have different levels of experience in usability evaluation (one without experience and the other an experienced evaluator) and they encoded a list of 47 points. Whereas the evaluators in [2] codified a list of 26 points.

Table 2. Comparison between the results of the two methods

	<i>Any-two agreement</i>		<i>Cohen's Kappa</i>	
	Percentage	Number of evaluators	Percentage	Fixed Points
Barendregt & Bekker (2006)	38.5%	4	92%	26
This work	44%	11 (divided into 4 groups)	64%	47

6 Final Considerations

Finally we conclude that such adaptations performed in the DEVAN method were suitable to evaluate interaction of children with Down syndrome.

Two measures have been implemented to verify the reliability of the method. Four groups of evaluators participated in the first measure used as part of the validation of the method, and then two new evaluators collaborated to compute the second measure. The result for each measure was satisfactory and the combination of these proves the reliability of the method.

Note that due to lack of experience of evaluators who participated in the first step of method validation (any-two agreement), it can be stated that the method has an easy application that its indications and definitions are clear. Based on the result of Cohen's Kappa (64% agreement) that included the participation of evaluators with

distinct experience levels, we can assume that even inexperienced evaluators will be able to apply the method after receiving an appropriate training. However both assumptions need to be further investigated.

As future work, we could combine the method with other previous investigations in which the user informs more directly how much fun he had playing the game. For example, by using the Smileyometer [9] it would be possible to verify the impact caused by the fault of the game as the criterion of enjoyment reported by the user as well as where the indications of the DEVAN method, are appropriate and effective to evaluate the fun criterion.

Based on the statement made by [10] that children between 7 and 8 years of age are able to understand and distinguish the concepts of usability, fun and potential for learning, we believe that the methods reported by [9] may also be suitable for children of the same age range of the participants in this study, because the methods are not composed of complex questionnaires and they are also easy to apply.

Besides that we intend to extend this method to estimate users interactions with others kinds of disabilities and also link the detected usability problems with appropriate design guidelines as those pointed by [8].

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Appendix

DEVAN Method for children with Down syndrome.

Code	Description	Definition
Breakdown Indication Types Based on Observed Actions with the game		
ACE	Wrong Action	An action does not belong in the correct sequence of actions. An action is omitted from the sequence. An action within a sequence is replaced by another action. Actions within the sequence are performed in reversed order. The user performs a wrong action unintentionally.
ACP	Intentional wrong action	The user knows that the action is wrong, but still performs this action only to have fun.
AJU	Help	The user cannot proceed without help or the researcher has to intervene in order to prevent serious problems. The user is helped to do some action.
ANT	Dislike	The user indicates disliking something.
CON	Puzzled	The user indicates not knowing how to proceed.
IMP	Impatience	The user shows impatience by clicking repeatedly on objects that respond slowly, or when it takes too much time to reach the desired goal.
PAS	Passive	The user stops playing and does not perform the expected action.
PEX	Execution Problems	The user has physical problems during interaction with the game. The user has motor skill problem.
PPR	Perception Problem	The user indicates not being able to hear or see something clearly, not understanding how to proceed.
RAN	Random actions	The user performs random actions.
STP	Subgame stopped	The user stops the subgame before reaching the goal.
TED	Bored	The user indicates being bored by sighing or yawning.

Prototype of a Virtual User Modeling Software Framework for Inclusive Design of Consumer Products and User Interfaces

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Abstract. The recent developments in technology inspire designers and engineers in creating more and more sophisticated and smart consumer products. However, the most ingenious device in the world will fail, if its users are not able to access the mastermind it provides. How can we best support product creators in the thorny task of inclusive design? In this paper a prototypic realization of a virtual user modeling framework to support designers in creating more inclusive products following the phase-based product development process is presented. A qualitative usability survey evaluated the acceptance of the proposed end-user applications among designers and the effectiveness of the recommendations-driven support – the paper provides insights.

Keywords: Virtual user modeling, digital human model, recommendations-driven design support, virtual usage simulation, user experience, inclusive product design.

1 Introduction

In this day and edge of rapid technological progress and growing economic competition, a lot of industrial effort is put into resource optimization. This can lead to a deterioration of product quality, in particular, as a result of failing to access diverse user requirements and to understanding user abilities and habits.

In this paper we describe a realization of a model-based approach that aims to involve the user's perspective at early phases of the design process. A detailed description of the proposed concept is provided in [1] and [2]. The product designer is therefore supported by appointed software tools throughout the three design phases: the sketch phase, the CAD design and the virtual evaluation phases. The supportive tools are connected to a *Virtual User Model (VUM)* that contains knowledge related to the product usage in the form of models of such entities like user, environment, product component, task, design recommendation and their interrelationships. The form of the support provided by the system depends on the stage of the design process.

The aim is to provide the industry with a cost efficient way to integrate inclusive design know-how into the existing workflow. We would like to emphasize at this point that the proposed concept does not suggest to replace involving human users into ergonomics evaluation. However, the hypothesis, that it is capable of focusing the development according to the principles of inclusive design and in preventing major design mistakes, has been confirmed by the results of the end-user¹ evaluation. For product manufacturers who still could not commit to the time and cost-intensive product evaluation with real users as an integrated part of their development process, the method can provide a possibility to benefit from inclusive design at least virtually. This might represent a first step towards an overall design improvement.

The concept has been realized in the form of a prototypic virtual user modeling software framework. Hereby inclusive design support has been focused on elderly people with mild to moderate physical and sensory impairments. End-user interfaces of the three supportive applications have been qualitatively evaluated with designers.

After an overview of related work, we describe the main principle, which drives the design support, namely the design recommendations. We then describe the implemented framework prototype, the end-user evaluation and its results. We conclude with a discussion of the key benefits and limitations of the approach we identified as a result of the user studies and our personal experiences.

2 Related Work

User modeling has been an active research topic for more than four decades. Since the beginnings of the 1970s many dedicated and general user modeling systems have been developed to enable user-adaptation in different domains [3], [4], [5].

In the last decade the simulation of virtual humans has been identified as a powerful approach to support engineers in the product development process. Virtual human modeling reduces the need for the production of real prototypes and can even make it obsolete [6]. During recent years, the research interest in using digital human modeling for ergonomics purposes has increased significantly [7]. The use of virtual humans and simulation in the automotive industry showed also great potential. Porter et al. [8] present a summary of applications of digital human models in vehicle ergonomics during the early years of personal computers.

Existing available tools and frameworks provide designers with the means for creating virtual humans with different capabilities and use them for simulation purposes. DANCE [9], for instance, is an open framework for computer animation research focusing on the development of simulations and dynamic controllers. SimTk's OpenSim² is also a freely available, user extensible software system that lets users develop models of musculoskeletal structures and create dynamic simulations of

¹ In the following the *end-users* refer to designers. The designers are the end-users of the proposed supportive system.

² <https://simtk.org/home/opensim>

movement. There are also many commercial tools such as JACK³, RAMSIS⁴, Any-Body⁵ and Santos⁶, offering considerable benefits to designers looking to evaluate their designs, as they allow the evaluation of a virtual prototype using virtual users with specific abilities. These tools are mainly based on anthropometric data sets based on measurements taken from healthy and the able-bodied groups.

Even though significant effort has been put into physical user modeling and many tools have been developed using virtual humans for simulation purposes, very little effort has been made to incorporate data for users with impairments or functional limitations, such as older users and users with disabilities. The present paper aims to demonstrate the approach, proposed and realized by VICON project, towards the design and evaluation of consumer products using the VICON simulation model considering the characteristics of older people.

3 Design Recommendations

Design recommendations play a key role in the proposed method for inclusive design support. Several research projects collect and classify guidelines for designers of ICT. The guidelines include advice and recommendations on accessibility issues for all types of disabilities [10]. A number of research projects make the guidelines, they have developed, publicly available online. See e.g. cariac-eu project website⁷. Published international standards, e.g. ISO Guide 71 [12] or CEN Guide 6 [13], provide basis for identifying design recommendations as well.

In terms of our approach, the available design recommendations have been collected and integrated into the VUM as a logical mechanism for relating the different entities of the usage context model to each other. To give a simple example, the recommendation “Avoid the use of glossy material to improve readability” [11] relates the following properties of the entities: user’s sensitivity to glare, environment’s lighting level and the presence of direct light sources as well as surface glossiness of a product’s component. The relation is expressed in form of a logic rule.

The recommendations usually contain qualitative information about the usage aspects, however there is an increasing number of recommendations available, which provide quantitative relational information, based on statistics and measurements. In our framework we differentiate between two types of recommendations:

- Informative (or qualitative) recommendations
- Quantitative recommendations

The framework intends to provide designers with recommendations-driven support throughout the three product development phases. The next section describes how it is realized in software architecture.

³ http://www.plm.automation.siemens.com/en_us/products/tecnomatix

⁴ http://www.human-solutions.com/automotive/products_r_auto_en.php

⁵ <http://www.anybodytech.com/>

⁶ <http://www.santoshumaninc.com/>

⁷ See <http://www.cardiac-eu.org/>

4 Framework Prototype

The system has been designed according to the requirements that have been identified for the industrial phase-based product development process. In the following the emerged workflow model and the system architecture are described.

4.1 Workflow Model

Fig. 1 presents all impact areas of the framework by means of the three applications that are used in each phase. For more detailed review, see [16], [17].

Sketch Application. Product development process can be seen as a sequence of phases [14]. Starting in a sketch of a rough idea, the product design is sequentially refined to a number of detailed two-dimensional sketches, showing the product from different perspectives. During this sketch phase, there is a big diversity of tools used by designers. Thus, the prototypic application for support of the design activities at this phase is a standalone application, i.e. independent from any particular sketching tool. Moreover, it can be easily extended to a web-interface.

The Sketch Application provides the designer with design recommendations for a given type of the target product. Selecting a target user profile, an environment profile and a task via the UI of the application enables filtering of the identified recommendations. The selection can be stored for the later use.

CAD Design Application. Based on a created sketch, 3d virtual prototype of the product is then created. In this phase different software solutions for CAD design such as CATIA or Siemens NX [4] can be applied.

Siemens NX is widely used in the industry. The CAD Design Application has been integrated into it. During the creation of a product prototype in CAD, designer can access the recommendations directly within the CAD environment. Moreover, by importing the data from the sketch phase, the predefined usage context is then accessible.

Now the product can be annotated, i.e. additional product descriptive information that is not contained in the geometrical 3d surface representation can be assigned to the parts of the product model. The product annotation assigns both kinds of information: semantic, e.g. “this product part is a button”, and non-semantic, e.g. color or label size. As soon as the product model is annotated, the designer can constrain the filtering of recommendations by selecting specific product parts, so the presented recommendations will refer only to the selected component. Furthermore, quantitative recommendations can be applied to the selected component, in case the measured properties of the component do not meet the recommended values. Annotated product model can then be virtually evaluated.

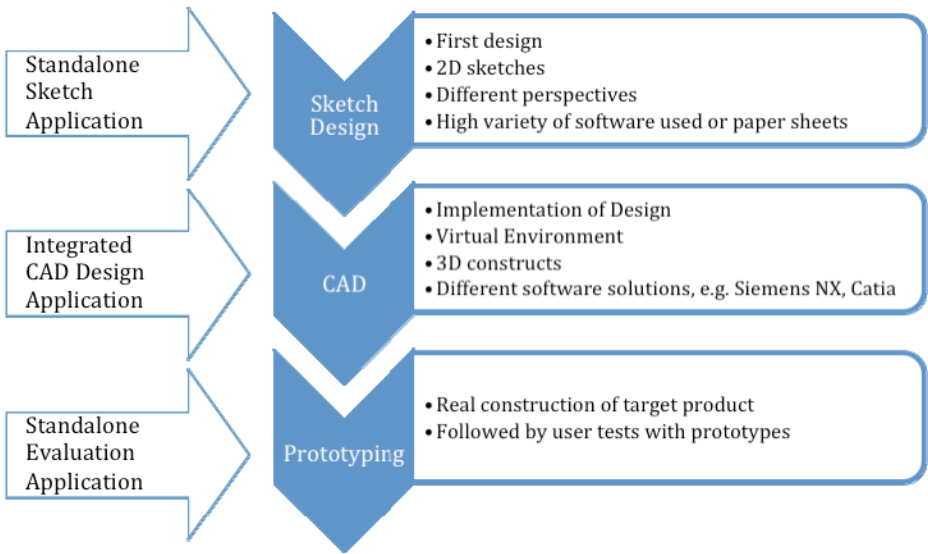


Fig. 1. Phase-based product development workflow (top-down directed arrows in the center) and key characteristics of each design phase (right). For each of the virtual user modeling framework application a target impact phase is depicted (left arrows).

Virtex – the Evaluation Application. Virtex stands for virtual experience. It is a virtual usage simulation platform that enables a designer to test the 3d product prototype virtually by running a set of different task simulations for a selected user and environment. The usage simulation is performed in real-time and is visualized in a virtual 3d environment. Hereby the user has the possibility to run the simulation for different usage context configurations. As confirmed by results of the end-user evaluation, that can help in dealing with changing requirements and provide more flexibility for the use.

Likewise the sketch and CAD design support tools, the product evaluation is driven by recommendations. However, only quantitative recommendations can trigger the system to report potential usage difficulties for a product component. Since informative recommendations do not provide measurable relationships between the component and the usage context, no evidence can be provided whether they are met or not by the product design. Hence an informative recommendation is then reported in the form of a warning, as soon as the recommendation applies to the usage context.

After each simulated task a detailed text report is shown to the designer. The evaluation results report follows the structure of a particular task.

4.2 Framework Architecture

The framework is designed following the service-oriented architecture (SOA) paradigm. The framework offers a number of services – each of them is part of one of the three subsystem tiers: front end, middleware and back end. Fig. 2 presents the software architecture of the framework. The VICON project deliverables [16], [18] describe the architecture in more detail.

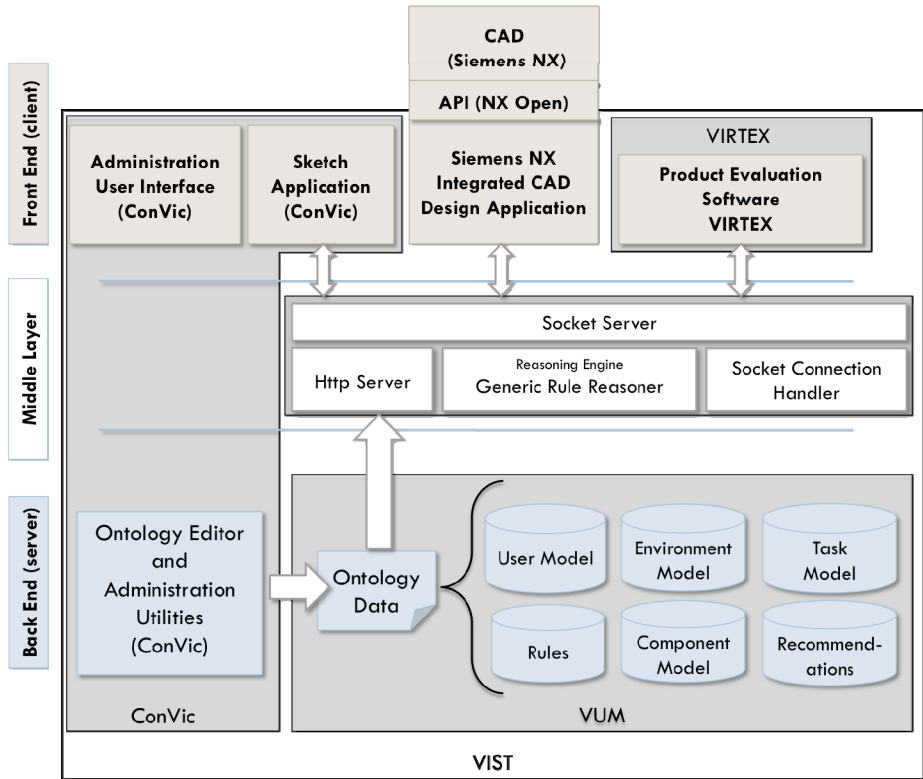


Fig. 2. The three-tier architecture of the virtual user modeling framework called VICON Inclusive design Support Toolset (VIST). The VIST is designed following the service-oriented architecture (SOA) paradigm. The framework offers a number of services, which can be dedicated to three subsystem layers: front end layer, middleware layer and back end layer. The Virtual User Model (VUM) defines the software part, which deals with all ontology data and references, and is used in the back end. The subsystem ConVic provides the configuration center for VIST supporting VUM editing. It also includes the Sketch Application. VIRTEX, the evaluation part of the framework, deals with virtual ergonomic tests using already existing 3d product prototypes and its meta-data coming from the CAD Design phase.

Front End Services. In addition to the services provided by the Sketch, CAD Design and the Evaluation applications, the front end includes the Administration UI. Via this interface a user with administration privileges can access the data stored in the VUM and edit it.

Middleware Services. The middleware services manage the connection between the different front end applications and the ontology data.

Back End Services. Depending on the type of request the back end provides different types of ontology data. In particular it provides the recommendations specific to the service for each of the three phases. For the evaluation application the results of the accessibility tests, which are encapsulated in the recommendations, are provided.

5 End-User Evaluation

The end-user evaluation of the virtual user modeling software prototype has been conducted qualitatively with maximum nine designers. Hereby two questionnaires have been prepared. The questionnaires were designed based on the ISO Norm 9241-110. For detailed evaluation results please refer to [19].

Overall, all designers responded to the workflow proposed by the framework as to a clear and straightforward. The knowledge provided by the recommendations and the references to the appropriate literature were very appreciated. We can say that the concept of such inclusive design support has been generally well accepted. However, some critics regarding the look & feel of the applications have been expressed, and minor usability issues.

The designers in the role of end-users of a system, are not only very sensitive to the system's graphic design, but also have learned specific software they use every day, i.e. they are also used to certain look & feel of their tools. In the case of the framework presented in this paper, no designer were actually actively involved in the design of the application's user interfaces. The feedback regarding the visual appearance of the interfaces suggests that it is indispensable to hire designers for graphic and interaction design of a tool that designers should use.

6 Conclusions and Outlook

In this paper we presented a virtual user modeling framework for the evaluation of virtual prototypes of consumer products throughout the entire design cycle beginning by the sketch, the design and the simulation phase. We presented the architecture of the framework and depicted its components and the workflow approach. We then evaluated the impact upon product development process with different impact strategies and implementations for each phase. We then presented the end-user evaluation process, which provided many encouraging results and entailed many points, which should be considered in future developments e.g.:

- The guidelines leading to recommendations should be added to the system seamlessly
- Quantitative vs. Qualitative recommendations should be studied in more detail under consideration of the needs of designers
- The presented approach did not consider the cognitive abilities in its user model. This lead to independent virtual user modalities. The addition of cognition to the model may lead to improvement of the recommendations and this will need to be resolved before the system truly mimics human-product interaction.

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Inclusive Design and the Bottom Line: How Can Its Value Be Proven to Decision Makers?

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Abstract. Designing technology products that embrace the needs and capabilities of heterogeneous users leads not only to increased customer satisfaction and enhanced corporate social responsibility, but also better market penetration. Yet, achieving inclusion in today's pressured and fast-moving markets is not straight-forward. For a time, inaccessible and unusable design was solely seen as the fault of designers and a whole line of research was dedicated to pinpointing their frailties. More recently, it has become progressively more recognised that it is not necessarily designers' lack of awareness, or unwillingness, that results in sub-optimal design, but rather there are multi-faceted organisational factors at play that seldom provide an adequate environment in which inclusive products could be designed. Through literature review, a detailed audit of inclusivity practice in a large global company and ongoing research regarding quantification of cost-effectiveness of inclusive design, this paper discusses the overarching operational problems that prevent organisations from developing optimally inclusive products and offers best-practice principles for the future.

Keywords: Inclusive Design, Cost-Benefit Model, Principles for Change.

1 Introduction

Over the last decade, inclusive design has increasingly gained prominence as a design approach that intends to expand the boundaries of product usage to the greatest extent possible. Today's fast-paced and short cycles of technological innovation give people little time to become cognisant of the latest technological devices and effectively utilise them in daily lives [19]. That, coupled with the unprecedented ageing of the world population [29] and the related increase in various ailments [31], makes the inclusive design approach even more valid than ever. Accordingly, the current 'we act despite the data' approach of many companies is no longer supported in the modern information-savvy age where evidence-based reasoning is key to informed decision making by industry and government. Hence, the responsibility is now on companies to support their designers and engineers in developing products and services that

could support today's rapidly changing population and the sustainability of the modern world.

The strong financial case for inclusive design, demonstrated by the commercial success of mainstream products, such as the OXO Good Grips line of kitchen and garden tools, the BT Big Button and Freestyle phones and the Ford Focus, indicates that the effort and cost investments involved in its application will be largely compensated for in the longer-term [14, 15]. For example, Karat [14] delineates a \$10 return on investment for every dollar spent on usability.

However, as has been shown by various studies on the uptake of inclusive design in industry [8, 9, 12], moving from an aspiration to designing inclusive products to the actual delivery of them in today's challenging markets is not straight-forward. Building on over a decade of research on the uptake of inclusive design in industry, through a detailed audit of inclusivity practice in a global engineering and communications company and a preliminary study on 'cost-benefit' modelling, this paper:

1. explores the operational challenges that consumer organisations face in their ambition to be truly inclusive;
2. offers best-practice principles for change;
3. demonstrates how cost-benefit modelling could help organisations understand the effect that the inclusive design approach can have on their profit margins (i.e. it can lead to faster delivery to market, reduced costs related to rework, support calls and product returns, and potentially higher revenues as a result of faster market presence and increased uptake of a more intuitive and satisfying product or service).

The act of designing (inclusively) is not just limited to the will of designers, but is primarily influenced by the complexity of the environment in which the design process takes place [1, 25]. In particular, as shown herein, it requires five key elements:

1. *Users* placed at the heart of every design decision;
2. *People* with authority;
3. a highly-optimised *Process*;
4. a well-executed *Practice*;
5. adequate *Profit* related projections.

When placed together, these core themes can work holistically to ensure that the correct *People* with authority are included in the design process, the most optimal and effective *Process* is laid out, best *Practice* is followed and ultimately that *Users* are satisfied with their product. *Practice*-related decisions and *User* satisfaction with the resultant product, in turn, have complicated interdependencies with one another, as well as the *Profit* element, via various direct and indirect channels.

Overall, this paper proposes that engineering a product in line with these five elements can lead to substantial cost and time savings in terms of project delivery and rework, higher quality products, more satisfied users, socially sustainable products and increased customer loyalty and advocacy.

2 Lessons from the Past

The process of learning to understand users and their experiences, particularly in an industrial context, requires commitment and a structured investment of time [32], and “a reward structure that motivates attention to usability” [1]. In response, Keates and Clarkson [15] have shown that the effort and time investments put into inclusive design early on and throughout the design cycle will pay dividends in the long-term.

Previous studies [8, 9, 12] have also examined the uptake of the ethos and practice of inclusive design in industry, describing both existing success stories and barriers to adoption. They found poor fit between the structure of many inclusivity support tools (i.e. they can be inaccessible and visually unstimulating) and the ways in which designers think and work, as well as poor awareness within senior and middle-management levels, and limited communication across the company and clients. Another study [20] has also uncovered that designers are given little chance and support to focus on inclusion because of cost and time restrictions, and that the tendency is to prioritise functional integrity over accessible and usable design.

To complement these previous studies by providing the most up-to-date view on these issues and to distill pragmatic recommendations for change, given the now legal obligation for companies to adhere to the Equality Act 2010 [28], the audit of the current state of inclusive design practice at a global engineering and communications company was conducted to understand more about how it is practised in everyday business, and what further improvements are yet to be made (if any).

3 Audit of Inclusive Design Practice

The audit of the current state of inclusive design practice at British Telecommunications plc (BT), which has many years’ experience of concentrating on inclusion and in 2007 co-developed the *Inclusive Design Toolkit* [26], was conducted to understand more about how inclusive design is practised in everyday business. This study was performed between January and April 2012 by the authors of this paper to specifically: (1) identify successful inclusivity-led processes, products and services developed to date and (2) explore existing challenges to employing inclusive design. The results led to the distillation of ten overarching principles for further development of inclusive design practice, which can be applied to other large and small organisations.

The approach to the audit involved interviewing 14 experts and stakeholders from across the business, selected for their good knowledge of inclusivity and internal processes in the company. Semi-structured interviewing technique was used to elicit the information and the general inductive analysis [27] approach was employed to identify the dominant themes inherent in the collected data. To complement these, additional analyses of the tools and resources mentioned by the interviewees were conducted. A high-level overview of the design cycle processes was also performed. Collectively these studies led to the identification of three overarching themes: *People*, *Process* and *Practice*, with the focus on *Users* being placed at the heart of them. The detailed findings from within these three themes were subsequently translated into ten principles for

change (as seen in Fig. 1) in order to help accessibility/usability practitioners and product/service managers from any large, medium-sized or small organisation make more informed decisions regarding the design of future products and services. Depending on the strategic intent of the organisation in question, these principles can be broken down into more specific steps, with more effort required in some areas than others to reduce the gap between current and desired practice.

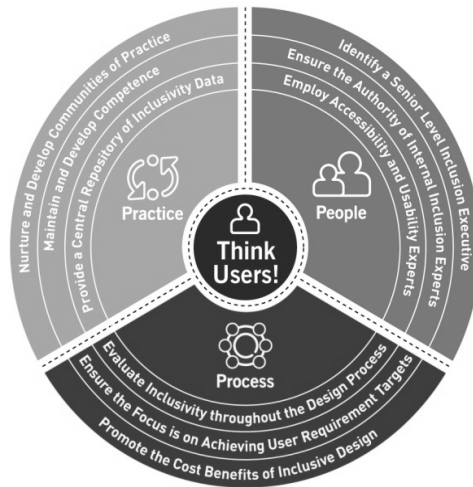


Fig. 1. Ten principles for the development of inclusive design practice

More specifically, within the *People* theme, most interviewees said that, although there is a level of proactive design for intuitive user experience, there are also concerns that inclusion can be de-prioritised by those who are dealing with numerous and complex business decisions. It was suggested that to raise inclusivity in the corporate agenda, a senior level executive could be appointed to champion inclusion across his or her peer group and at all levels of the company. It was also found that internal experts have good knowledge about inclusivity, but often and for many reasons, the expertise of external agencies is favoured over these internal experts. Enhanced collaboration between internal and external specialists is, therefore, seen as a potential solution to this issue.

Within the *Process* theme, participants said that, often due to time and cost constraints, a thoroughly-researched understanding of users' needs can be omitted from the requirements capture process and user testing can be performed at a late stage in the design cycle. Even if user requirements are considered early on, they may become de-prioritised as they pass through multiple project stakeholders with conflicting demands and finite budgets. Also, there is sometimes the issue of a trade-off between the design of back-end of systems and the front-end design. Therefore, it is important to articulate cost and benefits associated with inclusive design and build in appropriate project timescales from the very beginning.

Within the *Practice* theme, inclusion was found to be undertaken across the company but varied between teams. Although supporting tools and resources were plentiful, they were located across multiple internal websites, leading to challenges in accessing necessary data and keeping these online resources updated in line with best practice and market advances. A centralised repository of information is suggested as a solution to this issue. As a result of the audit's specific findings, informal or formal case studies regarding the success of previous inclusively designed products and services are currently used to demonstrate the effectiveness and potential benefits of the inclusive design approach, plus they are used to give a template as to the techniques deployed (e.g. prototyping, user testing, heuristic evaluation etc.). Similarly, education, training and support resources are presently being deployed across the business to bring those involved in the delivery of consumer products up to speed with the latest thinking and practices in inclusive design.

4 Cornerstone of All *Profit* Projections – Cost-Benefit Analysis

Among the four components critical for achieving optimal inclusion practice – *Users, People, Process* and *Practice* – *Process* underpins much of how *People* are organised and thus approach decision-making, and what particular *Practice* they will adopt to produce a given product for the benefit of *Users*.

Interestingly, a fifth element – one that emerged indirectly during analysis of results, but needs to be further investigated and commensurately calculated – *Profit*, in turn relates to what, why and how a given *Process* will be followed. In particular, one of the major findings of the audit and previous research was that inclusive design can be de-prioritised due to budgetary constraints. However, cost-cutting on inclusivity during the *Process* can result in higher costs later on as products are deemed unusable, leading, in turn, to product returns and costly helpdesk calls. Similarly, if inclusion is considered at a later stage, retro-fitting a product to be inclusive (i.e. re-designing it) also incurs extra costs. For example, Pressman [22] has shown that 80% of the software life cycle costs are spent in the post-release maintenance phase. He also argued that the relative cost of a change rises during development from 1.5 units of project resource in the concept phase, to 6 units during the development phase, to 100 units of resource during the post-release maintenance phase. Moreover, since buying decisions are generally made primarily based on usability, Wixon and Jones [30] demonstrate that revenues can be 80% higher for the second release of a product performed with a focus on usability engineering as compared to the first release without it. Inclusive design conducted over several iterations from the outset can also help to bring higher-quality products faster to market, which, in turn, can result in 10% higher revenues because of increased volume or increased profit margins [6].

It is a challenging act for a product development team responsible for allocating budget to inclusivity to adequately and appropriately quantify its benefits against the up-front costs (and the implications of not considering it) at the beginning of and throughout projects. While the success of a number of inclusively designed products illuminates a strong financial case for inclusive design (e.g. the OXO Good Grips

product range), before committing to the inclusion approach organisations quite reasonably want to see a quantifiable projection of their investment. This is because decision makers often view inclusivity activities as a potential risk to the deadline of their project, even when end users consider inclusion as an important product attribute [24]. In general, as shown by the abovementioned audit, the best way to achieve inclusion is by having its importance stressed to the development team by management.

The remainder of this paper is, therefore, focussed on investigating the *Profit* element, which largely governs the availability of options for the other four elements. In particular, the value and benefits of cost analysis (cost-benefit analysis) have long proven to be advantageous to companies in setting out *long-term* (e.g. looking at repercussions in the nearer and further future), *wide-view* (e.g. allowing side-effects of many kinds on many persons, industries, regions, etc.) and *desirable* business plans [13, 23]. More specifically, cost-benefit analysis measures all the positive (beneficial) and negative (costly) consequences of a design/decision in monetary terms [2, 3].

Previous research has shown that the use of quantitative data during the inclusive design process can be useful for designers, as well as business managers and decision makers [8]. Moreover, it is suggested that the use of projection models has a great advantage over other ways of information capture and representation in problem-solving because they are better, quicker, cheaper and safer at: capturing the complex and fast-flowing nature of design activities, grouping together related information, placing similar concepts at adjacent locations, minimising shifts of attention and automatically supporting a number of perceptual inferences [5, 16].

4.1 Existing Inclusion Cost-Benefit Analysis Models

A wide adoption of inclusive design activities in the product design process has been a challenge since the beginning of usability activities over fifty years ago [21]. One reason for this is that the benefits of better inclusivity are not always easily identified or calculated. For example, while the benefit of a decreased need for product support is rather straight-forward to calculate, the impact of better inclusivity on improved company reputation is significantly more complicated to quantify, even when it is clear that poor accessibility and usability hurt company reputation [17, 24]. However, Mayhew and Mantei [18] posit that the calculation of the cost of better inclusion can be fairly straight-forward given that the necessary user-centric tasks are adequately identified. In line with this supposition, two different approaches for identifying the costs and benefits of inclusive design have been proposed to date. Two of the models [4, 10] approach usability cost-benefit analysis through identification of the costs and benefits of user-centered design activities. Four of the models [7, 10, 13, 18] assess usability cost-benefit analysis through investigation of the costs and benefits of individual user-driven tasks. Among the core benefits identified by these different models are: increased sales, increased productivity (i.e. decreased customer support, overall savings in development time and cost), reduced design/development personnel costs and need for costly expert peer-support, fewer changes in late stages of the life cycle, reduced cost of training and greater satisfaction for the end user. However, the present limitation of the existing models is that they do not clearly present an overall formula

for calculating the value of inclusive design benefits. The ongoing work delineated herein, therefore, focuses on developing a tangible, but usable, formula for product managers to calculate quantitative cost and benefit data to justify expenditures on inclusive design.

So far, a review of existing models and modelling of inclusion processes at BT contributed to devising the following cost-benefit formula. It should be noted that there are two scenarios to which this formula can be applied: projects where inclusive design was not taken into account from the start and projects where it is planned to be considered from the onset. This proposed cost-benefit formula for inclusive design is:

$$\text{Benefit [value of increased productivity + value of increased sales]} - \text{Cost of selected inclusive method [(no. of experts * hrs * hourly rate) + (no. of users * hrs * hourly rate) + cost of equipment/rooms/travel]}$$

Where the *benefit*-related elements can be calculated using the following sub-formulae:

1. Value of increased productivity (e.g. less rework, fewer support calls, enhanced user learnability) = (no. operations/operators * hrs saved per operation * cost per operation);
2. Value of increased sales = (no. new sales * cost per sale).

The assumed key benefits from applying this inclusivity formula from the outset are:

1. *increased productivity*, as a result of putting more effort into inclusive design at the outset to better understand the design challenge under consideration and hence reduce rework task volumes and times at a later stage. More specifically, since planning generally constitutes only a small part of the *total effort*, the benefits can be significantly greater than the additional costs of increasing design effort. For example, assuming that *initial design effort* = 10% of *total initial effort*, a 20% increase in *design effort* (from 10% to 12% of *total initial effort*) would only represent 2% of the total. Yet it would save the cost of rework, which could easily amount to as much as 30% of the total costs;
2. *increased sales*, as inclusive design leads to better user interaction, lesser chance of misunderstanding of the interface, and thus fewer errors, and fewer support calls, complaints and returns. The number of sales may also increase due to more subjective factors such as increased customer advocacy – one satisfied customer is likely to tell eight other people about positive product experience on average through the traditional ‘word of mouth’ channel; good “word of mouse” will travel even further [11]. This, in turn, may lead to a ‘viral’ effect in the uptake of the product – an intuitive user interface design, as shown with the Apple’s *iPhone* and *iPad*, may be the unique selling point that enables this phenomenon to take place.

Furthermore, to calculate the total cost of development in a scenario where inclusive design is/was *not* considered from the outset, and were rework will be/was needed to correct the product, the following formulae have so far been devised by the authors:

Total Cost of Effort = *initial effort + additional effort to correct product (total man hrs * hourly rate)*, where

Cost of Initial Effort = *initial design effort (total man hrs * hourly rate) + initial planning and development effort (total man hrs * hourly rate)*

4.2 Case Study – How It Is Never Too Late to Adopt Inclusive Design Approach

A recent inclusion redesign example is given here to demonstrate how a user-centred design approach and close collaboration with technical teams can lead to cost savings and sale increases. An outbound sales system used by call centre agents was analysed in-depth by BT in terms of: (1) its user interface design (e.g. testing criteria such as learnability and efficiency); (2) its projected operational efficiency (at the time, to cope with demand, if the system stayed as it was the company would need to recruit 13,000 more call centre agents and incur the related costs); and (3) technological constraints (the underlying system could not be cost-effectively tailored).

The usability team conducted qualitative analysis of user needs, involving an ethnographic study of the agents' use of the tool within the call centre environment, taking into account the agents' roles and responsibilities, targets, skill levels etc., as well as their working environment in a day-to-day context. Prototypes of new user interfaces were then iteratively tested with these users to reach a final design. Adoption of the new system by agents was helped by this consultative approach. As a result of these and collaborative work with technical teams, a more intuitive interface, which enabled the advisors to 'walk up and use' the system, was deployed. The changes to the usability of the interface enhanced the learnability aspect of the system such that training time was reduced from 6 to 2 weeks (leading to associated cost savings). The efficiency of the transaction was also increased as the duration of the calls on average decreased by 18%. In addition, sales increased by many thousands of units.

Overall, the redesign of the system helped the company make substantial costs savings, but even more significant savings could have been made had the inclusive design approach been adopted from the outset.

5 Discussion and Conclusion

This paper has highlighted the value of inclusive design in contributing to production of good, satisfying, responsible, socially sustainable and commercially viable products. Ultimately, inclusive design can be achieved by: (1) placing *Users* at the heart of every design decision; (2) ensuring authority of inclusion-expert *People*; (3) laying out a highly-optimised *Process* committed to achieving user requirement targets; (4) following a well-executed *Practice* set on developing collaborations and continually developing competence; and (5) early on preparing adequate *Profit* related projections (i.e. cost-benefit models), which can be also manipulated throughout the design cycle, to ensure that the other four elements are implementable and that cost-heavy and time

consuming rework is minimised. It is proposed here that when these five elements are appropriately considered and methodically implemented from the onset, companies are likely to bring higher-quality products and services faster to market, increase customer satisfaction, have cheaper operational costs long-term and fewer rework projects, and free a lot of time for work on latest innovations.

Future work will focus on further developing the cost-benefit model for demonstrating to companies the value of considering and following the inclusive design approach from the outset.

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Designing Sustainable IT System – From the Perspective of Universal Design Principles

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Abstract. Since the concept of universal design is already extending the boundary of disabilities, it is significant to include different aspects of information technology where universal design enabled efforts can contribute towards better designed systems, products and services. Sustainability is an important and growing public concern in today's world. Nevertheless, attempts of designing IT system that can be called sustainable in nature are not so evident at present. In this paper we propose a framework originating from sustainable IT system design principles (also described in the paper). The universal design principles are used as a foundation upon which the resultant sustainable IT system design principles were derived. The concept of 'sustainable IT system' addressed in this research paper is beyond the common phenomenon of sustainability like green IT, CO₂ emission etc. Rather, the framework proposed in this paper incorporates more user inclusion and increased user satisfaction together towards higher usability. And an IT system designed in this manner is a sustainable IT system according to the argument of this paper which can therefore be designed by following the proposed design principles and framework.

Keywords: Universal design, Sustainability, Sustainable design principles, Design for all.

1 Introduction

Different concerns for the betterment of our future life on earth are one of the major issues that motivated a lot of people to use the word, "sustainable" [2]. However, frequent use of the adjective "sustainable" is not the only thing that is needed to create a sustainable system or society, although such belief tends to be noticeable [2]. "Sustainability" has become an important topic and more academics and professionals are using this adjective for promoting their research [2], without in fact serving the real purpose of sustainability. The terms "sustainable" and "sustainability" burst into the global lexicon in the 1980s as the electronic news media made people increasingly aware of the growing global problems of overpopulation, drought, famine, and environmental degradation that had been the subject of Limits to Growth in the early 1970s [10]. A great increase of awareness came with the publication of the report by the United Nations World Commission on Environment and Development, the

Brundtland Report, which is available in bookstores under the title 'Our Common Future' [3].

For many years, studies had been conducted on ways of improving the energy efficiency in our society. These studies have been given renewed impact by referring to them now as studies in the "sustainable use of energy" [2]. Often the very first impression about sustainable system or sustainable design reflects something to be environment-friendly, ecological and green. Information technology has also been influenced by sustainability. How to create green IT system, how to promote sustainable action through designing IT system are some of the hot topic of research and practice in recent time.

While universal design is based on the pillar of design with accessibility issues, the actual concept is far beyond only accessibility. Universal design has a lot more to offer rather than being limited accessibility issues. Whether something that is universally designed should also be sustainable or not and vice versa, is an interesting question to ask. Considerable amount of research has been conducted in different aspects of sustainability and within the accessibility domain of universal design. However a combinatorial approach of considering universal design beyond accessibility together with designing IT system sustainability has not yet been addressed in the research community, as of authors' knowledge. In this paper we analyze universal design principles together with general sustainable design principles and derive sustainable IT system design principles. The proposed design principles were then mapped into a framework, following which; sustainable IT system design can be accomplished. The paper has four major sections. The background section presents a thorough outline about sustainability, sustainable system design principles followed by universal design principles. The next section proposes the design principles for designing sustainable IT system. We then showed the theoretical framework and discuss it in the next section. Finally the paper is concluded by a discussion and the possibility towards further research.

2 Background

2.1 Sustainability

With an increased awareness of the importance of sustainability, the definition of sustainability diverges depending on context and authors; therefore no universal definition exists (for a detailed review of sustainability terms; see [7]. Sustainability acknowledges that human activities could have a negative impact on our environment, including ecological, social, and economic aspects. The Brundtland's Commission defined sustainable development as "... development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [13]. The aim is to improve our life without draining the resources for future generations or more preferably to minimize, reduce or reverse negative sustainable impact of current and future processes. Elkington's [6] triple bottom line (TBL) perspective considers organizational sustainability where the organization is an actor in a social context. TBL defines sustainability to include three components: society, economic performance, and

the natural environment. The organization is thus accountable for their actions in terms of social and environmental responsibilities, adding to their financial goal of profit maximization. Sustainable design is fundamentally a subset of good design. The description of good design can be a home design for the creation of a healthy and safe environment or energy efficiency that promotes sustainable goals like less transportation of physical products and the need of traveling. Unique and innovative solutions will increasingly become the objective of such design. For instance one eventual outcome of this integrated or sustainable design practice will be the development of buildings that produce more energy than they consume.

Sustainability in the field of information technology research has mostly been focused on reducing carbon dioxide emission from IT hardware [5] i.e. a resolution that is mainly focused on technical solutions. We think that the role of IT in a larger context including ecologic, economic and social attentions must be considered to achieve sustainable goals. If the design of an IT system includes these factors then the final artifact would lead towards sustainability.

2.2 Sustainable IT System- WHY?

IT systems are important for organizations since it is integrated into the organization structure and direct and restrict how business process can be done and the alignment between IT and business is important. Since organizations are more aware of the importance of a sustainability strategy the alignment between sustainable IT and business is significant. The design of the sustainable IT system is therefore important and must be done properly and should include as many stakeholders as possible this will also strengthen the equality of people.

Porter and Millar wrote that information technology would transforming the value chain [12] and it has proven that IT has a huge impact on organizations competitive advantage e.g. the change of business model on the distribution of music to customers from physical product the Compact Disc (CD) to digital files and streaming. A sustained competitive advantage is achieved when an organization have implemented a value creating strategy inimitable by others [1]. Technology per se is imitable but a sustainable IT system that supports the organizational strategy (including sustainability goals) could distinguish one organization from others and improve the chances of reaching sustained competitive advantage. The business value of a sustainable IT system is consequently high and could be crucial for an organizations strategy and future.

Sustainable IT system should focus on strategies that spur innovation, create new markets, and redefine processes [8]. Our definition of sustainable IT system is an IT system that unites user inclusion, increases user satisfaction, and gives higher usability. We assume that, if the specified design principles suggested in this paper is followed, the sustainable IT systems will have a larger chance of reaching the organizations goals for sustainability (the organizational sustainability strategy).

3 Sustainable System Design Principles

While we design something, we simply do not just design for the sake of design itself; rather we have a purpose for the design. By purpose we often mean that the design

should meet a particular need or that the design achieves a set of goals. This understanding is important whether the design is for something small or even a large industry. Following the definition of sustainability we can say that, if a system is designed by including the considerations for sustainability goals, the result can be a system which is sustainable. By this we mean that, a sustainable system will be used to improve the life of the users of the system, will make sure to meet the need of the users of that system. And these two things should happen without any compromise with human culture and the living world.

Sustainability, corporate social responsibility and related trends are part of the business agenda for an increasing number of companies worldwide largely due to media attention, customers' awareness, and society's demand on business. Understanding how to integrate these concepts into business planning can be an important part of a successful business. Pressure to integrate sustainability requirements will come from government, business partners, non-governmental organizations and citizen groups. Motivation (or pressure) to implement design for sustainability can come from two different directions: from within the business itself (internal drivers) or from outside the company (external drivers). Although there are overlaps amongst the people, planet and profit aspects of sustainability, usually a driver is connected to one of them. The following design principles of sustainable design are drawn from McLennan [9].

- Learning from natural systems (Bio-mimicry Principle): Nature is considered as a model, a measure and as a mentor. For instance in an ecosystem nature recycles everything and nature can show us its limits.
- Respect for Energy & Natural Resources (Conservation Principle): Learn from nature's example of energy concentration and storage. There are several processes like physical, chemical and biological involved in these examples.
- Respect for people (Human Vitality Principle): Houses, factories and buildings are characterized utilitarian and they are unfriendly and unsafe in different manner. An aim of this principle is to create a healthy place and to do that honoring diversity and giving back control to people for their personal comfort and safety is the goal of this principle.
- Respect for place (Ecosystem Principle): How to use places optimally and how can we contribute to the local environment easily, is the goal of this principle.
- Respect for future: Whatever is consumed by human today is not available for us tomorrow. And it is impossible to ignore the influence that happens over time. As stated by great law of the Iroquois Confederacy what we do today, we should consider the consequences on the next seven generations is the reflection of this principle.
- Systems thinking (Holistic Principle): The fact that things tend to create problems over time since they are connected to each other is evident but difficult to understand completely in order to overcome it.

The bottom-line of these design principles is that, while we talk about sustainable design, it is not only important to talk about the impacts of environments, but we should also give priority to consider the impacts on peoples which reflect equality and concurrently business prospects which reflects economy. This consideration of

equality and economic prospects brings the idea of inclusiveness or universal design into the deliberation within sustainable design; that is, we can include more factors into the concept of sustainable design and call this universal design in nature where inclusion or universality has nothing to do with physical accessibility. Also combination of such concept is going to generate new sustainable design conception which is more than environmental issues.

4 Universal Design Principles

The set of universal design principles were developed by a group of U.S. designers and design educators from five organizations in 1997[4]. The seven design principles' key terms are equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance of error, low physical effort and size & space for approach and use. A design should not stigmatize or disadvantage a certain group of people or group and should provide equal mean of use for all possible users. The design should accommodate a wide range of individual likings and capabilities by enabling different choices in the method of use of a system. By simple and intuitive use it is assumed that a design should be easy enough to understand and this should not depend on the past experiences of the user along with knowledge or any other special requirements like level of concentration and knowledge of language. Also information to the user should be arranged so it is consistent according to their importance [11]. Perceptible information design principles promises that the design should transfer information to the user in an effective manner and should not depend on any ambient condition of the user's sensory abilities [11]. Error tolerance principles states that hazards should be minimized and that any adverse consequences of accidental or unintended actions can be taken care of. This can be done by providing awareness and warnings of hazards and error for instance. Low Physical Effort: Universal design principle also states that the design should be used efficiently and comfortably, and with a minimum of fatigue [4]. This principle is titled as low physical effort also argues that the design should be in such way so that the user's body position remains natural with reasonable operating force required to perform a task. The final design principle is called size and space for approach and use. This principles states that appropriate size and space should be provided for approach, reach, manipulation, and use, regardless of the user's body size, posture, or mobility. A clear line of sight is also important for the user while they are dealing with several elements on a system for instance.

As the emphasis on environmentalism, safety and conservation continues to grow, it is becoming more essential than ever for the design and construction of new facilities to not only meet requirements for providing access for all individuals, but also to embrace this "green" philosophy. Relating universal design with sustainability in terms of accessibility, one example can be given like this. A healthy, sustainable home is a home that is designed for instance for all members of the family. Also the home will serve as an inviting home to family and friends, no matter what their physical ability is. Some factors impacting physical abilities can be invisible or silent (psychological problems or allergies) or visible (physical problems cause by stroke). However the truly sustainable home will "sustain" and thereby support that homeowner and their friends and family, usually as long as they wish to remain in the

home. So one could say that a universal home is not only sustainable but also gives the homeowner a sense of independence no matter what physical challenges may occur. Since universal and green (sustainable) designs are not technically design styles but simply points of reference, they often can influence the design (building construction process for example). When integrated together, they have the ability to drive the design process by creating facilities that are more user friendly and environmentally conscience as well. Rosemarie Rossetti in her statement during keynote speech at INTERIORS 2008 in New Orleans stated ‘‘ If it is not universally designed, it is not sustainable.’’ Following this we argue that the idea of using universal design principles in this article is, to integrate them with the sustainable design’s characteristics and thereby derive some new, better design principles; which will have positive impacts on creating IT system.

5 Proposed Design Principles

Since we argued that universal design is meant to reflect better design if we combine the characteristics from sustainable design principles together with universal design principles, a general matrix of sustainable IT system design principles can be established. Table 1 shows the keywords as design principles properties of sustainability and universal design principles. These key words are necessary to narrate the new design principles of sustainable IT system which are also shown in this section.

The properties described in column one on the Table 1, maps over with the properties in column two. The resultant matrix from these two columns is shown in the column three as an aggregated form of previous two columns. These are the foundation upon which the following derived sustainable IT system design principles are based on.

Table 1. Sustainability, universal design and their corresponding characteristic matrix

Sustainability	Universal Design	Design Principle Properties
Reduce gap between natural system model and practice	Equitability	Doing design following nature as a mentor guideline
Being conservative in using re-sources	Error Tolerance	Condense the use of resource in system design
Expand towards diversity	Approachability	Design for majority of users
Optimal use of local environment	Flexibility and Simplicity	Simple and flexible system that is customizable
Influence over time	Reduced Effort	Reducing adverse effects over time and enabling easy alternation of design
Systems thinking	Transparency	Understand synergies and emergent properties

Principle one: Practice IT system design following nature as a mentor

IT system design should be in a manner that uses fewer components in design phase and execution phase. Also following the nature's way of doing things, trying to produce a scalable system at once should be an aim for designing sustainable IT system.

Principle two: Reduce the use of resources in IT system design

Use of resources should be considered while IT system is designed. This includes planning from the beginning to the outcome of the system's effect during use and also effects after use. If a reduced amount of resources are used then it is better for the sustainability of the system. While executing the IT system, reduction of the use of resources are also necessary and safety consideration must be considered.

Principle three: Design IT system by respecting people

Designing several systems for different focused user group is a bad idea. This is not going to sustain over time since more resources will be used for each IT system. So designing IT system that supports the need of many different users should be the goal of the design. This reflects the concept of inclusive design beyond accessibility issues. Design should not exclude particular group of people because of their inability to use the system for different reasons apart from physical or mental accessibilities.

Principle four: IT system's design should be simple and flexible so that it can be customizable if needed

Designed system should be customizable for different circumstances where different users may feel challenge to use the system. That way, it will be more design towards people and for the people. A system that is appropriate and functioning in a certain situation with a certain group of users might not be useful for some other situations or for other group of users. Designing a complete new system is not an optimal solution for such circumstances. Customization for optimization is therefore important.

Principle five: Design IT system in such way that, any negative effects initiated by design gets reduced over time and to reduce these effects the design can be altered

We do not know what the negative influences are of an IT system, unless we use it. Any system tends to show its effects (positive or negative) over time. This should be considered during the design of an IT system. If any negative effects are initiated by the use of the system over time, then it should be designed such way so that it can reduce those effects without spending too much effort on the re-design of the system. That is, the system should be easily alterable to reduce or remove negative effects while in use for a longer period.

Principle six: Understand synergies and emergent properties of the designed IT system before, during and after design is in practice

The design of IT system should consider that negative synergies should be avoided while positive synergies should be accepted. Also any emerging properties that can arise during the practice of the design should be taken care of properly. It is important to remember for creating a sustainable IT system that, these effects will be connected

to create problems over time since they are connected to each other. Practicing to create an IT system for reducing these effects or trying to use the positive use of these effects will therefore result in a sustainable system.

6 Proposed Framework

The proposed design principles from the previous section are considered to generate a framework for designing sustainable IT system which is shown in figure 1. The framework is a recurring process which starts from the concept of doing design by following nature's principle. If we follow the nature's practice in our design then it should reduce the use of the resources during the design. It will also reduce the resources while we use the system or do further design to update it. Minimal use of resources means it will give the designer time to think about the design from different perspective. In this case it will be to design for the majority. Low use of resource opens the opportunity to enhance design in different manner and in this case it is practicing design for the people. While design is focused for people it should be simple and flexible so that it can be easily customizable in required circumstances. Without the opportunity of simple and flexible customization, an IT system cannot be meant to be designed for majority. A system which is meant for majority with reduced resource is the outcome of following nature's example but the system also needs to be designed in a way so that it can handle any adverse effect that might arise over time. Easy alternation should be a property of the designed IT system so it can reduce negative effects if necessary. This will go back to the nature's example of how to do sustainable design and then the whole process can iterate. The concept of systems thinking is in the middle of the circle in figure 1 which is connected bi-directionally with five other circles. This means that any of these phases of the design will have effect on the synergies and emerging properties generated by the IT system and vice versa. That is, proper use of the five phases will have positive effect towards the systems thinking of the IT system.

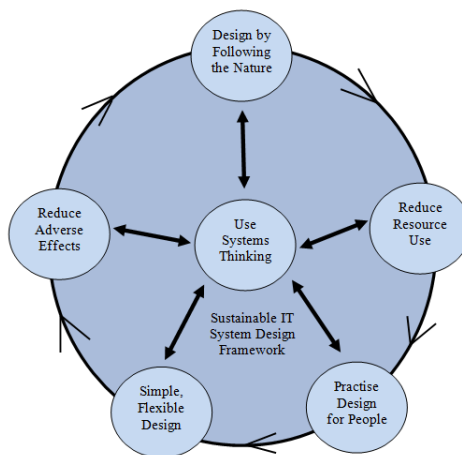


Fig. 1. Proposed framework for designing sustainable IT system

At the same time compromise of using any of the phases will also have negative effect towards the systems thinking of the IT system. The optimal use of five different phases leave an impact on the sixth phase and this sixth phase in return has effect on each of the phases. The result of following this framework is a simple, flexible to use sustainable IT system that is useful for majority user groups. The system also uses reduced resources while in practice. The properties of such IT system is that, it will have reduced negative synergies and builds up over time with positive synergies and emerging properties of the system.

7 Discussion and Conclusion

The proposed design principles support the trend suggested in the literature by McLennan [9], in terms of consistency. McLennan suggested that learning from nature will affect the sustainability goal in a positive manner. The existing universal design principles are mapped with the sustainable design principles to come up with the new principles which reflect that by following nature's way it is possible to design IT system to be more sustainable. The framework presented in this paper is theoretical in nature and we did not have any empirical evidence until now. Further research is needed to find out the reliability of the proposed framework. Quantitative data analysis from an experimental setup to design an IT system is the next step of the research that is initiated from the result of this paper. Finding statistical significance in different phases of the framework will give us further insights about enhancing the framework. Once the framework is statistically significant, it can also be used as a tool for an organization to measure the chance of achieving a sustainable IT system. The framework could also be used to benchmark different IT systems against each other to find out how well they reach sustainability in a comparison.

Use of existing universal design principles to come up with sustainable IT system design principles is a new concept which takes the argument of considering universal design beyond accessibility, one step further. Present trend of doing research in information technology with the concept of green IT, energy consumption etc. takes a new turn in terms of sustainable IT system design concept by relating with the universal design. Two major transfers are initiated in this paper which is worth mentioning. Psychosomatic accessibility is not the only restriction to consider while talking about universal design, is the first shift to consider. The second point to note is that, sustainability in IT system does not necessarily mean the consideration of ecological factors rather there are other different dimensions to deliberate and understand sustainability in the field of information technology.

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Usability in a New DCS Interface

New Model of Viewing in Operator Displays

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Abstract. The current operating displays of DCS (Distributed Control System) are designed for 2D environments. This limits the full awareness situation of the industrial process, since it is distributed across multiple operator displays and requires the operator to navigate among them. This inspired the idea of creating a single operation DCS display, in a 2.5D/3D environment that allows a full view of the entire manufacturing process. This increases the amount and quality of information that is given to the operator and prevents unnecessary operation navigation between displays.

Keywords: DCS, HCI, 3D, 2.5D, visualization models.

1 Introduction

The DCS (Distributed Control System) is a control device that is primarily used in the continuous process industry. This type of industry is characterized by having a critical production process, in which any failure or shutdown can create dangerous situations for both the environment and for people. Failures in this industry may involve shutdowns of several days, while the start-ups can stay for several days until process stabilization is achieved. 40% of these failures [12] are attributable to errors or failure in operation, which means that the efficiency of operators becomes a critical element of this industry. This requires increasing the quantity and quality of information that is given to the operator and to provide him/her with tools and frameworks that favor the selection of a wise operating decision.

This paper describes an innovative DCS operator interface, which increases the amount and quality of information that is perceived by the operator. This interface showed in a single 2.5D/3D graphic display, shows the contents of a previous set of 2D DCS operating displays. The first paragraph of this paper summarizes the main features of this innovative DCS operator interface. The following section describes the new operator display. The last section relates the experiences of operators that tested this interface.

2 Operator Displays of DCS

Optimal operator interface must provide accurate and complete "situation awareness" in all conditions of the industrial process status (normal, abnormal and emergency).

This reduces the number of unscheduled shutdowns, minimizes the variability of the process and improves safety.

Currently, operator displays have a 2D format, "Fig. 1", which hinders to access to an accurate situation awareness of the process, since it is not feasible to create a single operating display that contains all information of the industrial process. This requires creating overview displays with the most critical parts of the process and/or forces the operator to navigate through all the displays in the DCS. Both one as another option has advantages and disadvantages, but does not give an answer to the need to view the status of all operating variables, to be monitored in the industrial process.

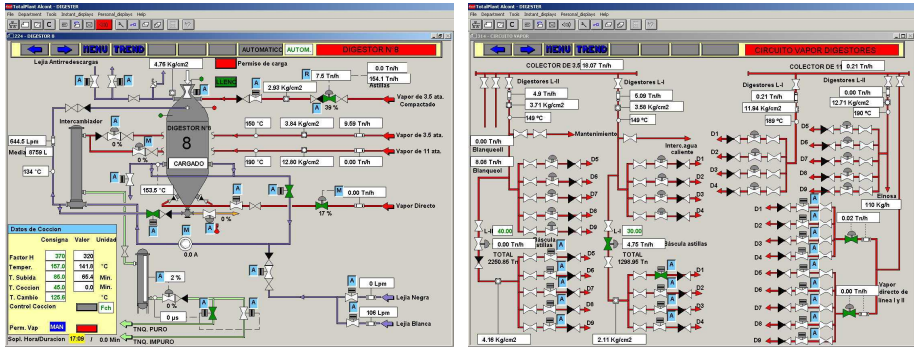


Fig. 1. 2D-Displays of Digester n° 8 and Steam Distribution (DCS of Honeywell TotalPlant)

2.1 Present Operator Displays

The DCS operator interfaces [4] [5] [6] [7] [9] that have been studied so far in the preparation of this paper, they had monitors 2D and also displays charts or diagrams containing process in 2D format. This means that if someone wants to have different views of the process is essential to create new displays. DCS alarms are indicated on the operator displays with a change in the color of the component that generates it and also they are listed in a table sorted by priority and/or areas, which are accessible from different sides of the display. All operating displays show the status of the components using a color code, and some of them allow access to programming manuals, device manuals (valve, motor, etc...), programs of logic blocks, wiring diagrams, piping diagrams or links to other management applications (Maximo, SAP ...). Also all the components allow the operator to select the operating mode (automatic, manual or remote) or to force their input and/or output values. The typical input interface of DCS is the keyboard and mouse, although in some cases, using a touch screen as advanced device, as it supports user defined configurations, which facilitate access and navigation through the operating displays.

Operators typically manage up to fifty DCS operating displays with several thousands of I/O signals associated; so there may be displays or I/O signals that are not accessed by operators, for several working shifts. Sometimes it happens that these components or displays are not serviced until an alarm or warning.

ASM (Abnormal Situation Management (Consortium)) [1] develops guidelines or recommendations about the best practices that can be applied in the design of the

operating displays. The purpose of these displays is to optimize the amount and quality of information in the industrial process, which must assimilate the operator to possess an excellent situation awareness and thus be able to make the best decision [2]. These guidelines were developed to apply only in 2D displays, but many of them could be extrapolated to design 2.5D/3D displays.

2.2 Revolutionary Interfaces

ABB and Interactive Institute of Umea have developed a prototype of a business management tool [10] which facilitates the monitoring of any KPI (Key Process Indicator) of the process. This information, which is showed in a display, is collecting from business management systems or from the industrial control.

This management tool has a monitor with a touch screen, which displays in the 2.5D environment the production building of the production plant and/or industrial equipment. This touch screen facilitates the rotation, displacement, increase or decrease of the scene. An overview of the plant shows only high-level KPIs, but if the operator wishes to view a section of the factory, then emerge new KPI or more specific variables, which are specifically related to that area and that, before, they were not visible in the upper level.

The software was designed to convert the graphic display in a tool that replaces the traditional portfolio. Thus, participants can add comments to the graphical elements in the form of notes, drawings and virtual sticky notes that remain attached to the item and not to a physical position of the display.

This tool was not intended to become a DCS operator interface, since it cannot allow interacting with industrial devices to browse or change their status. However, this software shows the direction that investigations are walking into the human-machine interfaces in industrial management environments and this suggests that the same trend is transferred to the area of the DCS operator interfaces.

3 New 3D/2,5D Operator Display of DCS

It has been created an application that shows a DCS operator display in 2.5D/3D format. The application can show 3D operator display, but can also show operator display in 2.5D format (if the computer does not have 3D peripherals). This operator display, "Fig. 2", replaces a set of 10 DCS displays with 2D format. This set of 10 displays is formed by 1 display of steam distribution display "Fig. 1-right" and by the 9 displays of each of the 9 lines of digesters. The display that represents digester number 8 is shown in "Fig. 1-left". Each line of digestion, "Fig. 3" is composed of a digester, a heat exchanger, a condensate tank, a recirculation pump, some steam valves, some liquor valves and all associated piping. The steam distribution display shows a set of common facilities for all these lines.

Navigation along the graphic scene is made using a 3D-joystick, while the selection of a graphical element is done with the mouse (only 2.5D graphic scene) and/or joystick. Similarly, these peripherals make it easy to spin, pan and zoom the chart of the manufacturing process to achieve visualize the scene from infinite views (front, side, rear, near, far ...).

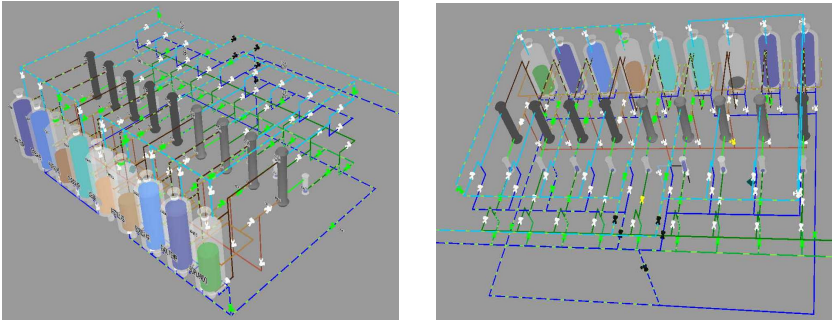


Fig. 2. Oblique and back view of the industrial process

This operating environment also reported the appearance of an alarm or warning, by issuing a voice message with emotion. The issuance of said voice messages with emotion facilitates immediate compression by the operator of the upsets that are occurring; because emotional intensity indicates the criticality of the alarm and the message indicates exactly, which is the component that generated it. The graphic scene also shows, in text, all physical quantities of the process, and the status of all devices and equipment (valves, motors, switches, etc.).

The application includes a dialog window in 2D format and control information on the components of the process, which have been selected with the mouse or 3D-joystick. This window displays in textual format, the status of the selected component and allows its control (change of state), by pressing buttons.

The background color of the graphic scene has been determined to be the gray, because it is recommended for displays, by ASM. The gray color intensifies the difference between the graphical objects and the vacuum, and also allows the use of the operating display in control rooms with different light intensities.

Graphical components must have a geometry format in 3 dimensions to be inserted into a graphic scene in 3 dimensions. However, all standard symbols [11] to identify a component are designed to be used in 2D representations. This requires some new designs of 3D graphical symbols, to allocate to the process components, so that can be used in a graphic scene to represent a real industrial process. It was decided that these new 3D graphical symbols must be generated by the axial revolution of the graphic representation of the symbol of the 2D component; since this allows them to be recognized or identified in a very simple manner, from any spatial position in which locate the operator. Similarly, the creation of these new symbols from an axial resolution of 2D symbols enables projection onto a 2D plane, which exactly reproduces the original 2D symbol. Occasionally, the axial revolution of the representation of a 2D symbol does not generate a 3D geometric figure, resembling the 2D symbol. This requires creating a new 3D symbol, from some geometric transformation of 2D symbol or by a new reference model for that component.

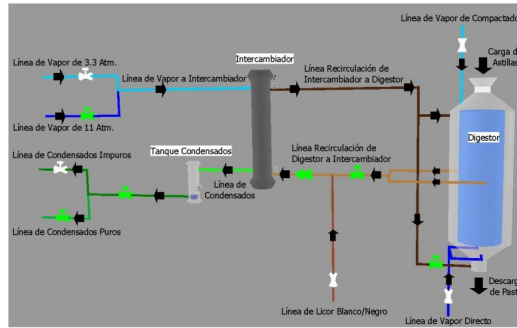


Fig. 3. View of one of the lines of the industrial process

The digester comprises a geometric revolution of a container with transparent color, which contains inside a cylinder of variable height, which indicates the charge level of the digester. The color of this cylinder indicates the state of digester: empty, loading chips and/or bleach, temperature rising, baking, puffing, etc.

Vertical heat exchanger is represented by a vertical cylinder with two flanges at the upper end and the lower end. This figure has a solid color of dark hue, and it has no operational status that is relevant to know.

The condensate tank is represented by a vertical cylinder with two flanges at the upper end and the lower end, but it contains within itself a cylinder with variable height. The height of this cylinder indicates the level of condensate in the tank, while its color indicates if it is in a steady state of operation or alarm / warning.

The 3D symbol of a valve is generated by the axial revolution of the normalized 2D representation of a valve symbol. The 3D symbol comprises the valve body and the handle thereof. The body is represented by a geometrical figure comprises two circular truncated cones, faced by their smaller radii and joined by a cylinder whereas the handle resembles a rectangular parallelepiped, which is connected to the body via a cylinder .

The axial revolution of normalized symbol of a 2D pump generates a sphere or a cylinder with a triangular prism inside. None of these geometric figures are easily identifiable with a pump 2D symbol and also cylindrically shaped figure has different visual appearance depending on the place where the operator observes it. The normalized symbol of a 2D pump is formed by a circle, within an equilateral triangle, where the vertex indicates the flow direction. Finally, it was decided that the 3D geometrical figure that represent a pump must be constituted by a set of two circular cones in series, where the two vertices indicate the direction of fluid flowing through the pump.

The red color is only used to signal an alarm condition, the yellow color is used to display a warning status and the violet is identified with a state of uncertainty component. The green and white colors are used to indicate different states of operation in which there is a physical component of the industrial process. Green indicates that a pump is running / active or a valve is open. The white warns that a pump is stopped /halted or that a valve is closed.

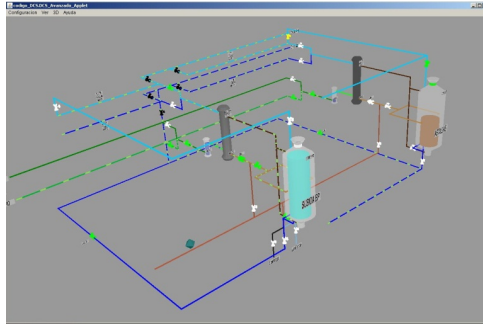


Fig. 4. Partial view of the industrial process

The pipelines have different colors depending on the transporting fluid inside them, while a change in a physical characteristic of fluid is noticed by a variation in its color tone. Blue indicates that the pipeline carrying steam; the green line denotes that contains condensates and the brown color shows that the pipeline is carrying bleach. The variation of the blue color tone denotes a change in vapor pressure, for example dark blue color indicates that the pipeline transports high pressure steam and light blue color containing low pressure steam. The graphic representation of the pipeline has an animation to symbolize the flow of the carrying liquid. The design of animation imposed the creation of a sequence of bright color geometries, alternating in a synchronized manner to give the appearance of movement. This sequence is assigned a frequency of 0.1 seconds for projecting an optimal illusion of movement.

The graphic scene is contained in a window, with several menus or tabs, which are used to select the different options for modifying the graphic scene. The application allows viewing and/or hiding the individual lines or pooled lines or digesters common line to all digesters "Figure 6", then this allows the operator to focus his/her attention exclusively on a limited set of lines. The animation of the pipelines is enabled / disabled on a menu option, and its activation is highly desirable in simulation tasks or learning the process, as it shows the flow of the various materials involved in the manufacturing process. However, it could be dangerous to have enabled animation pipelines in the routine process control; because the operator could become saturated with the vast amount of visual information that is given. This could cause the operator to relax focusing on key aspects of their work of process control and it can cause malfunction or accident of unpredictable consequences.

Some components or circuit sections should show numerical data or messages to the operator; because a color code provides a very limited amount of information. This requires labels to show process information, "Fig. 5", to report the status of the digester or the various physical quantities, which are used to keep the process within its limits. For example, the pump has a label with its electric consumption; steam pipelines show a pressure indication that transport fluid; liquor pipelines have an indication of flow and the temperature of the bleach flowing into them; and finally each process area has a label with an indication of its name or designation.

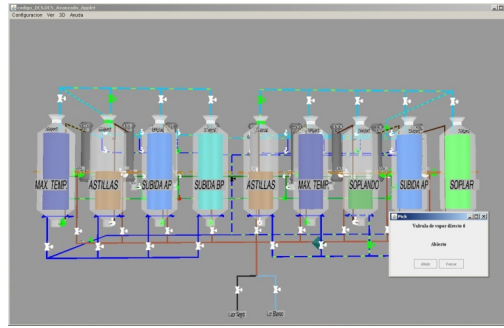


Fig. 5. Frontal view of the industrial process, with the commands window

The moment when an alarm or warning arises from a component, the operator cannot concentrate on visualizing the color change of the component; so it is advisable to give an audible message to notify the operator that exists a circumstance that requires his/her attention. Therefore, whenever a component goes into alarm or warning is issued a recorded message, including the name of the component and unambiguous critical condition (alarm or warning) that is. Also, the menu has a tab that permits the operator to enable or disable such alarm or warning messages. This option is very useful in cases arising in a lot alarms or warnings (e.g.: when starting the process). This suggests that it would be desirable to disable the broadcast of these messages, not to stun the operator with a large amount of sound emissions, which would generate a very noisy environment; the noise can completely decentralize him/her from their control work of the production process.

The graphic scene, showing the industrial process, has several options that facilitate viewing from other points of view. This implies that the graphic scene can be moved to any position, rotated about any axis or modified in size (zoom). These options allow the operator to navigate inside the process, to focus on specific areas of the same. This facilitates the visualization of the process from other locations and achieves that no area of the process remains hidden or distorted by other element that is in front of it. Therefore, the scene can be viewed, "Fig. 4" from the bottom, rear oblique, enlarged etc. The operator performs these operations with assistance of a mouse or a 3D-joystick. The 3D-joystick is the only peripheral device that can be used to interact with 3D scenes shown, since the graphics card prevents the use of the mouse. Similarly, a menu option or button joystick let you repositioning the graphic scene in its original position and thus facilitate this task for the operator.

Components (digesters, valves and pumps) of the industrial process can be selected, so that their information is displayed in a small command window "Fig. 5". This window provides more detailed component information, including its full name and the operating state it has got. Also, this window can also be used to change the state of the component, since this option was excluded on the application requirements. Component selection is done with the mouse pointer or by an advanced pointer. The advanced pointer needs to touch or cross a component to do this choice, while the mouse selects the first component that is located at the same depth coordinate. The advanced pointer is shown on screen with the geometrical figure of an octahedral and its movement is controlled via keyboard or 3D-joystick. This advanced pointer it is only available when viewing 3D scenes.

3.1 3D Visualization

The stereoscopic-3D view is achieved by obtaining two images of the graphic scene, which correspond to the images that are to be fetched by the left and right eyes of the user. The left eye image is obtained by directly capturing 2.5D image of the industrial process, but the right eye image is created by a rotation of 7° of the previous image. The hardware used for 3D visualization includes a 3D graphics card from Nvidia [8], a 120Hz 3D monitor and 3D glasses IR synchronized. The 3D scene cannot permit displaying the mouse pointer, so it is necessary to create a 3D pointer controlled by a 3D-joystick. This joystick is the only peripheral that can be used to rotate or move the graphic scene, as well as to move the 3D-pointer, which lets you select the components of the process. The frame rate of the 3D display is 2 seconds, which is within the permitted operating range from the ASM.

4 Operators Experiences with 3D Environments

The application was tested by DCS console operators of the Digesters Department of company "ENCE" in Pontevedra (Spain), as well as Technical Engineering Department of the same company [13]. This company has installed a DCS "Honeywell-TotalPlant" with 2D displays, where each operator is responsible for operating multiple monitors, which shows various operator displays.

It is observed that the application shows an exceptional quantity and quality of information available to visual range of operators, because one 3D display shows the same information as 10 old DCS 2D displays [15]. This prevents the operator have to navigating through all displays; whilst he ignores what it is happening in a display, because he/she is watching another one. The graphical process has a visual representation that is more natural and intuitive for the user, as it has a great similarity to the real process.

The symbols and colors used in the 3D graphic scene are immediately recognized by DCS operators, since the symbols used to represent 3D components are an evolution of 2D designs proposed by international standards. This graphic scene transforms hundreds of status signals from the physical devices (valves, pumps, etc...) in visual information based in colors. Previously, this information was displayed in numerical and textual format.

Lines or pipelines that are used to connect the components of the process are shown with up to 5 colors. It avoids the use of extreme tones (dark and light) because it is impossible to distinguish one color from another one 3D environments.

The font size decreases as a function of the depth, so the text can be negligible dimensions and unreadable. The width of the lines is a difficult parameter to use to report the importance of the flow, since the dimensions of the objects are reduced as they are at the bottom of the image. The flow of information depends on position of graphic scene because it can be rotate in any direction. E.g., the back views have inverted the ideal process flows (left to right).

Also, the use of different colors in the representation of 2.5D and 3D figures, showed in the graphic scene, they cannot strictly be considered incompatible with the principle of usability in computer systems. This is because the "risks evaluation" of the workplace of a display operator indicates that this position cannot be played by people with color blindness or with some other visual or physical impairment. This evaluation would also be applied to electricians, as an electrician with color blindness would not be able to perform their work properly, and he/she cannot differentiate all colors wires of a bundle cable.

It is observed that the operator requires less mental effort to comprehend the complete state of the industrial process. This allows to assert that the operating display meets the key concepts of usability, as it is very "user friendly" and very "easy to learn". This is reflected in the fact as how the operator "feels" all displayed components of the graphic scene.

It is appreciated, that operators and users need an adjustment period to the new 3D environment, and that they initially are surprised to the original format of the process. Also, some people aged more than 55 years or visually impaired are unable to view images in 3D and show that they continue viewing images in 2D, but some young people are extremely receptive to these 3D images. The user's position, the distance to the monitor and the phase angle of each eye images strongly influence the perception of the 3D image by the operator, because the presentation is designed so that it is centered in front of the screen at a distance of 60 cm.

The update rate of the process variables is 2 seconds and the speed of 3D rendering images is also 2 seconds. This implies that rendering speed 3D animations renders every 2-4 seconds; while the velocity in the 2.5D environment is 0.1 seconds. However, 3D operators are satisfied with this slowdown, as they believe that there is a great 2.5D point cloud on screen, it generates a lot of noise in the information in the image.

It is found that 3D images are not suitable as a user interface for some tasks or essential job functions of operation, and that those should be shown on 2D displays. Next, we list the features of the DCS interfaces, which are not adapted (at the moment), to 3D environments:

- Control charts and/or process variables are more understandable in 2D/2.5D format
- Windows command and a process component should be shown on a 2D display, as they have textual, graphical and command buttons.
- 3D navigation is done with a 3D-joystick that has a 3D pointer associated.
- The data entry in dialog box (passwords, numbers...) must be programmed in 2D.
- Windows scrolling menus or menus of 2.5D program should not be used in 3D.
- The block diagrams of control logic of DCS are very complex to follow and understand in 2.5D/3D.
- The help documentation about the process should be displayed in a 2D text format.
- Operator helper applications have to run on auxiliary 2D displays.
- Control rooms with several operators in 3D environments create problems of viewing to contiguous positions operators.

5 Conclusions

We present a new concept of DCS operator interface, dramatically increasing the amount and quality of information processing, an operator has available. This new environment brings together in a single operation 2.5D or 3D display equivalent to 10 old DCS 2D displays. Also, the use of peripherals 3D allows the rotation or displacement of the graphical process, facilitating its analysis from various positions and angles (front, rear, lateral, oblique, interior, etc.).

Similarly, it is found that there are some operating functions, which are hardly transferable to 3D environments. Finally, we note that some design methods for 2D displays are forbidden in 3D environments, so we are working to adapt them to the new environment, but trying to preserve their essence.

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Best Practice for Efficient Development of Inclusive ICT

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Abstract. This work aids ICT projects in delivering solutions which are highly accessible and usable in an efficient manner, i.e., with a minimum of additional costs. The aid comes in the form of guidelines / best-practice recommendations. The guidelines are based on a literature survey considering related research, and an analysis of development work conducted at our research institute which discusses possible pit-falls. This approach led to both high-level recommendations, such as which overall research methodology to apply, as well as detailed low-level guidelines, such as which activities to include in the project workflow and when. The advice is supported by a template for an example workflow with relevant activities. The recommendation from the literature is to extend general user centered methodology with particular activities to ensure that also individuals with impairments are accounted for, while our own development experience suggests an iterative approach with user involvement from early on in the project throughout the end.

Keywords: Software development, agile user centered design, IT, ICT, universal design, e-inclusion, accessibility, usability, impairments, iterative design, best practices, workflow.

1 Introduction

Since the introduction of the Agile Manifesto in 2001 [1], many areas in software development have undergone a development turning from traditional methods like waterfall towards methods that promise a better cost/effort ratio, such as Lean, eXtreme Programming, Dynamics Systems, Rapid, Iterative, Test-Driven, and others. These methods typically promise a reduction of the project risk and consequently savings of project expenses. Starting more than 10 years earlier [2], many software projects have been witness to another evolution step, with a turn towards user centered design (UCD) processes. Several factors have contributed to this recently, including the success of well designed Apple products, the open-source community with high degree of user engagement, the erection of Living Labs, and the participatory-design movement, to mention some of the most important influences. This development has eventually been acknowledged by documenting human centered design by multiple ISO standards, including [3].

It has, however, been pointed out in the literature that the influence of the UCD movement on agile methods is rather limited [4–6], as agility often is programmer and not user centered [7–9], and thus not helpful in increasing a solution’s accessibility and usability. Also, a great deal of projects are aware of supposed additional costs for universal design, at least in a suspected short-term view [10]. This picture is diversified by projects being aware of a wide range of costs of various UCD methods, where for instance an informal expert review is considerably cheaper than a field study.

Cost and efficiency are both important factors. Naturally, UCD is a bigger effort than, say, self- or ad hoc design. Moreover, the design community has warned against testing of every single design decision and hence overtest solutions [11]. More knowledge is therefore needed on how to efficiently apply UCD methods in relation to inclusive design in order to avoid unnessecary expenses.

This work reviews related research regarding recommendations for the efficient development of inclusive ICT solutions and also rates a number of own development projects. Applying the resulting best practices is supposed to lead to a high degree of accessibility and usability of ICT solutions given a particular budget and time frame.

This work is funded by the European AAL Program as part of the MobileSage project [12]. It is structured in a straight forward manner: First, we review related research and summarize recommendations from the literature. We then assess development projects conducted at our research institution, before we present a list of best practices based on a discussion of our findings. At the end of this work, the conclusion is drawn.

2 Recommendations from Related Research

There are several inclusive design approaches which share a common goal of making technology accessible to as many people as possible, including people with disabilities. While there is broad consensus that it is good practice to follow accessibility standards and guidelines in inclusive design, it is an increasing awareness of the fact that this is not enough to achieve inclusive ICT-solutions. The general recommendation is that inclusive design must be based on a user-centered design (UCD) process which includes user testing with disabled people. In the following, some central features of various inclusive design approaches are briefly described.

The concept of Universal Design was introduced in the mid-eighties by the architect Ronald Mace, and has since then been adopted in many fields, including more recently in the design of ICT [13]. The Universal Design process should be holistic, and this requires the participation of disabled people [14]. The emphasis is on counteracting unnecessary special solutions and to encourage equality. The seven principles of Universal Design represent the main qualities that a universally designed solution should fulfill [14].

The focus of Universal Usability is to design products so that they are usable by the widest range of people operating in the widest range of situations as is commercially practical [15].

A central part in Inclusive Design is to define and quantify the level of design exclusion in a product [16]. This is done by considering the spread of user functional capabilities (physical, sensory, cognitive) across a population. The basic assumption in this approach is that products exclude users because their features do not match user capabilities. By identifying the most excluding features in a design, they can be re-designed to be more inclusive [16].

In Design for All [17], the following areas are pointed out as important challenges: the need to include social context in analysis, the need to facilitate involvement of users with disabilities, the support of requirements engineering methods to facilitate the elicitation of requirements from different user groups, and the investigation of multimodality [18].

In User-Sensitive Inclusive Design [19], it is argued that greater empathy with users is needed, and that this must be reflected in design methods, research, and development. By using the term user-sensitive as opposed to user-centered, they want to communicate the lack of a truly representative user group, the difficulties of communicating with users, ethical issues, and the importance of the attitude of designers [19]. In this approach, it is suggested to consider a number of specific “extraordinary” users in-depth and design for them in particular. These “extraordinary” users are elderly and disabled users which also have characteristics that are particularly relevant for the ICT solution in question.

The emphasis of Ability-Based Design [20] is to base the design on what abilities people have rather than what disabilities they have. The focus is on making mainstream technology flexible enough to meet the needs of people with diverse abilities through adaptability or adaptivity.

More and more researchers agree that compliance with accessibility standards and guidelines are not enough to achieve inclusive design. Recent empirical studies have found that conformance with WCAG can solve up to about half of the problems encountered by users with disabilities [21, 22]. As a consequence, some researchers make a distinction between technical accessibility and usable accessibility [23, 24]. In order for an ICT solution to be inclusive, it needs to be both technically accessible and usable accessible for people with disabilities. A solution is technically accessible if it provides access to content and functionality for people with disabilities. This can largely be achieved by meeting technical criteria in the underlying code [24], and many such criteria can be found in guidelines and standards. An ICT solution has usable accessibility if it is usable by people with disabilities, and this can be achieved by applying UCD and usability techniques, and involving people with disabilities. It is well known that early focus on users and their tasks, and early user involvement is important in UCD. According to [25], it is much cheaper to apply accessibility work from the start of a project than applying them near the end.

We should mention, though, that not all methods and techniques in UCD are always suitable for people with disabilities. For example, working with paper prototypes has been found to be an inexpensive and useful method to involve various users early in design. While this method is found to work well with elderly [26], it is not particularly suitable for blind participants. On the other

side, while evaluation of working prototypes with the thinking aloud method has been found to be useful for many different user groups, including visually impaired and dyslectic users [27, 28], this method is difficult for elderly, possibly because it puts too high demands on their short-term memory [26]. It is thus necessary to consider what design techniques are appropriate for which users in what contexts and parts of the development process [16].

Empirical evaluation studies involving disabled participants usually find many problems that can be labeled as usable accessibility problems. Examples include issues related to navigation, ambiguous language and labeling, and inadequate help features [28, 29]. The same problems can often be observed across various types of disabilities [27–29], and will often be encountered by people without a disability as well, although non-disabled might not always be so seriously affected [24]. This means that evaluations with disabled people can be an effective way of uncovering general usability problems as well as for uncovering accessibility problems.

In summary, the overall recommendation from related research is to base the inclusive design process upon UCD, to complement with activities for ensuring conformance with accessibility standards and guidelines, and to extend and accommodate UCD methods and techniques to tailor people with disabilities. However, there is a need for more specific knowledge on how to handle the issue of diversity of users when moving from UCD to inclusive design [16, 30].

3 Experiences from Own Development Projects

Here, we summarize the experiences from development projects conducted at our research institute. These are as follows:

- DIADEM – a prototype for delivering inclusive electronic forms for impaired individuals and elderly [31]
- UNIMOD – a prototype for inclusive access to public services [32]
- KogNett – web pages for people with cognitive deficiencies [33]
- e-Me – a universally designed bill sharing application in social media [34]
- MobileSage – a smartphone application for context-aware adaptive guidance for elderly [12]

The DIADEM project had an effort of roughly 3.2 MEUR distributed over 36 months and involved 8 consortium members from three European countries. Its deliverable was developed on the basis of a spiral process. One development cycle consisted of the steps documentation (specification writing), implementation and integration, and evaluation. Unfortunately, multiple specifications (user requirements, system functional requirements, integration requirements, etc.) provided synchronization challenges to the programmer. It is deemed as beneficial to collect all implementation and integration requirements in a single document for the sake of simplicity. Next, the requirement specifications were mainly textual and not very specific when it comes to the user interface. It is thus recommended

to include mockups and wireframes in the technical specifications to aid the programmer in the decision finding process. Last but not least, early design drafts were evaluated by experts but not end-users, resulting in a situation where the first-iteration user trials uncovered a great number of necessary major changes in the user interface, which were expensive to implement. Consequently, we recommended to let end users find poor design decisions in the early drafts.

UNIMOD was in order of 1.7 MEUR over 28 months, with 9 national partners. The project deployed an iterative design method, with a number of small-step integrations. This approach was chosen such that the participating public authorities could modify their requirements at any time. Small development iterations alternated with expert evaluations, while user awareness was honored by applying scenario and the persona method. As with DIADEM, early multiple designs were not evaluated by the end-user but rather expert users, which led to insecurity concerning if the chosen design would fit the user's needs in the end. We also learned that a great number of iterations may require a great effort by the programmer, as many aspects of the solution can be altered in each cycle. The recommendation here is to restrict the evaluation in particular iterations to only parts of the solution to reduce the programmer's effort required to implement all changes.

KogNett was a small-scale (50 KEUR) project over 2 months with only 2 consortium partners. Due to its size and limited duration, it deployed a waterfall method. User centered development was mainly accounted for in terms of several development iterations with expert evaluations, while testing by the end user came not until the deliverable's final public release. In developer terminology, the developing stages Beta and Golden were merged to a single deliverable, and flaws were fixed also after the final release. This approach worked surprisingly well, mainly due to the project's simplicity. However, until the final delivery it was unclear if the project really would meet the needs of the target group as the initial user needs analysis had been conducted by experts. It is therefore recommended to quality assure any expert needs analysis by an evaluation with users from the target group.

e-Me had an effort of roughly 1.7 MEUR over 33 months and involved 9 consortium members from a single country. It was based on rapid prototyping. While the development was to a great deal ad hoc based, it was evaluated in infrequent expert tests, followed by a final user trial to verify results. This pattern let the prototype run into the danger of not converging into a satisfactory solution. It is thus recommended to limit the number of evaluations to a well defined value. The lack of an up-front design resulted in a higher degree of redesign effort in the long run. On the other hand, decentralized decision making led to quick code (but not necessarily optimal) changes.

MobileSage is a project in the order of 2.8 MEUR, has a time span of 30 months, and involves nine members from three European countries. It utilizes a spiral method, with in total three development cycles. Each iteration consists of the development steps planning, implementation and integration, and evaluation. The initial planning step involved focus groups, and the last evaluation will

be the verification of the final design. Other than that, each evaluation is based on the participation of users of the target groups. The spiral approach worked well, except that the initial focus group work was unable to discover some requirements that were viewed as important later on. It would thus make more sense to let an expert group conduct this step and have a focus group quality assure their work later on. Also, having user trials in each cycle is a cumbersome process which introduces some unplanned delay. Here, a number of issues could have been caught by an informal expert assessment in a more efficient manner.

4 Hands-On Best Practices

Few development methods foresee the involvement of users, be it traditional or agile. This must hence be handled by surrounding processes and/or the underlying framework. However, the majority of such frameworks, as for instance defined by the Living Labs movement, does not specify the exact method but rather suggests several alternative methods and techniques for user involvement, which must be selected on a best-fit basis for a given project [35].

Based on the aforementioned recommendations from the literature and our own development projects, we present the following best practices for an effective development of inclusive ICT. They are given on a general basis, to applied wherever possible. The user centered design activities are also shown in Figure 1 on the facing page, which can be used as a template for planning UCD.

- Have a user needs analysis brainstorming by experts to collect user requirements. This is cheap and accounts for system requirement as well.
- Prepare multiple designs in a co-design phase [36].
- Prefer paper prototypes over web mockups and grid building tools / wireframes, if possible, due to efficiency and cost issues.
- Sort out poor design and thereby merge good design decisions into a single Working Draft by means of a focus group with users from the target groups. With other words, combine parallel development with collecting the best design elements of each prototype, followed by iterative refinement.
- Plan with at least four development stages according to the activities needs analysis, automated testing, expert testing, and user testing.
- Let one development cycle contain the steps requirements formulation, implementation, integration, and evaluation.
- Do as much (semi-)automated testing as possible before evaluations that involve humans as this is a cheap process, but keep in mind that the majority of usability problems are found in user trials [21, 22].
- Let experts wipe out the most obvious usability and accessibility flaws before involving user groups.
- Prefer testing with people with disabilities over people without disabilities.
- Let at least the following subgroups be represented in each user evaluation: the sensor impaired (at least sight and hearing), the cognition impaired (e.g., dyslexia, etc.), the motor impaired (e.g., cerebral palsy), individuals with a combination of impairments (e.g., elderly), and individuals with low IT skills.

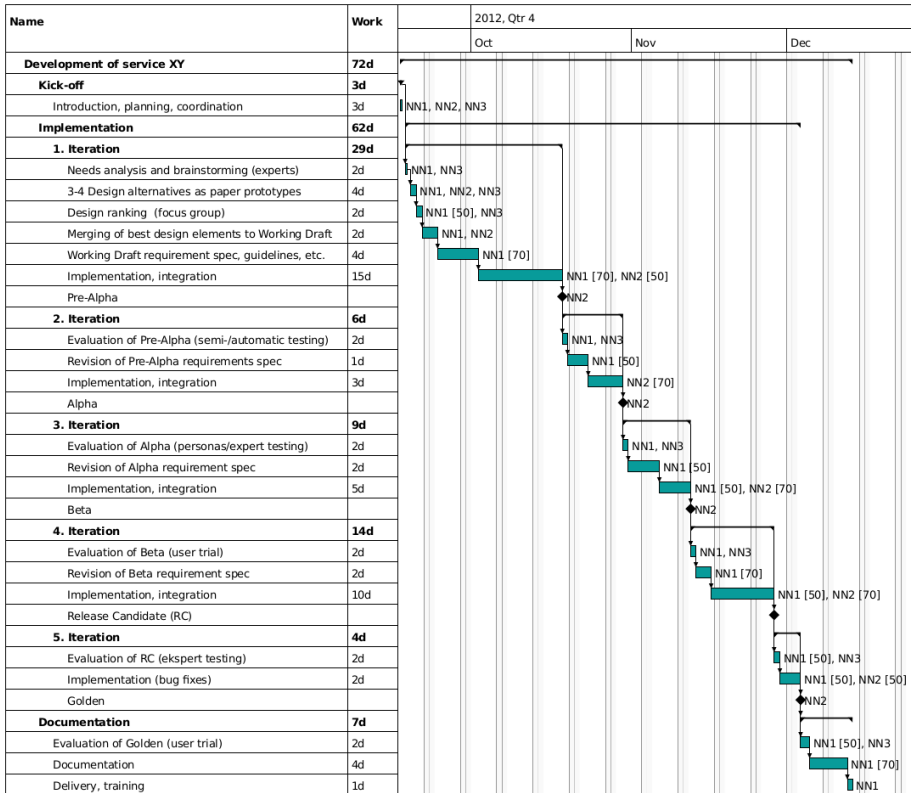


Fig. 1. Gantt diagram template for planning of user centered design activities. Activity durations are only set for illustration purposes.

- A subgroup should consist of five (three if more than two subgroups) to eight users; a minimum of five to cover 85% of usability issues, and a maximum of eight to avoid inefficient testing [37]. Bigger user groups should be split up into several iterations with smaller user groups; e.g., three iterations á five users instead of one iteration with 15 users [37].
- Design and test the user interface first, then complement it by the functionality of the underlying application and system.
- Make user trials as much hands-on/realistic as possible; e.g., let impaired users test with their own equipment and in their own context in the field, and let them use assistive technology.

5 Conclusion

We have discussed how universal-design aspects can be included in the software projects to develop inclusive ICT solutions, based on recommendations from

relevant literature and on our own experience with small to medium-scale development projects. We also presented a list of best-practice measures to be applied to projects with deliverables which have to meet universal-design requirements and want to do so in an efficient manner, and a workflow template which can be used as an example.

By sorting out possible pit-falls and summarizing recommendations, this work anticipates to aid projects in making the right decision regarding workflow, activities, activity order, etc., with the overall goal to make any ICT solutions as accessible and usable as possible, and to reach this goal in an efficient way. It is suggested, though, that the recommendations given here be not applied without thought, but should be considered with regard to the respective situation particular for each development project.

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The Evolving Global Public Inclusive Infrastructure (GPII)

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Abstract. We are facing a perfect storm where, just as access to ICT is becoming mandatory for meaningful participation, independence, and self sustenance, we find that we not only are nowhere near providing access to everyone who needs it, but we are actually losing ground due to reasons such as technical proliferation across platforms, increasing product churn (breaking existing solutions), decreasing social resources to address it, and an inability to effectively serve the tails of these populations because of the higher cost to do so. At the same time the incidence of disabilities is increasing as our population ages. This paper describes the Cloud4all and Prosperity4All projects and progress in building the Global Public Inclusive Infrastructure, an infrastructure based on cloud, web and platform technologies that can increase dissemination and international localization while lowering the cost to develop, deploy, market, and support a broad range of access solutions.

Keywords: Universal Design, Inclusive Design, Digital Divide, Cloud computing.

1 Introduction

Over 2 billion people worldwide have different types, degrees, or combinations of disability, literacy, digital literacy or aging related barriers that impede or prevent use of ICT. Not long ago you could live without access to ICT quite well. However today access to ICT is required for most education, employment, and commerce, and is increasingly required for travel, health, safety, daily living and participation in most of our society. Yet we currently only reach 3 to 15% of these - in developed countries. We cannot socially, economically or politically afford to have this cumulatively large percentage of our society offline going forward. Yet there is no way to reach them with our current model.

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There is a pressing need for a paradigm shift in access to ICT by people with disabilities and elderly. The current model and system are not serving the majority of those how need it and the challenge is only becoming greater and the consequences more severe.

Access to information and communication technologies and services is increasingly becoming essential for everyone, leaving those who cannot effectively access and use these technologies at risk of exclusion from education, employment, commerce, health information, and almost every other aspect of daily living and civic participation. Those at risk include those who cannot use ICT and services due to **disability, low literacy, low digital-literacy or aging related barriers.**

In the past those who could not access these technologies could get by, avoiding technology entirely. However, ICT is now becoming so engrained in all aspects of society that this is no longer an option. If we don't / can't provide access to these groups they soon will be unable to participate in education, employment, commerce, our health system, transportation, or even daily independent living. This need to ensure that everyone is able to access and use ICT however is occurring at the same time we are facing something of a perfect storm in accessibility; where a number of factors are all coming together at the same time to create a fatal combination.

1. **Fewer resources:** The new economic realities mean that we will have less, not more, resources to address the needs of this much larger population. It is impractical to think that we can solve the problem by sharply increasing expenditures on this. Is also impractical to believe that we can serve this much larger population with decreased resources by approaching the problem the same way we have done in the past.
2. **Many small groups – together large:** The problem is broader than just disability and includes people facing barriers to ICT from disabilities, literacy, digital literacy, and aging. All of these groups are threatened with an inability to participate, be productive, live independently, or participate as we continually 'technify' everything around them. Although it is many many small groups, they are cumulatively large, around 2 billion¹ worldwide.
3. **We never were reaching a reasonable fraction:** We must recognize that, even before the financial crisis, in the developed countries, we were never reaching more than a small fraction of those who needed special access technologies or features in order to effectively use ICT. There are no solid data, but AT manufacturers estimates of their market penetration, although varying widely, all fall in the very low range of between 3% and 15% of those that need assistive technologies being reached, cumulatively.
4. **Focus on the “mainstream” disabilities leaving the tails unaddressed:** Current solutions tend to focus on the larger populations or mainstream disabilities, with

¹ There are an estimated 1 billion+ people with types, degrees, and combinations of disability who face substantial barriers in daily lives [1] an unknown portion of which need special features or capabilities to use ICT; about 800 million people with literacy levels that prevent them from employment and other social participation [2] about 870 million (and rapidly increasing) people aged above 60 at risk of digital divide [3]. Even accounting for overlap on the fact that only some elders have problems, when you combine these with those who are not digitally literate the number is in the neighborhood of 2 billion+.

fewer or no solutions for individuals at the tails of each disability distribution; for low incidence groups. And with all the types, degrees, and combinations of disability, literacy, digital literacy, and aging, a large portion of threatened group falls outside of the large/mainstream/single-limitation category where all of the current focus lies, and it one of the many ‘tails or ‘tails of the tails.

5. **Existing solutions focus on biggest few platforms:** A majority of the solutions that we have tend to be for one or two major platforms. Yet industry, consumers, and public entities (schools, employment, transportation, etc.) are moving to a wide variety of platforms (operating systems, browsers, mobile technologies, etc.). Assistive technology vendors had great difficulty keeping up with even the one or two platforms they were supporting since these platforms were continually being advanced and upgraded, continually breaking the AT in the process. With the rapid proliferation of platforms vendors are completely unable to address all of these (disability, literacy, digital literacy, and aging) groups, across all of the devices and platforms that these groups are encountering in daily life (education, travel, etc.).

To make things worse for a key vendors, the advent of inexpensive mobile platforms (iOS, android, Windows phone, etc.) has dropped the bottom out of the AT pricing, making it harder for AT vendors to profitably market solutions for any group other the largest user groups -- and any platforms other the most popular platforms. And as accessibility features that are being built into mainstream products eat away at the bulk of AT vendor’s easier to serve customers, we risk losing the only group (AT vendors) that is capable of addressing those with more severe-, complicated- or mixed- disability/literacy/digital-literacy/aging problems. And although all of these “tail” groups are small and each requires different solutions, they cumulatively represent a significant population that must be served.

6. **Not just devices, also e-documents, media, and services.** The problem extends beyond devices, and also includes document and media access. Access to documents and media have always been critical to education and work but access to any and all documents and media, including locked electronic documents are also essential for participation in most types/areas of society, legal papers, and health records. As we shift to an increasingly all digital society, document and media access issues are becoming increasingly acute.
7. **It is not just vendors and consumers that are feeling the impact.** The rapid proliferation of platforms, devices, and solutions is leaving those who must deliver accessibility (clinicians, educators, libraries, public access points, government funding agencies, etc.) confused, perpetually behind, and unable to track or understand what is available, much less which solutions would be best or even effective for their different clients/patrons/citizens.

So we have a perfect storm; where just as access to ICT is becoming mandatory for meaningful participation, independence, and self sustenance, -- we find that we not only are nowhere near providing access to everyone who needs it, but we are actually losing ground -- due to technical proliferation across platforms, - increasing product churn (breaking existing solutions), - decreasing social resources to address it, - and an inability to effectively serve the tails of these populations because of the higher cost to do so (due both to the diversity the tails represent and the inability of

AT vendors to generate sufficient revenues to support serving these groups with our current infrastructure and assistive technology ecosystem).

2 The Role and Limitations of Research

We have applied science to the problem and it has given us some powerful new technologies for addressing some specialized and some general disabilities. However this alone cannot address the issues described above, and the lack of a good mechanism for moving these research results through to commercial and clinical availability leaves many of these developments in laboratories or journals rather than reaching the market and consumers/users who need them. They also are too few and often focus on technical innovation rather than on innovation that would result in more cost-effective ways to address the needs of the large population of underserved and un-served people who face barriers to ICT due to disability, literacy, digital literacy, and aging. We are left with:

- solutions for only for some of the different types, degrees and combinations of limitations, and only on some devices/operating systems,
- solutions that are available in only some languages, in some countries, and acceptable to only some cultures,
- solutions that are not reaching even those who can use what is available and can afford them, (which further increases the costs due to unnecessarily low sales),
- a development and delivery ecosystem that costs too much to allow us to develop for and serve even a fraction of those who need special access techniques or technologies,
- vendors (especially small to medium vendors) who are financially strapped, limiting their ability to innovate, develop for new platforms, develop for low incidence disabilities etc.,
- new techniques and technologies coming out of research but not making it beyond project review and publication -- no mechanism to commercially harden them or get them to market,
- disability solutions that don't really fit individuals with literacy, digital literacy and sometimes aging related barriers,
- solutions that are technology driven, or based on what sells most or what designers believe, rather than what users need/want,
- assistive technology vendors who are in trouble and narrowing their product line focusing on sweet spots in disability to be healthy,
- lack of involvement of most researchers outside of a small group that is dedicated to accessibility research;
- Poor awareness of what does exist, resulting in poor market reach and penetration which hurts both consumers and vendors;
- schools, companies, governments who find it difficult or impossible to ensure that students, employees, customers, patrons etc. with disabilities etc. are able to access all of the media and materials they generate and distribute;

...and no option except to find some new way to provide access to all these groups - if this cumulatively large and growing portion of our population is to be able to participate in education, employment etc.

Research can tell us about these problems. It can give us new tools. But it can't deliver solutions and provide all of the innovation – especially **user level innovation**. **For this we need the entire "AT – Mainstream – Provider – Funder" ecosystem**. Yet our current ecosystem can't serve but a fraction, focuses on "majority disabilities", can't address the tails, and is losing ground as technology accelerates and proliferates, etc.

3 Elements of the Solution

These problems are emerging despite the attempts of researchers, companies and policy makers to address them. But the problems have not been addressable using the model we have been using to date no matter how much effort is expended. The model has worked well for about 15% market penetration [2] with a stable technology landscape. But 15% penetration is not sufficient when access to technology is no long optional, and we no longer have a stable technology landscape.

3.1 Addressing Industry Needs

Industry is key to solving this, yet industry (mainstream and AT) has faced barriers in its attempts to address and grow the market. Any solution must therefore facilitate the private commercial sector efforts; help them reduce costs and grow their markets to cover as much as possible, while ensuring that those they cannot reach have access as well.

Any new approach must address the underlying problems commercial problems, such as:

- limited market penetration,
- the high cost for marketing, distributing and supporting assistive technologies,
- the high cost for development of new approaches,
- the high cost of just keeping existing technologies working with ever-changing ICT and web technologies,
- the difficulties faced by new innovators in developing alternate and innovative solutions and getting them to market, etc.

3.2 Addressing User Needs

The new approach also needs to make it much easier for users to:

- discover there are solutions to their problems,
- determine what types of access features or technologies would address their particular problems,
- locate specific solutions, and
- get these solutions delivered and set up on their computer(s).

Moreover, it needs to allow them to access and use these solutions not just on a single computer, or maybe two, but on all of the different computers and ICT that they must use (in different classrooms and laboratories, at home, at work, and the community, when traveling, etc.).

4 The Global Public Inclusive Infrastructure (GPII) Initiative

To address these issues, an international coalition of organizations and individuals is coming together and proposed the development of a global public inclusive infrastructure (GPII).

The goal of the GPII is to create the *infrastructure* from which *a new ecosystem can grow over time* that can address these problems. This work began with the FP7 project *Cloud4all*. The ongoing Cloud4all project is building the initial pieces of the infrastructure necessary to allow *instant auto-personalization* of software, devices, media, materials, and services *based on user needs and preferences* (stored in the cloud or on a personal device). See Figure 1. This infrastructure allows assistive-technology and mainstream-product manufacturers (software, hardware, media materials and services) to create products that can automatically change their interface or format to accommodate the needs of each individual as the individual encounters them. The long-term result can be a world in which each of us would find that essentially every device we approach would instantly and automatically change into a form that we are able to understand and use.

The GPII consists of enhancements to platform and network technologies to create an infrastructure that would simplify the development, delivery and support of access technologies and provide users with a way to instantly apply the access techniques and technologies they need, automatically, on any computers or other ICT they encounter.

In specific, GPII aims to:

- Simplify accessibility for users, schools, public access points, organizations, companies, governments, etc.
- Increase built-in accessibility in those places where it is practical and effective, to provide ubiquitous access that is natural, doesn't have a stigma, and doesn't 'tax' individuals with disabilities by causing them to pay more to access the same ICT as their peers.
- Grow the market for assistive technologies and services, in order to serve more people, lower costs, and increase motivation to innovate and invest in accessibility.
- Facilitate international, public-private, private-private and cross sector collaboration in order to lower costs, to reduce duplication and to accelerate innovation.
- Increase the number of new ideas and products that make it to market – and make it easier and much less expensive to market them internationally.

4.1 Origin and Support for the GPII

The GPII initiative is a synthesis of ideas and efforts from many people and programs in the US, Canada, Europe and other countries. It is a concept that grew out of the Raising the Floor initiative, which is now coordinating the international efforts on GPII. Raising the Floor, a non-profit association based in Switzerland, is a coalition of academics, ICT industry (IBM, Microsoft, etc.), AT companies, practitioners and of course consumers (individual and in all of the above). There are currently about 80 programmers, designers, researchers, practitioners working on the GPII and it's components -- and the participation is continuously growing.

Initial funding for the development of the GPII concept and components is coming so far from the US National Institute On Disability and Rehabilitation Research (NIDRR), the William and Flora Hewlett Foundation, the Canadian government, the Adobe foundation and the funders of the other participants in Raising the Floor.

The major components of the GPII Concept as it is currently conceived are shown below with highlighting on the areas on which Cloud4All will work.

Overview of the GPII. Figure 1 shows an overview of the Global Public Inclusive Infrastructure (GPII). The Infrastructure has three major functions, each with five major subcomponents.

The three major functions of the GPII are:

1. To provide the infrastructure - to make it easy for individuals who have difficulty in using ICT (for any reason) to be able to discover what features or technologies they need in order to make ICT usable for them. This information is then stored in the cloud or in a personal device.
2. To provide the infrastructure - to allow users to use their needs&preference sets to cause any software/devices/media/ebooks/edocuments/services to automatically change (or be changed) into a form that they can use - instantly - and without their understanding how to do it.
3. To provide the infrastructure - that can make it easier, less expensive, and faster to innovate and then move these innovations through development and to markets internationally; - as well as to enable the development of entirely new types of accessibility solutions and delivery systems.

Each of the rows in figure 1 represents components in the infrastructure needed to achieve the one of three major functions. *Cloud4all* focuses on the key components needed to enable auto-personalization from user (needs and) preferences a PFP). The lower row(s), focus on building the infrastructure needed to grow a new ecosystem that is capable of addressing the key factors preventing us from being able to create solutions for all the need them – and to reach them in a manner that is affordable to users, schools, libraries, companies and society.

Major Components of GPII

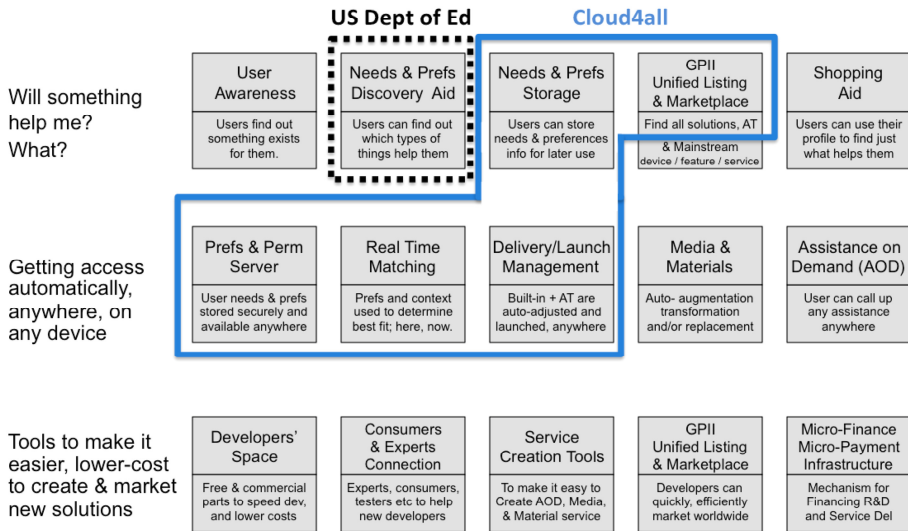


Fig. 1. The Global Public Inclusive Infrastructure and its relation to Cloud4All

Status

The *Cloud4all* project is well underway with mainstream and AT companies already demonstrating their products being auto-configured to user preference sets, that are retrieved from the cloud or a personal key-token (a USB stick, or an NFC tag or ring worn on the hand, facial recognition in the home, etc.).

Table 1. Technology Implementations of Auto-personalization underway in Cloud4all

Prototypes			
1	Linux/Gnome	11	SuperNova Suite of low vision and
2	Microsoft Windows	12	Maavis (cognitive aid)
3	Microsoft Internet Explorer	13	Mobile Accessibility (mobile phone AT)
4	Mozilla Firefox	14	ReadWrite Gold & BrowseAloud
5	Simple phone (JAVA)	15	Allan eC (communication system for deaf,)
6	Smart phone	16	eKiosk
7	WebAnywhere (Cloud/online based AT)	17	Microsoft PixelSense Platform ('surface' touch-based technology)
8	SAToGo (run from server AT)	18	Smart-house
9	Online banking web application	19	DTV(iTV)
10	ASIT Social networking application		

This Cloud4all/GPII instant auto-personalization provides many advantages to consumers including making individualization of ICT possible in a quick and very simple fashion. However auto-personalization cannot address all of the problems cited above, such as the lack of solutions for all types of users, access features for all technology platforms encounter, cost, etc.

Next Steps

The next steps in building the GPII will focus on addressing building the development infrastructure that will allow a new ecosystem to develop where these solution problems can be addressed. A project titled Prosperity4All proposed to the European Commission under FP7 will build an infrastructure that is based around cross-platform development techniques and that employs modern techniques such as crowdsourcing and gamification to both enable new strategies for the delivery of accessibility services and to enable an entirely new approach to accessibility solution development; an approach that can increase the percentage of research that actually makes it into the hands of users, increases the number of different types of researchers (especially researchers focusing on basic science areas) to contribute and enable breakthrough solutions; increase the number and variety of individuals and skills which can be brought to bear on the problem; and broaden the development process out toward users so that users and those living with them, or working with them, can get more directly engaged in the development of solution for them (selves). Prosperity4all, focuses on developing the infrastructure to allow a new ecosystem to grow; one that is based on self-rewarding collaboration, that can reduce redundant development, lower costs, increase market reach and penetration internationally, and create the robust cross-platform spectrum of mainstream and assistive technology based access solutions required. This will be done through a process based on true value propositions for all stakeholders and resulting in a system that can profitably serve markets as small as one, at a personally and societally affordable cost. This infrastructure will use cloud, crowd, game and smart technologies, to bring new players with both low and high technical skills into the development and delivery ecosystem, introduce accessibility as a ubiquitous service, and combine auto-configured access features built into mainstream products with assistive technologies and services to create the rich spectrum of options needed to bring this diverse 'population of populations' into our digital future.

5 Conclusion

Society is facing a looming crisis where access to ICT is becoming required but we do not have access solutions for all nor do we have anyway to deliver solutions to all that need them in an affordable manner. In order to meet the demand we are going to need to eat all a new ecosystem that can develop deliver and support solutions to a much wider range of users at a much lower cost. A consortium has come together that is beginning to address this problem. However it is a very large problem and the most important part, that of providing the economic ecosystem for developers, has yet to be realized. Without this key piece, we may have a way of effectively delivering solutions, but we will not have the range of affordable solutions that is needed in order to be able to provide solutions to the full range of people who faced barriers to accessing ICT due to disability, literacy, digital literacy, and aging.

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Universal Access: The “Universal” Is Not as It Seems

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Abstract. The quest for universal access, still today is faced with the expectation of a minimal knowledge of the use of interactive equipment in order to establish successful communication between these equipments and users. We propose to broaden the discussion on ways to include those unfamiliar with the use of computers, the internet and interactive devices, people with little education and/or illiterate, while not excluding those already accustomed to the use of information technologies. We are not unaware of the undeniable fact that the search for a fully universal interaction is utopian, however, we try to explain the problem here and provoke discussion about the concept of universality.

Keywords: universality, interactive systems, interface, usability.

1 Introduction

The general idea of the concept interaction is to establish a mediator language between two distinct players where messaging can happen so that participants can understand and be understood in action. Following this concept, the Human-Computer Interaction (HCI) searches since its inception, sets mediation languages between two actors: the human being and the computer. We have as the beginnings of HCI the need to allow people who did not participate in the computers construction could operate them to process data and get the desired results. Since then, the search of mediator language between machines and people evolved a lot, today it has very different forms of interaction and uses various types of software and hardware for this purpose. The technology advancement in itself and its reach in different social circles and services offered to the population caused a growing number of people who needed access to computer services. This increase of the computer technology search is democratic, that is, everyone needs to access its services and there is no distinction between its users that may have different characteristics and are classified in many different ways (by age, social class, educational level, expertise level, etc.).

From these events have emerged software engineering studies that no longer prioritized the applications functional aspect and computer systems, or process models of software production and tried to give greater emphasis to the specific needs of people who would use the system in question (Pressmann, 2009).

From the concern in creating systems that meet beyond the features that were proposed but were also visually interesting and brought satisfaction to the user in its use, it comes the concept of usability. This concept, in the context of computing devices,

cares how a system is pleasant to use, easy to learn and to remember its manner of use. Preece (2011, 18) sets targets that serve as guides for the design and evaluation of interactive systems: usability goals - that deal with features related to interactive devices - and the goals arising from the user experience - focusing the awakening in the user certain reactions to the use of interactive device.

According to Preece (2011, 10) the interaction design, seeking for aligning itself more and more to the end user needs, dialogues with various disciplines in many different areas of expertise (graphic design, information systems, ergonomics, software engineering, psychology, social sciences, etc.). In this context, the organization aspect of information within the device also changed the studies field called Information Architecture (IA) and brings several contributions regarding the expansion of human capabilities in discovering and locating information. Based on Agner (2009, 90), "the focus of IA is the design of structures (information environments) that give users the necessary resources to transform their needs into actions and to reach their goals successfully."

In this concepts mixture that raised the user to another level of importance within the design of an interactive device, there is the issue of access to information for people with special needs. For this line of thought was given the name of universal access, which promotes the use of various forms of interaction combined into a single interactive device so that it can comply with various purposes and needs. For example, for users with mobility impairments, were created ergonomically different devices and that meet them, enabling their access to information contained in the device; for users with difficulties related to vision, systems that suit, as the use of different fonts size in web pages, deployable through the use of Cascading Style Sheets (CSS), or the use of audio description.

The search for universal access can greatly increase the systems complexity, since in the same system are contemplated several different forms of interaction and, consequently, different languages mediating between the user and the interactive device.

Nevertheless, we can state that the use of audio-descriptive systems, ergonomic changes and even the employment of motion recognition systems or voice still does not come in a significant number, the universal access, because when it is heard about universal access, in general, it is thought, or in providing access to populations where technology is not present yet, or in terms of interface, in objectifying up access (to contents) of users regardless of their physical-motor and perceptual, cultural and / or social abilities.

However, although there is a concern with these users' limitations of the devices it is still expected that those have minimal knowledge of the use of interactive devices in order to establish a successful communication between actors.

We then consider an interface that, ideally, reaches a broader universe of users, including the unfamiliar with the use of computers, the internet and interactive devices, people with little education and / or illiterate, and that the same time, we do not delete those already accustomed to the use of information technology.

This concern becomes even more significant when we analyzed a global indices extract of absolute, functional and technological illiteracy. We focus then on the development of interactive devices that can be called universal with more validity considering that even an interactive system has audio description, which in turn aims

to facilitate its use by the visually impaired people, its effective functioning does not preclude the need for this user to have knowledge of interactive computer systems, and thus it becomes exclusionary to a portion of users who does not own this prior training. For this perspective are mutually exclusionary in the same way systems using interactive technology resources supported in natural language or in picking up movements of the user, that, although they have conceptual simplicity of operation, need to practice in interactive devices and often of the reading capacity of their contents. This concern becomes relevant when analyzing the data provided by the IBGE (Brazilian Institute of Geography and Statistics) of the 2010 Census where the Brazilian population of 13,933,173 inhabitants has a rate of 9.6% of people over 15 years who cannot read and write, totaling over 1,300,000 inhabitants. The region of highest rate, the Northeast, has a rate of 19.1% and in cities that have 5000 to 10,000 inhabitants in this region, this rate reaches 29.6% of people who do not read or write. (IBGE, 2012). This picture becomes even more interesting when we know that, according to the UNDP (United Nations Development Programme), Brazil ranks among 187 countries, placing 84th in the HDI (Human Development Index). These data show that thinking only in people with physical or sensory difficulties, excludes a large portion of the world population that also needs (and has the right of) access to information and interaction.

2 Proposal

The proposal is to produce an interactive system that complies with a larger portion of the population, seeking to create models for persons who do not have experience in these systems or who do not have sufficient training to understand or read texts. As a whole, the interface should be inviting, encouraging the user to experience, to interact with its content. The whole process should be guided by mnemonic information that create analogies with the tasks to be performed, metaphors with elements of the real world and, in cases whose needed actions are less intuitive, ie, are not likely to be perceived by themselves, small animations can explain to the user what to do. To contemplate such functionalities and features, we can make use of usability techniques, information architecture and game design to develop a suitable environment to our expectations.

Both the devices as gaming is desirable that the experience provided is meaningful and enjoyable. Meaningful, in order to make sense for their user, namely, it must seem consistent within its own proposal, otherwise may alienate those who do not understand the meaning of the actions they perform. Some concepts of game development have equivalents in the field of usability.

The concept of learning curve, for example, is correlated to the concepts of learnability. The learning curve takes into account the speed with which the player feels comfortable with the game controls, and the learnability concerns about the user's ease to learn how to use a particular software. Both depend on the user to understand the operation of the system, in other words, its intelligibility.

The games, usually, keep increasing the difficulty degree of the actions that the player must accomplish over time, starting with simple actions whose difficulty grows as the player will get used to the development of the previous action. Another concern is the reuse of actions, similar contexts that can be solved with similar actions.

In the games or in any other type of interactive system, it is important that its structure guides the user, both in the sense of letting you know where you are within the data set from that system, and in the sense of giving feedback to their actions. When the user acts within the environment is important that he realizes that his actions influence this structure and what are the consequences of these actions, receiving positive or negative feedbacks to their movements, including helping you to understand the rules and operation of the device through the discovery of what he is allowed and what is denied.

We bring so from the game universe, the concept of rules as being the ones responsible for determining what can or cannot be done and what happens as a result of the choices, guiding the user action in order to produce significant results within each application in particular. As in the games, the rules must be clear and unambiguous so that their understanding contributes for the user can increase his repertoire and skills while giving him a pleasurable and meaningful experience.

Although the concerns about a pleasurable experience are eminently linked to games, they must not be altogether discarded when there is a concern in meeting the user of a given device, whereas other questions to be analyzed, in terms of usability, is the attractiveness, that is, how attractive is that application to the user. Furthermore, we must consider that the playful aspect of the game is admittedly a learning powerful tool.

"The games can be used for a variety of purposes within the context of learning. One of the very important basic uses is the ability to build up self-confidence. Another one is the increased motivation." (Fernandes, 1995).

The feedback information from user actions, contextualizing him within the interactive system and explaining the results of his actions are important for the user to define his next step. The way as the actions are developed can be understood in terms of mechanics. The game mechanics are characterized by a set of available elements for interaction and modification of the gamestate, they regulate the actual interaction with the game and are shaped by the player's action who changes the game state, proposing a continuous challenge in pursuit of his goal. Thus, the mechanics should be characterized by the choice options available to the user and their multiple possible outcomes. Salen & Zimmerman (2003, p.63-64) describe the anatomy of a choice from five questions.

1. The first question approaches the context in which the choice is made, and it is concerned with the state (of the game) before the player has the choice.
2. The second asks how the choice is transmitted.
3. The next question focuses on how the player (user, in case of this system) makes the choice, concerned with the ways in which they are given the opportunities for action.
4. The result of choice and how it will affect future choices is at the heart of the fourth question. "This element of the anatomy of a choice speaks to the outcome of a player action, identifying how a simple choice impacts larger events within the game world."
5. The last question seeks to understand how the outcome of the choice is transmitted. This result will provide the context for the next choice, sending us back to the first step.

The more information the users has, the more informed his decision will be, which will result in smarter or more elegant choicest, besides it will provide him a greater sense of control over his progress. So, the system meaning emerges through this relationship that is established between the user action (due to his choice) and the result of this.

2.1 System Requirements Definition

To think an interactive system, we will use software engineering artifacts to systematize our creation. Initially, we thought the needs of the system in question comprehensively, which is pictured below in scope.

It is an interactive system generic, namely, which initially has no particular function except to promote the exchange of information between a user and a system. This system will be offered in a format that does not increase the complexity in its use: a hardware with touch screen would be more appropriate. The form of communication used by the iPad's appears to be quite suitable for use as touch screens and, in the first interaction, the only option with the device turned off is a button front, which simplifies to the maximum the initial step of the interactive process. The audience considered as users of such system is composed of people who have no formal schooling, thus it rules out the possibility of interaction through text. The end users also have no experience with interactive systems. Ideally the proposal is that the portrayed user receives the system in a device and be able to communicate and develop interaction with it even without any external help.

From the stated scope, we can define a list of system requirements:

"a format which does not increase its complexity":

- must be developed in a portable platform tactile interaction, based on the simplified operation of the iPad

"must not have text interaction":

- use of shapes and colors to portray the system functions.
- use of animation to explain more complex functions.

"able to communicate and develop interaction without external assistance":

- use of metaphors with elements of the real world.
- analogies to represent the functions performed in the system.
- constant feedback of user actions (tactile, auditory and visual).
- organize tasks in order to reduce the time he takes to learn how to use the system.

Analyzing these requirements, we can trace the interaction design goals of our system (PREECE, 2011, pg. 18) to be satisfied the necessary specificities to accomplish the project.

Table 1. Usability Goals and expected solutions

Goal	Expected Solution
Efficiency	<ul style="list-style-type: none"> The system will perform the function which it is intended, in the case of our project, its goal is not defined yet.
Effectiveness	<ul style="list-style-type: none"> The system will have fewer levels of interaction to simplify its operation. In a few interactions he must offer the result of a task; Its interface must be clear and with large size icons enough to facilitate its operation.
Security	<ul style="list-style-type: none"> The system must communicate constantly with the user through symbols and visual, tactile and sound signs, denoting the result of an action or the path to the next action; The organization of information will be designed so that the user feels comfortable and secure in his actions.
Usefulness	<ul style="list-style-type: none"> Our system has no specific function, but it will demonstrate the operation of an interactive system broader with respect to users who may operate it.
Learnability	<ul style="list-style-type: none"> The system will bring visual, audible and tactile elements to establish a language through comprehensible signs to the less skilled users, allowing its operation be learned with little difficulty; The use of game design techniques for the difficulties levels organization must provide a gradual and permanent learning.
Memorability	<ul style="list-style-type: none"> This goal must be achieved by the simplicity of its operation.

Regarding the resulting goals from the user experience, it is expected that this system is:

- **Satisfactory:** providing training for operation of an interactive system for a class of users with very little experience in process
- **Friendly,** fun and aesthetically appreciable: its interface of easy understanding must exploit to the full graphical capabilities of the device, providing an interesting sensory experience to the user.
- **Emotionally** appropriate: feelings such as fear, uncertainty and unpleasant surprises will be avoided to the maximum seeking emotional comfort needed for the user to operate the system as a whole.

3 Testing the Assumptions

The hypothesis treated here is that it is possible to transform applications and interactive devices so that they can serve a larger number of users, including those who are illiterate. To meet this goal, we will use signs, colors and action feedbacks that guide the user to accomplish a given task. The experiment consists of applications that will run on

a tablet. Each application brings in a progressive manner, the use of visual aids that help to fulfill a simple task. Moreover, it stores data covertly from user as solution time, mistakes and successes during the development of each step. For the experiment, we attempt to portray a sample of heterogeneous population, consisting of people from various levels of education, banks, employment agencies, parks and popular markets, in which volunteers who can devote a portion of their time to the test development would be approached. The test uses four applications and each of them will be shown to a distinct group of volunteers. All applications interfaces have three circles, and each one of them is in a color and also there is a background in a fourth color. The volunteer must be enlightened by the following text on screens 1, 2 and 3. "You need to touch the tablet in a sequence of circles which we expect you fulfill and for that you have three touches."

3.1 Screen 1: Gray Shades

On this screen are shown three circles of equal size, aligned and with different gray shades on a quarter gray shade. It is hoped that volunteers touch within the circle on the left, in the middle and on the right in this order, what action would be considered correct. However it is not expected that most of the volunteers fulfill this action order.

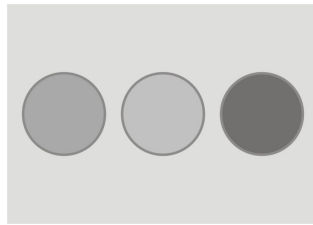


Fig. 1. Colors and Shapes Screen 1 of the experiment

3.2 Screen 2: Colors of Light

On this screen are shown three circles of equal size, aligned, the one on the left is green, the middle yellow and the third red, both of them on a blue background. These colors by themselves are a metaphor to traffic lights, which already indicate a possible order of action (there are no lights in the sequence green-red-yellow, for example).

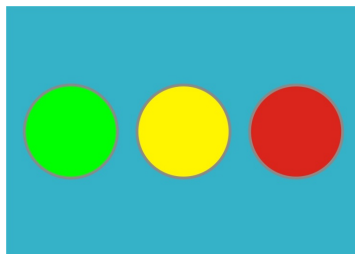


Fig. 2. Colors and Shapes Screen 2 of the experiment

The volunteers are supposed to touch the green circle firstly, then the yellow and finally the red one. It is expected that the number of volunteers who perform the action in the desired sequence is considerably larger than the ones from screen 1.

3.3 Screen 3: Colors and Indicator Light

On this screen the colors and the circles layout are identical to those applied on Screen 2. Furthermore, the circles to be clicked by the volunteer receive a highlight with a background 'light' indicating that it is correct at that time. The volunteers are supposed to touch the green circle firstly, then yellow and finally red in the same way as it is indicated by the backlight. The indicator light only will change for the next circle indicating the next one if the volunteer has performed the step correctly, but it remains in the circle which he should have touched until he finishes his chances of touch. It is expected that the number of volunteers that perform the action in the desired sequence is close to all the respondents.

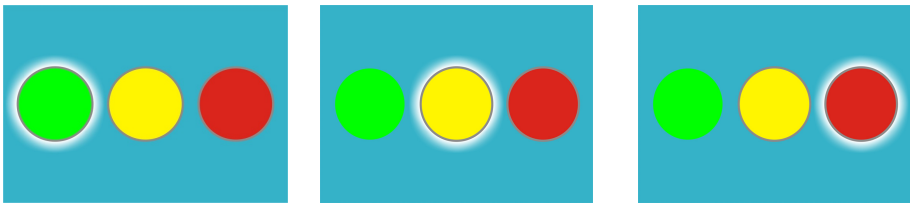


Fig. 3. Colors and Shapes Screen 3 of the experiment, with a color indicator light to meet the desired sequence. If the volunteer is wrong, the light continues until he performs correctly or his chances have finished.

3.4 Screen 4: Color, Light and Feedback

In this test, the volunteer must be enlightened by the following text: "You must touch on the circles in an order you are supposed to fulfill."

This screen has the same components of the screen 3 but, when the volunteer performs the sequence correctly, it appears on the screen a sign indicating correctness ("V") for about three seconds and it displays the light in the next circle to be touched. If the volunteer misses the sequence circle, the application displays an error indicating signal (red "X") and the indicator light continues to shine in the circle which is expected to be touched. At this stage, the volunteer can touch and miss (make right) as many times as necessary to accomplish the task. He is supposed to touch it in the same sequence shown on screen 3 (green, yellow and red), also his understanding about "V" indicates correctness and "X" indicates error, knowing now if he hit or missed the expected sequence. It is expected that in this test there is a minimum number of volunteers who miss the sequence.

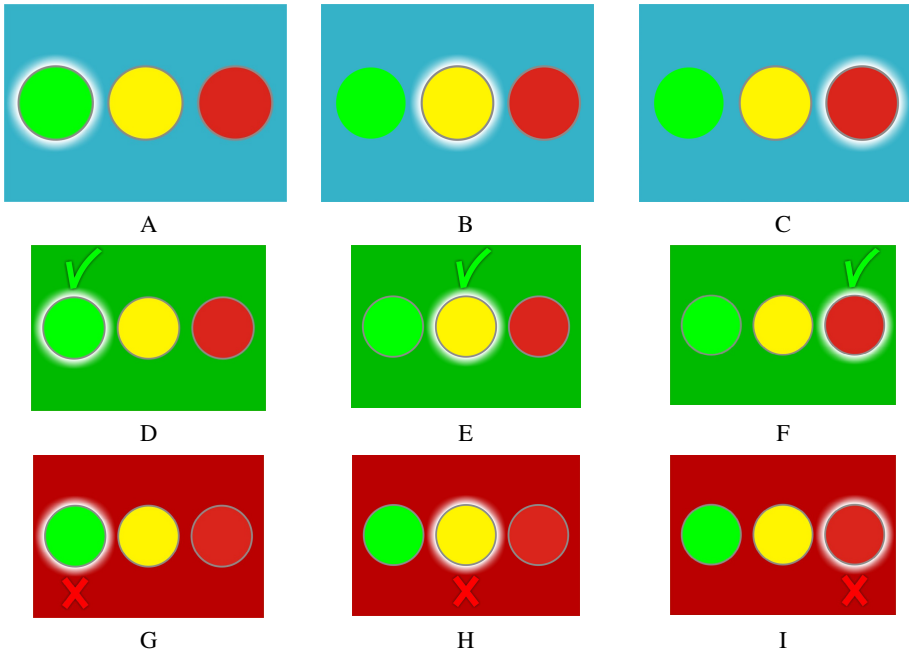


Fig. 4. Shapes and colors of the screen 4 of the experiment, with one color indicator light to accomplish the desired sequence (A, B and C). If the volunteer is successful, the light remains in the right circle, so the background turns green momentarily and a "V" appears as a form of feedback for the correct action (D, E and F) and then it returns to the home screen (A, B or C). If the volunteer is unsuccessful at the sequence, the light continues at the correct circle, then the background turns red momentarily and an "F" appears as a form of feedback for the wrong action (G, H and I), then returns to the home screen (A, B or C).

As noted, for comparison purposes, each screen will be shown to a distinct group of volunteers, in order to neutralize the learning factor that would result the screens demonstration in the sequence. It is hoped that this experience show quantitatively the direct relation between the amount of hits and the amount of tips and action feedback, demonstrating thereby that when more information is passed to the system user, the greater is his ability to correct responses, regardless of his education degree, age or gender.

In the future, this experience can be applied in other countries in order to verify if such interaction assumptions discussed in this text also work in other cultures, and if they do not work, investigate what are the reasons for failure.

4 Final Comments

It is undeniable that the search for a fully universal interaction is utopian, however, these new proposed challenges show also that the current exploitation of universality is far from meeting its concept.

This proposal, equally far from resolving this issue definitively, seeks to clarify the issue and provoke discussion about the concept of universality, since, although there is a concern (important and relevant) to include those with special needs, there is still exclusion of people with little or no knowledge of computing systems in devices developing often even proclaimed as "intuitive" and "natural."

And despite undeniable progress in achieving an increasingly larger number of people, a lot still needs to be done so that all people can exercise their right of access to information and interaction.

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Improvements in Interface Design through Implicit Modeling

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Abstract. Touchscreen devices are often limited by the complexity of their user interface design. In the past, iterative design processes using representative user groups to test prototypes were the standard method for increasing the inclusivity of a given design, but cognitive modeling has potential to be an alternative to rigorous user testing. However, these modeling approaches currently have many limitations, some of which are based on the assumptions made in translating a User Interface (UI) into a definition file that cognitive modeling frameworks can process. This paper discusses these issues and postulates potential approaches to improvements to the translation procedure.

Keywords: inclusive design, universal design, cognitive modeling, cognitive architectures.

1 Introduction

While accessibility guidelines exist that reduce the barriers to accessing Information and Communications Technology (ICT), guidelines alone do not guarantee a more inclusive¹ design. In the past, iterative design processes using representative user groups to test prototypes were the standard method for increasing the inclusivity of a given design, but cognitive modeling has recently become a feasible alternative to rigorous user testing. However, these modeling approaches currently have many limitations, some of which are based on the assumptions made in translating a UI into a definition file that cognitive modeling frameworks can process. Cognitive modeling tools require information about the interface to be provided in a certain format (hereafter referred to as *sampling*), but this type of format simplifies the interface in such a way that some information about it is lost (this process is referred to as *implicit modeling*).

An iterative inclusive design approach can only be realised if incremental versions of the interface are tested with actual representative users or, as has recently become possible, through modeling frameworks that employ cognitive

¹ Inclusivity in this context is defined by the BSI [2]: “The design of mainstream products and/or services that are accessible to, and usable by, as many people as reasonably possible [...] without the need for special adaptation or specialised design.”

modeling architectures such as ACT-R [1] or CASCaS [16] to represent human cognitive processes. These frameworks require the translation of interface features into a definition file that segments both the visual and conceptual elements of the interface into a form that is machine-interpretable by cognitive architectures.

Using a modeling approach for user testing provides multiple benefits, such as allowing the designer to (i) complete quicker iterations as a partial substitute for or in addition to time-consuming participant recruitment and testing, and (ii) utilise a tool that “learns” which prior knowledge the virtual user may have, a key element in the ability to interact with a new device/interface [14]. However, modeling approaches are currently limited by the loss of information through sampling; the process of translating an interface into a generic descriptive format. A cognitive framework can interpret this translation [21], but the drawback is that it results in a loss of detailed information about the interface.

While (i) and (ii) above provide obvious reasons (e.g. time, cost and convenience) for more widespread use of modeling tools by interface designers, the limitations currently still outweigh the benefits. This is characterised by the limited uptake of software packages that employ this methodology in industry applications. Furthermore, in the short term, no significant improvements in the accuracy of cognitive modeling frameworks are expected [19]. Hence, an increase in the accuracy of “sampling” an interface into a definition file is a feasible and often overlooked method of improving cognitive modeling approaches to interface design.

Sampling the interface may also be described as an “implicit” level of modeling. Currently, it is integrated into modeling tools through KLM-GOMS [13], a keystroke-level model which segments the interface into cognitively-processable actions, which in turn can be interpreted by cognitive architectures. Advancements can be achieved by critically assessing the limitations of the KLM approach and outlining mismatches between the principles of the approach and psychological theory, advancements can be achieved.

In this paper a set of proposed modifications to the descriptive model are introduced, which allow inclusivity features such as distractions and limited cognitive ability to become part of the cognitive model. These new actions in the definition file may consequently be interpreted by the cognitive architecture, allowing for improvements in the accuracy of this method.

2 Cognitive Architectures

Cognitive architectures are toolkits that combine theories of cognition to simulate human behaviour. The simulation is not purely a model of the behavioural output of the human mind, but rather aim to replicate structural properties of the modeled system. These do not necessarily physically replicate components of the system – rather, virtual machines replicate the behaviour and knowledge of humans.

Originally, more advanced modeling tools (that included capabilities for simulated knowledge acquisition) required extensive experience with the modeling

language and the underlying assumptions in order to accurately simulate cognitive processes. Recently, cognitive models have become more accessible to users that have limited or no modeling expertise [6]; examples for this include Salvucci and Lee's ACT-Simple [20] which uses a KLM-GOMS [12] based descriptive language to automatically construct ACT-R models. This approach is further emphasised by St. Amant and Ritter [21] who create ACT-R models based on the specification of the user interface and keyboard layout of mobile phones.

3 Implicit Modeling

In the process of translating an interface definition to a format that is interpretable by a cognitive architecture, the visual and interactive features of the interface (and the device on which the interface is displayed) must be simplified and expressed in a generic format. In this process (which, for the purposes of analysis may be equated with sampling) information about the interface is lost. The degree to which information is lost depends on whether the specifics of the interface can be described by the definition language used and if the variables, in which aspects of the interface are recorded, match the requirements set by an approximation of human behaviour through a cognitive simulation.

The above described translation procedure is summarised as an implicit modeling procedure because the process of translation includes disregarding elements of the user interface. Hence, a reduced amount of information about the interface design is passed on to the cognitive architecture, limiting the potential of the cognitive tool itself. Furthermore, by selecting specific criteria of the interface (e.g. the parameters of GOMS), the translation procedure has a significant effect on the modeling procedure.

3.1 Limitations and Repurposing

With the aim of implementing a variant of GOMS (Goals, Operators, Methods and Selection Rules) as the underlying description engine for a cognitive framework, the difference between traditional (CMN-) GOMS [3] and KLM [4] are of particular interest. CMN-GOMS (Card, Moran and Newell) consists of pseudocode with no formal syntax, is therefore very flexible and allows the definition of goals and subgoals. Methods within CMN are informal programmes and selection rules are defined in a tree structure where different branches are used for different scenarios. KLM-GOMS, on the one hand, is a simplified version of GOMS, where only keystroke-level operators are of interest to the framework and consequently place implicit focus on low-level actions by the user. There are no goals, methods or selection rules included in the model, therefore the definition is strictly sequential, making a KLM definition quick and easy but limited in scope.

Even though GOMS is a long-established route to defining interface and interaction routes, there are clear limitations when defining tasks. GOMS is only implementable with well-defined routine cognitive tasks and does not take error,

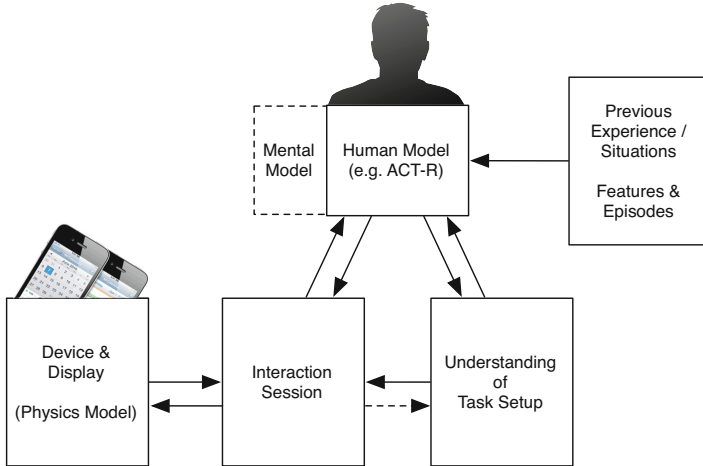


Fig. 1. An overview of what implicit modeling aims to achieve within the context of a simulated interaction between a human model and an interface definition

fatigue or differences in social surroundings into consideration, which are of particular interest when approaching ICT design processes from an inclusive design perspective.

John states that in the context of GOMS, operators were “command[s] and [their] parameters” [11] and at the time of her review (1995), “with graphic user interfaces, operators are just as likely to be menu selections, button presses, or direct manipulation actions” [11]. In the future, John defines operators to include “gestures, spoken commands, or even eye movements” [11]. With the growing prevalence of touchscreen interaction paradigms on mobile and desktop devices, John’s prediction holds true, yet GOMS techniques have not adjusted to include the requirements set by touch- and gesture-based input.

There are three potential outputs from the described GOMS techniques: timing of the execution of individual tasks, the time required to learn a specific task and the likelihood of forgetting elements of the required knowledge for completing a task.

One of the greatest limitations of all GOMS implementations (in their current versions) is that they are aimed at users that have mastered the elements of the task that he/she is required to complete. It is assumed that the “cognitive skill” required for the completion of the goals in a procedure outlined in GOMS will be mastered by the user. This applies to individual operators in the context of GOMS, but does not predefine methods or goals laid out by a specific GOMS procedure. This limitation highlights the need for a more inclusive approach to implementing GOMS techniques in the design process of interfaces and touchscreen interfaces in particular.

John addresses this issue in her review of GOMS techniques as a whole; while she concludes that “[if] you are designing a system that will only have novice

users, like a kiosk at the Olympics, then predictions of skilled behaviour are not necessary[; instead, it is] better to run a few representative users through a laboratory usability test or use Cognitive Walkthrough” [11]. As discouraging as this statement may sound in the context of inclusive design research, John suggests to “look carefully: coming up with the action sequences that form the basis for a Cognitive Walkthrough is almost the same as doing a Keystroke-Level Model” [11].

3.2 Need for Implicit Modeling

The motivation for this project is based on a range of issues that have not been adequately addressed in industrial or scientific contexts. This includes the problems associated with setup procedures on (mobile) digital interfaces, their implications for widespread device use, cognitive modeling tools acting as a stage-gate in the design process of inclusive user interfaces, the associated generational debate and last, but not least, the need for simplified usability evaluation techniques.

Stage-Gate in Use. The initial tasks on a mobile OS are setup procedures or require setup procedures to function. A user’s perception of being able to use software is highly dependent on the success of his/her first interaction with the software. Literature suggests that the perception of the user to be able to use software is a key motivational factor [5] for further use. Given the importance of first-time use as a key element in motivating the digitally excluded in using new technology, this project focuses on establishing new design practices for touchscreen initial setup tasks and, more specifically, virtual validation tools in this field.

Setup tasks are a stage-gate in further device usage. Initial studies by Wollner et al. [23] with a range of users in different age groups further support this hypothesis. Hence, it is of importance to improve the design process of setup procedures as a whole (e.g. for all age groups and levels of ability), either by empowering designers with better testing tools, which can be employed throughout all stages of development and/or to replace testing procedures employed prior to product deployment. Prior experience plays a significant role in bypassing this stage-gate [14], but there is further research that could be supported through improved cognitive modeling frameworks. Finally, these improvements would allow for further analysis of the effects of the context of use [18] on usability.

Stage-Gate in the Design Process. The complexity of using cognitive modeling tools excludes many interface designers from more frequent use [19]. By enhancing the sampling stage of user interface cognitive modeling, the overall process may be improved and hence made more accessible for interface design and development purposes. Concurrently, virtual user performance modeling tools in this field are constrained by the sampling procedure between the interface definition and the cognitive architectures they are evaluated by. This highlights the need for new interface sampling methods.

Simplified Usability Evaluation. Based on the increasing need for solutions for independent living with digital interfaces, there is a clear need for streamlining usability evaluation practices in industrial applications [15]. Resources for the time- and resource-intensive process of testing (in-lab and in-field) of new ICT will, in the long run, decrease. A potential solution for this is employing digital models of a wide range of users, allowing (iterative) product development/design and the subsequent validation processes to be completed more quickly and efficiently.

4 Proposed Changes

The literature presented in the previous sections, changes in the interaction paradigms of modern interfaces and an increasing need for the adaption of inclusive design methodologies in the area of interface design, highlight the need for an adaption of implicit modeling to better sample interface designs.

The basis for the recommended changes outlined in this section is based on the pilot experimental work conducted with novice users attempting to complete a setup procedure on a range of mobile touchscreen implementations [23], shortcomings of current implementations in relation to the changing demands of mobile interfaces the need for implicit modeling that is scientifically validated and practically deployable to an increasingly diverse population of interface designers, and the lack of inclusive measures in current implicit modeling implementations.

An outline of cognitive difficulties with, and the limited access to information systems, as given by [8], may provide a basis of input to the proposed adaption of implicit modeling. Likewise, with an emphasis on mobile devices, the conceptual framework and models for identifying and organising usability impact factors, as outlined by [9], may provide further insights in the definition of an extension to implicit modeling techniques.

In the process of defining a GOMS model for mobile touchscreen devices that includes scope for slips, error, fatigue or differences in social parameters which we define as *inclusive factors*, there is a host of variables that need to be defined. Equally, the constraints of new (touchscreen) interaction paradigms and a larger variance in screen sizes allows the definition of new operators. We choose KLM-GOMS as a definition basis because user modeling and validation requires a stringent definition, which has already been implemented in tools such as CogTool. Further development aims at identifying which parameters are missing from a range of perspectives, as outlined in the following sections.

4.1 Adaption for Inclusivity

The fundamental purpose of this project is to extend the inclusivity of cognitive modeling approaches in order to better approximate the needs and limitations of a wider demography compared to what is possible with current modeling approaches. This includes several explicit measures that directly relate to the

diversity of potential users of the technology that is being assessed with the simulation tool as well as implicit measures, which, overall, are able to improve the accuracy of modeling techniques – given the current state of technology.

One of the most significant challenges in adapting implicit modeling to include a wider range of capabilities and hence make implicit modeling explicitly more accommodating for a more diverse population of users, is to include parameter estimation for the interfaced cognitive architecture. This can be accomplished by providing a range of interface definitions in the implicit modeling approach, each with a weighting that relates to age- and capability-related limitations of the user. A further method would be adjusting the parameters that dictate cognitive ability, memory retention and factors of persistence (intrinsic motivation) in the cognitive architecture directly.

This also raises the question whether the framework's output should aim to establish a population mean for performance or whether it should integrate a range of capability levels in order to provide a more in-depth analysis of the inclusivity of a specific interface design. The next stages of our research will focus on the topic of parameter estimation – both in the implicit model as well as by passing parameters on to the interfaced cognitive architecture – and aim to develop a robust methodology that provides an insight into inclusivity factors without compromising the approach's feasibility in common design practices. A further aim of the adaption is the approximation of exclusion statistics for individual components of a simulated interface interaction.

4.2 Adaption for Touchscreen Interfaces

Another substantial limitation of today's implementation of implicit modeling is the lack of adaption to touchscreen interfaces. This is of great significance due to the high volume and quick turnover of the development of touchscreen interfaces, which are used by an ever increasing and diversifying population of users. Especially in the development of touchscreen interfaces – both on dedicated devices as well as in embedded systems – the design process is in need of a robust modeling-based evaluation tool that can assess potential shortcomings of designs at an early developmental state.

In its current state, KLM-GOMS does not support the definition of gesture-based input – a factor, especially from the perspective of its potential lack of inclusivity, that has become increasingly important. Touchscreens are also unique in terms of the wide array of available screen sizes and responsiveness. These are all factors that are currently not definable by a KLM-GOMS description of the interface.

Combining the two above-mentioned properties leads to the zooming and scrolling functions that are unique to touchscreen interfaces and are currently not describable by KLM-GOMS interfaces. For instance, the double-tap to zoom implementation on most mobile touchscreen systems is of vital importance from an inclusivity perspective (both from a functional and conceptional standpoint) but fails to be easily describable in current GOMS literature.

Another significant factor affecting the user’s performance is the absence of modeling finger- and hand-based occlusions when operating the device. Here, various touchscreen implementations have offset controls (mimicking an indirect interaction paradigm) when, for instance, selecting a letter on the keyboard. The issues of hand- and finger-based occlusions are, again, not describable using a KLM-based approach.

A further usability-centred variable is the presence of on-screen distractions and the method in which they are describable by a KLM-GOMS definition. Despite the fact that distractions have been present since the existence of graphical user interfaces, the number of off-task distractions is especially large on current (touchscreen) interfaces due to a stark increase in interface-based user interrupts (e.g. a pop up or notification about a message when looking at photos). Likewise, the prevalence of system-wide notification systems, as implemented by most mobile operating systems is an on-screen distraction which, equally, cannot be modeled by the *status quo* of KLM-GOMS. Here, we present two types of distractions: on- and off-task. On-task distractions relate to graphical features, which disrupt the users workflow but directly relate to the task, such as oversized additional options or colour-based distraction in a specific UI-flow. Off-task distractions relate to on-screen distractions which distract the user from the task and do not relate to the task, such as system-wide notifications or pop-ups relating to another process on the device.

Finally, a further, touchscreen-specific element that dictates a new definition in KLM-GOMS are finger-based requirements on what is described as “homing” in the original definition of KLM-GOMS. Whilst defined in previous implicit modeling implementations, it was previously based on the accelerated indirect interaction paradigm of mouse control.

4.3 Adaption for Mobile Environments

Previous work that may be described as implicit modeling was based on dedicated workstations with large screens. In this environment, there was little variability of the effect of external factors on operating the device. With a growing presence of user interfaces that are used in mobile environments, the conditions of the environment have not only become more variable but also more distracting to the task the user aims to accomplish. Hence, there is a need for implicit modeling to be able to describe both the environment and the degree of distractions of the modeled interface.

This adaption of implicit modeling not only improves the accuracy of simulating the use of the described user interfaces in mobile environments but also allows for modeling in specific environments. This is of particular interest when adapting touchscreen interfaces for elderly users, which oftentimes struggle using the devices in mobile environments.

Adaptions for the mobile domain exist by Dunlop and Crossan [7], who tried applying the standard KLM operators to different types of text entry systems of mobile phones that were later modified by How and Kan [10] with adaptions that lead to better results through 13 new operators, which map to the key

layout of a standard feature phone. Further work by Pavlovych and Stürzlinger [17] subsequently examined a similar issue (text entry on mobile phones) of non-expert users based on the cognitive workload analysed by GOMS. The work completed compares different types of KLM-GOMS implementations for mobile environments. In our implementation, a combination of the above introduced literature builds a basis for adapting implicit modeling to the conditions set by mobile environments.

5 Conclusion

In this paper we propose a novel approach to modeling user behaviour in the context of touchscreen interface design. Building upon existing and constantly evolving cognitive architectures, which unify cognitive theories and allow the simulation of human behaviour, we propose a method of analysing the usability of touchscreen interfaces.

In order to achieve this, we define implicit modeling to be the translation procedure from an interface definition to the input of a cognitive architecture. Whilst elements of this translation procedure exist – such as KLM-GOMS – the current approach is inadequate. Part of the proposal is to extend KLM-GOMS in order to account for the requirements set by touchscreen interfaces, inclusivity and mobile environments and, in a further step, to integrate these changes into a toolkit that will support designers.

Further work includes implementing a prototype translation tool, testing this prototype and validating the resultant data with real users. Likewise, once implemented, exploring the ways in which the simulation output of the cognitive architecture may be used for better analysing the UI defines an important next step. One such approach may be by employing Graph Theory, as previously explored by Thimbleby [22].

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Evaluating User Interface Design Using Hierarchical Requirements Extraction Method (REM)

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Abstract. The paper shows the hierarchical requirements extraction method in order to evaluate user interface design. REM has two functions, (1) extracting the source of systems, products and GUI problems, (2) constructing the ultimate purpose of systems, products and GUI. The process is as follows. After the problems are acquired by checklist and so on, the solutions for problems are derived using the function solved the problems. The purpose of solutions is defined from view point of the relation of “purpose and means”. The ultimate purpose is examined repeatedly based on the solutions from view point of the relation of “purpose and means”, and finally defined. Next the cause of problems is defined from view point of the relation of “results and cause”. The source of the problems is examined repeatedly from view point of the relation of “results and cause”, and defined.

Keywords: hierarchical requirements extraction method(REM), User interface design, usability.

1 Background

Now the essential problems existed behind systems become very important than collecting outward problems using usual usability evaluation methods such as protocol analysis and so on. Actually the usability evaluation methods can get superficial problems. Although these superficial problems are useful for improved products and GUI, the essential problems existed behind products and GUI guide designers in constructing solutions of products and GUI, not improved.

2 What Is REM?

Hierarchical requirements extraction method (REM) is developed for finding the ultimate purpose and source of the problem of system. The procedure is as follows.

1. The problems are acquired by direct observation, usability task analysis and interview.
2. The solutions for problems are derived using the function solved the problems.
3. The functions are described concretely.

4. The purpose of solutions is defined from view point of the relation of “purpose and means”.

Namely the purpose is decided from solutions as means.

5. The ultimate purpose is examined repeatedly based on the solutions from view point of the relation of “purpose and means”, and finally defined.

6. Next the cause of problems is defined from view point of the relation of “results and cause”

7. The source of the problems is examined repeatedly from view point of the relation of “results and cause”, and defined.

Fig.1. shows the structure and process of REM.

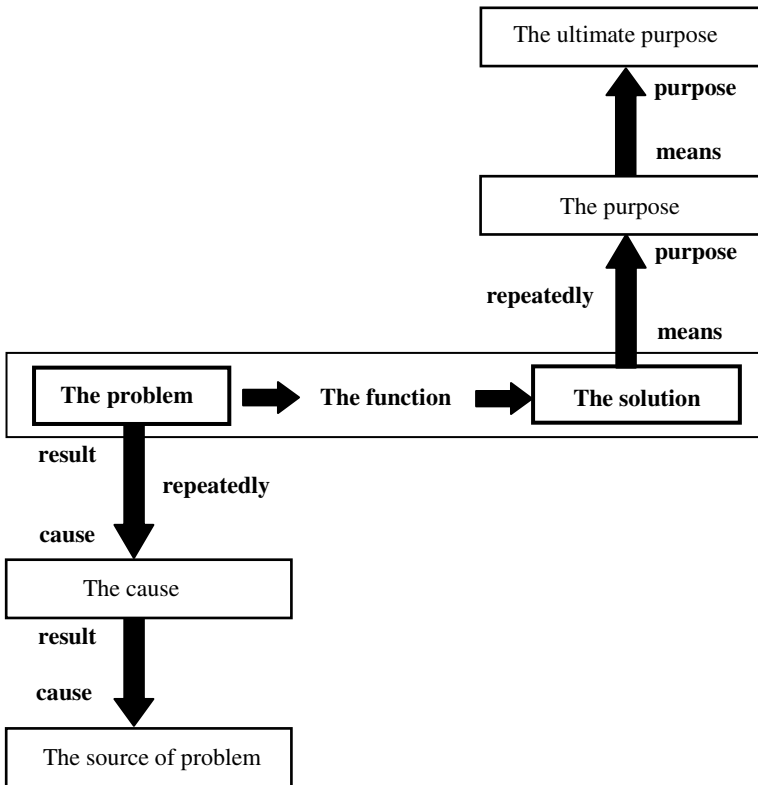


Fig. 1. The structure and process of REM

3 How to Extract Problems

GUI checklist and usability task analysis are used for REM. They are as follows.

3.1 GUI Design Checklist (1)

The GUI design checklist consists of 4 categories and 16 evaluation items. They are as follows. 4 categories and 16 evaluation items.

(1) The evaluation items based on the SUM explained later

- 1) Operation time is appropriate.
- 2) Presentation of various information
- 3) Easy to see

(2) The evaluation items based on the visualization three principles

(3) The evaluation items based on the GUI design six principles

- 4) Important information is emphasized.
- 5) Layout and information is simple.
- 6) Consistency is examined
- 7) The visual clues make acquirement of information and navigation of operation easy.

This item is also extracted from the SUM.

- 8) Understanding terms are used.
 - 9) The mapping among information is appropriate.
 - 10) The visual and feedback
 - 11) The user interface is constructed based on the mental model.
- (4) The evaluation items regarding the general user interface
- 12) The layer of systems is understandable.
 - 13) The operation time is understandable.
 - 14) To grasp the system wholly is easy.
 - 15) The error makes the system be not trouble.
 - 16) The user interface is flexible and customized.

The evaluation is done using five-point scale: strongly agree (5), agree (4), undecided (3), disagree (2), strongly disagree (1).

3.2 Usability Task Analysis (Table 1.) (1,2)

Usability task analysis was developed for product design and user interface design and so on. As the usability task analysis is also a kind of the task analysis, each task is evaluated from view point of the good and bad points of the task. The participants are asked the good and bad points regarding each task. Next they evaluate the good and bad points using strongly agree (3), agree (2) and neutral (1).

The good points become user requirements while the bad points are changed into good user requirements. The user requirements are structured.

This method is used for collecting problems regarding REM.

The procedure of collecting and specifying problems is as follows.

- (1) Bad items of each task are collected. They are problems.
 - (2) The collected problems are classified and structured.
 - (3) Important problems are selected from the problems structured.
- Important problems contain a lot of detailed problems.

Table 1. The format of usability task analysis

	Product-1	Product-n	
task(n)	Point []	Point []	evaluation
	good point	good point	user requirements
	bad point	bad point	problems
Synthetic evaluation	Point []	Point []	evaluation
	good point	good point	user requirements
	bad point	bad point	problems

4 The Merit of REM

Usual usability evaluation methods extract only problems of system, while REM can not only extract problems but also find the source of problems and the ultimate purpose from the solution which are hidden and not found by traditional usability evaluation methods.

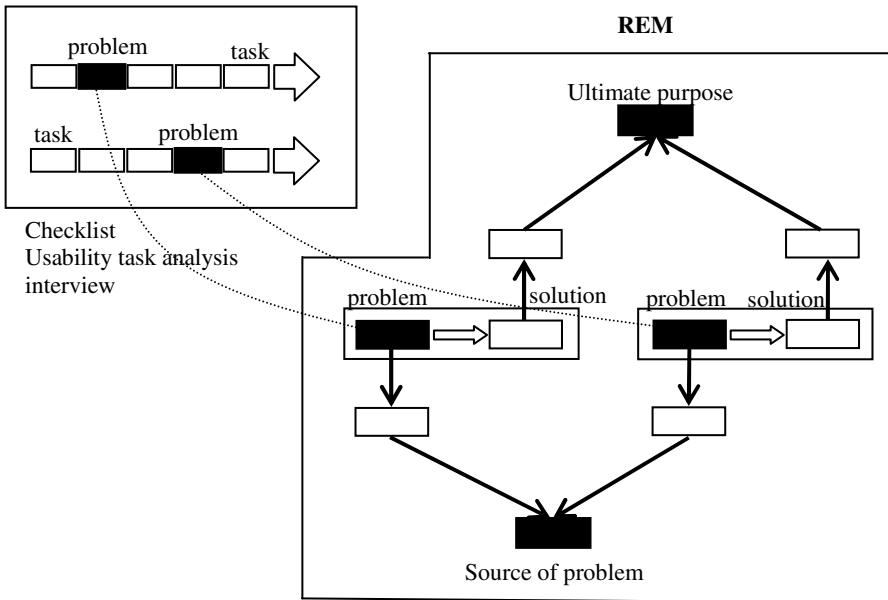


Fig. 2. REM and problem extraction method such as usability task analysis and so on

Not only observation but also questionnaire is also available. Namely REM can find essential qualities of system. The observation and questionnaire are used for collecting some problems. According to these problems, the source of problems and ultimate purpose are found.

5 Verification of REM

A GUI (<http://www.nite.go.jp/>) as one example of user interface design was verified using REM. The problems are extracted by the usability task analysis.

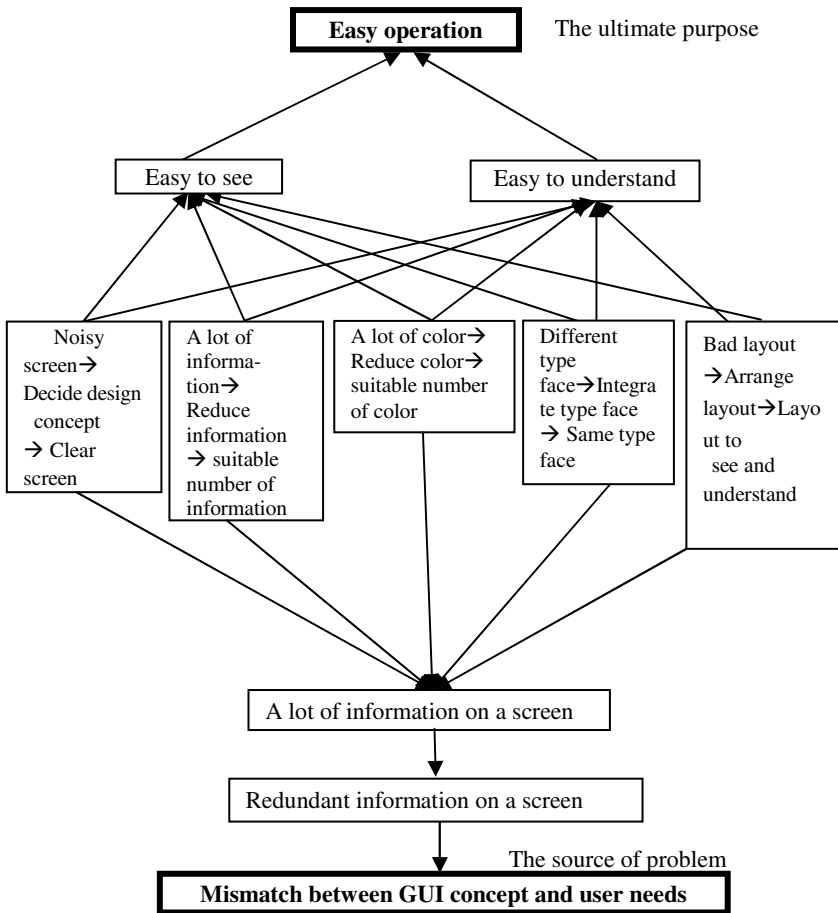


Fig. 3. Source of problems and ultimate purpose

According to REM results, the ultimate purpose is “ Easy operation”, and the source of problems is “Mismatch between GUI concept and user needs”. The diagram of results are shown in Fig.3.

6 Summary

REM has two functions to extract usability problems and construct the purpose of systems, products and GUI and so on. The procedure is as follows.

1. The problems of user interface are acquired by direct observation, checklist, usability task analysis and interview.
2. Problems are changed into solution using the function solved the problems.
3. The purpose of solutions is defined from view point of the relation of “purpose and means”.
4. The ultimate purpose is examined repeatedly based on the solutions from view point of the relation of “purpose and means”, and finally defined.
5. Next the cause of problems is defined from view point of the relation of “results and cause”
6. The source of the problems is examined repeatedly from view point of the relation of “results and cause”, and defined.

Actually a GUI (<http://www.nite.go.jp/>) as one example of user interface design was verified using REM. The source of problems and ultimate solution are obtained. They were to the point.

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A Conceptual Client-Designer Framework: Inspiring the Development of Inclusive Design Interactive Techniques

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Abstract. The adoption of inclusive design approach into design practice is compatible to the needs of an ageing society. However, tools and methods that promote inclusivity during new product development are scarcely used in industry. This paper is part of a research project that investigates ways to accommodate inclusive design into the design process in industrial context.

The present paper is based on the finds from the observations and interviews with industrial designers and interviews with stakeholders. The outcomes from the study supported a better understanding of the client-designer dynamic as well as the stages in the design process where information related to inclusive design could be introduced. The findings were essential to inspire the development of an inclusive design interactive technique to be used by clients and designers.

Keywords: universal design, design for all, new product development, industry, designer.

1 Introduction

Developed countries have faced the challenges of ageing populations. If on the one hand the fact that people are living longer means that the society has improved living standards, on the other hand, it means that the society has new challenges to cope with. The loss of physical, sensorial and cognitive capabilities is a typical problem that naturally results from the ageing process. In this case, the best practice in new product development would be to consider a wide range of user capabilities to promote independent living among the elderly population. This is the design principle advocated by inclusive design theory and methods. Hence, the adoption of inclusive design seems to be appropriate in such scenario.

Differently of what could be expected in an ageing society, inclusive design approach has not been widely used in industry [1-3]. Actually, the currently available tools and methods created along the last years to evaluate accessibility of new design concepts have been scarcely used. This may be a result of incompatibility issues of the available techniques with the design practice [4]; or the lack of incentive to companies to adopt inclusive design [5]; or both.

This paper is based on an ongoing research project that has investigated the design practice in order to propose tools and techniques that work tandem to the design process in industrial contexts. An exploratory study was conducted with designers and stakeholders to understand the reasons of non-adoption of inclusive design and how inclusivity could be accommodated into the design process. The study was carried out within six different companies to understand the design practice and contextualise the client-designer dynamic when defining user requirements.

The next session briefly describe the methods used and then, the following session presents the findings from the interviews with industrial designers and stakeholders. The outcomes supported a better understanding of the client-designer dynamic as well as the stages in the design process where information related to inclusive design could be introduced. The findings were essential to develop the conceptual client-designer framework presented on session 4, which inspired the development of an inclusive design interactive technique to be used by clients and designers.

2 The Study with Industrial Designers and Stakeholders

A total of 18 industrial designers and 6 project stakeholders participated in the study. The designers were from six design agencies and internal designers of one large multinational company. The stakeholders were from two large multinational companies.

2.1 Data Collection

Data was collected through unstructured interviews, an acknowledged method to conduct exploratory studies in qualitative research [6]. The method supported in-depth investigation of the design activity through opinions, knowledge, behaviour and experience of the participants [7]. The participants were encouraged to talk about their background and experience in the field, as well as to give a broad picture of their role in the consultancy or in the company. The interviews were audio recorded and transcribed afterwards.

Towards the end of the interviews with designers, they were presented with a tool built in Google SketchUp. The tool was in the very early stages of development, but attended the intention of exemplifying an interactive way to supply designers with information about inclusivity. The tool elicited reflections and further description about the way user requirements are dealt in the process and how designers currently evaluate accessibility and usability in their work routine [8]. In fact, the most valuable comments related to inclusive design came to light after presenting the tool.

Two examples were presented to the designers: For some of them a 3D modeling simulation of a remote control, and; for others a 3D modeling simulation of a simple medicine's pack, both inside Google SketchUp. The last steps of the simulation exemplified how the designers could check the legibility of the letters in the remote control or in the pack. The simulation followed the sequence below, the step 3 run the visibility test to check the legibility and the step 4 presented the result of the evaluation:

1. designing the box (with color and material) and adding the text (with font size, style and color);
2. setting the ambient light and setting the reading distance;
3. selecting visibility test in the inclusive design tool in the tools window;
4. receiving some advice from a window that pops up on the screen, which describes the range of population excluded from reading the text in the pack and some advices regarding font size, style and background/foreground color contrast.

The idea of the last screen was to understand whether the information about inclusivity would be useful. The information was given through the percentile of the UK adult population excluded from using the product due visibility issues. Additionally, in the same window, the percentile is followed by a recommendation that guides the designer towards creating more legible features. In this case it was “you could change the font type, font size or the background-foreground color to change the exclusion”.

2.2 Data Analysis

The interviews’ transcripts were coded and categorised using Atlas.ti software. The categorisation was based on patterns of text – utterances – that were related to the same idea. They were analysed following the principle proposed in grounded theory [9]. Every time a relevant fact was recognised in a transcript, old transcripts were re-analysed to find out the views of past participants related to that aspect. For example, as the research evolved, the role that clients play in the design process had to be clarified, as a result of which other questions were raised and past transcripts were re-analysed.

Care was taken to ensure that the same code was not duplicated for a single participant under the same interview topic. This procedure prevented the reoccurrence of codes only based on single views. Codes and categories were mapped according to the importance given to the concept (reoccurrence) and its connection to other sub-categories (co-occurrence). The maps of categories and codes were interpreted and represented in a framework format. The framework was presented to the designers and the stakeholders in what is called here as ‘feedback sessions’. These sessions were important stages to correct misunderstandings and to confirm some of the results from the interviews. Although few participants were not available to meet the researcher once again, most of them took part in the sessions.

3 The Design Process through the Eyes of Designers and Clients

The exploratory study described here started observing and interviewing designers as it initially intended to understand how designers create, evaluate and present their ideas. The intention was also to recognize the differences among design domains and the hindrances to inclusive design adoption [10],[8]. The study however, indicated the

need to understand the influence of another actor responsible for feeding the process with user requirements – here called the client. All the interviewers from different companies (design agencies) indicated the influence of the client as the fundamental one to establish a user-centred design process. The consistency among the interviews adjusted the research to also consider the client (project stakeholders that commission the project to designers) as part of the study.

The designers also expressed their opinions regarding an ideal inclusive design interactive tool.

3.1 An Inclusive Design Tool According to the Industrial Designers

The responses of the designers highlighted two main aspects related to the tool built into Google SketchUp: the interactive interface and; the information provided.

Inclusive Interactive Interfaces

The idea of developing an inclusive design interactive tool was well accepted. However, there was a controversy regarding the software interface used by designers. Product designers tend to use 3D modeling tools, such as CAD software, whereas in other design domains designers do not use 3D modeling, normally all the graphic design is done in 2D graphic software. Consequently, it is necessary to consider the variations across different design domains before proposing interactive tools incorporated into computer graphic systems.

Information about Inclusivity

Regarding as the information provided through the interface – the percentile of the population excluded from using the new concept – the designers were unsure about its value. They explained that generally they reason that the new design is targeted at a portion of the population. The target market is defined by or with the client. In their practice, the designers consider that a reasonable amount of people from the entire population are always excluded if they are not part of the target market. The following comments highlight the views of some of the designers related to target market:

“Most products are focusing on certain bits of that population [] you try to cover as larger market as possible, but it is very difficult to cover the whole market, and still have a credible product. Often products are developed to focus on those groups. There are telephones available which are made to be used by the elderly. They often haven’t been immersed with the technologies we have in our lives. So, there might be a bit of technophobia, they might not want the complexity of Facebook; they might want the ability to phone people. So, there are mobile phones out there which are focused on that group, which take all those things into consideration.” (39:05 – D3)

“I do not know if we have done anything for the extreme range of people. We’ve done products for specific sectors. We’ve done a couple of bariatric products for very heavy people, and I’ve done a couple of things specific for older users. I cannot think about a product that includes a very broad spectrum.” (12:25 – D4)

According to the designers' comments, unless clients request the design to include a wide range of people as end-users, the objective of providing information about inclusion will not succeed. Information about inclusivity therefore is not only a matter for designers, but also clients. As already mentioned by Gill [12] Small to Medium-sized design consultancies tend to face the pressure of costs and tight deadlines from the client, which constrain the designer's decisions.

Among all the interviewees the role of the client was always outlined as the main supplier of information of potential consumers and their needs. Moreover, if the client does not act as an information supplier, the designers would consider the type of research, and the amount of time the research would consume, based on the project resources defined with the client. The results indicate the importance of the client in the design process. Clients therefore were interviewed and the outcomes are highlighted in the next session.

3.2 Aspects Considered by Clients According to the Stakeholders' Interviews

The stakeholders highlighted the aspects they have to consider while planning a new project and before commissioning the project to designers. In this study the stakeholders are the people who represent the interests of the company that owns the final product. They often play the role of clients when commissioning the project to the designers.

Target Market, Market Share, Market Response

According to the stakeholders, the users' specifications are based on demographic data related to the target market and some other user requirements, which is result from market research. However, market research is generally conducted to understand the market needs, expectations and market share, not accessibility and usability issues. The tendency is to divide the market into groups of consumers and then to target at those specific markets. The comments from the stakeholders transcribed below highlight how the product is planned:

"We do try and target different groups. I mean we do look at, 'Right we know this segment exists, we know that segment exists' and what we try and do is tailor products around them. [] We're very focused on making sure that it does what it needs to for the people we're targeting the product at but it's not so extreme." (S3)

"Good designs always take into account people's needs anyway. There will always be extremes of users that you might decide that you can't afford, because it would make the product too expensive to deal with. [] So, you might decide that it makes more sense to design products in a first place, to meet the mass market." (02:09 – S1)

Difference on Sales, Competitors and Final Price

According to the responses, changes on design features, including changes towards improving accessibility or usability would happen if they make a difference on sales or brings advantages over competitors, which would increase the market share. Moreover, the expected cost-benefit of the changes to the consumers is also considered before investing in the product.

“It's a very competitive market in the UK and people's perception of what they are willing to spend and what they end up spending is actually quite different and I mentioned in Germany and in France people spend a lot more on these products so we are driven by cost to a large extent, unfortunately... because it's difficult to put prices up without people switching to competitors or not buying the products at all which I think would be a disaster. So that's probably the biggest challenge we face.” (S5).

Clients seem to deal with a number of factors related to the impact of design changes on market, competitors, final price, the brand and others. They mentioned that *“there is a kind of trade off”* within the company's requirements before they make decisions. According to the participants, the way the clients deal with the requirements is based on the resources (basically time and budget) allocated to the project, the company's prioritization and in some cases legal obligations.

3.3 The Influence of the Client in the Design Process

The influence that clients exert in the design activity is indeed a fact that has to be considered before proposing improvements to the practice. From the very beginning, when the brief is delivered to designers, until the end of the conceptual phase, when an idea is selected, clients influence every stage. In fact, the brief, the research and the evaluations carried out by the designers seem to be sturdily dependent on clients' views, procedures and funding for the project.

The quote below demonstrates the power that the client exerts in the process. The comment illustrates what was replicated among the interviews with designers and stakeholders.

“I have control over the brief for the products, I have control over the design, I have control over the cost, the specifications, but I also have control over the marketing messaging that we speak to consumers.” (S5)

It is therefore part of the designer's job to attend the client's interests. In cases where clients awareness of their market includes the understanding of end-users needs related to accessibility and usability, they could drive new ideas towards more user-centred design. According to the interviews, if the client is aware of critical parts of the project, they will then request, while briefing the designer, to conduct research, test or evaluation to ensure that there will not be any problem in the final product.

3.4 The Design Decisions Made by Client and Designers

The designers described the design process as a trade off activity that has to consider many aspects of the design, such as functionality, aesthetics, manufacturing process, materials, components, usability, disposal and others. According to the designers, the reasoning behind the requirements' prioritization is mainly the key requirements established on the brief; but also the research, tests and evaluations carried out by them, and; the knowledge and experience of the designer.

It seems to us that both, clients and designers, make decisions related to the design. This may happen while clients are defining the project, even before delivering the brief to designers; or when designers are creating new concepts. However, there are important stages along the design process that clients and designers make decisions together. These stages are the design meetings.

The client-designer meetings represent stages where design decisions happen. The meetings are used to specify the project, to discuss the project and to present and discuss the ideas. Therefore, to support the development of more inclusive designs, one way is to inform both - designers and clients - about inclusivity while design decisions are made. Therefore, design meetings were identified as the strategic phases to inform about inclusive design.

4 A Conceptual Client-Designer Framework

A conceptual framework was developed based on the findings outlined in the previous session.

The framework focuses on the very early stages of the design process, which is described by other authors as the planning phase and the concept development [13-14]. During these initial phases the client defines the brief; the client commissions the project to designers; the brief evolves within the client and the designer decisions, generating the design specifications; the designer carries out research, generate ideas, test them and present the ideas to the client; the client gives a feedback after reasoning on the companies requirements and the priorities for that project; the designers will work in the proposals and present them back to the client. The process of 'presenting and getting feedback' may happen once or several times, until the new design concept is selected for further development.

The framework is presented on figure 1, highlighting the designer and the client inputs alongside the process. The numbers shown refer to the phases when client-designer meetings are held:

1. Meetings to Specify or Discuss the Project:

The meeting(s) used to deliver the design brief and develop the design specification. These meetings are important stage(s) to introduce information about accessibility and inclusion if that has not been considered until that moment.

1. Meetings to Present and Discuss Ideas:

Initial ideas are embodied into presentations and delivered to clients in their meetings. Clients give feedback and directions according to their priorities, but clients also rely on designers' interpretations of better solution. Interventions that inform about the accessibility and inclusivity of the proposals being presented in such meetings could direct the project towards more inclusive products.

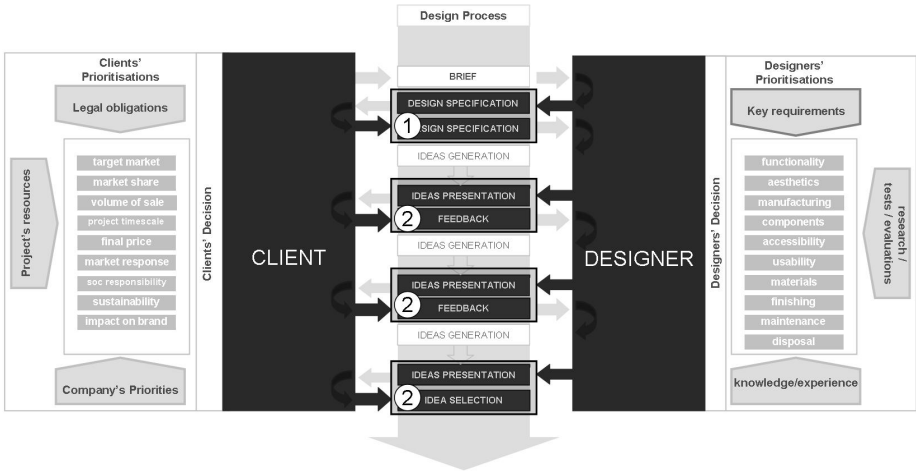


Fig. 1. A conceptual client-designer framework: defining stages to inform about inclusivity

5 Inclusive Design Interactive Techniques

Based on the outcomes described in the previous sessions inclusive interactive interfaces have been idealized. Figure 2 presents an example of an inclusive design advisor to be used in client-designer meetings, where the design concept under development is presented to the client. In this example, the interface has been

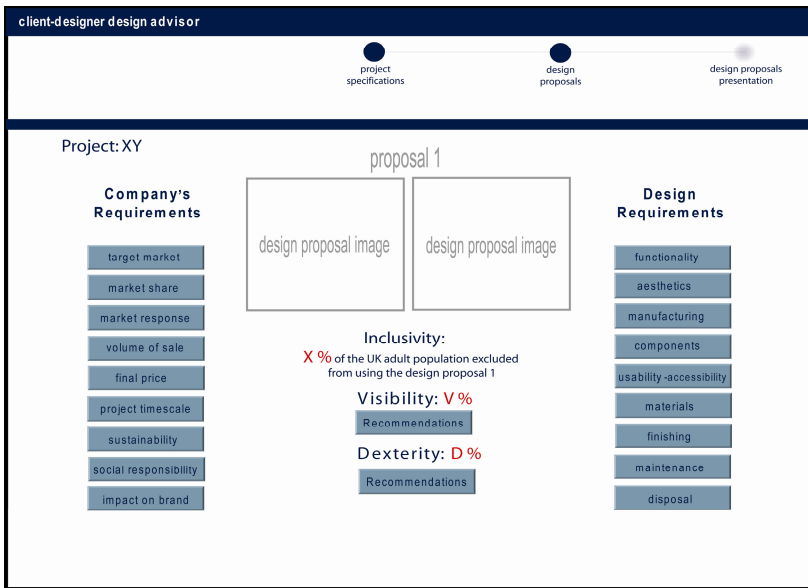


Fig. 2. Inclusive design advisor to be used by clients and designers in design meetings

developed to present both (client and designers) with information about inclusivity. The interface is supplied with buttons that links to information about inclusive design and its relationship with company's requirements as well as design requirements.

This inclusive design advisor has been developed to be tested with live projects. This would bring essential knowledge to the inclusive design research field, clarifying whether client and designers would consider the exclusion results related to the design proposals; change the design, and; to what extent inclusive design is part of the trade-off during design decisions.

6 Conclusion

The study presented in this paper was conducted to understand the design practice in industrial contexts in order to propose inclusive design interventions cognizant of it. The interviews supported the development of a framework that contextualizes the client-designer involvement with the design process. The framework emphasizes the influences that both – client and designer – exert during the initial phases of the process. Additionally, it highlights the stages – design meetings – where design decisions are made by clients and designers together and thus, information about inclusion might be beneficial to the project if supplied at this stage. The conceptual framework has inspired the development of an inclusive design advisor to be used by clients and designers, with information relevant to both in order to encourage inclusive design uptake in industry.

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Part II
eInclusion Practice

ICT Accessibility Criteria in Public Procurement in OECD Countries – The Current Situation

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Abstract. Public procurement is the process by which government bodies purchase their Information and Communication Technology (ICT) products and services. Including accessibility criteria in the procurement process may improve employment opportunities in government for people with disabilities and could have flow-on effects for increased accessibility. Various methods of incorporating accessibility criteria in public procurement need to be assessed to ascertain the most effective processes to achieve e-inclusion. This paper outlines a research project investigating the current status of legislation, regulation and policy of ICT accessibility criteria in public procurement in OECD countries. Using mixed-methods research to gather information, the paper draws on contrasting cases for comparative analysis. The research finds that voluntary schemes contributed to the failure of these programs. It is apparent that lack of understanding about ICT accessibility plays a key role. Mandatory processes based on uniform global standards coupled with compliance will have an impact.

Keywords: Public procurement, ICT accessibility, web accessibility, people with disabilities, accessibility.

1 Introduction

The primary aim for including accessibility criteria in ICT public procurement is to provide more equitable access to ICT office equipment such as phones and computer systems for government employees with disabilities. It can also have flow-on effects for increased ICT accessibility in the broader community.

Government, by virtue of its spending power, can influence the market in numerous ways. Government is able to influence the availability and costs of goods and services by virtue of the various roles it plays in the economy as a:

- buyer of goods and services
- supplier of services and
- regulator [1][2].

The use of public procurement to singularly create additional demand for accessible ICTs is relatively new [3][4]. The paper reports on a study conducted by the authors that explores the connection between public procurement of accessible ICTs and improving e-inclusion outcomes for people with disabilities [5]. By drawing on the experiences of OECD countries, the authors provided a comprehensive assessment of the use of ICT accessibility criteria in public procurement.

A mixed methods research design was employed to collect up-to-date information about accessibility in ICT government purchasing in OECD countries. Four principal methods were applied to the research design: systematic review [6]; benchmarking [7][8]; case study; and focus groups [9].

The paper begins by reporting the findings of the comparisons made between OECD countries in their use of ICT accessibility criteria in public procurement. This comprised the outcomes of the benchmarking exercise and in-depth case studies. The paper concludes with a discussion about a suggested course of action to more successfully implement ICT accessibility criteria in public procurement processes.

2 The Study

2.1 Benchmarking of OECD Countries

Benchmarking was undertaken to provide a global perspective on the ways ICT accessibility criteria are applied to the purchase of ICTs by national governments that are members of the OECD. ICT accessibility policies from these countries were systematically reviewed in order to determine key attributes of each. Information searches for Chile and Mexico yielded insufficient information to reasonably include these two countries in the benchmarking.

Table 1 summarises the findings. The findings include the monitoring mechanisms as this has a significant bearing on the application of accessibility criteria in public procurement. It can be seen from Table 1 that only two countries, the USA and Japan, were found to have comprehensive accessibility criteria that are mandatory in public procurement. Comprehensive accessibility criteria indicate that detailed standards were used. In the case of the USA, the application of these laws extend only to federal authorities while in Japan it appears that all levels of government are required to apply these laws. Further, it can be seen that the monitoring of the application of these laws yields two different scenarios. In the case of the USA, the use of an online procurement system called the *Buy Accessible Wizard* enables ICT purchases by federal government authorities to be tracked and checked. In the case of Japan, it is not possible to find an official mechanism for monitoring compliance with their procurement laws. Indeed, Yamada comments that the Japanese market is flooded with inaccessible ICTs and related services as a consequence [10].

Table 1. The application of ICT accessibility criteria in public procurement law in the OECD

ICT accessibility criteria comprehensively described in public procurement law	
External monitoring regime that makes a commitment to publish results	-
Internal monitoring regime that makes a commitment to publish results	USA
Internal monitoring regime – but no commitment to publish results found	-
Evidence of monitoring regime was not found	Japan
ICT accessibility criteria broadly described in public procurement law	
External monitoring regime that makes a commitment to publish results	-
Internal monitoring regime that makes a commitment to publish results	Italy, Norway, Sweden
Internal monitoring regime – but no commitment to publish results found	-
Evidence of monitoring regime was not found	Spain
ICT accessibility criteria acknowledged in public procurement law	
Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Slovenia, Switzerland, United Kingdom	
ICT accessibility criteria not found in public procurement law	
Australia, Canada, Israel, Republic of Korea, New Zealand, Turkey	

The second category of ICT accessibility criteria includes more countries; Italy, Norway, Sweden and Spain. ICT accessibility criteria in these instances were not prescribed by detailed standards or criteria but were more generally described. By way of example, Spain and Italy have broadly followed the Section 508 provisions but have not adopted the standards in their entirety. Norway has used the principles of universal design to describe ICT accessibility criteria. In Sweden's case, ICT accessibility concepts are laid down in equal opportunity law. These countries have also chosen different means by which to monitor compliance with these laws. In Italy, monitoring is the responsibility of equal opportunity authorities. In the case of Sweden and Norway, public administration authorities are responsible for monitoring the application of accessibility criteria in public procurement. It was not possible to find evidence of monitoring in Spain.

The third category of ICT accessibility criteria comprises countries in which ICT accessibility is merely acknowledged in public procurement. This category has the largest number of countries. This is primarily by virtue of a European Union (EU)

Directive on Public Procurement issued in 2004 that has been adopted by EU member countries. EU Directive 2004/18/EC requires EU member countries to adopt, along with other clauses, the following clause (29): “Contracting authorities should, whenever possible, lay down technical specifications so as to take into account accessibility criteria for people with disabilities or design for all users” [11].

The OECD countries that had not adopted ICT accessibility criteria in their public procurement laws were in the minority. As will become clear in the following cases, some of these countries’ governments have opted for voluntary strategies to encourage the use of accessibility criteria when procuring ICTs. For example, the federal government in Canada has sponsored the development of an online toolkit designed to guide purchasers through procurement decisions that are based on ICT accessibility principles. However, the final decision to adopt such principles is left to individual federal departments [12]. In the Republic of Korea, a set of national ICT accessibility standards have been developed but these are not mandatory in public procurement.

It is anticipated that the rankings of countries in Table 1 will change over the coming years, particularly in Europe, where considerable preparatory work has been undertaken to develop ICT accessibility standards for eventual implementation.

In the course of the research it became obvious that web accessibility criteria had been applied in many countries [5, pp. 18-19]. This was seen in the variety of ways that web accessibility guidelines have been codified in administrative regulations (particularly e-Government strategies) as well as equal opportunity law. These were almost universally based on W3C’s Web Content Accessibility Guidelines (WCAG) 1.0 or 2.0. While it is encouraging to note that a majority of countries had embraced web accessibility standards they are but a limited subset of the full range of criteria required for ICT to be fully accessible.

2.2 In-Depth Case Studies

There are a number of challenges that make the mandatory adoption of accessibility criteria when purchasing ICTs (or related services) less than straightforward. The in-depth study of contrasting cases provides a more nuanced appreciation of these challenges in the different approaches countries had taken to ICT accessibility criteria.

United States. The United States is still considered a pre-eminent example of a country that has legally enforceable ICT accessibility standards as reflected in their so-called Section 508 legislation. The relevant legislation from which Section 508 is drawn is the Rehabilitation Act of 1973. In 1998, amendments to Section 508 saw the creation of a set of enforceable accessibility standards that were embedded into federal procurement regulations in 2001 [13, p. 98].

In 2006, the realisation that Section 508 standards were being challenged by new technologies led to a review called the ‘Section 508 Refresh’. This was done by the US-government supported Telecommunications and Electronic and Information Technology Advisory Committee (TEITAC). TEITAC’s brief was to review and

update the standards that underpin both Section 508 of the Rehabilitation Act and Section 255 of the Telecommunications Act 1996, the latter relating to accessible telecommunications equipment for people with disabilities. TEITAC also considered new and converging technologies. These included:

- self-service machines and kiosks
- the growing market of gesture-based interfaces, such as touch screens
- the emerging trend in digital or biometric identification as an alternative to password protection
- hand-held devices and access for people with limited dexterity and refreshable Braille
- access for people with cognitive disabilities

TEITAC ensured that standards better address rapid technological changes by moving from specific product categories to product characteristics. This means that an Apple iPhone is not forced into a category such as mobile phone, computer or PDA but is described by characteristics that have accessibility requirements attached to them [14]. These new standards have not yet been adopted by the US Government.

In recognition of the need for increased compliance by procurement officials, the Office of Management and Budget in the Executive Office of the President issued a strategic plan in early 2013 to strengthen the management of accessible ICTs in the Federal Government. The key aims of this directive are: increasing transparency; strengthening accountability and improving collaboration between Federal agencies [15].

Japan. This is the only country, apart from USA, that has ICT accessibility criteria comprehensively described in public procurement legislation. These criteria apply to all levels of government throughout Japan. When government entities procure products and services, they are required by law to address accessibility criteria along with other standards available from the Japan Industrial Standards Committee (JISC). There are seven parts to JIS X 8341 relating to accessibility of various types of products. This series of standards has been influential in the harmonisations of standards within the international standards bodies such as the International Electro-Technical Commission's (IEC) Guideline 71 and the Web Content Accessibility Guidelines (WCAG) v. 2.0.

Despite the impressive work of the JISC to develop accessibility standards, it is doubtful if the mechanisms used have been effective. Yamada reports that, in practice, all that is required when procuring ICT is to include a sentence on accessibility [10]. Yamada explains that the onus of responsibility is on suppliers to explain how their products meet accessibility standards. Checking for compliance with accessibility standards is then left to individual departments as there are no uniform compliance guidelines and no sanctions are made [16].

European Union. The European Union favours the introduction of ICT accessibility criteria in public procurement across member countries due to the fragmentation of markets that can occur because of multiple standards and the resultant inefficiencies [1]. The EU's Mandate 376 has directed European standards bodies to develop a

detailed standards framework that can be applied in public procurement [17]. This is to be harmonised with Section 508 standards as much as possible. The European Accessibility Act is under consideration by the EU and this may have an impact on the adoption of ICT accessibility criteria in future [1].

Ireland. The public procurement system in Ireland does not require, but rather, encourages a pro-active approach to the purchase of accessible ICTs as reflected in the EU Directive 2004/18/EC on public procurement. It is disability discrimination legislation in the form of the Disability Act 2005, and associated regulations, which impose statutory duties upon public bodies to make their services and information accessible to people with disabilities (where practicable and appropriate).

The National Disability Authority (NDA) that administers the Disability Act 2005 has initiated a number of actions to support this encouragement. The NDA's Centre of Excellence on Universal Design (CEUD) has produced an excellent range of resources that assist government purchasers to consider the inclusion of accessibility criteria in their requests for tender. These comprehensive toolkits are written in a user-friendly manner and are designed to both educate and assist purchasers. However, there is no compulsion to use these resources nor to apply accessibility criteria to purchasing policy, thus resulting in limited impact on improving accessibility to ICT.

United Kingdom. The UK's procurement regulations are consistent with the EU Directive 2004/18/EC on public procurement. The promotion of accessible ICTs has been occurring within the eAccessibility Forum and Action Plan under the auspices of the Department of Culture Media and Sport [18]. Stakeholder-led processes that draw on a broad range of knowledge and experiences are considered preferable to government regulation.

The Business Taskforce for Accessible Technology (BTAT) has promoted ICT accessibility criteria as a key component of future productivity. The business benefits that they cite are improved interactions with new and existing customers, greater loyalty and productivity from employees, improved business processes within the organisation and improved financial outcomes [19]. Initial support of the BTAT Accessible Technology Charter has been obtained from companies such as Cisco, Microsoft, SAP, Oracle and Logica. This Charter includes accessibility in procurement practices. Notably, the Taskforce has developed a toolkit that enables businesses to assess their level of accessibility readiness through an Accessibility Maturity Model.

Canada. Canada's selection as a case study presents a number of interesting contrasts. The reliance of the Federal Government on the market to deliver accessible ICTs to people with disabilities has been a source of ongoing criticism [12].¹ The stance of the Federal Government has been one that encourages the adoption of

¹ Evidence from the Council of Canadians with Disabilities (CCD) website indicates continuing criticism of this policy.

See <http://www.ccdonline.ca/en/technology/> Retrieved 11 March 2012.

accessible ICTs based on its endorsement of the US Section 508 standards but does not mandate such provisions. Encouragement is found in the availability of an online toolkit that guides potential purchasers of ICTs through a number of steps that enables appropriate choices to be made. However, use of the online toolkit is not mandatory.

Provincial governments in Canada are able to regulate in many areas of social and economic life. For example, The Accessibility For Ontarians With Disabilities Act, 2005 imposes binding conditions on all organisations (public and private) and individuals when dealing with people with disabilities within Ontario.² The publication on 7 June 2011 of the *Integrated Accessibility Standards* makes explicit the conditions under which greater accessibility for people with disabilities in Ontario occur.

Australia. In Table 1, Australia is grouped with countries that do not make specific reference to accessibility criteria for ICTs in their public procurement procedures. This applies to federal, state and territory governments.

The federal government provides assistance under its JobAccess program to employers for workplace modifications for employees with a disability. Focus group research revealed that the current system suffered from a number of inefficiencies. The two most significant criticisms that emerged was the time it takes for changes to be implemented and the expertise of IT staff in accessibility. For example, screen-reading software was not installed properly.

3 Discussion

The case studies along with the data in Table 1 reveal a variety of approaches designed to improve the availability of accessible ICT products and services. The question as to which is the most preferred method is contentious given the different modes of application of these criteria by governments in their procurement regimes and the ability of industry to respond to these changes. These questions are often reduced to a simple distinction between ‘carrots’ in the form of market-based incentives and ‘sticks’ as demonstrated in the mandatory application of standards. However, such a simple distinction does not do justice to the complexity of the challenge, which ultimately will require a judicious mix of both.

From the outset, the analysis of case studies finds that voluntary incentives to encourage the adoption of ICT accessibility criteria ultimately lead to little change to the status quo. In the case of Canada, use of their online toolkit has declined over time rather than increased. Even in Ireland, where the government has world-class expertise in universal design at their disposal, compliance with national disability regulations by government departments fell far short of general compliance. Many governments have set for themselves a relatively low bar of web accessibility; and even that has proved a challenge.

² See ‘Accessibility for Ontarians with Disabilities Act, 2005’ available from: http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_05a11_e.htm
Retrieved 20 April 2012.

In order to achieve greater commitment, stronger measures in the form of mandatory requirements for ICT accessibility criteria appear necessary. The research indicates that the mandatory use of accessibility criteria in public procurement of ICTs provides an impetus that manufacturers and vendors respond to. While manufacturers and suppliers may initially believe that adding accessibility to their products will be an added cost with limited returns, the combined factors of ageing populations in countries such as Japan and the need to find new markets means that industry is slowly starting to see the commercial benefits in addressing the needs of individuals who have disabilities. With the mandatory use of accessibility criteria in public procurement of ICTs all manufacturers have a common set of criteria that they must address. The commentary from industry indicates that this level playing field is much preferred to a situation in which accessibility criteria have not been clearly defined or are not uniformly enforced.

Mandatory accessibility criteria in ICT public procurement will likely lead to greater awareness among ICT professionals of the needs of people with disabilities. Yamada makes the point that mandatory accessibility requirements in public procurement play an important role in educating designers about the challenges and limitations of current products [16, p.8]. This will ideally set them on a path to develop innovations in accessibility features. Given support from professional bodies, the teaching of accessibility principles should also find its way into university and technical training curricula.

The downside risks of making ICT accessibility standards mandatory in public procurement relate to the complexities of developing and implementing new standards. Yamada describes it as the tension between setting broad functional criteria as opposed to detailed quantitative criteria [16, p.7]. Add to this the rapid changes in technology, which challenge many of the assumptions about the technologies that the standards refer to. Is a smartphone, a telephone or a computer or personal assistant device or all three?

Yamada advises that the first response is to institute a lead-time to the introduction of mandatory accessible ICT procurement to give manufacturers and suppliers time to adjust [16]. As Thoren argues, rather than requiring manufacturers to respond to tender criteria on a one-by-one basis, the application of accessibility criteria is best achieved through a strategic relationship between government and industry [20]. These issues are given more detailed attention in this study's report and are ripe for further investigation through ongoing research.

The complementary issues of monitoring and compliance were found to be of significant importance. The case of Japan reveals that the absence of a transparent and effective monitoring regime with effective sanctions leads to poor adoption of accessible ICTs by governments. The latest developments in the United States that will see increased transparency and accountability being applied to Section 508 standards indicate the importance of effective compliance processes.

The work of various agencies to develop toolkits and build educational resources has been of significant value in advancing learning and conceptual developments in accessible ICTs. The work of Ireland's Centre of Excellence on Universal Design (CEUD) is a good example of this where they have been establishing important milestones in improving the profile of education and research in this area. Unfortunately, through focus group research and evidence from the countries studied,

there is still a significant gap in understanding of ICT accessibility by government procurement officials, IT systems staff and suppliers.

Therefore, a combination of both ‘carrots’ and ‘sticks’ appears to be necessary to encourage compliance with ICT accessibility criteria. Carrots are required to facilitate learning of accessibility concepts. Sticks are required to emphasise the importance of ICT accessibility and the need for commitment by government officials to ensure that accessibility criteria are widely used in public procurement.

Given a global market, the commercial impetus for innovation in accessible ICTs will increase significantly if global accessibility standards are agreed upon. Steiner looks to the World Trade Organization’s Government Procurement Agreements (GPA) as one possible way of promoting social goals through international treaties [21]. Such a development may lead to less complexity for smaller countries if the hard work of standards-setting occurs elsewhere. In being able to piggyback on the efforts of the United States, Japan or the EU, the economies of scale and improved knowledge development that is enjoyed there will be extended to all countries that choose to adopt such standards.

4 Conclusion

Mandatory ICT accessibility criteria in public procurement signal a government’s commitment in working towards universal access for people with disabilities. It is anticipated that increased adoption of such by the public sector will help to increase employment opportunities for people with disability and should gradually lead to the widespread availability of accessible and affordable ICTs.

While mandatory ICT accessibility criteria provide the strongest incentives for compliance, it is recognised that negotiated change with cooperation from industry at the various stages of implementation will be the key to future success. Consistent and uniform accessibility criteria will provide greater certainty for vendors and manufacturers to invest and compete thereby creating a sustainable commercial context for the supply of accessible ICTs.

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Rational Interfaces for Effective Security Software: Polite Interaction Guidelines for Secondary Tasks

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Abstract. States of the science and practice agree on the failure of security application to engage end users in the assurance of security and privacy in everyday personal computing. We propose as the cause an underlying irrational interface model of security related applications. Irrational Interfaces are counterproductive because they minimize the intended software utility and pay-off. In the case of security interactions, utility is minimized by the assumption of security primacy and the alienation of end user from the decision making process through disruptive messaging and disengaging content. Therefore effective security dialogues must be based on a rational interaction model. We present a small set of simple guidelines based on cognitive psychological research for polite interactions that appropriately optimize user engagement during tasks that users perceive as secondary. The guidelines for secure applications that politely interact with the end user are supported by a pay-off matrix that can be used to predict and evaluate rational secure interface performance. The rational, polite interface is a radical paradigm shift for security applications' design because it integrates end users as active stakeholders and resources in the assurance of security and privacy.

1 Introduction: Rational Interfaces and Broken Security

The state of non-expert users' understanding and utilization of computer related security is dismal. This proposition is substantiated with quotes from two leading experts in human computer interaction and computer security, respectively:

Donald A. Norman [1]: *“Without useable systems, the security and privacy simply disappear, as people defeat the processes in order to get their work done.”*

Butler Lampson [2]: *“The main reason that we don't have usable security is that users don't have a model of security that they can understand.”*

What is the reason that security applications software for end users do not work? The concept of a rational interface may provide a vantage point that gives us insight to the cause of the dilemma: The states of research and practice agree that interfaces are instrumental to provide information to users and that their design affects cognition in the form of attention and decision making. Rational interfaces empower the user to carry out their purpose for using the interface. Motivations may be task and goal driven such as working on a manuscript, designing a 3D vehicle prototype or virtually socializing with friends. The majority of interfaces are user benevolent and they are

designed to effectively support users. However, interface design has a dark side, which is evident in the deliberate manipulation of end users towards harmful decisions by malicious software. A real world example is the 9 year old child who is clicking on a fun-looking, animated but malicious popup, and installs a virus. This interface is user malevolent and yet rational with a high pay off because it accomplishes its own questionable purposes.

Our personal computing security is important but it appears that the connection between the expert defenders and the end users is broken. In fact, prior empirical research shows that security matters in personal computing are seen as a secondary task and even a nuisance [3]. We argue that the reasons for the dismal state are irrational interaction models that fail to appropriately involve the end user; instead of earning end user cooperation they generate dislike and annoyance. Based on prior research we propose that the low pay-off results from the *false* assumption that end users perceive security interactions as primary tasks. Built on the questionable assumption that *security has priority*, application designers use interaction models that are effective for primary tasks but not for tasks that end users perceive as secondary and subordinate. To ameliorate this problem we propose a set of simple polite interaction guidelines using a context sensitive smart interface. The guidelines are based on cognitive psychological research and their objective is to make effective security dialogues possible because of our understanding of how end users process information at cognitive and affective levels. One may say that we have chosen our security motto, "If you want a busy person's attention to help you make a decision, don't make yourself a nuisance but be polite!" The expected pay-off of polite security computing is mindful user participation in security tasks and positive user affect, which together enable a cooperative relationship between system and user for the long term, deep defense of personal computing. The rationale of this paper is outlined by the following statements:

1. Rational Interfaces are effective because they optimize the intended pay-off of the interface
2. Irrational interfaces are ineffective because they minimize the intended pay-off of the interface
3. Interface design includes pay-off consideration in line with benevolence or malevolence towards the end user.
4. The majority of interfaces have benevolent motivations, like security applications. Malicious Software (malware) does not.
5. Malware is rational because it manipulates the user to its own ends and therefore has high pay-off; Security applications are irrational because they rely on the primacy of security assumption and have low pay-off.
6. The reason for the low pay-off is the false assumption that security has priority. Pay off can be increased by accepting security as a subordinate interaction component.
7. Subordinate interaction components, like security, can be optimized by learning lessons from common human courtesy, which give rise to polite interaction guidelines.
8. The pay-off of polite interaction guidelines must be measured and hence we present a utility matrix for future performance and evaluation.

2 The Dark Side of Rational Interaction

To elucidate rational (high pay-off) interfaces, we turn to the dark side of human computer interaction. A taxonomy of malicious user interfaces may seem an unlikely topic until we accept that they (a) are effective and (b) are similar to security messaging. [4] discussed the impact of malicious interface design on users and they present a brief taxonomy, particularly of abusive advertising practices. The table below lists nine of their eleven rubrics in the left column. (The rubrics “shock” and “tricks” were deleted for obvious reasons.) The equivalent techniques used in system and security messaging are listed with examples in the right column. We combine the categories of system and security related communications because prior research has shown that users do not distinguish them [5,6].

Table 1. Taxonomy of Rational, Malicious and Security Interface Techniques

Effective Techniques Of Malicious Interfaces	Ineffective Equivalent in System and Security Messaging
<i>Coercion</i> – Threatening or mandating the user’s compliance.	Windows Vista UAC pop-ups; anti-malware popups blocking downloads until users manually override.
<i>Confusion</i> – Asking the user questions or providing information that they do not understand.	The classic example is “Abort, Retry, Fail” of DOS.
<i>Distraction</i> – Attracting the user’s attention away from their current task by exploiting perception, particularly preattentive processing.	The primary example is the animated corner pop-up used for dialogues and notifications.
<i>Exploiting Errors</i> – Taking advantage of user errors to facilitate the interface designer’s goals.	Not applicable
<i>Forced Work</i> – Deliberately increasing work for the user.	End users regard security task as additional and secondary work.
<i>Interruption</i> – Interrupting the user’s task flow.	Primacy of system and security interrupt the user.
<i>Manipulating Navigation</i> – Creating information architectures and navigation mechanisms that guide the user toward interface goals.	Windows Vista UAC pop-ups.
<i>Obfuscation</i> – Hiding desired information and interface elements.	Misuse of security indicators (Stebila, 2010), Fake UAC-like interfaces.
<i>Restricting Functionality</i> – Limiting or omitting controls that would facilitate user task accomplishment.	Ambiguous security messages combined with Yes/No choices & modal dialogs.

After perusing the table, one might summarize that there is nothing consistent about malicious interfaces except that they successfully deceive the end user; in fact, they manipulate user decision-making in line with the motivation of the interface. Whether malicious interfaces are annoying, loud, quiet or subtle their design is carefully chosen to optimize pay-off. Although sinister intent and successful manipulation of the user for dark purposes is clearly not a goal of our research, these

tools and practices may give us food for thought: for example, the effectiveness of malware is based on interaction design that is goal driven and creative; malware that appropriately involves the user is an example of a rational (albeit malicious) interfaces with high pay-off. One must wonder how irrational security applications can defend end users when they are ineffective by definition due to their failure to appropriately interact with end users. The next section reviews the wide range of approaches to end user computing security.

3 Scholarly and Industrial Approaches to Security Interactions

The difficulty of attracting users to engage in security decision making has inspired scholars as well as practitioners and industry to solve this problem. For instance, [7] presented a tool to aid users in making security decisions that enhanced security-related pop-ups by displaying system status information in a more user-friendly manner and providing additional information on the impact of the user's decisions. Their results suggest the possibility of enhancing user decisions, but were not statistically significant. Similarly, recent research has presented new ways to improve the effectiveness of security-related pop-ups and dialogs. [8] studied ways to enhance security dialogs by adding context-sensitive guidance, polymorphic displays and auditing the user's interaction with the dialogs. Their approach had certain elements of coercion and forced work similar to malicious interfaces. The investigators found mixed results but suggested enhancements which may lead to improvements. Likewise, [9] sought to improve security dialog messages. They introduced a new approach to security-related popups called Adaptive Security Dialogs (ASD). They found no single factor that influences users' security behaviors and the investigators concluded that there is a need to conduct further research.

Given the lack of a solution for effective security messaging to engage the user in the decision making process, industry has opted to remove the end user from the security loop. For instance, Dell states on their enterprise website that their security system centralizes and automates security processes and thereby minimally disrupts end users. They acknowledge disruption as a key problem and rely on standard, less effective approaches to address the problem: centralization and automation. For example, automated system reboots are announced in advance and PC infections are diagnosed remotely. There are no data or metrics presented that end users benefit from this approach [10].

Nevertheless, taking the end user out of the loop does not solve the problem. We conducted an informal survey with security experts and IT professionals who work at the frontlines of system defense and are aware of user weaknesses. Along those lines any impromptu Google search on variations of the terms "dumb user and computer security" yields a plethora of documentation and editorials describing how not-so-smart end user decisions have reliably created job security for security professionals. It has been argued that complete automation and the use of artificial intelligence may be the solution to security in the future, but today's end users remain involved in security decision making; they often underperform on this task and unintentionally put their systems at risk. Below is a listing of risky behaviors that were provided by

security professionals who responded to an informal survey we conducted on “your favorite not so smart user security decisions”. The results fall into four categories: false beliefs, spontaneous interactions, memory minimization, careless networking. (The complete listing is available <http://research.fit.edu/carl/endusers.php>).

False Beliefs

- Believing that a bank would ask for account passwords via an email/web link
- Believing that shoddy looking or poorly spelled browser popups are legitimate
- Believing that fake AntiVirus is actually going to help clean a malware infection

Impulsive Spontaneous Interactions

- Passing on email chain letters
- Saying yes to install a pop-up or toolbar in IE
- Not logging out
- Not completing updates

Memorization Minimization

- Shared credentials (user names and passwords)
- Using the same password for many online accounts
- Using weak or easily broken passwords

Careless Networking

- Turning off User Account Control
- Using open or unencrypted wireless public networks
- Not securing home wireless networks with a password key
- Allowing strangers access to their computer via Remote Desktop or Sessions
- Using an insecure login, such as FTP instead of SFTP

Numerous studies have been conducted on the question how end users make use of cyber security tools [11, 12, 13]. In the end, we accept that the dialogue between end user and security applications is broken and that empirical research demonstrates that developing an effective interaction that results in engaging the user in effective security dialogues is not a trivial task and has not been successful. One might argue that effective security messaging is impossible because users do not care about the security of their computer. However, preliminary research may have revealed a crucial component of the solution to this puzzle: *end users do care about security but they do not see security as a primary task.*

4 Security Is a Secondary End User Concern

The section presents a summary of previous research by [3] who investigated end user security interactions mediated by standard pop-ups. They made a number of discoveries, for example: end users consider security related pop-ups annoying and frustrating and do not enjoy pop-ups. They report negative emotions consistently for all pop-ups *regardless* of the ongoing task (gaming, studying or writing an essay), *regardless* of the enjoyment of the task (engaging, boring, difficult, easy) regardless of pop-up dimensions and timing. Without exception, users do not like pop-ups and report being highly annoyed by them.

It does not necessarily follow that dislike and annoyance result in dismissal. Our lives are replete with unpleasant tasks that warrant our attention. Nevertheless, users rank security related pop-ups a secondary task during their computer session while studying, gaming and writing a short essay from memory are considered primary occupations and remain in the foreground of cognitive attention; on the other hand, pop-ups are rated as interruptions and distractions and furthermore users report that they try to ignore them. The self-report measures converged with behavioral measures of eye-tracking. While pop-ups consistently captured initial attention as soon they appeared on screen and elicited relatively stable response times (the time from the first glance until the decision button is clicked), the *actual time users spent looking at the pop-ups* was not stable: after the first two pop-ups, the time spent by users actually looking at the pop-ups dropped sharply. This means that although a given pop-up was on screen, it did not visually engage the user and visual attention was invested in the primary task. It only took two exposures to pop-ups before the participants had adapted to the situation by dismissing the pop-up message. It appears that users operated using a mental model for future pop-up stimuli that classified them as meaningless and disruptive so that they could be eliminated using a “Close or cancel” heuristic, considered relatively safe. Selecting a response that is based on a heuristic is appropriate for a subordinate, secondary task because it does not require content knowledge or deliberation but only the recognition of the situation that triggers the use of the heuristic.

5 A New Way of Thinking: Polite Interactions for Rational Security Interfaces

People use computers. Computers are vulnerable. Users are the first line of defense to protect their vulnerable systems. Instead of eliminating the user through automation or through irrational interfaces, we propose to involve the end user as a stakeholder and leverage their cognitive capacity (yet unequalled by AI) to secure their personal computing environment.

Conventional dualistic approaches to human cognition have divorced reason from affect; at the same time, current cognitive neuroscience makes it clear that decision making and the selections we make from the set of choices are moderated by the limbic system, a system of systems in the human brain involved in emotions, learning and memory [14]. In turn, we suggest that HCI is a collaborative process between human and system, mediated by keyboard, mouse (used by users) and the dynamic changes in the GUI (caused by users and by the system). This process engages users at the motor level (typing, scrolling, etc.), at the visual level (looking at the screen), at cognitive levels (remembering how to use an application, using software, making decisions, etc.) and affective levels (feeling frustration with new software, feeling happiness over an email from an old friend).

If we accept that HCI is a collaborative process between system and user that influences end user cognition, then we must not only examine how the user communicates with the system but how the system communicates with the user and

how it makes the user feel. Since they are ubiquitous in human computer dialogues, especially security related messages, we focus on pop-ups here. What are their characteristics? They appear at any time regardless of context; they force interaction regardless of the importance or relevance of their content; they contain text, which triggers an automated reading response in humans [15]. They originate from multiple sources, including the operating system, the web and anti-virus applications, but their provenance is neither distinguishable nor verifiable by end users; they may or may not be urgent; they may be legitimate requests for user interaction or may be malicious, i.e. phishing, etc., attempts. Given these traits one might argue that an anthropomorphized pop up shares some features with an annoying colleague from the security department who is forcing interaction.

6 The Importance of Mutually Courteous HCI

For example, [16] suggested that polite computing is defined by software that respects user information ownership by asking for permissions. Our approach to polite interaction is not based on information ownership but on *information processing*. We focus on the cognitive state of the user who is processing information while working at the computer and who is fully engaged in his or her primary task. To the busy user a security related task is not primary. If we relate this observation to security related pop-ups and consider the characteristics of pop-ups within the context of a social situation, it is obvious why pop-ups fail to engage the user in a meaningful way. One might argue that pop-ups are similar to annoying or rude colleagues who interrupt one's current task and insist on interaction. Conversely, what are the actions of a polite and thoughtful collaborator who needs decision support? For example, the polite co-worker finds a time to interact with you when you are available based on the consideration whether you are already engaged (e.g., on the phone). Once this polite co-worker decides that it is a good time to approach you, he or she asks if you are free. If your reply is positive, only then does the thoughtful and polite coworker articulate the request that motivated the interruption. This polite strategy includes four steps that apply to HCI:

1. Assess whether the person whose attention is required is busy;
2. Approach the person when he or she appears available;
3. Confirm that the person is indeed available;
4. If the response to item three is positive, state the request.

These four steps are self-explanatory because our experience of social interaction makes us aware that interruptions carry the risk of resulting in negative affect and thus will influence the resulting interaction. In addition to abundant anecdotal evidence, related research in HCI has shown the cost of task switching resulting from interruptions and the preference to delay interruptions while engaged otherwise [17, 18, 19]. Similarly to the above, socially savvy humans know that causing an interruption during work flow can provoke annoyance and comprises a poor strategy when attempting to obtain decision support from a colleague. The polite and thoughtful colleague will only interrupt in case of an emergency. From the human interaction analogy it is evident why pop up mediated security messages do not and cannot work.

7 Polite Interaction Guidelines for Security Messaging

Once we model the steps of our polite colleagues, three requirements emerge for a rational interface that optimizes dialogues required by applications that end users view as secondary or subservient:

1. *Do not interrupt the user while the user is engaged in an ongoing task.* This is not a trivial problem but may be solved by monitoring existing user interaction data and using them as signals and heuristics for determining user cognitive engagement. We propose the use of a smart or context sensitive interface to address this guideline.
2. *If you interrupt the user during a task it has to be a true emergency.* This should and must be a rare event. If all dialogues are escalated to the emergency level their importance and distinctiveness are diminished, which de facto reinvents the current pop up practice. This may be accomplished by prioritizing security interactions.
3. *Be subtle and allow the user to choose when to engage.* Once an appropriate time has been detected in the dynamic flow of the user activity, the interruption may be presented as a subtle alert (no text) that puts the security message on the user's cognitive radar but does not require the user to fully engage. Subtle alerting prevents the high cost of externally driven task switching, acts as a mnemonic aide for the user and enables the user to give his or her whole attention when ready. We propose secondary task messaging that is proportionate to the available attention of the end user.

7.1 Utility Matrix for Polite Security Interaction

Security software is motivated to obtain user engagement for decision making (including acknowledgements, and granting permissions) and uses pop-up messages. Current personal computing security applications do not consider users' state and readiness. Instead, they interrupt the user without consideration of his/her primary tasks. This model of security interaction design is irrational because it minimizes user engagement by annoying the user who in turn dismisses security related interactions.

We conclude that a rational security interaction model optimizes user engagement and increases the utility of security messaging by *engaging the user appropriately and timely in the decision making process*. To engage the human user one must consider the user state and optimize likelihood of user compliance. As seen, humans who seek cooperation from other humans (over whom they have little influence or power) use courtesy and timely opportunities. Therefore polite interactions for security messaging have three minimal rules: 1. avoid interruptions of the workflow, 2. avoid drawing user attention unless an emergency arises and 3. provide subtle and graduated alerting aimed at low levels of cognitive processing. In this first version of the pay-off matrix for polite security interaction we have not yet included emergency handling:

Table 2. Pay-off Matrix for Polite Security Interaction

		Security Interaction Model	
		Irrational (disruptive)	Rational (polite)
User state	User is busy	<i>Negative Engagement:</i> User dismisses prompted interaction. Negative user affect over time.	<i>No engagement:</i> Application does not act, i.e., does not prompt for input. No negative user affect.
	User is available	<i>Ambivalent Engagement:</i> User may or may not engage. Negative affect due to previous interruptions.	<i>Positive Engagement:</i> User participates in decision making process. Positive affect over time (liking, feeling protected)

The next step is to define metrics that test the predictions about user behaviors and attitudes. Metric and measurement construct development will be the topic of the next paper. Likewise, formalizing the pay-off matrix as a cooperative game, emergency handling and assessing any changes in user affect and trust over time will be covered in future work.

8 Conclusion

The assumption that security has priority is not valid for end users. Security interaction models are irrational because they built on this assumption and hence have not been effective. Empirical research based on a human information processing model that includes cognition as well as affect, suggests that secondary tasks, such as security applications and malware interactions, can be designed to optimize pay-off. Their effectiveness depends on the end users and how much attention and resources they are inclined to invest in the task. To this end we present 3 simple rules for polite interaction that apply to security interactions but more generally to the optimization of end user involvement in secondary tasks. Specifically, polite interactions rely on system recognition of user activity in order to find opportune times and non-disrupting formats that (a) engage the user in collaborative and more effective security decision making and (b) generate positive affect and trust over time.

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Social Dimension of Sustainable Development – Safety and Ergonomics in Maintenance Activities

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Abstract. The paper considered the issue of the impact of maintenance services for the safety and health of workers. This is undoubtedly an important issue as statistics show that in Europe 10 to 15% of fatal industrial accidents can be traced to maintenance operations. The role of these services in the modern enterprise is increasing, as companies increasingly depend on the proper functioning of its technical systems. In addition, the maintenance process involves not only technical services company employees, but also the employees of other functional areas and external agencies. All this makes, that maintenance in terms of security is a complex issue. Activities of maintenance services are generally associated only with phase of the operation of machinery. In the paper authors consider the effects of enlargement of operations maintenance services for all phases of the life of a technical object, including not only operation but also design, manufacturing and disposal phases. Such approach is able to provide more effective, proactive and preventive health and safety system.

Keywords: Maintenance, maintenance stakeholders, safety culture levels.

1 Introduction

Since the end of the 1980s of the previous century, as a result of the report ‘Our common future’ published by the World Commission on Environment and Development, politics, economy, and science have been dominated by the term ‘sustainable development’ ([1]; [9]). In the report, sustainable development was defined as a process of change in which exploitation of resources, new investments, concentration on technology development, and institutional changes are focused on present and future needs of society. At the macro level a model of economy based on the concept of sustainable development assumes appropriate and conscious forming of the relations between economic growth (economic aspect), commitment to environment (environmental aspect) and quality of life (social aspect). Including sustainable development into business activities of organisations we reach the micro level and may define it as a process in which satisfaction of the organisation’s development needs and improvement of its present become a priority. All at once we assume responsibility for the risk of satisfying the same aspirations in the future.

Despite the fact that sustainable development requires integration of the economic, environmental and social aspects, this paper focuses only on the social dimension and its aspects pertaining to health and safety of employees. Ensuring healthy and safe working conditions in a business organisation is often the first social impact identified by local communities and employees [15]. Both the groups want to be reassured that they work in a place that is safe for people and causes no harm to the environment. Health and safety of all people in a business organisation, no matter employees or visitors, are the basic social requirements of any development [5].

This paper covers issues of employee health and safety from the perspective of maintenance personnel’s activities. The statistics show that in some European countries 20% of all industrial accidents relate to maintenance activity, and in some sectors this percentage rises to more than half. In Europe 10 to 15% of fatal industrial accidents can be traced to maintenance operations [2]. Hence, it is a fundamental issue. Furthermore, business organisations become more and more dependent upon proper functioning of its technical systems. Consequently, the importance of maintenance personnel will grow.

Technical service personnel are not the only players of the maintenance processes. Other functional area employees and external organisational units also contribute [4]. By contributing to correct operation of plant and equipment they also demand (Fig. 1).

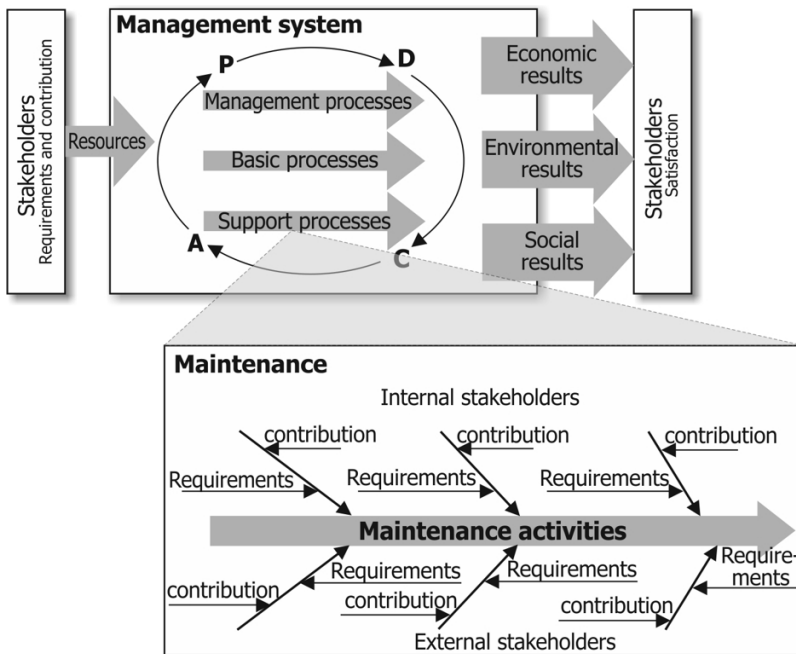


Fig. 1. Internal and external stakeholders involved in maintenance

These requirements refer not only to the economic and environmental aspects but also to the social one, in particular safe and healthy working environment. It should be stressed that maintenance is an essential instrument for preventing hazards in the workplace.

2 Maintenance, Safety and Human Factor in Technical Object's Life Cycle

Maintenance can be defined as the combination of all technical and associated administrative actions intended to retain an item or system in, or restore it to, a state in which it can perform its required function.

Traditionally, the scope of maintenance referred to production processes. It was widely agreed that the main aim of maintenance was the optimization of equipment availability at the lowest feasible cost. However, the shift from production paradigm to sustainable development resulted in a change of the maintenance paradigm towards the product life cycle management; as well as taking into account economic, environmental and social aspects. The maintenance objectives can be summarized under four headings: ensuring system function (availability, efficiency and product quality); ensuring system life (asset management); ensuring safety; ensuring human well-being. The many decisions made during the process of a technical object's design, production and operation directly influence the effect and outcome in the social dimension. Maintenance managers hold all the instruments that allow a business organisation's technical service workers participate in all phases of a machine's life cycle and thus engage them in the implementation of the social dimension of the organization's strategy [6].

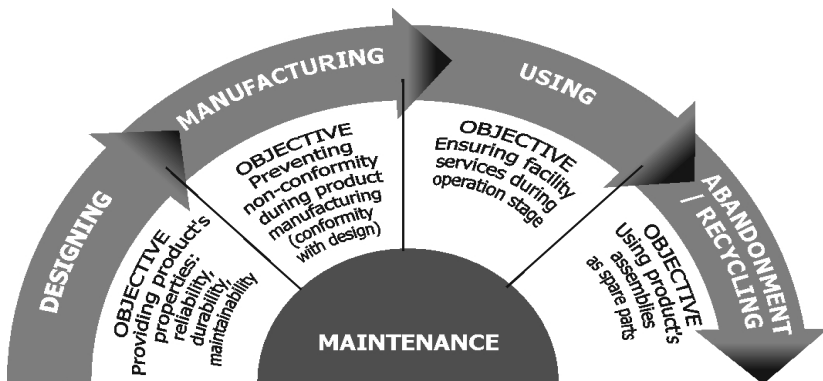


Fig. 2. Maintenance in product's life cycle. Source: [6]

The first stage of a machine's life cycle is the design. At this point technical parameters concerning efficiency are defined. Also here adequate level of reliability and ease of performing maintenance and repair is determined. Thus, the safety of

implemented processes and its participants is ensured. From the point of view of maintenance personnel work safety, it is crucial to minimise the probability of error occurring during maintenance works. Plant and equipment should be designed for maintainability. In engineering, maintainability is defined as ease of maintaining technical objects, e.g. identify defects or their cause, correct defects or their cause, automate fault detection and isolation tasks whenever possible to make future maintenance easier etc. Although the main purpose is to ensure easy and quick performance of service-and-repair tasks, maintainability promotes safety and ergonomics of work. This has an impact on minimizing the human error risk by reducing phases during disassembly and reassembly works. It may also guide employees to take good decisions. Finally, maintainability is linked with cognitive ergonomics. Minimizing the number of components to be replaced, connected, disconnected etc. promotes both effective task execution and reduces cognitive load during the task. Suitable solutions concerning the safety of operational and maintenance activities at this stage of a machine life cycle must be searched in two areas. Firstly, in cooperation between designers and end users, that is engineers and employees forming maintenance personnel of a business organisation. Their suggestions, comments, and initiatives should constitute major input for designing. Secondly, providing machine designers with tools supporting carrying out and documenting of risk assessment at all stages of the machine designing process [3].

The second stage of a machine life cycle is manufacturing. The main task here is to ensure conformity between the requirements included in the design documentation and the actual outcome of the manufacturing process. This conformity is the resultant of materials used in the manufacturing process, knowledge and skills of people as well as machines and equipment applied in production [11]. Their fitness for use has a major impact on the final effect.

Another stage, on which maintenance personnel may have an impact, is the stage of machine operation in a business organization. For safety reasons, at this stage maintenance of infrastructure is focused on ensuring systems, procedures, and training to build operational knowledge, skills, and functional capabilities of systems to prevent, manage, and eliminate risks. From the moment of deciding about the purchase of a new machine one must think about the tasks of maintenance personnel resulting from the mere fact of owning the object. Whether or not the machine works some maintenance activities must be performed. The next stage is designing of the work stand the machine is installed. From the point of view of operator and maintenance-and-repair staff this is a crucial point. As far as the operator and his/her activities are considered in the designing process, the necessity of future service activities is usually neglected. An analysis performed in 2012 in three serious companies with reference to the so called 'Kaizen events' proved that out of 123 improvement activities proposed by maintenance personnel, 14 were linked to work space connected with carrying out of repair works. This situation resulted in non-adherence to rules of conduct and safe performance of work.

Once the technical object is installed and started up, the proper phase of use starts. The machine now performs the functions for which it was designed. From this moment on, the proper use of the equipment's usable resource starts. Apart from the normal wear from use, damages and failures may occur that result from incorrect operation e.g. machine working parameters, work place, etc. [13]. Degradation contributes not only to the reduced capacity of the machine but also has an impact on deterioration of its operational use safety (it may constitute a hazard to operators and other participants of the process). Consequently, it is required to perform regular overhauls, maintenance, and repairs. Such activities provide detailed information on the progress of equipment degradation processes and are the key element in the course of securing health and safety of all participants. It is, therefore, necessary to choose suitable maintenance policy for each piece of the production equipment (Corrective Maintenance - CM, Time Based Maintenance – TBM, Condition Based Maintenance – CBM, Predictive Maintenance - PM, etc.) based on identification and assessment of the risk connected with a machine failure. This enables scheduling of the production equipment service activities in a suitable context (Fig. 3). The main purpose of these activities is to reduce the general risk that may lead to an unexpected failure of equipment [10]. To minimize the total risk, priorities of service actions (overhauls, maintenance) are defined according to quantitative analysis of the risk caused by machine assembly breakdowns. Such an approach enables finding of the right proportions among individual maintenance policies, allowing not only for financial but also environmental and social issues (safety of people).

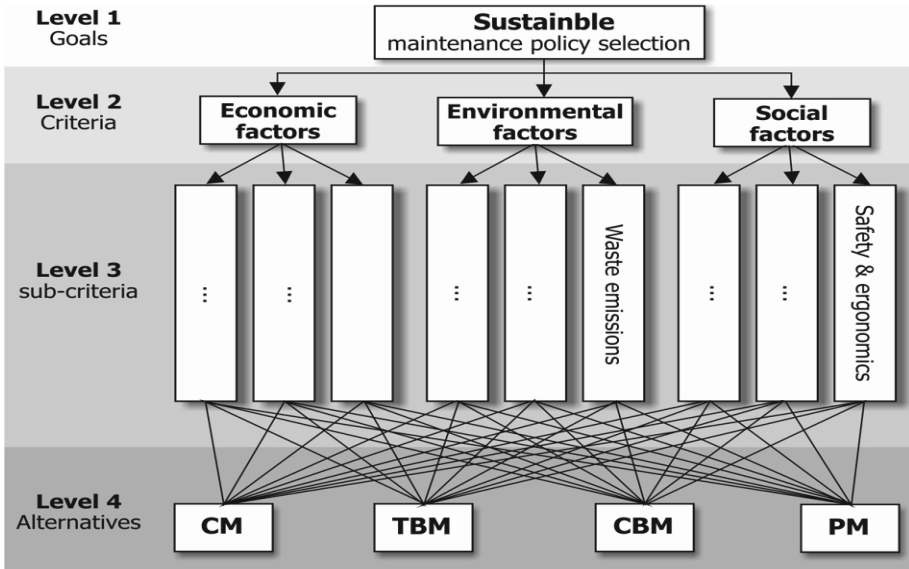


Fig. 3. Maintenance policy selection model

Maintenance is rarely part of the production plan and is mostly considered a waste of time. As a result of such maintenance, personnel work under stress to complete the tasks in a very limited time and under constant pressure, on pieces of machinery that are not always well maintained. Procedures are not followed, maintenance technicians often improvise and the quickest methods are used at the expense of their own safety. A consequence is that the maintenance schedule, when present, rarely includes testing the safety gear (for instance safety switches, light curtains, sirens, emergency buttons, signs and interlock switches) that are an integral part of the equipment, and which have a limited operational life. As it results from the survey made by Scroubelos [14] among maintenance personnel the causes of incidents (accidents and near-accidents) are linked to first-line personnel and supervisory personnel (Fig. 4).

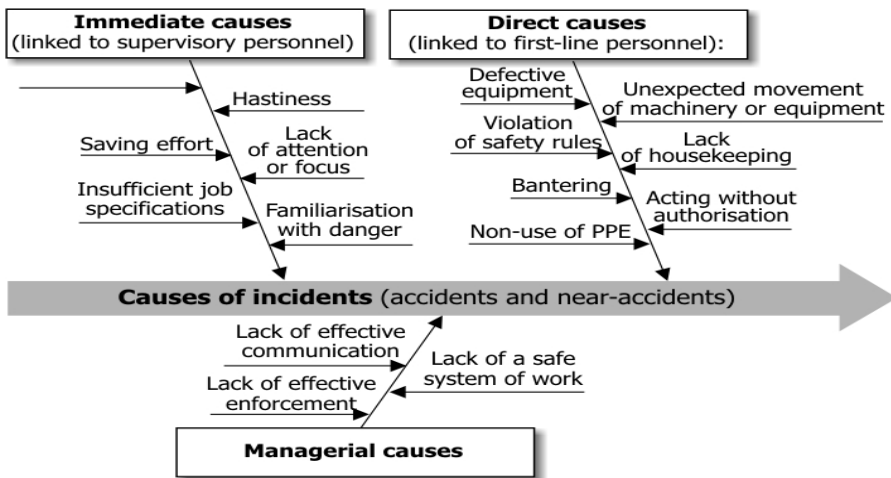


Fig. 4. Causes of incidents among maintenance personnel

After gaining an insight into the causes one may see that they refer to organisational aspects. As practice shows, many actions in the area of safety and ergonomics are taken following occurrence of an incident. In other words, once an error occurs, actions are taken to prevent similar errors in the future (rules of proceeding are developed, training is carried out, protection is implemented). This is the co-called ‘reactive’ safety. Implementation of the sustainable development concept in a business organisation requires proactive actions, i.e. anticipating of the occurrence of adverse incidents. With reference to safety, this means pursuing the goal of ‘zero incidents and unsafe behaviour’ (Fig. 5).

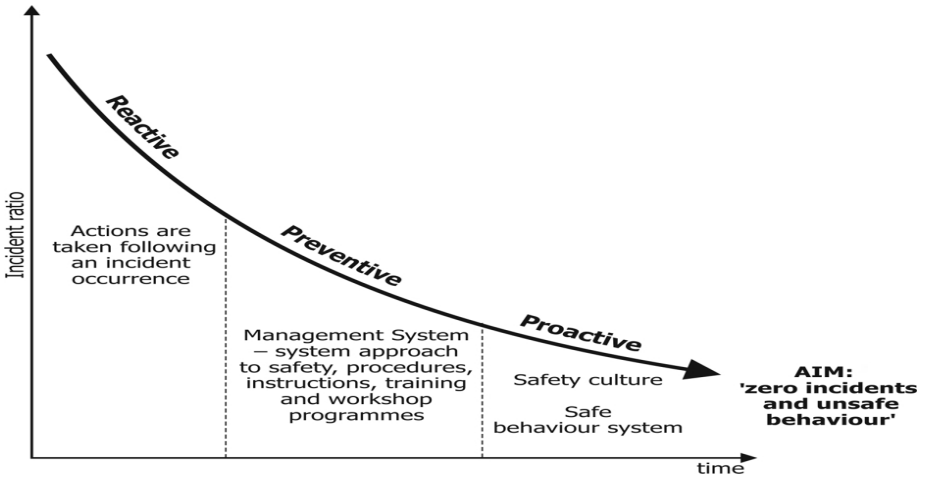


Fig. 5. Evolution of safety culture levels. Source: [7]

Hence, for safety reasons, actions of maintenance managers should be oriented to scheduling of works, supplying resources necessary to perform the works (materials, tools, personal protection equipment, procedures, manuals, etc.), consistent monitoring of adherence to the assumed proceeding methods and results thereof, motivating, conscience building, and ‘good practice’ promotion (Fig. 6).



Fig. 6. Examples of good practices supporting maintenance safety

Implementation of safety procedures and safe working systems must be supported by training, interactive communication between all participants of work processes [12], and activities shaping safe behaviour. Shaping of safe behaviour is connected with a change to perception of risk by employees. The factors that influence the way risks are perceived and actions taken are as follows:

- conception each person has, influences whether or not such person perceives his/her behaviour unsafe or potentially causing injuries. Activities described by low probability of risk occurrence tend to form the conception that employees are safe, while in fact they were just lucky.
- habits that makes employees easily forget about risks attributed to the work or task. It is in the nature of human to adapt to the environment and losing sight of the risk that accompanies our work every day.
- barriers or obstacles that prevent employees from taking precautions and force them to expose to risk, unfit tools, pressure connected with achieving the production target.

For that reason, building a responsible behaviour regarding safety requires shifting from natural instincts, i.e. intuitive perception of risk, to an attitude of team and conscious shaping of the work environment, paying attention to the behaviour of oneself and colleagues (Fig. 7)

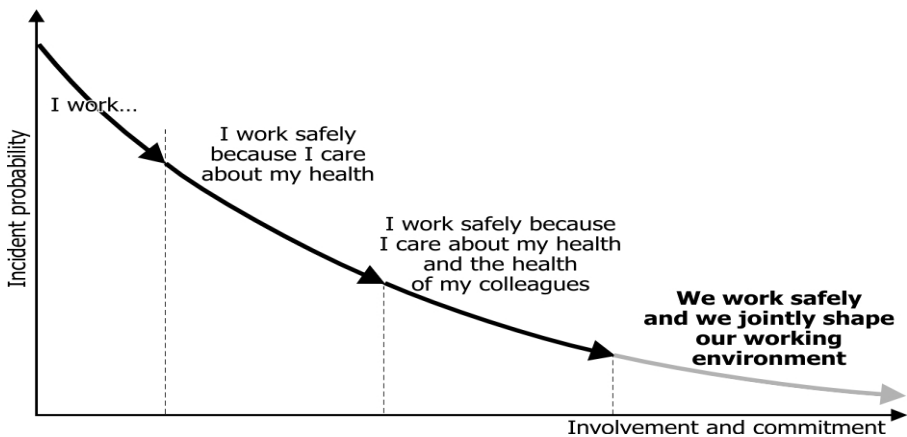


Fig. 7. Model of safety culture expansion among personnel. Source: [8]

3 Conclusion

In recent years, maintenance has been the subject of fundamental change and is now regarded as an essential function within companies. Maintenance is not only necessary to ensure reliability of technical structures or productivity of the company, but regular maintenance has an important role in providing safer and healthier working conditions. Lack of maintenance or inadequate maintenance can cause serious and deadly accidents or health problems. Maintenance is one of the workplace

activities that can affect the health and safety not only of the workers directly involved in it, but of other workers and third parties, if safe work procedures are not followed and work is not performed properly. However, maintenance-related risks continue to receive limited attention and little research has been devoted to the impact of maintenance on the safety of those who work in maintenance and their co-workers. It is essential to take a structured approach to maintenance, seeing it as a process rather than a task. The wider perspective of maintenance refers not only to the service life of technical equipment. Contemporarily, maintenance must be extended to all phases of service life, from design to liquidation. As early as in the phase of designing the basic property of any object, in terms of safety and health of workers performing maintenance and repair tasks, is formed. That is maintainability. When designing machines it is a common trend to minimise the amount and scope of service performed by human. We wish each next generation of a machine to be completely self-operating. However, irrespective of the complex automatics it is equipped with or the amount of work that is performed using wireless technologies, elimination of work performed by human (zero maintenance) in a production company is not possible. There will always be activities that require performance by man. Every effort must be made to lessen the physical and psychological arduousness of such work.

Social sustainability in maintenance activities (similarly to other areas of operation of a business organisation) is realized in concepts such as preventive occupational health and safety, human-centred design of work, empowerment, individual and collective learning, employee participation, and work-life balance.

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Using Human Factors Standards to Support User Experience and Agile Design

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Abstract. The ISO 9241-210 standard provides a framework for human-centred design (HCD) activities comprising the four stages: context of use, specification of user and organisational requirements, design solutions, and evaluation against requirements. Other parts of the 9241 standard cover user interface design and usability. This paper uses the HCD framework to emphasise user experience (UX) design and methods used to help create good user experiences. It also relates the framework to an agile software development environment. It is concluded that the flexible and iterative nature of ISO 9241-210 makes it a good basis for both user experience design and an agile development process.

Keywords: Human-centred design, User experience (UX), Usability, Agile, Standards.

1 Introduction

Despite the development of electronic products that people become attached to and the prevalence of user friendly graphical interfaces, many of them are hard to use. This leads to a poor user experience causing people to abandon them or fail to use them effectively. The same applies to work systems where poorly designed user interfaces can cause frustration for those who have to work with them on a daily basis leading to inefficient working and costly technical support. Redeveloping a product or system to improve both the usability and user experience is always more expensive once it has been developed. An agile approach allows a system under development to be adapted more easily to user feedback and changing user needs.

Three important concepts for producing more acceptable systems for users are *user experience (UX)*, *usability* and *agile design*. Although there are many definitions of each of these concepts, some useful and concise ones are as follows:

User Experience: ‘A person’s perceptions and responses that result from the use or anticipated use of a product, system or service’ [1] and ‘All-aspects of the end-user’s interaction with the company, its services, and its products’ [2]. In general UX is concerned with how people feel about a system. Guo [3] defines four elements of user experience: value (is it useful?), usability (‘is it easy to use?’), adoptability (is it easy to start using?’), and desirability (is it fun and engaging?’). The last of these seems more relevant to consumer products than traditional systems although the

‘gamification’ of work systems is now a hot topic for research. Rubinoff [4] considers the UX of websites and expresses the main components as: branding, usability, functionality and content. He also provides opinion rating scales for evaluating each component.

Usability: A common definition is ‘the ease of use and learnability of a human-made object [5]. The ISO 9241-11 definition is ‘The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use’ [6]. In this way usability is often seen as a quality objective forming part of the user experience, and focusing on the user’s ability to achieve objectives or tasks. This definition lends itself to the objective measurement of task achievement, while satisfaction in completing the tasks requires subjective assessment. However usability is also defined as a set of attributes which must be designed into a software product to make it easy to use [7], [8]. This allows the use of design principles or heuristics to evaluate the usability of a system.

Agile: ‘A group of software development methods based on iterative and incremental development, where requirements and solutions evolve through collaboration between self-organizing, cross-functional teams. It promotes adaptive planning, evolutionary development and delivery, a time-boxed iterative approach, and encourages rapid and flexible response to change.’ [9]. Thus it is seen as a more flexible approach to system development that breaks the design into smaller chunks with frequent reviews and adaption of user requirements if required. These ideas have existed for some time [10] but the term was introduced in 2001 with the ‘agile manifesto’ [11].

The human factors community has done much work to develop a human-centred design (HCD) approach to system design and dialogue design principles and guidelines for specific user interface styles (menus, form-filling, GUIs, etc.) This paper looks at how human factors standards can be used as a framework for supporting usability and UX design and agile software development.

2 The HCD Process and User Experience Design

According to the ISO 9241 human-centred design standard [12] there are four essential activities which should be undertaken in order to incorporate user needs into the software development process.

- Understand and specify the context of use;
- Specify the user and organisational requirements;
- Produce design solutions;
- Evaluate designs against requirements.

The activities are carried out in an iterative fashion with the cycle being repeated until the design objectives have been attained. These activities are described in more detail and how they relate to user experience design. It is also shown how they can be applied to agile software development and how they can support this process, as illustrated in Figure 1 below.

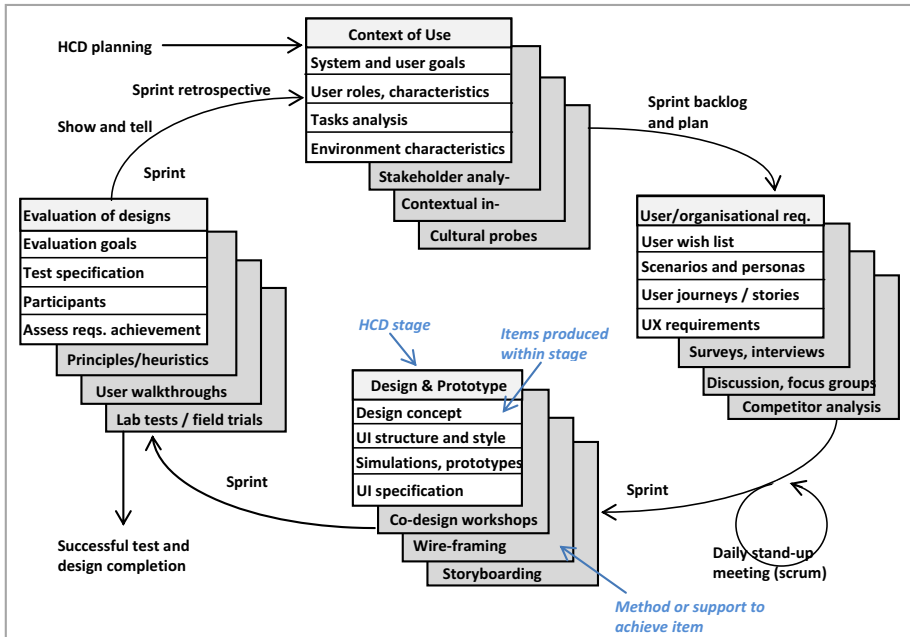


Fig. 1. ISO human-centred design process annotated for UX design and agile development

The HCD framework is extended as follows:

- Each of the main four activities (context of use, user and organisational requirements, etc.) is shown as part of a cycle. For each activity there is a set of outputs or items produced within that stage (e.g. system and user goals, user roles and characteristics, etc.).
- Methods that might be used to generate those outputs are shown as boxes overlaid by each activity (e.g. stakeholder analysis, contextual inquiry, etc.). These methods are applicable to either or both multi-user system and consumer product development.
- The iterative cycle is annotated with labels indicating possible stages related to an agile development process.

An agile process starts with a wish list of user requirements, and a plan for a set period of time (e.g. two weeks) to implement a subset of those functions. This could form one iteration around the HCD activity cycle, called a 'sprint'. The activity involves a multi-disciplinary team of people in different roles: the product owner, business analyst, team leader (or 'scrum master'), UX team, front and back end developers, and QA testers. At the end of each sprint, there is 'show and tell' session to review what functions have been implemented, and amend the 'sprint backlog' to show what functions are left to be developed. The aim at the end of each sprint is to produce a potentially shippable product increment (although this would not be

appropriate for all types of system). Another feature which contrasts with traditional systems design processes is that agile is open to user requirements changing and the sprint backlog being amended ready for a new plan for the next iteration. To help monitor progress there is a daily stand up at the beginning of each day where the whole team highlight any problems or ask questions before work continues. This meeting is called a 'scrum' and is led by the scrum master who acts as a buffer between the team and any distracting influences. See [13] and [14] for full details.

The HCD activities described by the ISO human-centred design standard can be seen to fit into an agile process, with each iteration conducted over a relatively short period of time. Thus the human factors activities may need to be carried out in a less formal way than traditionally while still maintaining validity and high standards.

The following sections describe the four main HCD activities and how they might be adapted to emphasise user experience and agile design. Before these activities commence, there should be a planning phase to organise how they fit into the overall system development process. This will determine the formation of the human factors or UX group and how they will integrate with the development team to make effective inputs and evaluate prototype designs.

2.1 Understand and Specify the Context of Use for the System

The quality of use of a system, including usability and health and safety aspects, depends very much upon the context in which the system will be used. For example in an office or workplace there are many features of the environment as well as characteristics of the users and tasks which can impinge on the usability of a new software product. Capturing this information is not only important for informing design decisions but also to provide a sound basis for later evaluation activities. In some cases contextual information may already be known, particularly where a system has been used for some time and only upgrades or enhancements are being made. If a new product or system is to be introduced, then the relevant context information must be collected and understood. The characteristics of the users may include features such as the users' age range, gender, task and IT skills, motivation and knowledge. It will be useful to record what training or skills the users already have in using certain types of software e.g. a particular operating system or application. This may be based on professional or work experience but equally may be acquired through the use of personal technology e.g. a home computer, tablet or mobile phone. Task descriptions may include the procedural steps identified through task analysis, frequency of performance, level of complexity and accuracy required. To assist with this process, the ISO/IEC DIS standard 25063 specifies how context of use descriptions should be compiled for existing or new systems [15]. The socio-technical system in which the system is placed may also influence usage such as interruptions by other workers, requiring that the user be able to save work uncompleted or to perform tasks concurrently. See [16] for a discussion of how user interface design may affect or be affected by the socio-technical system in which it is placed. Effective user representation covering the different stakeholders is necessary for all this information to be made explicit.

Supporting User Experience Design. A range of methods exist to explore the context of use. In a multi-user system, stakeholder analysis needs to be done in order to ensure that all the different user roles and types are covered. Interviews and observations may be conducted as part of a *contextual inquiry*, studying the user's current activities in their own natural environment – at the user's workplace, at home, on the move, etc. The researcher watches users perform their own work tasks and discusses with them any artefacts they generate or use. In addition, the researcher gathers detailed re-tellings of specific past events when they are relevant to the project focus. The aim is to find out what motivates them, what frustrates them and what would really help. This is the starting point for creating a good user experience [17].

Where it is necessary to gather information from users with minimal influence on their actions, or when the process or event being explored takes place intermittently or over a long period, *cultural probes* are useful [18]. For example, they could be used, to explore errors in process control caused by the equipment used in order to re-design it, or situations where people have found the consumption of video at home particularly enjoyable, with the aim of designing AV equipment to promote them. Selected participants are briefed, given a kit of paper, pens, diary, cameras, etc. and briefed what to record i.e. specific events, feelings or interactions over a specified time period. Typically, a follow-up interview is conducted after the briefing session to ensure that participants are actively engaged, and are collecting the required information. At the end of the specified period, the materials are collected and analysed with a de-briefing session. Hearing about people's lives through their own documentary records helps to understand what is important to them – key information for UX design.

2.2 Specify the User and Organisational Requirements for the System

Requirements elicitation and analysis is widely accepted to be the most crucial part of software development. Indeed, the success of a software development programme can largely depend on how well this activity is carried out. Building on the context of use descriptions obtained from the previous activity, an explicit statement of the user requirements for the new software should be formulated. These may include the functional and non-functional requirements (including usability and UX requirements). The functional requirements for a cooking application might include the range of recipes stored, audio instructions for cooking them, and the resulting energy cost calculations. The non-functional requirements of an application may be for it to be usable by at least 90% of a sample of users without instructions, for users to be able to find a recipe in no more than 3 steps, and to receive user satisfaction ratings of at least 4 or 5 on a five point scale from 80% of the user sample. Potential metrics are provided in [6]. The requirements and metrics should relate to the user or task characteristics and the organisational or physical context in which it is located (although these may not necessarily be replicated in the test). It is sometimes hard to specify usability requirements in a testable form as users often find it difficult to specify what metrics and criteria values should be applied and there is the danger that designing to pass the tests may be to the detriment of the whole design. Also requirements are likely to change during system design as users see the early designs and envisaging new usage possibilities.

Supporting User Experience Design. User requirements are normally captured in a user requirements document and then once a contract has been signed are fixed. However with agile development the design can remain flexible and functions may be dropped and new functions proposed as the design develops. The initial list is specified as a 'wish list' and the customer, design team and user representatives will agree on which subset of functions to develop first and then make further selections in subsequent interactions. To assist with the process, *scenarios and personas* [19] may be developed, recording typical usage situations and illustrating different user types based on the context of use activity. They are intended to act as stimulus for the design team of different user characteristics and situations that should be designed for.

User journeys are another useful technique [20]. These are the step-by-step journeys that a user takes to reach their goal with the current system. A journey may, for example, consist of a number of website pages and decision points that carry the user from one step to another to reach their goal. This journey is then redesigned to form an 'ideal' user journey free from frustration. The output is traditionally a flow diagram demonstrating each page and decision point throughout the entire process.

Another technique in agile development is the creation of *user stories*. Each story is one or more sentences in the everyday or business language of the system user or stakeholder that captures what a user does or needs to do as part of his or her job function [21]. User stories are used within agile software development as the basis for defining the functions a business system must provide and to facilitate requirements management. It captures the 'who', 'what' and 'why' of a requirement in a simple, concise way, often limited in detail, by what can be hand-written on a small paper notecard. User stories are written by or for the product owner as that user's primary way to influence the functionality of the system being developed. They may also be written by developers to express non-functional requirements (security, reliability, performance, quality, etc.).

User experience requirements may overlap with the user wish list and include both functional and non-functional requirements. It may be helpful to categorise them appropriately and use them to create statements for testing their achievement during the evaluation of the design.

For example from [4] in relation to websites:

- Branding: “The site provides visitors with an engaging and memorable experience”;
- Functionality: “Users receive timely responses to their queries or submissions”;
- Usability: “The site prevents errors and helps the user recover from them”;
- Content: “Content is structured in a way that facilitates the achievement of user goals”.

UX can then be assessed by asking users to what extent they feel that the proposed design meets each of these statements.

2.3 Produce Designs and Prototypes of the System

Having identified the relevant contextual information and usability requirements for the system, the next stage is to explore ideas for design solutions. This will then lead to the creation of a high level UI flow chart to show the main structural elements of the design. The general style of the design should also be considered including high level screen layouts or wireframes. Designs are brought to life by creating visualisations, simple mock-ups or interactive prototypes representing the proposed design and presenting them to representative samples of users to perform tasks and provide feedback (within the assessment activity 2.4).

Early prototypes may be made using basic materials such as paper, card, post-it notes, and stickers, to create representations of screens, menus and windows that can be manipulated by hand to support user testing. Alternatively the prototype may be software based and interactive, giving a closer representation of the final product. However while realism can have its advantages, it is better to avoid putting too much effort into a particular version until the design concept has been worked out and validated. Programs such as Visio and PowerPoint are often sufficient to create simple prototypes, although specialist prototyping and wire-framing tools exist such as Axure RP and Balsamiq which can provide more advanced interaction capabilities.

As the design develops, a user interface (UI) specification should be produced to ensure that the design covers all aspects of the interaction required to support the user's tasks [22]. The specification should include a visual overview of each screen and include display rules, specific messages in specific conditions, and links to other screens. This helps the design team in thinking through the UI design and how users will actually experience content within it.

The ISO 9241 standard includes many parts on software user interface design. These include guiding principles (parts 110 onwards); user support (121 onwards); dialogue techniques such as menus, commands, direct manipulation (130 onwards); technology dependent interface components and technologies (141 onwards); application-area specific (151 onwards) and tactile and haptic interactions (900 onwards). Guidance on software accessibility is provided in part 171 and [23]. These documents can be used to assist the creation of design solutions and can provide the basis for creating checklists to evaluate prototypes.

Supporting User Experience Design. The first step in the process of developing a design is usually to conduct a conceptual design meeting to generate ideas for the first user prototype. This should be done using the list of UX and usability requirements generated previously. In accordance with the brainstorming method, all ideas should be recorded no matter how radical or improbable they may seem. They are all then considered and a selection of them made as a basis for one or more potential designs. Before mapping out design solutions, it is useful to stay at a high level and think about the overall experience that the design should offer the user. This may be thought about in terms of the general impression to be conveyed, major features, likely starting points for different tasks and possibly visual style and colour schemes. It may be beneficial to try out various styles, stimulated by the scenarios and personas

or to make up a *mood board* – a collage of images, text, and objects to illustrate visually the direction or style of design to be pursued.

User-computer interface or dialogue principles are also a helpful reference to ensure that the design will offer a good user experience. The ISO 9241-110 standard [1] describes seven user-computer interface or dialogue principles which, as shown in Table 1, give some coverage of Guo’s four elements of user experience [3]:

Table 1. ISO 9241 Dialogue principle categorised by UX elements

<p>Value:</p> <ul style="list-style-type: none"> • Suitability for the task 	<p>Usability:</p> <ul style="list-style-type: none"> • Self-descriptiveness • Controllability • Error tolerance
<p>Adoptability:</p> <ul style="list-style-type: none"> • Conformity with user expectations • Suitability for learning 	<p>Desirability:</p> <ul style="list-style-type: none"> • Suitability for individualisation

Within [1], each principle is accompanied by recommendations to illustrate it together with examples from specific contexts of use. These are expressed in general terms and not specific technologies. Within the other parts of the ISO standard, user interface technique descriptions should be kept updated with new styles of interaction that promote a good UX e.g. touch screen gestures to manipulate content (swiping, enlarging and reducing) and remote gestures for device control. These styles of interaction may be of benefit to all sectors and not just consumer and mobile products.

2.4 Carry Out User-Based Assessment of the System or Prototype

Once a prototype or an operational version of the software is available, a user-based assessment of the product can be carried out. This activity will confirm the extent to which usability and UX objectives have been met as well as providing further information for refining the design. It is advisable to carry out evaluations at the earliest opportunity, before making changes becomes too expensive. There are a number of aspects to this activity including: choice of assessment method, planning the evaluation, recruiting user participants, collecting and analysing the results, and reporting recommendations for change. The activity is repeated for each design iteration to evaluate whether the user and organisational objectives have been met.

Supporting User Experience Design. A number of user scenarios, based on the personas, should be developed relating to the different stakeholders and their tasks. During testing, each scenario should be carried out by each user with the latest design prototype. The test session should record task effectiveness (completion and accuracy), task efficiency and user satisfaction (see [6]). The user should also be given the chance to comment freely on the design once they have experienced it. The results are assembled and metrics calculated. A decision should then be made to

decide whether the design is acceptable or needs to be refined with a modified prototype. A heuristic evaluation may also be carried out based on dialogue principles [1] or heuristics, for example [24] and [25], to help show where the usability or UX problems lie. When conducting user assessments, being aware of user attitudes is also important. Users may complete the tasks satisfactorily but a lack of enthusiasm may indicate that it is unappealing in some way.

3 Conclusions

This paper shows how the ISO 9241-210 Human-centred design standard [12] represents a useful framework for user experience design in an agile software environment, while other parts of the standard such as ISO 9241-110 Dialogue principles [1] and ISO 9241-11 Guidance on usability [6], can support it. The agile concept was also developed in order to create software efficiently and flexibly which in itself can promote iterative human-centred design. It may be argued that adopting the ISO framework as part of an agile process helps to ensure that the human factors activities are given a clear structure to help ensure that they are carried out effectively to create software that both meets user and organisational needs and gives a great user experience.

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Secure, Usable Biometric Authentication Systems

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Abstract. Biometrics are physiological features that allow individuals to be identified. Popular biometrics include fingerprints, faces, and irises. A common use of biometric systems is to authenticate users desiring access to a system or resource. Universal Access can be promoted with biometrics. Biometrics provide a secure way to access information technology, although the use of biometrics presents challenges and opportunities unique to other authentication methods (such as passwords and tokens). Biometric systems are also vulnerable to poor usability. Such systems must be engineered with wide user accessibility and acceptability in mind, but also need to provide robust security. This paper considers the application of biometrics in Universal Access systems with regards to usability and security.

Keywords: universal access, biometrics, security, usability.

1 Introduction

Universal Access (UA) seeks to provide the utility of modern information technology to as broad a range of individuals as possible [1]. Security is essential to the functionality of this technology, although it is seldom the subject of universal access research [2]. As real-world adoption of UA increases, so too will the severity of related security and privacy issues.

There are several ways to implement security in conjunction with UA. This work focuses on biometric authentication technologies. Biometrics are unique physiological features that can be used to authenticate a person's identity. There are a variety of biometrics, including fingerprint, face, iris, gait, palm print, and voice. Fingerprints are the most commonly used biometrics due to their widespread acceptance and usability [3, 4]. Face recognition has been favored in research environments due to the availability of face databases for development, although iris recognition may ultimately provide superior accuracy [5]. The selection of a biometric trait for a particular system depends on many environmental and situational factors.

Biometrics are a natural choice for implementing authentication in UA systems [6]. Biometrics are more usable than memorization- and physical token-based methods of authentication, although the usage of biometrics can introduce

risks as severe as permanently compromising an individual's security [6]. The potential to integrate security and usability effectively is greater with biometrics than with other authentication methods [7–11]. Traditional methods of authentication, including passwords, identification cards, and tokens, have not yet been able to bridge the gap between security and usability in UA systems [9].

If properly implemented, biometrics can reconcile security and usability disadvantages of authenticating users without the need for memorization or tokens. This work investigates both the usability and security of biometric systems within the context of UA.

The remainder of this paper is organized as follows. Security is discussed in Section 2. Section 3 presents biometric systems in the context of authentication. Usability topics are treated in Section 4, while usable security is considered in Section 5. The application of usable security to biometric authentication is shown in Section 6. Conclusions appear in Section 7.

2 Security

Security is important in UA systems. In many scenarios, UA provides access to sensitive, personal information – in these cases, privacy must be maintained. In other cases, UA systems can be integrated with broader computational infrastructure. Here, UA should not introduce additional security vulnerabilities. Of particular concern to UA systems are consumer data, health data, demographics, and location privacy [2]. For example, use of a UA system may unintentionally expose a user's geographic location or demographic information.

Cybersecurity can be summarized as a set of methods and techniques that guard against adversaries. These methods are essential to modern computation. Contemporary information technology environments are characterized by increasingly common persistent connections to the outside world (or even just internal networks) and massive collections of data. Adversaries constantly seek to obtain or compromise this data through these external access points.

At a high-level, there are three key requirements for securing a system. The system must be able to provide confidentiality, integrity, and availability [12, 13]. These security requirements may cause tension with both UA and usability objectives (discussed later in the paper). As UA seeks to provide access to information in a broad and accessible manner, appropriate safeguards must be put in place. These safeguards must ensure that data privacy is ensured (confidentiality), that data cannot be modified without consent (integrity), and that the data is present and accessible when needed (availability).

As adoption of UA systems increases, so too will threats to security. Security must be considered alongside usability in the design of UA systems. The following section discusses biometrics and their role in securing systems. Subsequently, usability is considered.

3 Biometrics

UA aims to provide the benefits of information technology to all individuals, but this access must be provided in a secure manner. Information should only be provided to those with the proper credentials and permissions. Biometric are a potential solution to implementing authentication within the context of UA.

Central to the secure access of UA systems is authentication. Individuals may authenticate with a system by providing one or (preferably) more of the following:

- Knowledge: for example, a password or response to a question. Such knowledge should be unique to the individual or group needing access to the resource. Security depends on the knowledge remaining secret
- Proof of possession: this may be an identification card or other token. Possession of the token is used to determine if a claimed identity is genuine (e.g. the token may contain a picture of a person or be used in conjunction with other methods of authentication)
- Intrinsic characteristics: biometrics – for most individuals, these are physiological characteristics we are born with – they cannot be lost or forgotten

There are benefits and drawbacks to each of the three methods of authentication. Knowledge-based methods are straightforward to implement, but result in increased cognitive load on the user due to having to remember their credentials [14]. Compounding this, knowledge may be forgotten or shared with an adversary. More complex password requirements can provide better security, but at the expense of usability because longer passwords burden users with the more complex password creation, memorization, and recall. Simple passwords are more usable but less secure (shorter passwords are easier to attack). Token-based methods require possession of a physical item to gain access, which is not always practical. The physical token may be lost, forged, or stolen. Biometrics are always on-person (in the cases where the person is able to provide the biometric). They cannot be forgotten. Biometrics are more tightly-connected to an individual's identity than passwords or tokens. The main weakness is that in the event biometrics information is forged or stolen, an individual may not be able to access any systems – the information cannot be changed.

Biometric authentication systems produce an authentication decision based on a comparison to user-provided input and a database of previously-sampled records. The method of producing an authentication decision may be supplemented with a human administrator and an exception mechanism for cases where the biometric data cannot be presented or recorded. The components of a biometric system include humans (both users and administrators), software, and hardware. A general overview of a biometric system is shown in Figure 1.

The *user* is the subject with regards to which the system must make a decision. The user can interact with the system directly and explicitly (for example, presenting their fingers to a scanner), or indirectly (such as when a photograph is used for facial recognition).

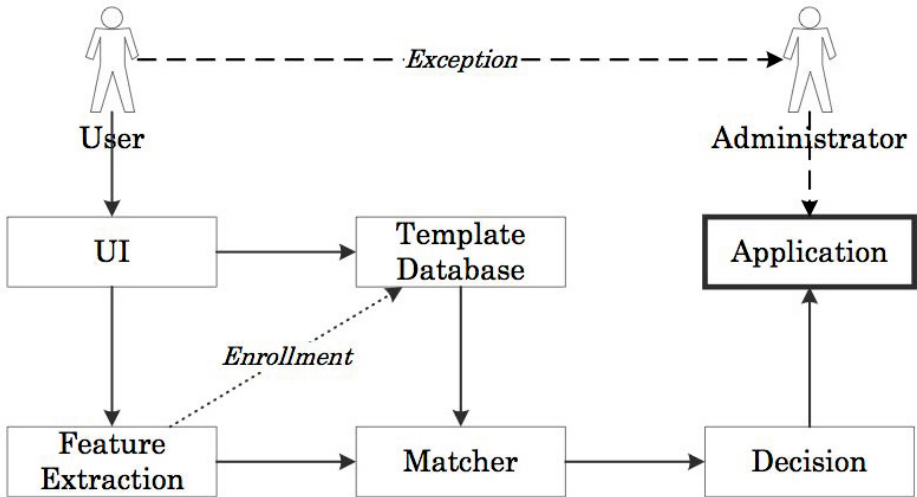


Fig. 1. Overview of a biometric system

The *administrator* handles system *exceptions*. Biometric systems must often provide an alternate method of authentication (such as a photo identification card) in the event the primary method of verification does not work. This may happen coincidentally (perhaps due to poor sensors or directions), due to a missing trait in the user, or explicitly – as part of a deliberate attack. The administrator must verify the user’s credentials using the alternate means and make the authorization decision manually.

The *user interface* may be hardware, software, or a combination of both. It can be visible or invisible to the user. The role of the user interface is to collect the required biometric information in a reliable manner. A poor user interface risks false negatives and frustrating legitimate users. A good user interface provides a better experience and potentially better security.

The *feature extraction* module translates the successfully sampled data into a more compact alternative representation – a *template*. The purpose of the templates is to reduce storage requirements (for example, instead of storing an image, a much smaller feature vector may suffice) and to reduce the time needed to compare biometric samples time. Generally, most of the original sample is discarded after feature extraction and only the template is maintained.

The *template database* stores the extracted data. An entry in the template database is created the first time the user accesses the system. Subsequent authorization attempts are verified against the entries in the template database.

The *matcher* compares the template generated from the current access attempt to the information stored in the template database. Generally, a threshold is used in order to render a decision. Matching can be challenging as it is unlikely (and suspicious) to have a perfect match – a certain degree of dissimilarity must be permitted. Matching results in a *decision* (allow or deny access), which is forwarded to the *application*.

Authentication begins by acquiring biometrics traits from the user. These traits are acquired using a sensor tailored for that particular modality. The sampled data is then processed to isolate the desired trait and reduce or assess the amount of noise present. The processed traits are transformed into templates and stored. Subsequently, stored templates can be compared to new samples in order to allow or reject a person desiring access [5].

There are many different biometrics, and many ways each of the processing steps can be performed. As a result, each sub-process may have its own usability and security concerns. However, these sub-processes have not yet been investigated in terms of usable security [15].

4 Usability

Usability is defined as the range that legitimate users can operate a product to preform particular tasks in specified methodology with an accepted level of satisfaction, and in an effective and efficient way [16]. Usability is essential to UA (“universal usability”) [17]. Information and services should not only be made available to all, but be made usable for everyone as well.

Usability is evaluated by testing one or more constituent factors (including product effectiveness, efficiency, learnability, memorability, accuracy, and user satisfaction). Effectiveness is described as the user’s ability to successfully achieve the goal of operating such a product. Efficiency is defined as user’s ability to successfully perform a particular task and complete it within an acceptable time-frame. Satisfaction is the user’s degree of happiness of operating a product [18]. Learnability is the user’s ability to learn how to operate a product. Memorability is user’s ability to remember how a product is operated and also remember the required information to operate such a product. Finally, accuracy is defined as user’s ability to operate a product and obtain accurate results. There are many other human, environmental, hardware, and software characteristics that are impacted by usability. The factors that are important to creating usable systems are also key to UA.

5 Usable Security

In certain situations the objectives of usability and security can compete against each other. In others, security is implemented, but not in a fashion that is intuitive to the user. Security in software is usable if users are made aware of the security tasks to perform, how to perform those tasks, and how to prevent dangerous errors, all while maintaining comfort with the user interface [19]. Usable security mechanisms are a set of techniques and methods for security that are usable for genuine users, but not for adversaries [8].

Figure 2 shows the intersection between usability and security from a user-centered design perspective. Each of the usable security principles [20] shown in Figure 2 is a result of a combination of usability and security considerations. The principle of *least surprise* maintains that security mechanisms and users should

Usability	Usable security	Security
<ul style="list-style-type: none"> • Effectiveness • Efficiency • Accuracy • Learnability • Memorability • Satisfaction • Additional factors 	<ul style="list-style-type: none"> • Least surprise • Good security now • Standardized security policies • Consistent, meaningful vocabulary • Consistent placement of controls 	<ul style="list-style-type: none"> • Confidentiality • Integrity • Availability • Authenticity • Additional factors

Fig. 2. Usable security lies at the intersection of usability and security [20]

have mutual cooperation, understanding, and expectations – users should be aware of the tasks that must be performed [20]. The *good security now* principle prescribes that available security technology is better than none at all [20]. *Standardized security policies* are preferred to frequently customized ones as they are easier for users to understand [20]. Similarly, a *consistent, meaningful vocabulary* should be applied and appropriate terms used to convey intended ideas and concepts [20]. *Consistent placement of controls* improves the mental stability and perception of users [20].

Security and usability in UA systems must be considered together, through a usable security approach that extends from the initial concept through development and then maintenance. Application of the usable security requirements and principles can guide development towards more effective implementations of both usability and security.

6 Usable Security for Biometric Authentication

Biometrics authentication systems have promise as gateways to UA. This potential must be tempered by both usability and security considerations. A substantial amount of research has investigated the use of biometrics for authentication in order to address the usability-security conflict. Sasse et al. anticipated that biometrics in combination with security systems may be suitable for user, task, and context configuration [11]. Sasse also claimed that biometrics can reduce both the physical and mental load placed on users despite privacy-related risks [10]. Cranor et al. stated that biometric systems should be used in lieu of passwords for authentication [8]. Kumar also recommended alternative authentication schemes including biometrics in place of alphanumeric passwords due to the better usability of biometrics [9]. Braz and Robert suggested that biometric systems in combination with other methods of authentication (e.g. passwords and identification cards) would produce robust, usable, and secure authentication systems. [7].

Usability considerations affect nearly all aspects of biometric systems, from the early design to operations. The selection of the biometric itself is critical. A

comparison of the usability of three types of biometrics (fingerprint, signature, and voice) was undertaken in [4], where it was concluded that fingerprints are the most usable among the evaluated traits. However, certain biometrics are not available in all situations. Fingerprints may not be the optimal choice in a dirty environment or cold weather where gloves are worn. Face recognition may be more user-friendly as it can be done from a distance without requiring physical contact.

A cross-cultural survey regarding user acceptance of biometrics in the United Kingdom, India, and South Africa found that culture has a direct impact on user acceptance of biometrics [21]. Al-Harby et al. studied the acceptance of fingerprint biometrics specifically in Saudi Arabia [3].

Errors in biometric systems can be due to hardware, software, or users. Hardware (specifically, sensors) may not be sensitive or reliable enough to sample the desired information (potentially resulting in a failure-to-enroll or failure-to-acquire error). Software algorithms can produce imprecise and inaccurate results resulting in false positives and false negatives. Users can use a system improperly or ineffectively.

In certain cases, sensitivity to errors is a design decision. An implementation may require more restrictive conditions to allowing a user into the system, resulting in an increased number of false negatives (legitimate users who are incorrectly rejected). False negatives reflect poorly on the usability of a system but may be necessary depending on the security context. In contrast, a design may deliberately lower the threshold to acceptance, resulting in more false positives (users who are mistakenly accepted).

The design of biometric systems, particularly usable, secure systems for UA, must consider the nature of application. Decisions here can have a significant impact on the design and performance of the implementation. These considerations include [5]:

- User cooperation: will users willingly use the system? A biometric that requires physical contact may not be appropriate if user participation cannot be assured.
- User habituation: a system that will be used only once or seldom may have a different set of usability requirements from a system that is used on a regular basis. This consideration can impact the instructions that are delivered to users, the pace at which the user interacts with the system, the tolerance for errors, and other elements of the user experience. Experienced users may be inconvenienced by steps that are necessary for new users.
- Attendance: the presence of a human operator will alter the usage of a biometric authentication system. A human in attendance can help ensure proper usage of an authentication mechanism. An unattended system must be able to anticipate a wider range of contingencies.
- Control: certain biometrics, such as face recognition, are sensitive to environmental factors, whereas others, like fingerprint sensors, can be placed in a fixed position that is not sensitive to light, wind, and other factors. User

participation can help with minimizing the impact of uncontrolled environmental factors.

The impact of these factors on two different biometrics – fingerprint and face recognition is considered in the following subsections.

6.1 Fingerprints

Fingerprints are patterns of ridges and valleys at the extremes of our digits that help us grab and feel items and surfaces. They consist of several patterns – arches, wholes, and loops. There is a large body of cases where fingerprints have been used in forensic investigations to determine an identity. The patterns on fingerprints are produced by the random stresses that occur during gestation [5].

Fingerprints are recognized by analyzing key points known as minutiae. Minutiae occur at locations where ridges terminate or split – ridge endings and bifurcations. The relative locations and orientations of minutiae can be represented as a compact template and efficiently compared to other templates.

The process of fingerprint recognition begins with sampling the finger. A variety of technologies (e.g. thermal, capacitance, reflectivity, and others) can be used to map the ridges and valleys. This map – an image – is processed in order to determine the location of minutiae. The accurate accounting of minutiae locations and orientations is key to the performance of fingerprint recognition systems.

Poor usability can decrease the performance of fingerprint recognition systems and frustrate users. For example, a failure-to-acquire error can be caused by users pressing their finger against the sensor improperly. The temperature of the environment can also impact the ability to sense fingerprints. A usable system that correctly guides users and system operators to presenting fingerprint and credential information in an effective way can reduce technical errors and improve security. Consequently, when usability-related technical errors are reduced and security is improved, fingerprint recognition systems can be more effectively, efficiently, and satisfactorily used in UA.

6.2 Face Recognition

Face recognition is a popular method of biometric authentication. It can be accomplished using cameras that are increasingly available and affordable. For example, a smartphone camera could potentially be used to authenticate a user without the need for any extra hardware. In contrast to fingerprint recognition, face recognition does not require physical contact.

Global characteristics, face geometry, the structure of facial components, and the presence of landmark points can all be used to distinguish faces, although there are a number of challenges. The uniqueness of faces can be difficult to determine without sophisticated (high resolution) sensors, and there is a large degree of similarity between relatives (and certainly twins). Compounding this, faces change over time. Over long periods of time, people grow and age. Even in

the short term, facial hair or fashion (e.g. hats, sunglasses) may change. All of these factors present challenges to facial recognition.

Facial recognition begins by taking an image. This image is processed to detect the presence of one (or more) faces within the image. Then, the detected faces are segmented. Templates can be generated using a variety of algorithms. An important component of face recognition systems is liveness detection – otherwise, a system may be fooled by a photograph.

The performance of face recognition systems is greatly affected by the behavior of users. A face that is recognizable indoors during the day may not be outside that same evening. In certain cases, the timing of the system's use is under user control. Similarly, a user may need to remove their glasses to improve the system's accuracy. Factors that are within a user's control can be kept consistent in order to improve performance and security.

7 Conclusion

Universal Access is an important area of research and development that aims to provide access to information technology to everyone. Both security and usability are essential to UA, and each has their own technical challenges. Resolutions to these challenges can sometimes be in conflict. Biometrics can be used to provide security to UA systems in a potentially more usable and effective manner. System designers must be aware of the specific impediments to the effective implementation of biometric systems. Poor usability of biometrics can adversely impact the security of a system. A comprehensive UA system design must consider security and usability together.

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Breaking Psychological Barrier toward Changes: Two Experiences

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Abstract. The paradigm of multilayer interface was created to promote universal use of software. We previously revisit this concept and adapt it to smooth the transition between two versions of software involved in a critical activity. Then we generalized this idea by proposing multilayer interface as a technical and psychological way to ease transition between software versions. We resumed two projects applying this paradigm and observe common results into those two different contexts. It mainly enabled to break a psychological barrier toward changes and improve the acceptability of new versions of software and new working methods.

Keywords: Multilayer interface, learning, transition, universal usage.

1 Introduction

As every other piece of software, upgrades involved the question of usability. But, more than this issue, upgrades must tackle too the question of continuity: continuity in the interaction paradigms and continuity [10] of the service involving the software use. A user well accustomed to a piece of software work in a comfort zone. As every other working method changes, rupture in interaction paradigms or reorganization of the interface may require a new learning phase. It may make the user to leave his comfort zone, and then generate a rejection of the software upgrades. This behavior can occur even if this rupture improves highly the global usability of the software. Moreover, some services cannot afford the users' temporal lack of efficiency induced by the changes (services dealing with a critical activity involving human lives for instances). In these contexts, the upgrades must be completed by a user training campaigns that not always succeeds. For instance, in spite of the formation, the introduction of a new train reservation system, in France in 1993, brought down the commercial agent performances during the heavy loaded holidays period and generated a large discontentment [7].

We previously studied the concept of multilayer interface as a way to ease the acceptance of upgrades by smoothing the transition between the versions of a piece of software involved in a critical activity [14]. The multilayer interfaces were initially designed to promote universal use of application and allow users (novice, amateur, expert) to use the interface efficiently with both heterogeneous objectives and training

levels [20][9][8]. These interfaces enable different kinds of uses for the same application (from the most superficial to the most complex use), by activating [20] or refining [4] the use of functions and adapting visual density to the user's skills [5][6].

We argued that the multilayer concept would enable to make a progressive introduction of the upgrades in order to: avoid brutal changes in the evolution of the application; limit the loss of efficiency caused by the takeover of the new system; adapt the rhythm of changes to the user receptiveness; and at last involve the user in a continuous evolution process of his software. To reach this goal we defined guidelines for the creation of the layers.

In this article, we propose to relate two independent experiences that applied the concept of multilayer interface as a way to ease the acceptance of software evolution. The first experience occurred in the context of the project ASTER/ACROPOLE dealing with modernization of air traffic control tools in France. The second application aims at easing the acceptance of new a layout for soft keyboards. In spite of the large project differences, we observed several common benefits in the multilayer interface application.

The rest of the paper is organized as follow. In section 2, we discuss the concept of multilayer interfaces. In section 3 and 4, we detailed the two applied experiences that lead us to use multilayer interfaces in order to help software transition. In section 5, we discuss the similar impact of multilayer interfaces use into those two experiences before concluding.

2 Multilayer Interfaces Paradigm

The paradigm of multilayer interface was created to promote universal use of software. We revisit this concept and adapt it to smooth the transition between two versions of software involved in a critical activity. Then we generalized this idea by proposing multilayer interface as a technical and psychological way to ease transition between software versions.

2.1 Multilayer Interface and Design for All

The multilayer interfaces were initially designed to promote universal use of application and allow users (novice, amateur, expert) to use the interface efficiently with both heterogeneous objectives and training levels [9][8]. These interfaces enable different types of uses (from the most superficial to the most complex use), by activating [20] or refining the use of functions [4] and adapting visual density to the user's skills [5]. The multi-layer interface aims to lead the user gradually improve his efficiency with the software while retaining continuous control of it. To reach this goal we have to define guidelines for the creation of each layer.

A group of functions and the available visual entities define a layer. Transitions between active layers are controlled either by the user or by the system; when the layer selection (or composition) is automatic, the selection is based on user activity analysis [4].

But, multilayer interface paradigm does not only tackle the heterogeneity of expertise levels. For instance, Reinecke observed that layouts and interaction paradigms are related to cultural aspect [19] and she explored the usage of multilayer interface to lead with these cultural differences [18].

Moreover, it enables to integrate population with restricted access to computers. Leung [12] implements a multilayer interface to ease the appropriation of mobile tools by older adults. Lalji [11] evoked it as a way to integrate illiterate populations and Brunet [3] as a way to adapt the interface for vision impairments.

2.2 Smoothing the Transition between Two Software Versions Involved in a Critical Activity

In 2008 we extended the concept of MLI in order to smooth the mutation into an operational systems [14, 15] involved in the context of critical activities. The new paradigm focuses on two additional issues:

- How to reduce the training period and to increase the application’s acceptance during the transition between two systems;
- How to avoid brutal changes in the evolution of the applications;
- How to maintain security during the transition.

We propose guidelines to design the layers tackling the specific following objectives:

- Limit the loss of efficiency caused by the takeover of the new system;
- Smooth out the evolution of working method;
- Adapt the rhythm of changes to the user receptiveness;
- Maintain a complete dominated system the whole transition period.

3 ASTER/ACROPOLE: MLI for Modernization of Air Traffic Control Tools

During the last decades, the air traffic controllers mainly used a radar view and paper strips (cf. Figure 1) to organize their work and prevent flights from accidents. Mainly, the radar view enables to detect the conflict between flights and the paper strips enables to plan the controller work. The paper strip is too an implicit but powerful cooperation tools between controllers working on the same area.

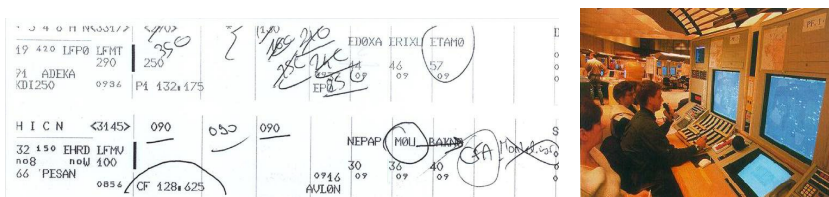


Fig. 1. Main air traffic controller tools: paper strips and radar view

The initial goal of the ASTER [1] project was to study the security and ecological impacts of a vertical representation of air traffic. This auxiliary representation should help air traffic controllers to better manage flights into the vertical plan. However, even if the experimental results were positives, the air traffic controllers did not feel comfortable to use it.

In parallel, other projects aimed at integrating the paper strips into an electronic environment in order to inform the system of the controller intentions and help to a better cooperation between the system and controllers. Those projects focus on integrating the main function of the paper strips into the electronic environment: a planning tool. However, they forgot to reproduce several other secondary roles played by the strips (and mainly the cooperation one). Consequently, these tools were systematically rejected in every area with high traffic density (in Europe) and did not play efficiently their role in the area with low traffic density (air controller just stopped to use a planning tool formerly played by paper strips).

After 2006, the ASTER project (that became ACROPOLE project) reached a new step and was charge to design an operational tool integrating an electronic strip system, a vertical representation of traffic and several other new air traffic control paradigms. The new tool was designed during a user centered design process involving actively air traffic controllers in prototyping and evaluation sessions (cf. Figure 2).



Fig. 2. Main prototypes created during the user centered design process

The user centered design process ensured that the tool responds to the user needs. It enabled to define new working methods integrating harmoniously the different roles played by the strips and new paradigms of air traffic control. However, even if an effort had been made to maintain former references to the paper strips and to the

existing working methods, the new working methods remain significantly different comparing to the current ones.

This gap could prejudice the general acceptance of the new tool. Indeed, air traffic controllers explained that their job is to create absolute certification that an accident will not happen. So, every significant change into their working environment or into the sequence of actions performed to control the flights introduces doubt and makes the controller leave a comfort zone. The stress is amplified by the human life responsibility.

From controller point of view, this responsibility and this stress justify a high reluctance to changes. It encourages us to propose a strategy to smooth the transition between former and new working method.

We founded this strategy on multilayer interface. The first layer of the application reproduced, into an electronic environment, the working method through paper strips with a high fidelity. The user was encouraged to adopt the other layers by himself and was always able to go back to its former working method by a simple interaction. To motivate the controller to adopt the other layers, we aggregate several fancy and very useful functionalities to each one of them. So, in order to benefit of these new functionalities, the user had to adapt his working methods. He was never obligated to adopt the new layers. At least, every controller was able to perform his work with the first layer of the application.

During the experiment phases, the MLI plays an efficient psychological goal. The controllers the most reluctant to change had to admit that they were able to control with the new tools with the same efficiency than with paper strips. It broke down a psychological resistance barrier, and by adopting the tool, they easily adopted the other layers observing naturally that they were a progress toward the first one.

The first layer never really be used and the users converged quickly to the new working methods. However, the intermediary layers enabled the progression for three reasons. At first, the gap from a layer to a next layer did not impact severely the working methods and the user did not feel uncomfortable during the transition. The transition between layers happened naturally. At second, this strategy never pressures the user to change. The user adhered spontaneously to the changes and began to feel curious to discover what change came next.

4 Multilayer Keyboard

The Multilayer keyboard [16] came from a basic observation: several studies demonstrated the lack of efficiency of the QWERTY layout to input text on soft keyboards and proposed other layouts that should much more efficient [17][21][13]. However, the QWERTY layout is still universally used. The new layouts failed to convince users.

Observing more attentively the experiment results, we observe that the subject always reach performances higher with the optimized layouts than with the QWERTY layout, whereas these performances are obtained after several practicing sessions. In general, during the first sessions, the performances obtained with a new layout are

catastrophic. Obviously, a user well accustomed to use the QWERTY layout turn back beginner in front of a new layout.

To be accepted, a new keyboard should not only enable to reach good performances in the long term but it should satisfy users in the short term and encourage them to adopt the new artifact.

In order to limit this problem, Bi [2] proposed a compromise between obtaining performances at long term and maintaining the user's references during initial use: the quasi-QWERTY keyboard (cf. Fig 3). The quasi-QWERTY keyboard optimizes the layout toward linguistic properties but allows only permutation of neighboring characters. Thus, the visual search of characters is eased for a mini-QWERTY user beginning with this new keyboard. During the first usages, Bi demonstrates better performances than performances with a layout freely reorganized, whereas the user still remains less efficient than with the mini-QWERTY.

q	w	d	r	t	u	y	l	k	p
z	a	s	e	h	n	i	o	m	
	x	f	v	c	g	b	j		
q	w	e	r	t	y	u	i	o	p
a	s	d	f	g	h	j	k	l	
	z	x	c	v	b	n	m		

Fig. 3. Keyboard layouts for Quasi-QWERTY (up) and QWERTY (Down)

We were convinced that this strategy of smoothing the transition from the QWERTY layout to another layout was promising. So, we propose and studied the concept of multilayer keyboard inspired by the concept of multilayer interface. The multilayer keyboard enables to progressively improve the layout by proceeding casual permutations converging through an optimal layout¹. The principal goals of the keyboard are: Maintaining the users complete efficiency with the keyboard during the whole time (no learning period must be needed); making the keyboard and the users evolving progressively during a transition period; and stimulating the user to require the further evolutions.

To obtain his new layout, Bi performed one round with several simultaneous permutations. As a consequence, the resulting keyboard layout does not enable to reach the performances obtained with a keyboard layout freely reorganized; the cost

¹ With a physical keyboard and some experience, a user can easily perform text input without looking at the keyboard. So, the permutation of two characters gets an important impact on the input. However, to input text with a soft keyboard a visual retro-control is needed. Thus, switching two neighbored keys should not have a deep impact on text input.

for a beginner is lower than the cost with a layout freely organized, but it remains significant due to the multiplication of the permutations performed simultaneously.

With the Multilayer Keyboard, we proposed to perform the permutations one by one and spaced in the time. The permutations enable to progressively improve the performances by reducing the distances between the characters frequently enchainned in the language. When a user has completely absorbed the consequences of one permutation, the next one is performed. Thus, the user must learn one permutation at a time that should not have a significant impact on the key search. Moreover, permutation after permutation, we can progressively reach the configuration of a freely organized layout.

We performed a first evaluation of the multilayer keyboard. It aimed at testing if the user was able to assimilate the permutations without prejudicing his performance and if the user was understanding the benefit of these permutations.

Users performed 80 sessions (about 8 minutes per session at the beginning) at a rhythm of 5 sessions per day. During every session, each user input 10 short sentences. The 10 first sessions were performed with the QWERTY keyboard. 30 successive permutations were planned. During the further sessions, the user decided when to perform a permutation. They were not obligated to do it and did it voluntarily.

Some results are illustrated figure 4. During the 80 sessions, every user performed the 30 planned permutations. As forecasted, between the 10th (beginning of the permutations) and the 80th session, they increased their input speed by 40% without the feeling to loose their complete domination of the keyboard at any time. No regression of the performances was noticed.

The major critic toward the system was that, sometimes, the users would have performed the permutations in a different order. It proved the user's implication in the process and the perception of the permutation interest.

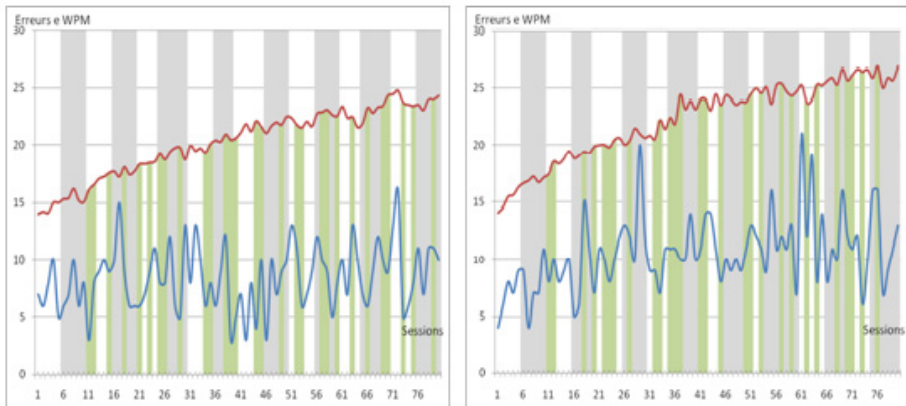


Fig. 4. Individual results for the two first users (in red the input speed, in blue the errors rate x, the green bars identify the sessions when a permutation where performed, the gray and white bars identify the day alternations)

The Multilayer Keyboard (so as to the Quasi-QWERTY keyboard) does not only target the long term performance at the long term but also focused on maintaining acceptability of the new layouts. By introducing insignificant changes into the user layout, the Multilayer Keyboard turn these changes acceptable. It enabled to break the QWERTY paradigm and to raise the enthusiasm for other layouts.

At last, the experimentation illustrates that if we performed at least one permutation every 6 months simultaneously on every soft keyboard, the whole population would improve its performances by 40% after 10 years without a real cost for anybody.

5 Conclusion

We exposed two different projects that applied the concept of multilayer interface as a way to smooth the transition between two versions of software. Despite the deep difference of context, we observe several common results between the two projects:

- At first, by maintaining the same paradigms into the first layer of the new software, the user remained completely efficient with the new system without requiring any training period.
- By progressing gradually into the layouts, the users did not encounter any difficulty to adopt to the new paradigms proposed by the new version of the software.
- The progression into the new layers did not concretely require a training period. It not means necessarily that the user exploited quickly the last layer. But, during the transition between the first layer and the last layer, the user was and felt completely efficient with the software. The training period has been substituting by a discovering period. This discovering period may be longer than a training period required to learn directly the last layer whereas it less stressful for the user.
- As a consequence, the multilayer interface enables to break a psychological barrier and facilitate deeply the acceptability of the new software. The user tolerated easily the changes because he did not have to leave his comfort zone to do it.
- At last, the process put the user into a constant mutation of his ambient and stimulated him to look for new changes and suggest new mutations.

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Design Principles of Open Innovation Concept – Universal Design Viewpoint*

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Abstract. The concept of open innovation is becoming an increasingly popular topic of interest and seems to promise a lot in organizational development. However, to date there are no certain design principles that can be followed by organizations on how to use open innovation successfully. In this paper seven design principles of open innovation concept have been proposed. The derived principles are the outcome which is based on the principles of universal design. The open innovation design, based on these principles could create better business values and new business strategies. Finally a theoretical framework is also proposed that shows how to use these principles for successful open innovation design.

Keywords: Open innovation, Universal Design, Design Principles for Open Innovation, Design Principles.

1 Introduction

The competition between corporations has sharpened in last two decades. Products and services offered by corporations need to become better and more useful for the customers. It also seems that it is more and more difficult to maintain a competitive advantage [1] among several similar corporations. Research and development done by large corporations has in the past mostly been done internally e.g. AT&T's Bell Laboratories and IBM's Thomas J. Watson Research Center [2]. Corporations have in the past mostly relied on their own capabilities and their own resources for innovation. The innovation could be in the form of developing existing product and service or be entirely new products and services. Open innovation is a relatively new approach and concept concerning innovation. The basic idea is that a corporation should harvest outside the organizational boundaries to access new ideas that could be used in innovations (also innovations that does not fit within the organization could be divested into a new business or sold/licensed to external corporations that could benefit from it) [2].

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The idea of universal design is that, it offers a greater extent and possibilities of using product or service for the end users. Although the majority tends to consider universal design concept as a pattern that was strictly initiated and meant to be for people with disabilities and elderly, the attitude towards such thinking has been changing prominently in the last decade [3]. Mainstreaming universal design concept has already extended the boundaries of disability on which universal design was supposed to be considered to be based on. However universal design principles can be seen in different perspective and be altered according to the design necessity of some important design concepts like open innovation to initiate effective design [3].

Hitherto to the authors knowledge design principles for open innovation has not been explored. Considering better design principles in open innovation should increase the likelihood of successful use of the open innovation concept. In this paper we propose open innovation design principles that are derived from the universal design principles and open innovation concept's characteristics. The paper is divided into five main parts. After the introduction, in the background section we give an overview of open innovation and universal design. The next section, proposes the open innovation design principles. In section four we propose a theoretical framework that describes how to use the proposed principles. In section five a verification of the proposed principles is given followed by the last section discussion and future research.

2 Background

2.1 Innovations

Innovation has always been a force for product development and enhancement and a source for competitive advantage. The goal for all organizations is to create value and the organization uses a defined business strategy to achieve this goal [4]. The value could be created in different ways in accordance with the value chain [5]. An important way to create and capture value is to seize technological opportunities [4] through innovations (e.g. new features, new ways to use products and services etc.). Joseph Schumpeter is considered to be a pioneer in innovation theory, Schumpeter viewed innovation predominantly as innovative combination of existing things but innovation could also be in the form of new products [6]. The old paradigm on how to innovate has now been challenged by the open innovation concept.

2.2 Open Innovation

No definite definition of open innovation exists [7] and even the originality of open innovation is argued [8] but both open innovation as a term and as a concept was first described in articles written by Henry Chesbrough. A key part in the open innovation concept is that the business organization in the past could by itself rely on their own resources (e.g. monetary, people and material etc.) for their innovation (i.e. closed innovation) [7]. In the closed innovation model, only internal ideas for innovation is used and the corporation themselves commercialized the innovation; ideas that do not

match the organizations business strategy is abandoned [2]. Open innovation is a paradigm shift in innovation according to Chesbrough since no single organization any longer can have all the knowledge and resources that is needed for innovation themselves [18], perhaps this could also be derived from shorter product life cycles and an increased risk of disruptive technological changes. It therefore becomes necessary for the organization to harness ideas for innovation from external stakeholders; such as customers, suppliers or even competitors. A marketplace for innovations is constructed by following the open innovation concept and this will enable better access to ideas and innovations both internal and external. Internal innovations of no value for the organization could be of value for other stakeholders and sold or licensed [9]. The collective intelligence of groups has in research revealed that more minds are often better than one; collective intelligence seems to be a good approach for idea creation [10]. Existing open innovation projects is e.g. “Connect + Develop” that Procter & Gamble uses to improve their innovation portfolio [11]. Also the computer manufacturer Dell use open innovation in their “IdeaStorm” to use end-users as a source for new innovations and ideas [12]. “Connect + Develop” was a drastic change in Procter & Gambles’ approach to innovation and business strategy, it has now generated more than 1000 agreements with innovation partners [17]. It has also been observed that commercial organizations attach to or complement user innovation communities; examples can be found in the software development industry and sport equipment industry [13]. Open innovation is therefore becoming more important for organizations.

User involvement in the innovation process can influence and change the direction of innovation. The users enhance services and products to better serve their needs. The innovation can happen once a new set of design possibilities (“design space”) is recognized by users [14]. A community consisting of users with similar needs and interest is then often formed and in the community users can share their ideas and help each other. The individual community members do not innovate in isolation or secrecy; instead they assist and help each other [15]. Active stakeholder involvement is thus crucial for successful use of open innovation without it no new ideas is generated or refined.

2.3 Universal Design and Its Principles

Universal design concept has been there for more than fifteen years which promises to guarantee that the surroundings, products, services and interfaces work for everybody regardless of their age and physical or mental abilities [16]. Universal design is a general approach of system design and by this approach designers ensure that their designed product or services discourses the needs of the widest possible users [3].

The original set of universal design principles was developed by a group of U.S. designers and design educators from five organizations in 1997 and is used internationally, though with variations in number and specifics analogy [16]. The seven principles summarize the properties of a design to be called universal in nature. These properties include providing equality during use, providing flexibility in use, simplicity and intuitiveness by the use of the design, easy perceptible information through the design, and high error tolerance for error, lower physical effort for the use of a particular design and optimal size and approach [3] [16]. Although based on the pillar of

accessibility these principles has a lot more to offer than designing product of services for people with special need or disabilities. The idea of using universal design principles in this article is to integrate them with the characteristics of open innovation and thereby bring some new, better design principles; which will have positive impact on the use of open innovation. It is also important to remember and understand that universal design should not and is not a concept but a design strategy which cannot be introduced at any phase of design of a product or system. This means that, if we can integrate the strategy of universal design from the early phase of open innovation design concept, the result should be better open innovation design.

3 Open Innovation Design Principles

Based on the discussions of open innovation and universal design in the previous sections we understand that, since universal design is meant for reflecting better design if we can combine open innovation's characteristics with universal design principles, a structure for open innovation design principles can be established. Table 1 respectively shows the keywords of design principles properties, open innovation and universal design principles. These key words are necessary to narrate the design principles of open innovation concept which are shown in section 3.1.

Table 1. Open innovation, universal design and their corresponding characteristic matrix

Open Innovation	Universal Design	Design Principle Properties
Gap Between Research and Development	Equitability	Practice of Research for the Majority
External Stakeholder Involvement	Flexibility	User Participation in Broad Perspective
Expansion of Academic Research	Approachability	Expanding Contact Through Academia
Ability to Change Business Model	Simplicity	Simplicity in Business Model Design
Introduction of Competitive Strategy	Error Tolerance	Use of Innovation in Error-Free Way
Value Chain Construction	Transparent Perception	Understanding of Corporate Strategy
Marketplace Creation	Reduced Psychosomatic Effort	Ability to Trade Innovation

The properties described in column one on the Table 1, maps over with the properties in column two. The result from these two columns is shown in the column three which is in the form of aggregation of previous two column's properties. These are the foundation upon which the following derived open innovation design principles are based on.

3.1 Proposed Open Innovation Design Principles

Principle one: Practice of research for the majority

Design of open innovation should focus on decreasing the gap between research and development since a gap often existed between research and the implementation of innovations into products. This could result in a superior product idea that is not possible to build in an effective way or maybe not even demanded by customers. So finding a type of equitability between research and development is anticipated.

Principle Two: User Involvement in Wide-Ranging Perspective

External stakeholders get involved in the innovation process and not only internal input is used. To create alternative paths to market and be ready to license innovation or adjust the business model especially for a major technological change, user involvement in wide ranging perspective should be considered while using open innovation concept. This could also be considered to be good risk management since more input from different stakeholders reduces the risk of negative surprises.

Principle Three: Expanding Contact through Academia

Harnessing university around the world where state of the art research is done and collaboration could be very advantageous; to do this the corporation needs to be in contact with academia. Also the corporations need to be ready to support joint collaboration with others through academia, perhaps a joint venture or business incubator. That is to maximize the leverage on investment in innovation should be considered in open innovation design.

Principle Four: Simplicity in Business Model Design

The business model should be designed in such way that it will be possible to update simply and intuitively to take advantage of open innovation. This would also make it easier to follow changes in the business strategy. Doing this will give simplicity and agility for organizational change.

Principle Five: Use of Innovation for Reducing Error

Incorporate open innovation into business strategy to gain and hold a competitive advantage towards competitors. The more stakeholders involved the less probability for undetected fault in the product or service or developing something that will not be used. That is also, to handle errors efficiently for maintaining advantages.

Principle Six: Understanding of Corporate Strategy

The design should be such that, it simplifies the understanding of where the corporation can create values and where it should outsource or buy resources. If the corporate strategy is understood by all shareholders they all can aim for the same goal. Any perceptible information in organization meant for open innovation should therefore be transparent in nature.

Principle seven: Ability to trade innovation

The open innovation design should motivate towards creation of a marketplace where innovations can be traded. The open innovation design should also lead towards creating a portfolio of innovation to manage innovations like a stock portfolio. The creation of an effective innovation market would diminish the transaction cost. All these should be done with mental and physical efficiency.

4 Proposed Framework

The design principles for open innovation design proposed in the previous section results a theoretical framework that is shown in Figure 1.

The seven proposed principles are in a relation shown in Figure 1. Reduction of gap between research and development will allow flexibility in the participation of more stakeholders. This in return will allow expansion of academic research possibilities. Together research and development with more stakeholder participation and more academic enhancement will allow a business to think analytically to design their business model so that it is simple to alter. With an appropriate business model it is then possible to add any specific competitive strategies that will increase error handling ability. This can create a value chain within the corporation. Finally creation of a marketplace for trading innovation is the result of the combinatorial effect of these principles. Together these principles can result increased stakeholder involvement which is a key to successful use of the open innovation concept.

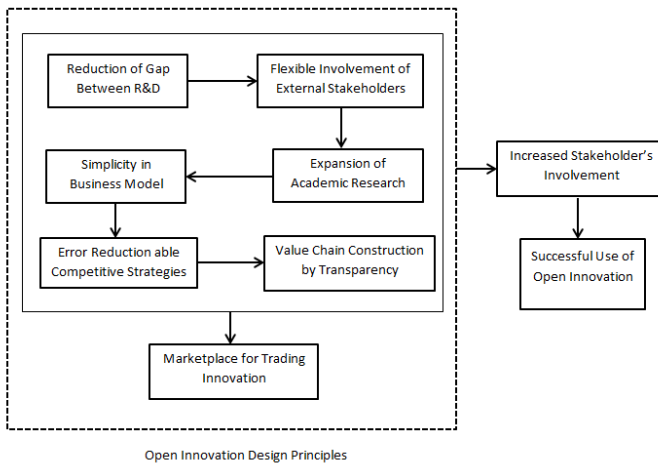


Fig. 1. A framework for open innovation design using the design principles

5 Verification of the Principles

5.1 Methods

We wanted to study how well the proposed principles' characteristics are understood and perceived by the participants of the study. Therefore, the impacts of seven design principles towards designing system with open innovation concept have been studied by a quantitative field experiment from 31 participants. The basis for the analysis was questionnaire responses. The questionnaire items were designed to capture the variables that make up the framework. All scales used in the research were prior to the fieldwork tested and optimized for face validity with senior researchers and qualitatively tested with respondents. The test bed was set up by allowing a participant to answer a set of specific questions. They were requested to answer the questions, which were based on ranking on a scale of 1 to 7. None of the participants had any kind of physical or mental disability that could affect understanding the survey. Basic demographic information has been collected. The age ranges of the participants were from 20 to 35. Participants were all university students. The answers from the survey were carefully analyzed by the researchers. Few participants' data were then eliminated since they did not complete the survey. The results from the questionnaires were then coded in to SPSS (version 19) and statistical operations were run to come up with results. We ran factor analysis (with factor loading value 0.40) together with reliability analysis to check which variable's data was not or less reliable. The rejection level was 0.7 for Chronbach's Alpha. The corrected item total value was set to be at least 0.3 for reliability analysis. The findings are described in the following section.

5.2 Results

Our result shows that the participants thought external stakeholders involvement, expansion to academic research and ability to change business model are something important, while they were thinking about open innovation design. Marketplace creation and introduction to competitive strategy was less prioritized as open innovation design principles by the participants. However our factor analysis returns a one factor solution (Figure 2) for explaining gap between research and development, business model changing, competitive strategy introduction, value chain creation and marketplace creation. This result is interesting because we found high statistical significance on these variables of open innovation design principles. Also Figure 3 shows one factor solution for expansion of academic research variable. Statistical significance was found here also to explain one factor which is related with other factors of the framework.

Our reliability analysis shows that data set was highly reliable with Chronbach's alpha value 0.862 (Table 2). We finally plotted the mean values of each questions and observed which questions were prioritized and less prioritized for explaining the variables of the framework. Figure 3 shows that question five and seven were ranked poorly by the participants while question two and four were highly prioritized.

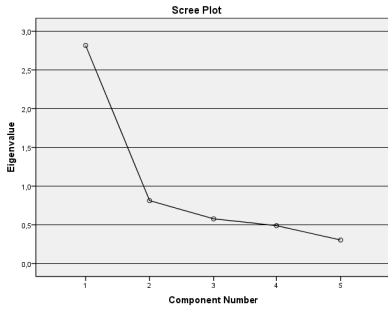


Fig. 2. One factor solution explaining five variables of the framework

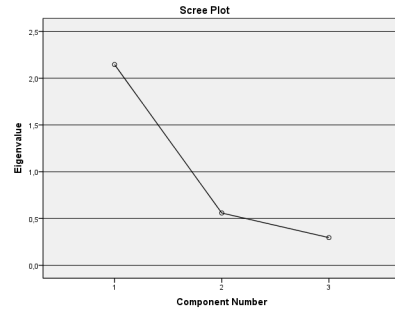


Fig. 3. One factor solution explaining academic research expansion variable

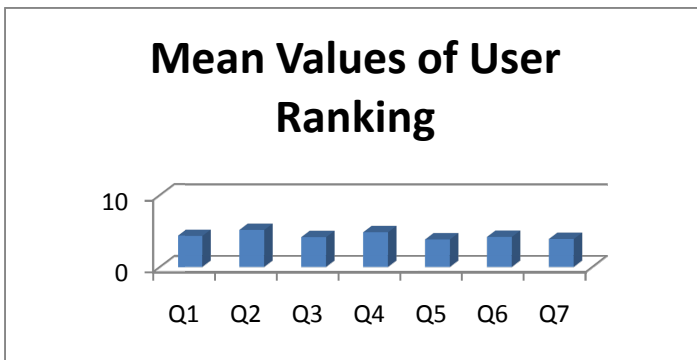


Fig. 4. Mean values of the user rankings of seven questionnaires

Table 2. Reliability analysis of the data set

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.862	.865	7

We came to few conclusions from these results. Ability to change business model will be optimally possible while we reduce the gap between research and development, introduce competitive strategy in business by introducing value chain construction for marketplace creation is the first interesting result. Secondly, expansion of academic research initiates by reducing gap between research and development. This in return can lead towards business model modification in a simple way with the knowledge of academia. We believe the lack of more participants and also designing of questionnaires were the primary reason for finding reduced statistical significance in understanding competitive strategy and market place creation variables. However, it was understood that the design principles that are derived by mapping universal

design principles are not void rather valid. Also the principles follow certain steps while considering implementing them in design. The framework in Figure 2 shows the sequence at which the principles can be followed for successful implementation of open innovation strategy.

6 Discussions and Future Research

As of authors knowledge since there is no certain design principles available to date for using open innovation concept, the principles proposed in this paper are appealing to observe in open innovation design process. The use of open innovation is not technology dependent. Corporations find it challenging sometimes to deliver new ideas hence it should be some good reasoning towards using open innovation and factors that will motivate corporations not to use closed innovation strategies. Some of these reasoning are addressed by the proposed design principles. The proposed theoretical framework shows a combinatorial structure of successful use of open innovation using the proposed principles. The proposed framework should be interesting in the creation of new business model or altering existing business model. The idea of using universal design principles as a ground, upon which the open innovation design principles are based on, is to enhance the design principles in a more structured and better way. So far open innovation design principles proposed in this paper is one of many possible design principles, but they are surely better design principles which can be successfully applied to open innovation design concept. The idea of deriving these principles is a very new concept. Another interesting approach would be to build a larger matrix (7x7) with the different characteristics of open innovation and universal design to map design principle properties. The results from this paper open new possibilities of research in the field of open innovation and perhaps are imitative to design and development in HCI. The proposed framework validation and verification is an important piece initiated from this paper's result. Collecting data to verify this framework will come up with the new possibilities of understanding new design principles. Analysis of organizations using open innovation is possible in further research, which was not the scope of this paper. This in return could help improving the understanding of business strategies and how to design new business models for open innovation design.

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E-Inclusion as the Next Challenge for Sustainable Consumption

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Abstract. In this paper we highlight how small producers of quality food, depositary of traditions that nowadays are running the risk of being lost, could be included in the benefits provided by digital technologies, through an interactive system that could enhance their old communication habits. Within PIEMONTE Project we adopted a co-design process to include these social actors in the design development. The result is an interactive system that, based on three technological pillars (a visual recognition algorithm, an ontology based knowledge manager, and a social network engine) and a vision of intelligent objects as a mean to promote the access and the interconnection in the world of quality food, tries to keep alive the cultural heritage of a territory.

Keywords: co-design, sustainability, gastronomy.

1 Introduction

Nowadays, a lot of the value, in terms of cultural heritage, tied to specific territories disappears because it is no longer financially affordable to “maintain” it. Globalization makes often unsustainable the maintenance of small productions, traditional methods, and shared knowledge, with the risk of losing the cultural and bio diversity developed over hundreds of years. The effects of this loss are already evident: “sustainability” is becoming a more valuable word everyday. In this work we want to orient the use of technology to ensure that sustainable consumption can be promoted and communicated by individuals, making the information society not an harm but an opportunity to regain visibility to practices that are running the risk of disappearing.

Telecom Italia, the Computer Science Department of University of Torino, Slow Food¹ and the University of Gastronomic Sciences of Pollenzo set up some years ago the PIEMONTE Project, to enhance the possibility of sharing the cultural heritage of a specific territory and support sustainability through a social network of smart objects.

¹ Slow Food is an Italian based non profit agency that support quality food.

The value of a territory is made by tangible and intangible elements which reveal their specific character: landscapes, buildings, artifacts and, last but not least, food. Imagine these things could speak: they could tell us about the world around them, their stories and traditions, enhancing our experience of any specific place. Technology could realize this kind of scenario. On the one side the miniaturization of electronic components and the increasing computing capabilities are enabling a gradual integration of digital content and artificial intelligence into things. On the other side the increasing easiness of use of the interactive system interfaces available on the market allows users, even traditionally excluded actors (e.g. small communities that use traditional methods to produce their goods), to manage their digital communication activities.

From these premises smart things can play the role of gateways, enhancing the information exchange between people and the knowledge included in a specific area. Physical things, within the PIEMONTE Project, typical of our everyday life, as human artifacts or even landscape elements, are able to “socialize” with people and other objects, sharing their relationships with other elements of the same area. Keeping track of what is going on to and around them, these “enhanced things” become able to tell stories and, through a direct interaction, to give people a richer experience during their stay in a specific place. Starting from this point of view, PIEMONTE Project created an interactive system with different entry points, in which a mobile application and a website for consumers interact with a different environment addressed to small food producers in need to gain visibility for their products.

2 PIEMONTE Framework

PIEMONTE Project developed a suite of applications named Wanteat which apply the idea of “smart objects” to the quality food domain [3]. Food is a fundamental part of the human life which is strongly related to the identity and the history of a territory or a community, and which plays a central role in our everyday activities. If food items could interact with people, they could tell us about the territory they come from, the people who produced them, the recipes which use them as ingredients, the other products that have similar organoleptic qualities, and so on. The basic idea of Wanteat is to make a product a kind of anchor for the territory: this gives visibility to other things beside the anchor that can be further explored, purchased, and visited.

Wanteat framework is based on the following concepts:

- **Smart Objects.** They are able to create and manage links with other objects and people, share knowledge about themselves and the world around them, structure, aggregate and synthesize contents and personalize their interaction with users.
- **Ubiquitous Interaction.** The interaction with smart objects allows users to access knowledge which is strongly related to the surrounding physical context and to their “here and now” experience.
- **No Infrastructures.** In order to make interaction as natural as possible and not to intervene on existing production and distribution chains.

- **Playful and Entertaining Interaction.** Promoting curiosity-driven exploration, allowing final users to engage in a step-by-step navigation process starting from a first physical object.
- **Relationship Centrality.** Based on the possibility to discover related objects whenever a certain item is chosen as a focus of interest.

Furthermore, Wanteat consists in a suite of applications which target different categories of users.

- **Wanteat Backshop** is a Web application that implement our idea of e-inclusion for quality food stakeholders, such as small producers or shop owners, allowing them to register their products as smart things in the system. Moreover, stakeholders can visualize the stats of their products and their activities and know how people interact with their profiles, what tags are assigned to their brands, the votes and the comments that users applied to their goods.
- **Wanteat Mobile** is a smartphone application which targets final users such as tourists or foodies. It supports users in exploring the gastronomy domain, starting from a physical object recognised through an image recognition mechanism, and in exchanging information with smart things, offering a novel and peculiar curiosity-driven interaction paradigm.
- **Wanteat Web** is a web companion of Wanteat Mobile, supporting a continuum of experience with it. For example a bookmark made with Wanteat Mobile is available on the web and vice versa. This supports a seamless movement between real world (interaction with things with the mobile application) and virtual world (web interaction).

Wanteat has been designed as a partially distributed system where we distinguish: a “server side” which is in charge of the creation and the management of the network of objects and people and which contains the logic for creating an intelligent adaptive behavior; the “client side”, available on mobile smartphones and on the Web, that is in charge of managing the interaction between people and the networks of smart things. The system is primarily constituted by an ontology of the food and wine domain, defining the concepts and the relations among them. It includes a taxonomy of gastronomic products (e.g., different types of cheeses with different properties like the production techniques) linked to actors (e.g. producers or vendors) and to places. Hence, the system can associate inferred properties to objects. In fact, one way to create a link between two objects is deducing it from some properties they share in the ontology. A second important agent present in the system is the social network manager. It is in charge of managing links in the mixed social networks of things and people. Wanteat, besides, is an adaptive application which maintains an explicit user model and exploits a recommender system for selecting and ranking the information that has to be provided to a specific user based on her/his profile. Finally, the image recognition mechanism allows user to recognize physical object simply framing the label on a specific product, minimizing the infrastructures required and the intervention in the production and distribution chains.

3 E-Inclusion Vision in PIEMONTE Project

Information and Communication Technologies play a central role in supporting everyday life in the contemporary world. If e-inclusion means an inclusive use of technology to allow participation of all individuals and communities in the information society, enjoying the benefits of the digital communication means and the new interactive systems that are spreading all over the world, nobody has to be left behind. While nowadays the e-inclusion argument is mainly referred to the inclusion of older adults [e.g. 4, 7, 11], people with disabilities [e.g. 1, 6] and more in general people that either have or do not have access to ICT and either use or do not use ICT [9], it has not yet given sufficient attention to that social actors that play a fundamental role in the preservation of the cultural heritage of our society: these actors, since an insufficient access to digital technologies, cannot share their knowledge with a broader amount of people. The gastronomic domain is an optimal exemplum of this phenomenon: many small food and wine producers of quality goods preserve the traditions of their territories, but have some difficulties to share them and to promote sustainable consumption behaviors that are tied to their production techniques, since their communication habits are still tied to technology-free practices, such as word of mouth, or very traditional digital practices, such as mail and basic internet navigation. They also cannot compete in terms of costs, advertising, visibility with the mass production market, although they can compete and win in terms of quality: for these reasons they seem to be relegated to a marginal role in our world with a little effect on our consumption practices.

Nowadays, most technological projects in the food and wine domain try to trace and identify food products using the RFID technology: for example, Gandino [5] traces gastronomic goods in the food chain, while Bruser [2] recognize products with RFID tags and provide recommendations to customers in shops, with a personal assistant integrated in the shopping basket. These technologies, however, involve the adoption of a new technological infrastructure, since producers must incorporate within their products RFID tags. Considering that these actors suffer from a digital divide, it is very hard to think that they could adopt invasive technology solutions.

The PIEMONTE Project, instead, do not intervene on existing production and distribution chains, trying to include these social actors with an interactive system that could easily be introduced in their daily routines, since it is based on a playful interaction and on the direct contact between consumers and producers. Let see how through a usage scenario (Fig. 1).

PRODUCER SCENARIO - Mr. Giorgio, a cold cuts producer, registers for Wanteat using Wanteat Backshop, indicating that he produces various types of cold cuts, among which is “Salampatata”, a traditional pork and potato salami (a). Tourists who meet Mr. Giorgio’s “Salampatata” (for example, at a local farmer’s market, at a restaurant, or in a shop) could interact with it using Wanteat mobile application: in this manner they can add to it stories about the territory it comes from, well-matching wines, recipes which use it as an ingredient. Besides, they can know what Giorgio has to said about his product and discover other elements that are related to it, since they belong to the same territory. They can also comment on the product and its stories,



Fig. 1. Small producer scenario

tag, rate or bookmark them (b). As a result of users' social actions, new relationships can be established among Mr. Giorgio's "Salampatata" and other things in Wanteat system: for example, "Salampatata" can be related to a new restaurant, if several users said they tasted it there (c).

Accessing Wanteat Backshop again, Mister Giorgio can now examine what users said about "Salampatata": he can read all user comments, access statistics about user actions which refer to "Salampatata" and examine its relationships, thus discovering that it is served in a restaurant he was not aware of (d).

4 A Co-design Process

Through all the PIEMONTE Project we adopted a service design user-driven approach. Thus, we performed a serie of evaluations starting at an early stage in the project.

The whole suite, named Wanteat, has been developed and tested involving territorial agencies, institutional stakeholders and users of the system through an effective co-design framework. Co-designing ensures, through the understanding of the application context and the constant comparison with the domain expert view, the success of the system developed in terms of acceptability and user experience. The aim of all the co-design activities is to provide a solid foundation for the system through the identification of the objectives and needs of the reference users and to obtain feedback on the validity of the choices made. This process started from the first day of the project and the final step was conducted in October 2012 when the system was presented and tested by a wide public. During this period all the elements of the suite were evaluated and designed with their final user: the mobile application, for example, was tested in different contexts, from laboratory tests to field trials in huge gastronomic events [8, 10].

The part of the system with the aim to include the small producers of quality food was instead evaluated and developed in their everyday contexts, starting from a series of contextual interviews in order to understand their needs and desires and enrich early requirements. The final evaluation phase was carried out with an extensive field trial, involving both producers and consumers. More specifically, Wanteat was introduced to, and tested by, a wide public at “Salone Internazionale del Gusto 2012”, a huge event dedicated exclusively to the exposition and tasting of high quality food from all over the world, organized in Torino every two years. During the five days of the international fair the application has been used by several hundreds of casual users, and to a large sample of producers exposing at the fair (one hundred) were asked to take part in the last step of system design.

4.1 Step 1 – As Is Analysis and Requirements Definition

At the beginning of the project a phase of “As Is Analysis and Requirements Definition” has been carried out with the objective of outlining the list of actors and relations that could characterize the world of small-scale production of quality food. We selected two types of production (small wine producers and small cheese producers) according to the different production processes and techniques, and two production areas (Langhe and Asti region in Piedmont), differentiated by the type of the local economies and the development opportunities. In total 12 contextual interviews were collected, 3 for each sector of the matrix resulting from the intersection between the production types and the production areas. The interviews were focused essentially on the production practices, the actual communication habits, the daily routines and the most common means used for the distribution and the advertising of the goods produced.

The results highlighted that small producers aim to preserve and increase the quality of their products, maintaining their own distinctive individuality and using the word of mouth as central mean for their brand promotion. Cheese producers expressed the need to monitor the performance of their goods on the market, but without changing their packaging, carefully designed to evoke the tradition and the natural processes used: for this reason the hypothesis to introduce RFID or QR code technologies was refused. The wine producers of the Langhe area expressed the need to safeguard the message of tradition and authenticity on which they built their success, earning the trust of their customers with a direct relationship based on a face to face communication. The possibility of introducing an E-Commerce system to expand their market was firmly rejected, since the perception of a possible risk of depersonalization during the purchase process. Instead, the wine producers of the Asti region emphasized more strongly the desire to emerge on the market thanks to the new communication technologies, sharing the knowledge related to their territories even using digital means. From these insights we began to develop a first prototype that could encounter needs and perceptions of these social actors, in order to include them in the benefits that an interactive system could give to their work.

4.2 Step 2 – Prototype Evaluation

Once developed the first prototype the co-design phase continued with a second round of contextual interviews. At this point it was possible to evaluate and use the

first version of the system in order to gather additional requirements. We came back to the same small producers interviewed in the first phase of the project, showing them the functionalities of Wanteat and discussing possible improvements and new requirements. Producers underlined the need to highlight personal communication with their customers to inform them about events, promotions and new products. It emerged that a key feature to push the adoption of a new interactive system was the possibility to develop a personal relationship with and between their customer, first promoters of their products, enhancing the old communication habits based on the word of mouth.

The inclusion of traditional producers in the information society passes even through the demonstration that digital technologies does not drain the “authentic” face to face communication, but can provide opportunities to develop long-distance relationships based on trust, sharing their knowledge about the tradition behind their work and their territories, and expanding the market for their potential customers in areas that could not be reached in any other way. The statistical functionalities of the system could be seen under the same point of view: knowing how the consumers consider the goods produced, what could be improved in terms of quality, what they think about their production techniques, and which are their socio-demographic characteristics can be considered as a new way to receive feedback about their work, decreasing the distance that separates them from their customers.

The playful interaction that mobile application of the system promotes, allowing customers to navigate through a social network of people and things, following their curiosity and their willingness to discover, appears at the producer eyes as a manner for giving visibility to their work, giving them the possibility to differentiate their products from that of the industrial production: the connection that the system establishes between products, people and stories is seen as a way to keep alive the traditions of their territories. Even the "image recognition" feature was rated highly, since it does not require to change the product packaging or mechanisms during the production and distribution chains. Then, the overall acceptance of the system was rated very high, confirming our hypothesis that for including this kind of actors it is necessary to offer new technological means that could be inserted smoothly in their daily routines, presenting them as a way to enhance their communication habits and not to completely change them.

4.3 Step 3 –Field Trial at Salone Internazionale Del Gusto 2012

The last phase of the co-design process for including small producers in Wanteat system was carried out at Salone Internazionale del Gusto 2012, between 25 and 29 October 2012. In this occasion we had the opportunity to confirm the results gathered during the contextual interviews of the previous phases and to get useful insights about the economic sustainability of the project. 100 of the 700 producers present at the fair were interviewed, presenting them the final application of Wanteat, and asking them open (with a contextual interview) and closed questions (with a questionnaire structured in 10 point likert scales). The research investigated the economic model that could sustain the adoption of the system by the producers and gave us the perception about its acceptability and its possible integration in their daily routines.

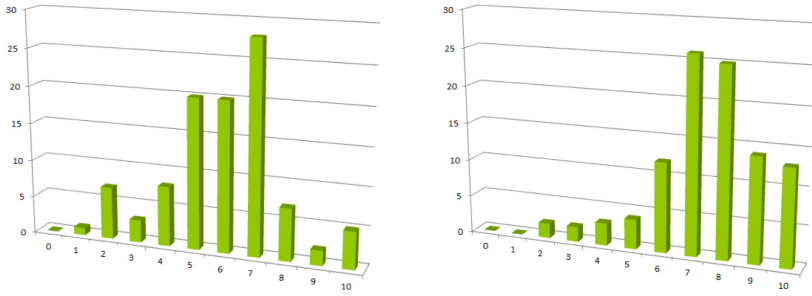


Fig. 2. Wanteat (a) to increase the proceeds and (b) to enhance brand visibility

The research about the perception of the system by the producers highlights how the value of this interactive system is located not in the possibility of increasing the proceeds (Fig 2 (a), average of 5,9), but rather in the opportunity of enhancing the brand visibility (Fig. 2 (a), average of 7,4).

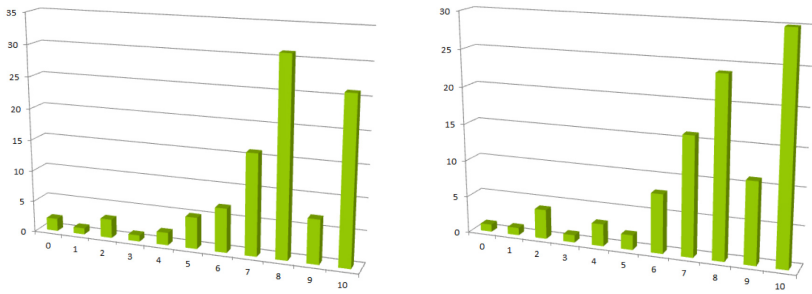


Fig. 3. Wanteat (a) to better understand the customers and (b) to get in touch with customers

Another important value of the system is the possibility to know the preferences of consumers, their desires of improvements, their opinion and their critics: the statistic features of the system are the most appreciated, since they could give to producers a better knowledge of their customers (Fig 3, (a), average of 7,2). Besides, Wanteat allows producers to get in touch with their clients, notifying them in real time where they could find their products, events, fairs, sharing information about their production techniques and stories behind the territories in which the production processes take place (Fig. 3 (b), average of 7,8).

Hence, the results of the last evaluation phase confirmed the insights gathered in the previous steps. Wanteat could be adopted easily by small producers focusing on its ability to not replace in a whole new way their communication habits but improving them thanks to the features provided by digital technology.

It was more difficult, for the producers, to individuate a sustainable economic model for this service. The pay-per-click model seems to be the most acceptable one.

5 Conclusions

In this study, closely conducted with all the stakeholders of the quality food supply chain, it has been addressed a declination of E-inclusion. In all the system design phases the project aimed to find ways for producers, today at serious risk of disappearing, to participate in the global quality food marketplace. The technology was therefore not considered an enemy augmenting the distance with bigger competitors but rather an opportunity to regain a worldwide visibility. What has emerged as a critical point of the research is the need of a preliminary phase of information and education, addressed to the small producers, about the opportunities that technology represent in an e-inclusion perspective. One aspect that should instead be considered in future research are the business models that will sustain this proposition. It is probable that the perceived value of the system and therefore its marketability is linked to a well conducted preparatory education phase about its benefits on the long term.

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Effect of Accommodation Training in Foreign Labor

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Abstract. By relaxing the contracted focus-adjustment muscles around the eyeball, such as the ciliary and extraocular muscles, improvement of the pseudo-myopia is expected. This understanding has led to the accommodation training in which the visual target is given by stereoscopic video clips. However, it is pointed out that the motion sickness can be induced by viewing stereoscopic video clips. In the measurement 1 of this study, we verify whether the new 3-dimensional (3D) technology reduce the severity of motion sickness in accordance with the stabilometry. We then evaluate short-term effects of the accommodation training utilizing new stereoscopic video clips on foreign labors (11 females) suffering from eye fatigue in the measurement 2. The foreign workers were trained in 3 days. We could show that the new 3D technology reduce the severity of motion sickness in accordance with the stabilometry. The effect of the accommodation training utilizing the new 3D video clip was investigated in foreign labors suffering from eye fatigue, and the eye strain was reduced by the continuous accommodation training for a short-term period.

Keywords: Visually induced motion sickness, Stabilometry, Sparse density, Liquid crystal displays (LCDs), Accommodation training, 3D video clip.

1 Introduction

With the development of computers and widespread use of the internet, near visual tasks, such as visual display terminal (VDT) activities, have increased in young to elderly persons, causing social problems. Near visual tasks for a prolonged time strain the ciliary muscle, which may cause abnormalities in the accommodative function of the lens. This condition is called pseudomyopia, considered to be a part of refractive myopia. Prolonged near visual tasks have been reported to possibly induce cervicomo-brachial syndrome and psychoneurotic symptoms [1]. The main cause of these vision problems is an accommodative function error. Therefore, we assume that it is possible to improve an abnormal accommodative function of the lens by activating the muscles by alternately repeating negative and positive accommodation. By improving the abnormal accommodative function, we can improve or prevent these vision problems. We call this operation “accommodation training.” In Japan, an

apparatus called MD-SS was developed [2]. This apparatus works by using a Landolt ring drawn on a flat plate that moves back and forth over a distance of 2 m in order to encourage alternately repeating negative and positive accommodation in the observers. However, the moving distance of the target object is very short. Therefore, the back-and-forth motion of the objects might have no effect on the observers. In order to solve the abovementioned problems, we suggest that the accommodation training is accomplished by gazing at an image in 3D films, which simulate the back-and-forth motion in a stereoscopic space by using a computer and a liquid crystal display (LCD).

For pseudomyopia, stretching exercise of the ciliary muscle, involved in accommodation of the lens, by alternately repeating negative and positive accommodation alleviates strain of the ciliary muscle. Miyao et al. experimentally showed that the lens was accommodated by following stereoscopic video clips when gazing at them displayed on a CRT or LCD [3], [4].

Stereoscopic videos utilizing binocular stereoscopic vision often cause unpleasant symptoms of asthenopia, such as headache and vomiting, depending on the audiovisual condition [5]. Ataxia in simulator-induced sickness has been reported. The influence of video-induced motion sickness on the body has been measured employing subjective scales, such as the Simulator Sickness Questionnaire (SSQ) [6], and by quantitatively investigating the relationship between external factors and internal conditions using physiological indices [7]-[10], such as respiratory function, electrocardiogram, skin electrical activity, electrogastrogram, and the body sway.

Mathematically, the sway in the center of pressure (COP) is described by a stochastic process [11]-[13]. We examined the adequacy of using a stochastic differential equation and investigated the most adequate equation for our research. G_z , the distribution of the observed point z ($z = x, y$), is related in the following manner to U_z , the time-averaged potential function, in the stochastic differential equation (SDE),

$$\frac{\partial x}{\partial t} = -\frac{\partial}{\partial x} U_x(x) + w_x(t), \quad (1.1)$$

$$\frac{\partial y}{\partial t} = -\frac{\partial}{\partial y} U_y(y) + w_y(t), \quad (1.2)$$

which has been considered as a mathematical model of the sway:

$$V(\vec{x}) = -\frac{1}{2} \ln G(\vec{x}) + \text{const}. \quad (2)$$

Actually, G_z is estimated by the histogram of the time series data. The nonlinear property of SDEs is important [14]. There were several minimal points of the potential. In the vicinity of these points, local stable movement with a high-frequency component can be generated as a numerical solution to the SDE. We can therefore expect a high density of observed COP in this area on the stabilogram.

A new 3D video construction method has recently been developed to prevent video-induced motion sickness [15], [16]. Humans perceive 3-dimensional (3D) objects by simultaneous convergence and accommodation of the lens, but stereoscopic video

clips generally consist of unnatural images perceived along a fixed visual line, negating such convergence and accommodation. In order to reduce inconsistency between experience and the actual senses, we prepared a 3D video clip which was created by the POWER3D method (Olympus Memory Works Corp.) [17]. We focused on stereoscopic videos prepared using this method. An LCD displaying the stereoscopic videos and visual acuity recovery device utilizing liquid crystal shutter eyeglasses (Dr.REX Eye Care Program [17]) include several stereoscopic video contents, which induce near and distant visual conditions. The alternating presentation of these with appropriate intervals is expected to improve and prevent myopia and presbyopia.

In the measurement 1 of this study, we verify whether the abovementioned 3D technology reduce the severity of motion sickness. We then evaluate short-term effects of the accommodation training utilizing new stereoscopic video clips on foreign labors suffering from eye fatigue in the measurement 2.

2 Material and Methods

The objective and contents of the study and consideration of protection of personal information were explained to all subjects before the experiment, and written informed consent was obtained. The measurement was performed in a dimly lit room (about 260 lx) air-conditioned at 25°C.

2.1 Measurement 1

Ten healthy subjects (age, 23.6 ± 2.2 years) voluntarily participated in the study. The subjects stood without moving on a detection stand of a stabilometer (G5500; Anima Co. Ltd.) with their feet together. The subjects were positioned facing an LCD monitor (S1911- SABK, NANA O Co., Ltd.) on which three kinds of video clips were presented in no particular order: (I) a visual target (circle) whose diameter was 3 cm; (II) a conventional 3D video that shows a sphere approaching and going away from subjects irregularly; and (III) a new 3D video clip that shows the same sphere motion as in (II). The new stereoscopic video clip (III) were constructed by Olympus Power 3D method [17]. The distance between the wall and the subjects was 57 cm.

The subjects stood on the detection stand in the Romberg posture for 2 min before the sway was recorded. Each sway of the COP was then recorded at a sampling frequency of 20 Hz during the measurement; subjects were instructed to maintain the Romberg posture for the first 120 s and a wide stance (with the midlines of heels 20 cm apart) for the next 60 s. The subjects viewed one of the video clips, i.e., (I), (II), or (III), on the LCD from the beginning till the end. The SSQ was filled before and after stabilometry.

We calculated several indices that are commonly used in the clinical field [18] for stabilograms, such as “area of sway,” “total locus length,” and “total locus length per unit area.” In addition, new quantification indices that were termed “SPD”, was also estimated.

2.2 Measurement 2

The subjects of this experiment were 11 female foreign workers. These subjects were also divided into two groups. One group (accommodation training group) underwent the accommodation training, in which they viewed a stereoscopic video clip for 6 min after their visual inspection work, and the other group (control group) was not given any task to perform during the first three consecutive days. Thereafter, the groups switched tasks, and the experiment was performed in a similar manner to collect data without the influence of task order.

Before the visual inspection work on the first day morning (Pre) and after the task every experimental day (Post), the tests: (1) simulator sickness questionnaire (SSQ), (2) visual analog scale (VAS) to measure the severity of eye strain, (3) objective refractometry, (4) binocular visual acuity test (distant vision), (5) monocular visual acuity test distant vision, (6) binocular visual acuity test (near vision) were performed in this order.

The auto visual acuity meter NV-300 (NIDEK) was used for the visual acuity tests that were employed for binocular and monocular visions. Time-course changes in the VAS, the best visual acuity (BVA) at a distance, and that from near were investigated. Findings on Pre and Post values were compared employing the Friedman's test, setting the significance level to 0.05.

3 Results

3.1 Measurement 1

The results of the SSQ include the scores on nausea (N), oculomotor discomfort (OD), disorientation (D) subscale and total score (TS) of the SSQ. No statistical differences were seen in these scores among video clips presented to subjects. However, increases were seen in the scores for SSQ-N and SSQ-D after exposure to the conventional 3D video clip (II).

In stabilograms, the COP was not isotropically dispersed but characterized by much movement in the anterior-posterior (y) direction. The amplitudes of the sway observed during exposure to the video clips tended to be larger than those of the control sway. In that time (II)/(III), the diffusion of COP was also large in the lateral (x) direction. Although a high density of COP was observed in the stabilograms, the density decreased in stabilograms during exposure to the conventional one (II).

Except to the total locus length per unit area, a main effect was seen in the exposure factors (Table 1) in accordance with the Friedman's tests ($p < 0.01$). As the results of post hoc test, area of sway, total locus length, and SPD S_2 in the stabilogram observed during exposure to the conventional 3D video (II) were significantly larger than those to a static circle ($p < 0.05$). There was no significant difference between indicators except for the total locus length in the stabilogram observed during exposure to the new 3D video (III) and those to a static circle.

3.2 Measurement 2

Although the other subjective indices (SSQ sub scores) did not significantly increase, the VAS for the evaluation of the visual fatigue increased after their work (Post 1-3). Moreover, the VAS decreased with the time course of the accommodation training and there was significant difference between the VAS in the control group and that in the accommodation training group as shown in Fig.1.

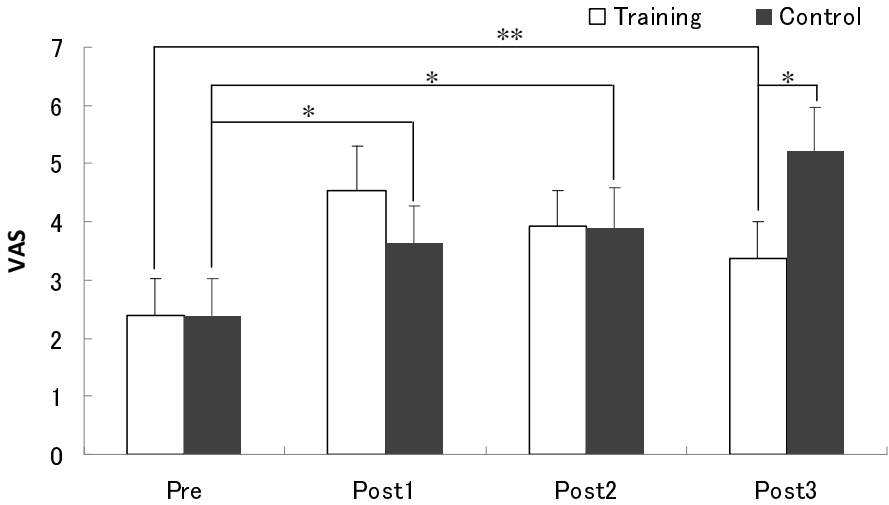
Variations in the BVA of the 11 subjects at a distance and from near with the experimental dates are shown in Table 2. Irrespective of the subjects undergoing the accommodation training, there was no significant difference in the visual acuity in accordance with the Friedman's test. The BVA for the left eye of the accommodation group tended to be greater than that of the control group in the 2nd experimental day ($p = 0.079$). The dioptric mean did not also increase throughout this period. However, the gravitational mean BVA from near increased with the date. According to the Wilcoxon's signed-rank test, the BVA of the control group was significantly greater than that of the accommodation group in the first experimental day ($p < 0.05$). The order was switched in the 3rd experimental day ($p < 0.10$).

Table 1. Results of Measurement 1 (mean \pm standard deviation)

Index	(I)	(II)	(III)
SSQ-Nausea	-	14.31 \pm 14.31	8.56 \pm 7.92
SSQ-Oculomotor Discomfort	-	16.68 \pm 12.13	17.43 \pm 10.20
SSQ-Disorientation	-	22.72 \pm 27.98	16.70 \pm 18.47
SSQ-Total Score	-	19.82 \pm 17.39	16.46 \pm 11.24
Area of sway	0.92 \pm 0.52	1.41 \pm 0.68	1.86 \pm 1.03
Total locus length	38.26 \pm 14.50	49.47 \pm 11.99	46.20 \pm 10.64
Total locus length per unit area	51.69 \pm 27.70	50.03 \pm 43.08	36.90 \pm 23.52
SPD S ₂	1.23 \pm 0.09	1.32 \pm 0.11	1.33 \pm 0.12

Table 2. Results of Measurement 2 (mean \pm standard deviation)

Index	Pre	Post1	Post2	Post3
Control group				
BVA at a distance (binocular)	1.12 \pm 0.38	1.05 \pm 0.45	1.10 \pm 0.41	1.06 \pm 0.42
BVA at a distance (monocular)	0.89 \pm 0.42	0.83 \pm 0.46	0.81 \pm 0.43	0.94 \pm 0.46
BVA from near	0.80 \pm 0.43	0.90 \pm 0.43	0.92 \pm 0.35	0.87 \pm 0.46
Accommodation training group				
BVA at a distance (binocular)	-	1.07 \pm 0.39	1.14 \pm 0.40	1.12 \pm 0.41
BVA at a distance (monocular)	-	0.81 \pm 0.47	0.87 \pm 0.47	0.94 \pm 0.46
BVA from near	-	0.75 \pm 0.45	0.89 \pm 0.42	0.90 \pm 0.43



(** $p < 0.01$, * $p < 0.05$)

Fig. 1. Time course of the VAS for measuring the severity of asthenopia. Subjects replies the category 7, owing to the serious case in their asthenopia.

4 Discussion

In this study, we presented video clips on an LCD and showed that the POWER 3D method could reduce the severity of the VIMS in the measurement 1. The 3D video clip for the accommodation training was then created by the POWER 3D method. In measurement 2, a short-term effect of the accommodation training was investigated in foreign workers suffering from eye fatigue. The myopic tendency had increased due to their visual inspection work. It takes three days at least in order to reduce their eye strain.

In measurement 1, sickness symptoms seemed to appear more often with the conventional video clip (II), although there were large individual differences in results of the subjective tests, SSQ. On the contrast, a theory has been proposed to obtain SDEs (1) as a mathematical model of the body sway on the basis of the stabilogram. The variance in the stabilogram depends on the form of the potential function in the SDE; therefore, the SPD is regarded as an index for its measurement. The video clips decrease the gradient of the potential function [20]. The new 3D video clip (III) reduces the body sway, owing to the consistency between convergence and visual accommodation. The reduction could be evaluated by the SPD during exposure to the video clip (III) on an LCD screen. Performing the Friedman's test for a posture with wide stance, we have succeeded in estimating the decrease in the gradient of the potential function by using the SPD as shown in Table 1 ($p < 0.05$). However, the total locus length could not evaluate the change of form in the potential function to control the standing posture.

In measurement 2, we showed that the foreign workers suffered from eye fatigue after their work as shown in Fig. 2. The subjects might become skilled in the visual

acuity test. This is why the binocular BVA increased considerably in the Table 2. In our previous study for visual inspection workers in Japan, the visual acuity of the control group without the accommodation training also showed an improvement [21]. However, the results showed that the distant visual acuity in the training group had increased significantly compared to that in the control group on the 3rd experimental day ($p < 0.05$). In this study, the remarkable improvement in the distant visual acuity was not seen for the foreign workers because they have good eyesight originally. On the other hand, the BVA of the training group was statistically greater than that of the control group in the 3rd experimental day ($p < 0.10$).

There seemed to be not only visual acuity improving effect but also reduction of the visual fatigue by the accommodation training for more than 3 consecutive days. The VAS in the control group had increased significantly on the 3rd experimental day as compared to that in the training group ($p < 0.05$).

The authors have verified a middle-term effect of accommodation training that uses the strategy of presenting a stereoscopic video clip to 32 myopic youth (20 ± 1 years) for 2 weeks. The video clip consists of one to five balls moving back and forth in the stereoscopic sky background. At a viewing distance of 60 cm, the stereoscopic ball is viewed to move from 30 cm (forward) to infinity (backward). This ball completes a round-trip movement more than 25 times in 3 min. The uncorrected distant visual acuity increased in 17 of the 32 subjects (53.1%) participating in this study. Although there were some variations, the visual acuity improved in the accommodation training group and not in the control group. We found that the visual acuity on the 11th experimental day was considerably higher in the accommodation group than in the control group ($p < 0.05$). This result suggests that the accommodation training using a stereoscopic video clip has a cumulative positive effect on eyesight and prevents the deterioration of visual acuity. Although the myopic tendency improved slightly in the accommodation training group, there was only slight progress in the control group. These results suggested that the accommodation training using the stereoscopic video clip did not deform the lens, thus not improving myopia fundamentally [19]. This tendency was also seen in the present measurement 2.

We assumed that these effects of the accommodation training were temporary, but the findings suggest that the continuous accommodation training will promote a ciliary-muscle-stretching effect, leading to an improvement in visual acuity. Accommodation reflex for near vision may be defined as the mechanism of working the ciliary muscle. This may also inhibit a reduction in the visual acuity.

5 Conclusion

In this study, we could show that the new 3D technology reduce the severity of motion sickness in accordance with the stabilometry. The effect of the accommodation training utilizing the new 3D video clip was investigated in foreign labors suffering from eye fatigue, and the eye strain was reduced by the continuous accommodation training for a short-term period. We are planning to investigate the effect of the device employed for a prolonged period.

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A Study of Accommodation Training by Stereoscopic Film Presentation

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Abstract. By relaxing the contracted focus-adjustment muscles around the eyeball, such as the ciliary and extraocular muscles, improvement of the pseudo-myopia is expected. This understanding has led to the accommodation training in which the visual target is given by stereoscopic video clips. In this study, we verify short-term effects of the accommodation training on eyesight of visual inspection workers (22 females) suffering from eye fatigue and 12 middle-aged persons. In the Measurement 1, the workers were trained in 3 days. Moreover, the middle-aged were investigated on several trials of the eyesight recovering apparatus in the Measurement 2. In the Measurement 3, we verify the effects of the accommodation training on eyesight and asthenopia of the young. The accommodation training is compared with close work on VDTs. As a result, the visual acuity was statistically improved by continuous accommodation training which will promote a ciliary muscle-stretching effect.

Keywords: Myopia, Presbyopia, Spherical Diopter (SPH), Visual Acuity (VA), Stereoscopic Images, Ciliary Muscle, Accommodation.

1 Introduction

With the development of computers and widespread use of the internet, near visual tasks, such as visual display terminal (VDT) activities, have increased in young to elderly persons, causing social problems. Near visual tasks for a prolonged time strain the ciliary muscle, which may cause abnormalities in the accommodative function of the lens. This condition is called pseudomyopia, considered to be a part of refractive myopia. Prolonged near visual tasks have been reported to possibly induce cervicomo-brachial syndrome and psychoneurotic symptoms [1]. The main cause of these vision problems is an accommodative function error. Therefore, we assume that it is possible to improve an abnormal accommodative function of the lens by activating the muscles by alternately repeating negative and positive accommodation. By improving the abnormal accommodative function, we can improve or prevent these

vision problems. We call this operation “accommodation training.” In Japan, an apparatus called MD-SS was developed [2]. This apparatus works by using a Landolt ring drawn on a flat plate that moves back and forth over a distance of 2 meter in order to encourage alternately repeating negative and positive accommodation in the observers. However, the moving distance of the target object is very short. Therefore, the back-and-forth motion of the objects might have no effect on the observers. In order to solve the abovementioned problems, we suggest that the accommodation training is accomplished by gazing at an image in 3D movies, which simulate the back-and-forth motion in a stereoscopic space by using a computer and a liquid crystal display (LCD).

For pseudomyopia, stretching exercise of the ciliary muscle, involved in accommodation of the lens, by alternately repeating negative and positive accommodation alleviates strain of the ciliary muscle. Miyao et al. experimentally showed that the lens was accommodated by following stereoscopic images when gazing at them displayed on a CRT or LCD [3], [4].

Presbyopia represents senile impairment of near vision due to a reduced accommodative function of the lens with aging. The major cause of the reduction of accommodative function is thickening of the lens with aging, increasing the radius of the frontal curvature of the lens. In addition to this increase in lens volume, the elasticity of the lens capsule decreases, which results in an insufficient increase in the lens curvature even when the ciliary zonule is relaxed by ciliary muscle contraction, reducing the amplitude of accommodation [5].

Stereoscopic videos utilizing binocular stereoscopic vision often cause unpleasant symptoms of asthenopia, such as headache and vomiting, depending on the audiovisual condition [6]. Ataxia in simulator-induced sickness has been reported. The influence of video-induced motion sickness on the body has been measured employing subjective scales, such as the Simulator Sickness Questionnaire (SSQ) [7], and by quantitatively investigating the relationship between external factors and internal conditions using physiological indices [8]-[11], such as respiratory function, electrocardiogram, skin electrical activity, and fluctuation of the center of gravity.

A new 3D video construction method has recently been developed to prevent video-induced motion sickness [12], [13]. Humans perceive 3-dimensional objects by simultaneous convergence and accommodation of the lens, but stereoscopic videos generally consist of unnatural images perceived along a fixed visual line, negating such convergence and accommodation. Stereoscopic images using the POWER3D method (Olympus Visual Communications Co., Ltd.) prepared in order to reduce inconsistency between experience and the actual senses [14]. Some preceding studies showed that the degree of sickness was reduced by viewing stereoscopic videos prepared using this method [15], [16]. We focused on stereoscopic videos prepared using this method. An LCD displaying the stereoscopic videos and visual acuity (VA) recovery device utilizing liquid crystal shutter eyeglasses (Dr.REX Eye Care Program [14]) include several stereoscopic video contents (Figs.1), which induce near and distant visual conditions. The alternating presentation of these with appropriate intervals is expected to improve and prevent myopia and presbyopia.

In this study, we investigated the short-term effect of the accommodation training with the device utilizing stereoscopic videos on visual inspection workers suffering from eye fatigue, middle-aged subjects becoming aware of presbyopia, and young myopic person.

2 Material and Methods

The objective and contents of the study and consideration of protection of personal information were explained to all subjects before the experiment, and written informed consent was obtained. The measurement was performed in a dimly lit room (about 250 lx) air-conditioned at 25°C. Before (Pre) and after (Post) the accommodation training of measurement 1 and 2 stated below, the tests:

- (1) Simulator Sickness Questionnaire (SSQ)
- (2) Visual analog scale (VAS)
- (3) Objective refractometry
- (4) VA test (distant vision)
- (5) VA test (near vision)

were performed in this order. The auto VA meter NV-300 (NIDEK) was used for the VA tests that were employed for binocular and monocular visions. Time-course changes in the VAS, the best VA (BVA) at a distance, and that from near were investigated. Findings on Pre and Post values were compared employing the Wilcoxon signed-rank test, setting the significance level to 0.05.

2.1 Measurement 1

The subjects of the experiment were 22 female visual inspection workers, aged 37 ± 6 years. These subjects were also divided into two groups. One group underwent the accommodation training, in which they viewed a stereoscopic video (Fig.1a) for 6 min after the visual inspection work, and the other group was not given any task to perform during the first three consecutive days. Thereafter, the groups switched tasks, and the experiment was performed in a similar manner to collect data without the influence of task order. The above -mentioned items (1)-(5) were performed before the visual inspection work on the first day morning and after the task every experimental day.

2.2 Measurement 2

The subjects of the experiment were 12 middle-aged persons, aged 46.6 ± 3.5 years (6 males and 6 females). The accommodation training was performed, in which the subjects viewed 4 contents of the Dr.REX Eye Care Program (Figs.1) for 6 minutes each in a random order. Before the accommodation training and after viewing each contents, the tests (1)-(5) were performed in this order. The subjects then viewed the 4 contents in the same order for 6 minutes each, and the above-mentioned tests (1)-(5) were repeated.

2.3 Measurement 3

The subjects of the experiment were 32 young myopic persons, aged 20 ± 1.0 years (16 males & 16 females). The study participants were divided into two groups. Far-vision tests were carried out by using auto optometer NV-300 (NIDEK) to test vision

from the right eye and vision from the left eye before the study commenced. In this case, measured eyesight was under 0.1, measurement of eyesight was circumstantially carried out by using a Landolt ring posted on a wall due to the difficulty of measurement with the optometer. The study schedule and processes is shown in Table.1. One group used the Dr.REX apparatus for 6 min, and the other group carried out simple close work on VDTs, which required a steady gaze for the same amount of time. Each group carried out their assigned tasks every day for 11 days. Far-vision tests and entry on degree of eyestrain in visual analogue scale (VAS) were carried out immediately after loading the works. On days 5 and 11 (the final day), we made an addition to previous far-vision tests and asked the participants to fill out a simulator sickness questionnaire [7] (SSQ) before and after each assignment in the foregoing tests.

When the study was completed, each group took a two-week break in order to recover from the effects of the study. Then the groups switched assignments and the study was resumed on the same schedule.

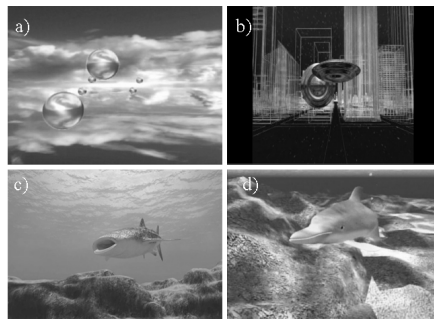


Fig. 1. Dr.REX Eye Care Program [14] includes several stereoscopic video contents: Sky vision a), Cyber vision b), Under the sea c), Dolphin d)

Table 1. This table is a study schedule. One group is taken as Measure 1 and the other group is taken as Measure 2. This schedule was carried out twice, with each group switching assignments.

Schedule [day]	1-4	5	6-10	11
Processes	Measure1* or Measure2**	SSQ**** Far-vision tests	Measure1 or Measure2	SSQ Far-vision tests
	VAS*** Far-vision tests	Measure1 or Measure2 SSQ VAS Far-vision tests	VAS Far-vision tests	Measure1 or Measure2 SSQ VAS Far-vision tests

*Measure1: Close work using a recent VDT system ***Visual Analogue Scale
 Measure2: Carrying out the eyesight recovering apparatus **Simulator Sickness Questionnaire

3 Results

3.1 Measurement 1

The VAS for the evaluation of the visual fatigue significantly increased after their work although the other subjective indices (SSQ sub scores) did not significantly increase. However, the VAS after the accommodation training was significantly lower than that of the control group on the 3rd experimental day.

Variations in the BVA at a distance and from near with the experimental dates are shown in Table 1. The gravitational mean BVA of the 22 subjects increased with the date. Irrespective of the subjects undergoing the accommodation training, when the Wilcoxon signed-rank test was used to compare the BVA before and after the initiation of this experiment, a significant difference in the VA was observed ($p < 0.05$). The monocular vision test yielded a similar statistical significance. Although in comparison to the values obtained from the previous test, the VA after the visual inspection work increased significantly on the experimental days ($p < 0.05$), the dioptric mean did not increase throughout this period.

Table 2. Results of Measurement 1 (mean \pm standard deviation)

Index	Pre	Post1	Post2	Post3
Control group				
BVA at a distance (binocular)	1.01 \pm 0.38	1.03 \pm 0.41	1.07 \pm 0.38	1.03 \pm 0.37
BVA at a distance (monocular)	0.80 \pm 0.39	0.76 \pm 0.48	0.79 \pm 0.40	0.86 \pm 0.43
BVA from near	0.94 \pm 0.36	1.01 \pm 0.37	1.01 \pm 0.31	0.99 \pm 0.40
VAS	1.72 \pm 1.74	3.49 \pm 1.94**	3.81 \pm 1.99**	4.46 \pm 2.33**
Accommodation training group				
BVA at a distance (binocular)	1.01 \pm 0.38	1.10 \pm 0.33	1.15 \pm 0.35	1.13 \pm 0.37
BVA at a distance (monocular)	0.77 \pm 0.39	0.81 \pm 0.43	0.89 \pm 0.44	0.87 \pm 0.44
BVA from near	0.94 \pm 0.36	0.97 \pm 0.40	1.00 \pm 0.37	1.07 \pm 0.34
VAS	-	4.01 \pm 2.54**	3.59 \pm 1.91**	3.10 \pm 1.89**

The VAS was enhanced significantly by the accommodation training. (** $p < 0.01$)

3.2 Measurement 2

Subjective indices did not significantly increase with viewing frequency. The time-course changes in the VAS were shown in Table.3. The degree of asthenopia tended to decrease at 5th and 7th Post viewing than that measured at Pre viewing ($p < 0.10$).

Changes in the binocular near and distant visual acuities with the frequency of video viewing are shown in Table.3. The gravitational mean binocular near and distant visual acuities of the 12 subjects increased with the viewing frequency from the 1st to the 8th viewing, although there was some variation. On comparison of the uncorrected near VA between the Pre and after the 7th video viewing employing the Wilcoxon signed-rank test, a significant difference was noted ($p < 0.05$).

Table 3. Typical Results of Measurement 2 (mean \pm standard deviation)

Index	Pre	Post3	Post5	Post7
Control group				
BVA at a distance (binocular)	0.23 \pm 0.17	0.30 \pm 0.17	0.33 \pm 0.17	0.31 \pm 0.16
BVA at a distance (monocular)	0.13 \pm 0.17	0.15 \pm 0.14	0.17 \pm 0.15	0.17 \pm 0.13
BVA from near (binocular)	0.95 \pm 0.14	0.93 \pm 0.13	0.95 \pm 0.14	1.03 \pm 0.15
VAS	-	-	-	-
Accommodation training group				
BVA at a distance (binocular)	0.87 \pm 0.15	0.84 \pm 0.13	0.95 \pm 0.12	0.92 \pm 0.11
BVA at a distance (monocular)	0.67 \pm 0.11	0.79 \pm 0.12	1.06 \pm 0.43	0.78 \pm 0.06
BVA from near (binocular)	1.03 \pm 0.10	1.06 \pm 0.08	1.13 \pm 0.08	1.20 \pm 0.09*
VAS	5.14 \pm 0.82	4.60 \pm 0.63	4.30 \pm 0.72#	4.32 \pm 0.72#

The visual acuity was enhanced significantly by the accommodation training. (# $p < 0.10$; * $p < 0.05$)

3.3 Measurement 3

The geometrical mean of eyesight before and after carrying out Dr.REX on days 5 and 11 is shown in Table 2 in order to verify short-range effects. The far-eyesight on both days 5 and 11 improved slightly (day 5; both vision: 0.015, right vision: 0.009, left vision: 0.017), (day 11; both vision: 0.033, right vision: 0.012, left vision: 0.019). Although the eyesight before and after carrying out Dr.REX was compared for statistical significance by using the Wilcoxon matched-pairs signed test, the increase of statistical significance was found on both vision on day 5 and left vision on both days 5 and 11. ($p < 0.05$)

The geometrical mean of eyesight after carrying out Dr.REX is calculated in order to verify middle-range effects [19]. All the geometrical mean of eyesight is higher than in the pre-far-vision test (both vision: 0.037, right vision: 0.055, left vision: 0.043). When eyesight was compared for statistical significance using the Friedman test, the increase of statistical significance is found on all the eyesight. ($p < 0.01$) In addition, when carrying out the multiple comparison (Scheffe's test), the increase of statistical significance compared with pre-vision is found on right vision on days 8, 9 and 11 and left vision on 8,10 and 11. ($p < 0.05$ or 0.01)

The adding mean value of VAS after carrying out Dr.REX and the close work were 3.63 ± 1.80 and 4.57 ± 2.18 , respectively. The mean value after carrying out Dr.REX is lower than the mean value after carrying out the close work (Close work: 4.57, Dr.REX: 3.63). When each type of work was compared for statistical significance using paired t-test, a significant difference is found for each work type. ($p < 0.01$)

The mean asthenopic score calculated SSQ before and after carrying out Dr.REX and the close work on days 5 and 11 is shown in Table 4. All of the scores after each work type on both days are shown to increase slightly. When the eyestrain before and after carrying out the each work was compared for statistical significance by paired t-test, a significant difference is found only close work on day 5. ($p < 0.01$)

Table 4. This table shows the change of eyesight after carrying out Dr.REX on days 5 and 11. The eyesight on both days 5 and 11 increased slightly. (* $p < 0.05$)

Index	Pre5	Post5	Pre11	Post11
Control group				
VA at a distance (binocular)	0.13 ± 0.25	0.15 ± 0.28	0.15 ± 0.23	0.15 ± 0.29
VA at a distance (Right vision)	0.11 ± 0.20	0.12 ± 0.22	0.11 ± 0.23	0.12 ± 0.23
VA at a distance (Left vision)	0.09 ± 0.16	0.10 ± 0.15	0.09 ± 0.13	0.10 ± 0.22
Accommodation training group				
VA at a distance (binocular)	0.14 ± 0.30	0.16 ± 0.29	0.14 ± 0.27	0.17 ± 0.33*
VA at a distance (Right vision)	0.11 ± 0.28	0.12 ± 0.24	0.13 ± 0.26	0.14 ± 0.24
VA at a distance (Left vision)	0.09 ± 0.18	0.11 ± 0.20*	0.10 ± 0.19	0.12 ± 0.21*

4 Discussion

In this study, we presented a movie using the POWER 3D method as the movie for the accommodation training, and a short-term effect of the accommodation training was investigated in visual inspection workers suffering from eye fatigue and middle-aged people. In both measurements, the motion sickness could not be induced by viewing 3D video clips in accordance with subjective tests, and the VA was improved by continuous training.

In measurement 1, we showed that the visual inspection workers suffered from eye fatigue after their work. Although the dioptric comparison between the control and the training groups showed that there was no significant difference between the values for the groups ($p < 0.05$), the binocular BVA increased in 13 of the 22 visual inspection workers (59.1%) [17].

The VA of the control group without the accommodation training showed an improvement. The myopic tendency had increased due to the visual inspection work. Moreover, it was possible that the subjects became skilled in the vision test. However, the results obtained from the Wilcoxon signed-rank test showed that the distant VA in the training group had increased considerably compared to that in the control group ($p < 0.05$). As compared to the near VA in the control group, that in the training group had increased significantly on day 3 ($p < 0.05$).

The VAS in the control group had also increased significantly on day 3 as compared to that in the training group. There seemed to be not only VA improving effect but also reduction of the visual fatigue by the accommodation training for more than 3 consecutive days.

The authors have verified a middle-term effect of accommodation training that uses the strategy of presenting a stereoscopic movie to 32 myopic youth (20 ± 1 years). The movie consists of one to five balls moving back and forth in the stereoscopic sky background. At a viewing distance of 60 cm, the stereoscopic ball is viewed to move from 30 cm (forward) to infinity (backward). This ball completes a round-trip movement more than 25 times in 3 min. The uncorrected distant VA increased in 17 of the 32 subjects (53.1%) participating in this study. Although there were some variations, the VA improved in the accommodation training group and not in the

control group. Upon comparing the value obtained on each measurement day using the Wilcoxon signed ranks test, we found that the VA on day 11 was considerably higher in the accommodation group than in the control group ($p < 0.05$). This result suggests that the accommodation training using a stereoscopic movie has a cumulative positive effect on eyesight and prevents the deterioration of VA. Although the myopic tendency improved slightly in the accommodation training group, there was only slight progress in the control group. These results suggested that the accommodation training using the stereoscopic movie did not deform the lens, thus not improving myopia fundamentally [18].

We assumed that these effects of the accommodation training was temporary, but the findings suggest that the continuous accommodation training will promote a ciliary-muscle-stretching effect, leading to an improvement in VA. Accommodation reflex for near vision may be defined as the mechanism of working the ciliary muscle. This may also inhibit a reduction in the VA.

In measurement 2, both the binocular near and distant visual acuities were improved, suggesting that the viewing of the stereoscopic video reduced strain and increased the flexibility of the ciliary muscle, which temporarily recovered the VA. In contrast, findings on objective refractometry at Pre and post viewing stereoscopic videos were compared employing the Wilcoxon signed-rank test, setting the significance level to 0.05 [19]. The spherical diopter of individual eyes with the frequency of video viewing was also measured. The mean SPH was about -3 diopters in both eyes, showing no significant changes with the viewing frequency. Therefore, diopter measurements did not change in either eye. The duration of the accommodation training may have been too short to modify the eyeball (lens) structure. It was suggested that the short-term repeated use of the accommodation training increased the near VA, for which the improvement and prevention of presbyopia may be expected.

The effect of short-range recovering eyesight was verified by the results of the far-vision test on days 5 and 11. The effect of recovering eyesight was noted so that the mean value of eyesight was increased. However, the constant increase of statistical significance was not found. One of the reasons for this was the measurement interval of the far-vision tests. In this study, when measured eyesight is under 0.1, the result is obtained at 0.01 intervals. On the other hand, when measured eyesight is over 0.1, the result is obtained at 0.1 intervals due to our use of an auto optometer. The other reason for this was the status of the subjects' eyes. Subjects who abused their eyes before measurements obtained the largest effects of recovering eyesight; their focus-adjustment muscles around the eyeballs were strongly contracted. In contrast, the subjects whose muscles were relaxed obtained hardly any improvement.

The degree of asthenopia from using the Dr.REX apparatus and the close work was verified by VAS and the asthenopic score calculated with SSQ. In the VAS, the mean value from carrying out the close work was statistically more significant than the value from using the Dr.REX. In the SSQ, although the mean value for carrying out the close work indicated higher than the value of using the Dr.REX, a significant difference is not found between each work. We consider that these results depend on the each subject's psychological state or their eye condition due to subjective assessment.

The manufacturer of the Dr.REX apparatus suggests the use of this apparatus within 10 minutes each time. Thus, in this study, we expected the subjects to obtain hardly any asthenopia while using the apparatus in the recommended time. Dr.REX had the effect of relaxing the subjects and also the effect of semi-compulsory stretches. We consider that these effects gave the subjects a temporary pseudo-asthenopia. On the other hand, the close work in this study was designed to induce asthenopia compulsorily. We consider that the close work certainly gave the subjects asthenopia. Thus, we estimated that asthenopia from the close work was relatively heavier than that from the Dr.REX due to the results of study. This conclusion, however, needs to be verified continuously.

5 Conclusion

The VA-improving effect of the VA recovery device utilizing stereoscopic videos was investigated in visual inspection workers suffering from eye fatigue and middle-aged subjects becoming aware of presbyopia, and the VA was improved by the continuous accommodation training for a short-term period. We are planning to investigate the effect of the device employed for a prolonged period.

In this study, it became clear that pseudo-myopia could be improved by relaxing contracted focus-adjustment muscles around the eyeball, such as ciliary body and extraocular muscles, by using a stereoscopic movie shown on LCD. On the other hand, a feature of the Dr.REX apparatus was inexpensive and unlimited of installation space as previously indicated. Using the apparatus freely, a trainee might interrupt the training in terms of his/her negligence. Therefore, we came to a conclusion that the apparatus was used for improvement of eyesight due to relaxing the contracted muscles continuously.

The effects of asthenopia from close work were more pronounced than it is from Dr.REX. A tangible result in terms of asthenopia, however, was not obtained by the asthenopic scores due to the lack of significant difference. These results need to be verified continuously by using the other index of asthenopia.

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Part III
Universal Access
to the Built Environment

The Impact of Visual Impressions on Human Work Environment—Based on the Example of Industrial Design

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Abstract. This paper presents an original method for evaluating aesthetic factors in the work environment. The study assumes that the aesthetic appeal affects the behavior, enhances the identification, positive effects on the emotional attitude toward work. On the contrary, ugliness causes negative attitude, discourages creativity, causes indifference. In reality between perfection and aesthetic ugliness there is a whole range of intermediate states, which are in very different ways shaping our emotional relationship to the environment. The aim of research is to associate those emotions with characteristic aesthetic features of industrial forms.

Keywords: work environment, visual quality, emotions.

1 Research Problem

Visual quality of the surroundings people work in plays an important role among fundamental factors which determine psychological situation of people in work environment. It is connected with a person in a functional, intellectual and emotional way. The appearance of the workplace constitutes an everyday reference system which presents an interpretation of current standards in terms of technology, work organisation, and aesthetic preferences. Visual characteristics of work environment become emotionally and symbolically marked in employees eyes and consequently they affect their behaviour.

The interest in the studies on perception and behaviours in work environment stems from an assumption that people evaluate their workspace and this process affects their performance. Such assumption is linked with a more general belief, according to which there are very clear interrelation between visual qualities of the surroundings and patterns of human behaviour. Still, some questions remain - which elements of contemporary psychological, sociological and anthropological theories can be used in work environment design. Although it is difficult to imagine that Freud's [1], Skinner's [2] and Benedict's [3] behavioural theories could be used directly in this context, still many authors try to create an emotional theory of work, residential, and recreational space design. The emotional maps of urbanized space prepared for Poznan Metropolitan Area [4] are an example.

Visual characteristics of the surroundings have an impact on levels of human activity – they can stimulate or inhibit this activity. Here, stimulating role of the appearance of the surroundings is present in two forms:

a) The appearance of the surroundings affects people's senses. To a higher or lesser degree, it constitutes a factor that determines levels of activity. For example, brightly illuminated light objects affect human neurological functions triggering reactions typical for the irritation of sympathetic nervous system. Colours can stimulate or inhibit activity (increase work motivation, help maintain vigilance). Specialised research determined colour preferences, optical illusions, and psychological consequences of various types of lighting used for different kinds of work. The impact of colours on human psychological activity has long been a subject of studies carried out by many authors. The examples they refer to include increased labour efficiency (between 10%-35%) achieved due to appropriately chosen visual stimuli [5]. Visual impact on human sensory system can cause activity loss, optimum activity, or overstimulation leading to tiredness and an early inhibition of activity.

b) The appearance of the surroundings has an impact on human behaviour, formation of his/hers value systems, it triggers identification processes. From this point of view, as a result of visual characteristics things become objects of desire or objects that we try to avoid. The degree of their attractiveness varies. This attractiveness is shaped by a set of general components, such as: functionality, safety of use, contemporary character (psychological strain related to equipment operation), as well as individual elements – aesthetic preferences, the style of objects, their form, texture, shape, etc. The appearance of the surroundings affects human emotions. It builds or disorganises human personality, provides work motivation or discouragement. From the emotional point of view, surroundings can be a source of anxiety, fears, and hope. For example, a substandard work environment together with increasing requirements in terms of efficiency can cause stress, anxiety, fears, and consequently result in a chronic aversion to work, which can manifest itself as a desire to take early retirement or so called “sickness escape” [6].

The above mentioned concepts are part of emotional ergonomics. The emotional ergonomics is defined by Siddique [7] as a discipline that examines the impact of employees' emotions on labour efficiency. In particular, this refers to the adaptation of the appearance of work environment to the emotional profile of a person. From this point of view, emotions have a great impact on following areas:

- strengthening self-confidence,
- self-esteem,
- increased self-confidence,
- work motivation.

Thanks to the identification of employees' emotional needs it is possible to improve their satisfaction from tasks they perform and eliminate factors that discourage them from work, trigger indifference, and sometimes aggression. Here, appropriately selected visual characteristics of the surroundings affect creativity and the development of employees' emotional intelligence, which consequently leads to increased

efficiency. The impact of the appearance of objects on human emotions is visible not only in work environment. Architects, designers of functional forms, and marketing specialists know it well. Many authors point out that the aesthetic quality of an object affects the assessment of its practicality more than real functionality [8]. Norman [9] points out that the appearance influences our emotional attitude towards things. People are ready to spend thousands of dollars on a Gucci handbag, Rollex watches or new models of iPhone mainly because the possession of these things is linked with positive emotions. This type of stimuli particularly affects young people who highly value products' fashionable appearance. This is highlighted by Chuah [10] when analysing preferences related to the shape of glasses. Japanese Kansei method, which is based on the adaptation of product characteristics to customers' feelings, fits well in this stream of research. This approach is based on an analysis that identifies certain product characteristics which are most likely to evoke positive feelings in potential buyers [11]. The method has been successfully used in car industry, appliances design, as well as architecture. Nagamachi and Lokmman [12] present interesting examples of the Kansei method application. They also describe failures caused by designers unable to understand emotional needs of customers.

In many cases, emotional attitude of a person towards objects is personified, i.e. objects that we feel emotional about are given human characteristics. And hence, in our surroundings we distinguish between disliked, friendly, funny, and amusing objects. People personify everyday objects, and often treat them as an equal partner in psychological interactions. Feelings related with the personification express our attitude towards objects. This attitude can be positive or negative; it can have various emotional connotations and various intensity. Cerulo [13] points out that an increasing number of inanimate objects play a key role in social interactions, acting not only as mere tools used in order to fulfil certain practical objectives, but also as equal elements participating in emotional relationships. Tzeng [14] presents results of a research into emotional relationship between an individual and computer interface. By analysing the behaviour of computer users they have been noticed to remain "loyal" to certain machines. Similar "loyalty" can be observed among car users.

So, our attitude towards objects is influenced not only by functional and practical characteristics, but also by emotions. These emotions create motives which decide about a wish to possess a product, such as for example:

- happiness brought about by the product,
- higher prestige related to the possession of a product,
- better mood related to the possession of a product,
- a feeling of attachment to the product,
- personality expression of an individual by the means of a product,
- a feeling of jealousy caused by a desire to possess a product.

This has a significant impact on the success or failure of a product designer (architect, designer) whose designing efforts can be appreciated or not by a potential client. Therefore, it is vital to recognize emotional reactions triggered by the way products look. Such recognition is a subject of this analysis.

The research was carried out in order to establish interrelations between employees' emotional state and the appearance of office furnishings: furniture, computers, printers, telephones, and other standard office equipment. It must be emphasised that employees' emotional state is closely related to job satisfaction [15]. In many interpretations the frequency of experiencing positive emotional states is considered to be a measure of this satisfaction [16]. The research was undertaken with an assumption that visual attractiveness of office furnishings significantly affects behaviours, stimulates identification processes, and positively influences job attitudes. On the contrary, ugliness triggers negative behaviours in people living in degraded surroundings, and it discourages activity. In reality, between aesthetical perfection and ugliness there are a number of intermediate states which can shape employee's attitude to the surroundings in very different ways. The purpose of the research was to identify these feelings and their relations with characteristic visual features of the elements of office furnishings.

2 Research Methodology

Research sample included 150 items which constituted elements of office furnishings. Following visual characteristics of these items were analysed: colour, shape, texture, form, composition, stylistic references, and surface finish type. The research was divided into four methodological steps.

A. Identification of emotions stimulated by the product described by a set of partial visual characteristics.

B. Construction of a model of emotions evoked by products with different visual characteristics.

C. Analysis of employees' preferences in terms of emotions evoked by the product. The analysis was carried out on three groups of employees including:

- employees who perform routine clerical duties,
- employees who perform conceptual work,
- management staff.

D. Determination of visual preferences in groups of employees based on the assessment of the representative sample. As a result, visual profile of a product was obtained, dedicated to each tested group of employees. Visual preferences were presented by partial visual characteristics of a product.

Re. A. In order to identify emotions stimulated by a product, a random research sample was selected and it included office furniture (chairs, desks, and cabinets), telephones, computers, laptops, lamps, coffee makers, and utility ceramics (150 products altogether). Products' models were designed by students of the Department of Architecture at Poznan University of Technology.

Then, 12 emotional states (feelings) evoked by the appearance of the products were distinguished:

- y_1 . admiration, fascination,
- y_2 . liking, attachment,
- y_3 . amusement,
- y_4 . prestige,
- y_5 . curiosity,

- y₆. boredom,
- y₇. empathy,
- y₈. depression,
- y₉. aversion,
- y₁₀. anxiety,
- y₁₁. ridiculousness,
- y₁₂. irritation.

In the research the appearance of a product acted as independent variable X, while emotional states were dependent variables y_1, \dots, y_{12} . Then, relations between the appearance of a product (independent variable X) and emotional states it evokes (dependent variables y_1, \dots, y_{12}) were analysed. In other words, an attempt was made to answer the following question: which independent variable X dependent variables y_1, \dots, y_{12} depend on? All variables have qualitative character. It is important to point out that the relations between the appearance of a product and identified emotional states are probabilistic. The assessment by 20 competent judges was used in the research (expert assessment), which increased reliability of the assessment. During the assessment the appearance of a product (X) was attributed with appropriate emotional states (y_1, \dots, y_{12}). This procedure was used for each product included in the representative sample. The research was carried out using surveys. Five point Likert scale was applied in order to measure the relations between the appearance of a product (independent variable X) and emotional states it evokes (dependent variables y_1, \dots, y_{12}). Expert assessments (their intuitive believes) have been quantified in a range between 1 and 5, showing the intensity of a given feeling evoked by the appearance of a product. Experts were asked to fill in a survey prepared in advance, the template of which, used for product assessment. This technique enables quick collection and further processing of data.

The results included an emotional profile of each product included in the research sample. Then, the products were divided into 12 groups matching individual emotional states in accordance with highest expert assessment. In this way, groups of products were identified, which evoke (to a highest degree) admiration, liking, amusement, pride, curiosity, boredom, empathy, depression, aversion, anxiety, ridiculousness, an irritation. Then, each group of products was analysed in terms of partial characteristics describing their appearance. The appearance of products was described using partial visual characteristics. Partial visual characteristics describing the appearance of a product included:

- **gloss** – the scope of the characteristic: *gloss* (x_1) \leftrightarrow *matte* (x_2),
- **shade** – the scope of the characteristic: *light* (x_3) \leftrightarrow *dark* (x_4),
- **colour** – the scope of the characteristic: *contrasting* (x_5) \leftrightarrow *monochromatic* (x_6),
- **shape** – the scope of the characteristic: *angular* (x_7) \leftrightarrow *rounded* (x_8),
- **silhouette** – the scope of the characteristic: *slender* (x_9) \leftrightarrow *chunky* (x_{10}),
- **texture** – the scope of the characteristic: *soft* (x_{11}) \leftrightarrow *hard* (x_{12}),
- **style** – the scope of the characteristic: *innovative* (x_{13}) \leftrightarrow *traditional* (x_{14}),
- **form** – the scope of the characteristic: *abstract* (x_{15}) \leftrightarrow *figurative* (x_{16}).

Next, an independent expert assessment was performed in order to find an answer to the following question: to what degree (“intensity”) products included in 12 “emotional” groups are characterised by partial visual characteristics? In other words, it was about assessing the significance (importance) of a given partial characteristic compared to the overall appearance of the product. Paired Comparison Analysis was used in order to do so. It is a method which uses “forced choices” where an individual partial visual characteristic of a product is compared with each and every remaining feature [17]. As a result, partial visual characteristics were distinguished which are most important in the overall appearance of a product (included in the identified “emotional” group).

Re. B. Construction of a model of emotions evoked by products with different visual profile.

The research presented above enabled us to construct 12 emotional models of a product. The models were described using a degree of occurrence of partial visual characteristics, such as: gloss, shade, colour, shape, silhouette, texture, style, form, and composition, in a product. Diagrams in Figure 1 show emotional models for 12 identified types of feelings: admiration and fascination, liking and attachment, amusement, prestige, curiosity, boredom, empathy, depression, aversion, anxiety, ridiculousness, an irritation. It is worth noticing that the construction process of the emotional model of a product was divided into two stages. In the first stage, 20 experts expressed their opinion about an emotional state evoked by the overall appearance of a product only. In the second stage another team of 10 experts was supposed to decide which particular visual characteristics are present in the overall appearance of a product (and how significant they are). The other team did not assess emotional states but only the “visual structure of a product”. By dividing the assessment process into two independent stages we were able to obtain more reliable results.

Re. C. Analysis of employees’ preferences in terms of emotions evoked by the product. The analysis was carried out on three groups of employees including:

- employees who perform routine clerical duties,
- employees who perform conceptual work,
- management staff.

Representatives of each group of employees were to decide what emotional state (mood evoked by the appearance of furnishings) they prefer in their own work environment. Please note, that respondents did not assess specific products but they were supposed to express their opinion about the desirable (or undesirable) emotional states in work environment, choosing from the following: admiration, liking, amusement, pride, curiosity, boredom, empathy, depression, aversion, anxiety, ridiculousness, an irritation. Each of the 12 emotional states was to be attributed with values ranging from +5 (highly positive attitude) to – 5 (highly negative attitude). The research was carried out in 2012 with 60 participating employees equally representing individual groups. Representative groups were selected at random among people employed in five Poznan offices. Forced-choice procedure was used in the form of paired comparison of individual emotional states.

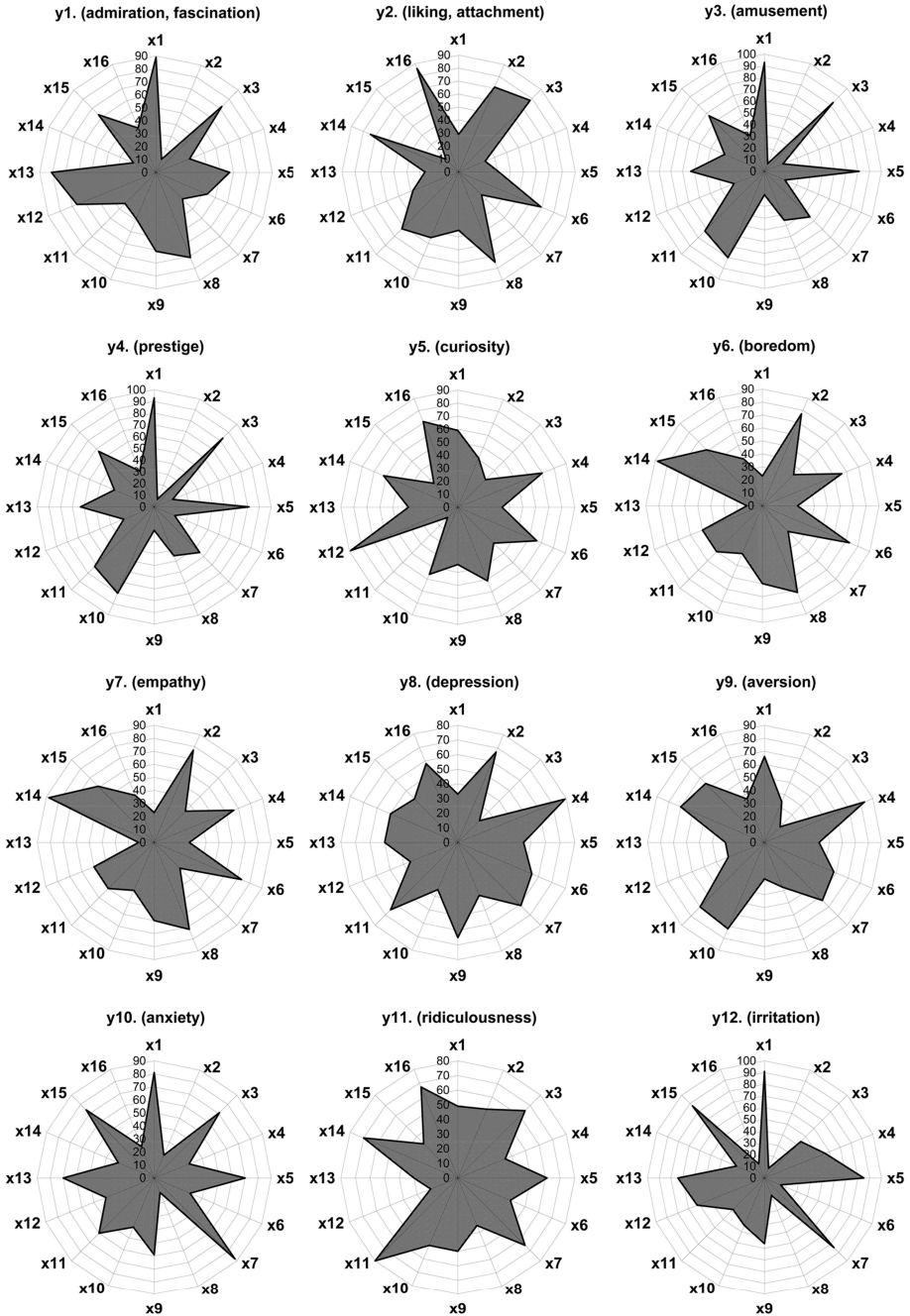


Fig. 1. Feelings ($y_1 - y_{12}$) evoked by a product. Model described using a degree of occurrence of partial visual characteristics in a product (prep. by the author).

Re. D. Determination of visual preferences in groups of employees based on the assessment of the representative sample. Diagrams in Figure 2 show visual profile of products dedicated to each tested group of employees. Visual preferences were presented by partial visual characteristics of a product.

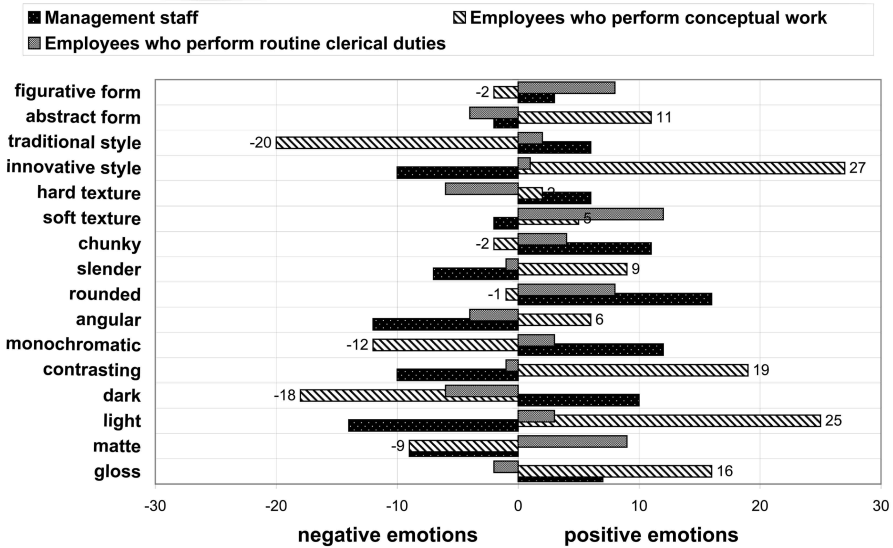


Fig. 2. Visual profile of products dedicated to:
 - the group of employees who perform routine clerical duties,
 - the group of employees who perform conceptual work,
 - management staff.

3 Conclusions

Preferences related to emotions stimulated by the appearance of furnishings in office environment in individual groups of employees were diversified. These emotional preferences are connected with certain visual characteristics of office furnishings. And so, employees performing routine office duties value most soft textures, matte surface finish, rounded shapes and figurative forms. They have more negative attitude towards dark colours, hard texture, and abstract forms.

Management staff has more positive attitude towards glossy, dark, monochromatic colours, rounded shapes, and traditional style. Greatest aversion in this group is evoked by light contrasting colours, and angular shapes.

Creative workers have entirely different priorities in terms of visual characteristics of work environment. They value light, glossy items with contrasting colours and innovative style. They demonstrate negative emotional attitude towards dark, monochromatic colours and traditional style.

The results have an important applicable significance especially for the completion of orders related to office furniture and equipment. The research showed that the selection of visual characteristics of office furnishings should take into account type of duties performed by the employees.

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Facade Retention Accomplishments in View of Ergonomic Design

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Abstract. Both individual buildings and large complexes of buildings that are now being adapted or revitalized may have been withdrawn from using due to some general economic tendencies progressing, as well as in consequence of technical deterioration of the given object or just not being able to keep up-to-date maintenance standards. These objects, although appreciated for their monumental value and favorable location near the center of a big city, may easily fall into ruin if they are not properly used and maintained. The reconstruction and modernization of the interiors in such buildings, with the original facade retained– which sometimes is a necessary condition imposed by the local planning authorities– may be a chance to restore the building functionality and thus avoid the costly, energy- consuming demolition.

Keywords: facade retention, facade technology, ecology, re- use, sustainable design.

1 Introduction

The beginning of 21st century is characterized by a visibly growing popularity of eco-friendly solutions in architecture. This results from more and more strictly defined legislative requirements concerning the parameters applied to the maintenance and construction of buildings, as well as in consequence of a more recognized exploitation of natural environment, which from the beginning has inevitably accompanied the industrial revolution and in the long run may bring disastrous effects. As for the leading design tendencies in contemporary architecture, one of the leading trends is the re-using of materials and existing building structures, which is sometimes performed as the architectural adaptation.

The range of the jobs done within the adaptation may involve: the retaining of the original construction and functional systems, along with the simultaneous modernization of the inner installations and the replacement of finishing materials; the retaining of both the external walls and the main load-bearing structure with the functional system changed, all installations modernized and finishing materials replaced; the retaining of all external walls and modernization of the existing bearing structure in order to adapt the object to its new function; the retaining of all external walls or only selected ones (for tenement houses usually front facades only) along with a

complete replacement of the inner functional and bearing system, which is the main issue discussed in this paper. The decision of how much we can interfere in the building structure depends on the technical condition of the object, as well as the time of its construction and the kind of a new function planned for it which is usually different than the original one.

While re-using the external masonry walls, one should consider a number of different technical and ergonomic factors of the adaptation process combined. It is essential to choose appropriate solutions, such as: a proper kind of the steel system to stabilize the existing façade or building envelope, while a new bearing system is being founded- as this guarantees a safe using of the object in the future, as well as the comfort and safety of the work being done at the moment (like the manoeuvre space big enough within the building site), only minimal negative impact on the closest surrounding in the vicinity of the investment (i.e. noise, dust, the freedom of transport hampered, the safety of pedestrians influenced, etc.). What seems equally important is the influence of the re-consumption process on the quality and aesthetic value of the space being created, as well as the need to preserve a compact urban tissue and the comfortable using of the interiors according to the contemporary standards (acoustic and thermal insulation, energy consumption, etc.).

Both individual buildings and large complexes of buildings that are now being adapted or revitalized may have been withdrawn from using as a result of some general economic tendencies progressing, as well as due to the technical deterioration of the given object or not being able to keep up-to-date maintenance standards. These objects, however, may have a monumental value and are often located in the vicinity of a big city center. The potential possibility to change the way of using and a thorough modernization of the object is often regarded as the dominant factor while making a decision about retaining the whole existing object or just a part of it.



Fig. 1. This is what was left after the textile factory "Silesiana" at Dzierzoniow in Lower Silesia, Poland. The object is to be adapted for a shopping and leisure center (Source: Author's photography of December 2012)

2 Advantages Resulting from the Re-using of External Masonry Walls

The decision to re-use the existing external walls in their original location may bring some substantial advantages as it allows to:

- Achieve the eco-friendly character of the investment as the exploitation of non-renewable resources can be reduced, as well as the consumption of energy and pollution resulting from the manufacturing and transport of the building materials. Another positive aspect is that the amount of waste can be limited, as well as the transport and dumping of the waste. The study carried out by the scientists from the University of Loughborough referring to a typical building in the city center (a brick building situated in the center of London built in 1930, the dimensions of the front wall: H 25m x L 85m), show that the total amount of the energy needed to construct a new facade is four or even five times bigger than the amount of energy needed for the preserving and restoring of the existing wall [1];
- Reduce to a minimum the negative impact on the surrounding, which seems specially important in view of the ergonomic aspect, as the re-using of the existing building envelope makes it possible to reduce the noise and dust usually created while the demolition involving the crushing of the building elements is being performed. This is essential for a comfortable using of the space in the city center. Usually, the investments of this kind are situated in a close vicinity of other objects, very near or just in the middle of the town center;
- Gain a higher score in the building assessment tools, such as LEED or BREEAM. The possibility of being included in the certification systems in Poland is still a rare occurrence. The PLGBC (Polish Green Building Council) is presently working to adapt both systems mentioned to the Polish conditions [2]. Yet, even now one can observe a growing interest in these issues by Polish investors, as well as the potential users and the media. The buildings that have been given the certificate are usually sold or rented very quickly as this guarantees a low cost of maintenance. What should also be considered is the creating of a positive image of the investor as the one who cares about the natural environment;
- Achieve a representational character of the building through exposing the originally used, traditional and often valuable elevation materials. This makes it possible to take advantage of the representational character of the building while designing objects planned as the residences of important financial institutions, such as banks, offices, or luxury hotels and galleries (See: Fig. 2);
- Preserve the character and compactness of the urban tissue in the area near the existing building whose interior has been irreversibly destroyed due to not having been used for a long time;
- Save the architectural monuments in order to create a modern space that meets the needs of its users while preserving the cultural heritage embodied in the urban system of historic merit. In extreme cases, the building work involves the deconstruction and restoring the original facade (with the use of new materials, hardly any the original ones). It may happen that the preserving of the front elevation unchanged, or at least a part of it untouched, was officially demanded by the local planning authority. The historic-merit facade to be re-used poses numerous restrictions limiting the work being done;

- Use the whole inner space of the building effectively and profitably. The problems, such as inappropriate story-height or anachronistic construction system can make it difficult to adapt many of the existing buildings to the contemporary requirements. Having demolished the inner system, one usually finds it possible to adapt the object for the new function allowing that contemporary standards and design trends are respected. When the front wall is saved, it is still possible to build additional underground levels which can be used for arranging services, car parks, etc. there;
- Obtain a bigger potential space than in new buildings designed according to the requirements of the local authorities (when the stories are high one can arrange the mezzanine between them), which creates extra profits for the investor;
- Apply for different grants and financial support given by public funds, which eventually may significantly lower the total cost of the investment;
- Take advantage of the simplified administrative procedure necessary to validate the design documentation in some European countries, e.g. in Scotland– according to the Town and Country Planning Act 1990, it is not necessary to obtain the planning permission when the outer walls are preserved, although the inner functional and construction systems have been rebuilt [3].



Fig. 2. The Granary La Suite Hotel, Wrocław, Poland (Source: Author's photo of December 2012)



Fig. 3. The front façade of the Granary La Suite Hotel-view on site before re-use (Source: Author's photo of May 2005)

3 Safety and the Best Possible Solutions for the Building Work Carried Out

One of the main technical problems while carrying out the retaining process of external walls is the necessity to build a temporary stabilizing construction, as well as the choosing of the appropriate method to connect the existing facade to a new bearing system and making the foundation of the preserved masonry walls strong enough to keep them firmly while the newly designed elements are being settled down in the close vicinity of the existing part of the object. The operation whose aim is to retain the outer partitions of the object is usually begun by the stabilizing of individual building elements. The quality of this phase significantly influences the safety and effectiveness of the further adaptation work. With the stabilizing system properly chosen one can rebuild the interior totally, as well as the ceilings and the whole inner construction of the building. Facades can be supported with various configurations of frame and brace systems. In most cases these are steel systems made to measure which should be conformed to the specific qualities of the groundwork, the height and method of renovation work, as well as other factors determined by the location of the building site. Those jobs are mostly done by specialist's building companies.

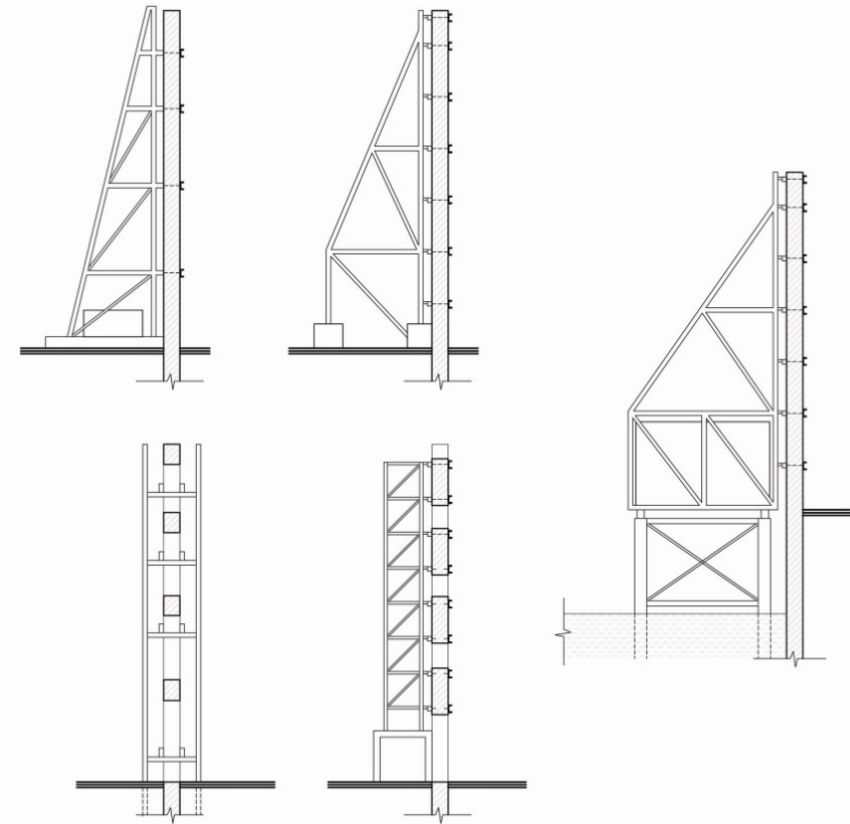


Fig. 4. Exemplary constructions of the steel stabilization systems [4]

As the investments may be located differently, the temporary supporting structures are made as either the outer or inner ones. For individual cases a mixed type can be applied. The outer systems offer some advantages, such as minimal problems while the demolition of the original construction is being done and a new bearing system constructed. The inner supports make the building process somehow more complicated. Yet, there are some advantages too, such as the fact that those supports are situated straight in the place of the investment and do not hamper the pedestrian and vehicle traffic. Thus, there is no need to obtain the permit for occupying the road or sidewalk, which allows for a quicker and more effective investment process done in a big town center. The systems constructed to stabilize the walls during the building work must be based on a good temporary foundation. This functions as a ballast for the whole construction preventing from its possible lifting or moving to the side.

Some design solutions are fairly innovative as the strengthening steel-systems make it possible to reduce the consumption of the so-called 'embodied energy' and limit the cost normally generated by the necessary stabilization of masonry walls. The possibility to achieve the expected factors during the work being done should be considered as early as at the design-stage when one of the possible procedures should be taken into account:

- While the building work is being done, the steel construction of the future object of destination serves as a stabilizing system for the saved external walls;
- The facade of the building is supported by keeping some of the internal bearing walls saved. The strengths affecting, as well as the horizontal elements of the temporary system are stretched between selectively saved internal walls, which makes it possible to avoid erecting the very costly steel towers of the security system;
- Having been disassembled, the foundation of the temporary construction is used for settling down the bearing elements of the object of destination [1].

While designing the temporary stabilizing construction, one should consider the following conditions:

- The power of wind affecting the facade, as well as its supports (to calculate this one should take the outline of the elevation area measured including the window openings which are usually walled up). In those calculations the two-direction action of the wind should be predicted;
- The need to maximally reduce the negative impact of the construction work on the close surrounding of the building site, such as disturbances in transport; it is also necessary to guarantee the safety of pedestrians, and- in order to reduce the noise and dust- keep the windows bricked up;
- The forces that may result from a possible collision of vehicles crashing into a lower part of the system supporting the wall (it should be emphasized that the supporting construction must be properly lit and marked with proper signs);
- Other local factors which can cause some elements of the construction to be bent or declined;
- An appropriate safety co-efficient in order to prevent the foundation of the temporary construction from sliding down or shifting;
- The necessity of a regular technical check-up and conservation within the temporary bearing construction (the examination of the existing elements with their supports ought to be done regularly, and some extra check-ups should be taken up if necessary, especially when the weather conditions worsen significantly);
- The aspiration to achieve an optimum shape and ideal spacing of the supports while keeping a free access to the existing elements to make it possible for heavy building machines to move freely and avoid any possible collisions while constructing the final-destination frame of the new building. Good access to the adapted cladding walls for the workers carrying out installation and assembling jobs, as well as stock-taking and permanent monitoring of the building elements, installing new joinery, flashings, repairs and maintenance of sub-assemblies when necessary.

4 The Comfort of Using

To use the object safely and comfortably, with the aesthetic value preserved throughout the many years of its maintenance, some specific technological solutions assumed at the designing stage of investment, including the assembling instructions, should be carried out. What specially should be guaranteed is the proper connection of the

retained cladding walls with the new bearing construction. The engineering solutions applied must involve the natural situation when both parts - the existing one and the newly constructed one (expansion joint) - settle down independently. One should also prevent the possibility that the load is shifted from the newly designed part to the existing elements of the object, as well as guarantee that the facade cannot be shifted or inclined and all the joints are durable even at extremely unfavorable external conditions, such as: high temperature or powerful suction of the wind.

The high quality of the space designed results from the favorable climate of the interiors, which can be achieved by a proper acoustic and thermal insulation in the rooms guaranteed. As for the buildings of an important historical and architectural value whose outer elevation must not be changed, it is likely that the only permitted solution while carrying out their adaptation would be the thermal insulation of the building envelope only from the inside. The market of building materials is now offering a lot of confirmed technological solutions that can improve the parameters of the outer partitions along with eliminating the risk of too high humidity resulting from a high condensation of steam. The most effective solution is to apply the specialist's blocks made of autoclaved cellular concrete. They improve the thermal parameters of the walls and prevent the condensation, fungi and mold, and do not require any additional moisture insulation layer to be applied. The blocks are characterized by a high steam permeability, as well as accumulation qualities of the material they are built of [5].



Fig. 5. Hearst Tower, New York, USA (Source: Author's photo of July 2010)

A good example confirming that the retaining of the existing facade can be fully comforted with the contemporary requirements for the energy consumed by the building is the realization of the Hears Tower in New York. The load-bearing construction of this high-rise has been executed in a new technology making it possible to save 20% of the construction steel comparing to the conventional solutions. 80 % of the steel used came from recycling. The building, in which the facade was saved, consumes 25% less energy than the neighboring high-rise objects carried out fully with the use of high-tech methods [6].

5 Conclusion

The adapting of the buildings that were withdrawn from using and are now to be adapted to a new function can be fairly understood as an example of green architecture. Contrary to the demolition of buildings, it appears to be significantly less destructive for the natural environment and at the same time makes it possible to improve the standard of living for the people who still inhabit the worn-out urban tissue. Yet, the main drawback of the modernization process executed in empty building is its high cost (compared with the object built from scratch), as well as an extended investment process. The re-consuming of external walls or partitions ought to respect the principles applied to the monuments conservation and general building craft. Any construction or building work done in the objects withdrawn from exploitation should be preceded by a detailed examination of the technical condition of the load-bearing structure. Also, the materials should be examined in order to define their mechanical properties. While the adaptation and modernization work is being done, it is necessary to guarantee the security of the construction at every stage of the work, i.e. to secure the existing construction so that the work planned could be started, as well as during the replacement of the bearing system and all the time when the investment is executed- up to the securing of the destination object with its construction system adapted to a new usable function.

The "facadism"- a colloquial label defining the idea of retaining outer walls of the building- may be understood as a kind of compromise between: the tradition and contemporary time, or the demolition and the retention of the existing building, or the investor who would like to achieve a modern space that meets the needs of contemporary maintenance along with designer's trends and the local planning authority who wants to preserve the original form of the building. As a consequence, the deserted buildings can be revived, their functionality and aesthetic values improved, the quality of living and the comfort of interiors in respect of comfortable using enhanced, with the preserving of the compact urban tissue. The issues referring to such ideas as: the improving of the technical and maintenance conditions of the existing facades, combining modern high-tech constructions with traditional structures of significantly lower parameters, as well as the ability to preserve the monumental values while an adaptation of the object is being done, mount a serious challenge to contemporary designers.

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Creating Public Space in Wroclaws Urban Housing Environment

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Abstract. Despite the passage of time the polands housing built in panel technology is not modernized sufficiently. More and more interesting examples from abroad appears, which shows how this kind of housing can be transformed. Actions should be carried out in three areas, starting from town-planning and architectural transformations (macro scale), thru the neighborhood spaces transformation (mezo scale) to the individual functional-spatial flats transformation (micro scale).

Keywords: concrete slabs technology, estate environment, housing.

1 Introduction

Wroclaw (Poland) is a mid-sized city with a population of 636,268. The average population density is 2,173 people per square kilometer. Czech, German, and Polish influences are vividly recognizable throughout the history of Wroclaw. The city has changed hands many times. Wroclaw was devastated during the carnage of the World War II. It was declared to be a fortress-city and it was under siege for four months. During that time the city was practically razed to the ground and fierce fighting caused damage to 90% of all the existing buildings.

After the World War II Wroclaw underwent a slow reconstruction and rebuilding process. The first priority was to rebuild the city center. In the coming years subsequent investments spread out to the further districts of Wroclaw. The most strenuous time in multi-family housing development took place in the 1970's and 1980's when cheap, affordable, panel technology housing estates were built.

They were mostly built in the 1970's with the development decline observed in the 1980's. Their design was based on simplified normative standards regulating the size of each flat, height of the buildings, exposure towards the sun, transportation infrastructure, distance from the street, and the size of the unit. Such an approach resulted in the creation of concrete jungles- standardized eyesores that don't give their users chances for improvement of their standard of living and contribute to the rise of social dysfunction.

Examples of arrangement of such housing estates in Wroclaw is shown in fig.1. Most such housing estates were located in the Fabryczna district where the biggest

industrial plants prevailed. The choice of Wrocław housing estates for theoretical studies on its modernization was based on the following elements:

- Implementation period - the 1970's and 1980's,
- Technology used for task completion – large panel technology buildings,
- Variety of forms and urban arrangements – arrangements expanding possibilities of alternation throughout the variety of modernization activities,
- Location of housing estates – estates located in the eastern part of the city,
- Transformation possibilities.

Considering the above-mentioned, the following districts were chosen: Bartoszewice, Krzywoustego (Psie Pole), Jana III Sobieskiego (Psie Pole-Zawidawie) and Huby (Huby). Selected housing estates have some certain characteristics (attributes) which reflect their influence on the quality of residence. They were attributed with some significance and based on that it was concluded that these housing estates have the most beneficial potential of transformation possibilities (tab.1). The following features of the housing estates were selected and they were attributed the following significance, tab.1:

- Location – very good (3), good (2), poor (1), very poor (0)
- Neighbourhood – very good (3), good (2), poor (1), very poor (0)
- Urban solutions – very good (3), good (2), bad (1), very bad (0)
- Architectural solutions – very good (3), good (2), bad (1), very bad (0)
- Green Amenities – very good (3), good (2), moderate (1), none (0)
- Technical condition – very good (3), good (2), bad (1), very bad (0)



Fig. 1. Wrocław's panel technology housing estates location

For the selected housing estates a course of action was adopted to improve their reputation and the quality of life of their residents. Such activities were carried out in three areas, starting from urban-architectural modifications of the whole housing estates (macro scale), through modifications to the smaller areas which can be described as community space (mezo scale), up to individual modifications comprised of functional and special changes to the flats (micro scale). It has to be taken under consideration, of course, that marking definite boundaries between such spaces is very difficult because they are inter-influential.

Table 1. The following are the characteristics influencing the choice of housing estates for modernization

Housing estates characteristics	Bartoszowice	Jana III Sobieskiego	Bolesława Krzywoustego	Huby
Location	3	2	2	3
Neighborhood	3	2	2	3
Urban solutions	0	1	1	1
Architectural solutions	1	1	1	1
Green Amenities	1	2	1	2
Technical condition	2	2	2	2
Potential modifications	10 – very big	10 – very big	9 – big	10 – very big

The first step in the design procedure was to carry out detailed analyses of four selected housing estates. The analyses conducted were based on my own experience together with some questionnaires and interviews with the residents. All four housing estates presented the same downsides and inconveniences.

Due to the limited size, only one of the four housing estates mentioned above – Huby – was submitted for analysis in this paper.

2 Housing Estate Characteristics

Housing estate described here consists of multi-family buildings with a regular layout of composition. It includes 21 simple and identical 5 – and 11- story block of flats forming 5 urban spaces (each space consists of 2 low, 5-storey buildings orientated east-west facing the sun and 2 high 11-storey buildings orientated north-south facing the sun. Low buildings have 5 staircases and the tall ones 3. These buildings form square of the buildings and are located in the northern part of the plot. Between these square of the buildings, in the central part of the plot we can find a school building and a kindergarten. In the northern part of the plot, however, there are four 11-storey buildings with a varying amount of staircases– 11, 7 and 8 located in a linear, east-west distribution alongside Śliczna Street – three of them in the northern part of the street and one in the southern. In between the quarter development in the north and the linear development in the south there is an open lawn for community recreational purposes. This housing estate can be characterized as a relatively big land development, fig.2.

The housing estate layout is not rooted in the architectural-urban tradition. It was based on the panel-technology building.

While characterizing the housing estates the following should be mentioned:

- All buildings are covered with a flat roof
- Infrastructure: all the buildings are equipped with: water and sewage system, gas-fittings, electrical installation, central-heating, central hot water, phone division, diversity TV antenna, heat distribution units.
- Particular buildings are, when using horizontal projection, rectangular divided into lots with 3 flats on each floor.
- The layout of housing estate comprises of two, clearly separate parts. In the northern part there are 5 open urban interiors with shared zone and a line of 4 buildings along Śliczna Street located in the southern part.
- The estate is equipped with many amenities like a school, a kindergarten, dispersed little local shops and a bigger, self-service chain supermarket - Biedronka.
- Proximity to public transportation cannot be easily described since it is quite unclear and confusing. The predominant means of transportation are shared zone and local streets (pedestrian networks). The interior sidewalks are characterized by through-traffic. Bicycle traffic was introduced making the area less pedestrian friendly and changing it into car parks. External car parks were introduced only by Śliczna Street as two sets of car parks but they do not meet the needs of their residents.
- The housing lacks urban management plans and spatial conception such as: public spaces, semi-public spaces, semi-private and private spaces. It is strictly related to the fact that there is a lack of home gardens, front gardens, utility spaces and green belts.
- The housing estate lacks functional and assumption values of its sport and recreation areas. Community green spaces, playgrounds, recreational areas for senior citizens need more care and attention.
- Functional and spatial lay-out of the flats does not make it easy for the families with many children and extended families to function properly. The flats are standardized and identical; predominate with little, two-roomed flats. Floor space of the rooms measure from 9 m² to 16 m². The flats do not comply with contemporary standards of living.
- The flats are equipped with little loggias or balconies which, due to their size, cannot serve for recreational purposes and are often built up for storing purposes.
- The housing is accessible for both: people with disabilities and mothers with strollers.
- The buildings are characterized by poor architectural detail which is very typical for panel technology developments. Each floor of the building has the same, monotonous façade. Entrance halls need some arrangement solutions.

Since the end of the 1990's the buildings have been modernized. They are successively thermo insulated and on this occasion the façade was painted in abstract color and design which do not truly reflect the individual character of the façade and do not make it individual.

Social issues:

The housing estate is under housing co-operative "Huby". There are two types of flat ownerships: cooperative member's right of ownership and cooperative member's right of tenancy. The residents commute to work by bus, cycle, or go on foot. These are mostly middle-aged people (30-49) with secondary education whose life is stabilized. The families consist mostly of four members and have low income. Among them there are blue-collar workers and white-collar workers with secondary school or university degrees. This type of housing is characterized, due to a large number of residents, variety of social groups, and spatial arrangement by specific social situation.

The residents do not know each other, there are very limited neighborhood ties. The community spaces are shared by all residents but at the same time they do not have one owner; they are no one's. These elements contribute to the limitation or even elimination of social control over community spaces resulting in increased organized crime, vandalism, and numerous transportation offenses. Having consulted the residents and evaluated the questionnaires, the following social problems arose:

- Lack of car parking spaces, malfunctioning motor-vehicle communication system, heavy traffic on one of the access streets (Śliczna Street).
- Playgrounds lack aesthetic values.
- Recreational and green spaces and spaces between the buildings lack land development which instead are used as car parking spaces.

Some residents complained about:

- Their flats being too little forcing them to build up the balconies.
- Isolation of the flats from green areas. To change this situation, the residents adopt the green areas close to their balconies and change them into home gardens.
- Noise and air pollution as a result of being located in the city center, in close proximity to busy traffic roads.
- Poor urban planning which they would like to improve.

The residents would really welcome: sunny terraces, home gardens and renovated elevation. Generally speaking, the residents are quite happy living in this area which largely results from their attachment to this particular housing since they have been living here for so long. Most residents have been living in this housing estate since it was built.

3 Modernization

In the light of the analysis carried out above, it has to be stated that the housing estate requires modernization in order to improve the quality of life of its residents, community spaces and their aesthetic. Urban-architectural improvements are also needed. In the housing modernization project various forms and schemes of development were used which were adapted to the existing geometry of the development, walkways, and effectiveness of the street network, fig.3.

Urban-Architectural Transformations – Macro Scale

Development transformations cover both northern and southern part of the land. In the northern part of the housing, the buildings are grouped around courtyards. The main shortcoming of such solutions is a lack of intimacy since the corners are too open and the residents do not perceive them as closed urban interiors. That was the reason to transform the existing development and to create more closed and clear urban interiors.

The height of all the 11-storey buildings was changed since they were considered too high for the development and infrastructure of the housing development on the analyzed area because the neighboring, old buildings, are much shorter. Another reason for that decision was the arrangement of the group of buildings located in the southern part of the land which cast a shadow over the recreational areas. The buildings were lowered to five and in some parts to six floors. In some buildings the inside parts were removed to shorten their length and enable yard lighting. Glazed elements designed on the roofs lead to the commercial terraces. Previous flat elevation got extended sculptures by means of introducing front-ended elements, loggias, green rooms, and portfenetr. The ground floor flats were equipped with window balcony doors overlooking the terraces and gardens.

The traffic route was redesigned in line with the principle of the steady traffic so that it would be located outside the housing estate and city blocks without any disruptions to the urban interiors.

An important issue is the fact that the housing development lacks space that could be used to build car parking spaces so needed in the area. The problem was solved by:

- Using the existing reserves of spare land
- Introducing underground car parks

The recreational area located between the northern and southern built-up belt has been divided into smaller parts to give it more intimate character and to create the possibility of developing and adapting it for individual needs of different social groups. Sports and recreation grounds for mothers with children and senior citizens will be located here.

The façade was changed in the spirit of contemporary modernism, adding some postmodernism details. Flat roofs have been designed. Elevation combines plaster, wood and facing clinker which are enriched with glazed loggias of the living areas. Architectural monotony has been corrected by:

- Introducing architectural detail, changing colors, and diversifying elevation materials: plaster, wood, tiles. The changes concerned mostly higher floors of the buildings where a completely different elevation material was introduced to visually lower their height.
- Introducing in some parts of the development lean-to roof which helps to obtain extra living areas (they can be easily extended or reduced)

Housing Estate Space Transformation – Mezo Scale

The primary task of the housing estate space transformation was to create conditions that would facilitate social relationships and community building which would

encourage cooperation mentality between the residents, and thereby would improve living safety. The following project activities were undertaken:

- The housing estate space was divided into the following commercial use zones: public, semi-public, semi-private and private. Land division was clarified in a way that a particular user (a family, social group) would know what it is designated for.
- Hierarchy of accessibility and land development was introduced: from widely accessible public areas, through group areas with limited access, to isolated private areas belonging to only one family. Many spatial and system changes were introduced to encourage different free-time activities (entertainment, recreation, neighbor ties). Separation of front gardens, gardens and terraces on the ground floor was also introduced. Private gardens constitute ground flat extension and face south, east or west.
- Different premises were divided with green belts, noise-reducing and trespasser-reducing fencing, elements of landscape architecture, developments e.g. utility or ancillary rooms. Special attention was paid to isolating the housing area from the neighboring, busy Kamienna Street. The isolating green belt was introduced alongside the street.
- The entrances to the housing development and individual units were clearly marked by speed limit signs, trees forming entrances, and elements of landscape architecture. Clear entrance indications make it easier to identify and limit the trespassers.
- The area around the building entrances was made more attractive by making it more diversified in comparison to the techniques used in German housing estates by introducing bicycle parking zones, information notices, mail boxes, aesthetic canopy roofs and front doors.
- To create intimate, attractive, and enjoyable meeting areas, courtyards and elements of landscape architecture were introduced (pergolas, walls, gates, benches, canopy roofs, utility rooms).
- Safety was improved by introducing appropriate lighting, providing adequate green areas and using natural topography which makes the area more easily monitored. Cameras monitoring the most important areas for the residents send images to a chosen TV channel were also introduced.
- Some parts of the ground floors were redesigned to introduce some community facilities like:

Flat Transformation – Micro Scale

As part of the housing modernization changes of the flats were included. The following are the proposed solutions:

- Extending the flats with new elements that would be front-ended from the wall face and adding balconies, loggias, or other elements of horizontal communication elements.
- Redesigning the interior layout of the flats by adding built up elements, such as: roofs, balconies, green houses, penthouses, and loggias by introducing moissonnette type of flats.

- Rebuilding the flats by: extending or reducing them, connecting or dividing them within the existing outline of the buildings in order to adjust them to the changing needs of the residents. On the last floors the bigger, dual-level flats were introduced to meet the expectations of larger families, those consisting of four or five people. The lower floors include one-level flats. The pictures 2 and 3 present the housing before and after the modernization.

The results of all the studies, analysis, surveys, and site inspections carried out indicate that the housing estate described in this paper should undergo wide modernization process. Built in the 1970's and 1980's, they serve as a perfect example of prefabricated technology and struggle with the typical problems connected with this type of housing development (social, architectural and urban problems). As a result of my considerations, sociological research, psychological analysis and the overall analysis of the resident-friendly contemporary housing developments, the preferences and systems of values were identified and they serve as the basis for housing developments modernization.

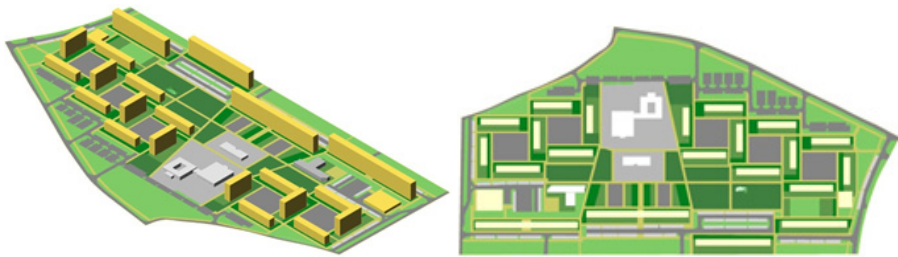


Fig. 2. Huby, housing estate before modernization

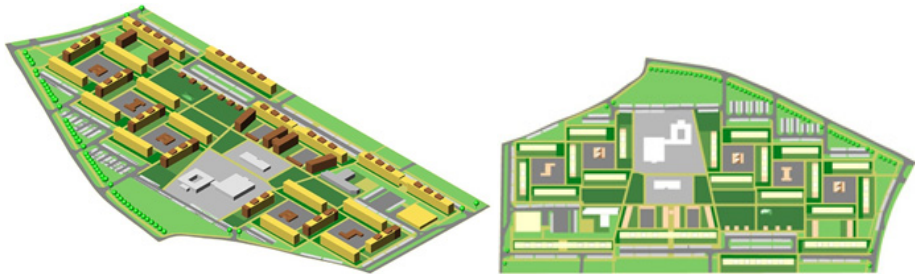


Fig. 3. Huby, housing estate after modernization

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The Current Possibilities for Controlling Parameters of Environment of Housing and Workplace Based on the Selected Architectural Realizations

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Abstract. In the introduction the author outlines the scope of the present possibilities to control internal parameters of internal climate in buildings. As an example the author analyzes the relationship between the systems applied in MGP office building in Katowice, Poland and the quality of work environment, comparing at the same time the financial aspects of using building management systems in public and residential buildings.

Keywords: parameters of inner environment of a building, sustainable design, tri-generation system, Maria Goeppert-Mayer building in Katowice Poland.

1 Introduction

Deep analysis of human-computer interaction in a building, which nowadays is an artificial environment of life, leads to the observation, that in this particular area a computer is a tool, which scope of activity is focused on controlling and regulation of conditions of life to ensure the required parameters. This artificial environment is nowadays increasingly controllable. We can adjust the temperature, the amount and intensity of light, humidity, we provide inflow of fresh air and control noise reaching from outside, assure security against trespassers or fire hazard. Tools to achieve the above-mentioned parameters are the final link in the chain, because technology addresses the needs of modern man and is not an end in itself. This is a special group of tools (devices or systems together with appropriate software) meant strictly for controlling and influencing the above-mentioned parameters and not for the intangible culture or interpersonal interaction. However, back it has an impact on physical and mental health of man, his well-being as well as finances, so it has to be carefully designed, programmed and used. It is also associated with the specificity of the present times, when other spheres of life such as work and commuting take more time, and a man needs a tool that would free him from the burden of remembering to and spending time on monitoring and maintaining the buildings where he lives or works. Examples and discussion of solutions is specific to the territory of Poland, in the field of devices or systems for achieving specific parameters of an environment of

contemporary building. Modern possibilities to apply these devices or systems are closely related to financial capacity, as well as economic, cultural and climatic conditions.

2 Specific Climate of Poland

“Poland has a moderate climate with both maritime and continental elements. The seasons may look quite different in consecutive years. This is particularly true for winters, which are either wet, of the oceanic type, or - less often - sunny, of the continental type.” [1] „The average temperature in the summer ranges between 16.5 ° C and 20 ° C, in the winter - between -6 ° C and 0 ° C. The average annual air temperature in Poland is 7-9 ° C (non-mountain areas).” [2] “Day length at selected locations Polish varies depending on latitude. Warsaw longest day is 16 hours 47 minutes, and the shortest 7 hours 42 minutes.” [3] As you can see our climate in Poland demands buildings to be designed in response to varying weather and solar conditions.

3 Parameters Which We Control

As already mentioned, we tend to control as many parameters of inner environment of a building as possible. The level of complexity of electronic control depends on the type of a building as well as preferences and the wealth of the investor (user). The basic group of parameters is temperature of air and service water, the amount and intensity/direction of light, humidity, and inflow of fresh air, levels of acoustic and thermal insulation. The required (calculation) levels of the-above parameters are specified in building regulations. Generally speaking, in our country the most popular is the use of electronically controlled heating and mechanical ventilation systems, together with the use of recuperator and safety monitoring. The more complex systems one incorporates in a building, the more money it takes but also the more comfort and efficiency it brings. This is not very often though, because the purchase and implementation of advanced equipment and systems often exceed the benefits of saving on the cost of building maintenance.

3.1 Economy: From Air-Conditioner to Intelligent Houses

Very rarely an investor planning to build a single family house in Poland can afford more sophisticated equipment, but if so, then we are dealing with so-called “intelligent house”. There are companies offering wired or wireless solutions, in various options. Such buildings provide significant cost savings, thanks to the heat management. This makes them not only functional, but ecological and less expensive to maintain. Simple and intuitive handling of the system according to the author is nowadays not much more difficult than operating a single device. In public buildings, such as office buildings, we take for granted that the level of adaptation of the system to individual preferences must be limited to some extent, due to the well-understood and well-being of all employees and proper operation of the building, especially because these buildings are mostly much larger than single-family houses and thus the system of installations is

much more complicated. Example would be office building, so-called MGM named after Nobel Prize winner Maria Goeppert-Mayer in Katowice¹ Poland.

3.2 Human-Computer Interaction in MGM Building

As starting point very important information to find the man's place in this high-tech environment: „The Upper Silesian Industrial Park (“Gornoslaski Park Przemyslowy”, GPP) has celebrated the opening of its first office building erected within GPP Business Park.² This is the first office facility in Poland that uses a green infrastructure of the tri-generation system. The innovative system enables a simultaneous generation of electricity, heating and cooling from gas*. The energy will be produced in the building. ‘Thanks to the applied solutions we expect to save up to 40-50 percent of energy that is used in a typical A-class office building’ – explains Miroslaw Czarnik, chairman of GPP. ‘We decided to apply the tri-generation system as the building has to be competitive on the office market in 20 years from now. Also it has to meet future requirements of EU directions concerning the policy for low-cost buildings.’ Demand for heat energy in the building will not exceed 72 kWh per one square meter yearly. [4] „The Goeppert-Mayer building is the first office building in the country using the tri-generation” – commented Lukasz Sajewicz, director at Viessmann Polska, a company that provided the system for GPP. Also, GPP is applying to obtain a BREEAM certificate for the building. The initial assessment carried out by Buro Happold proved that the project has a chance to achieve a high rating in the assessment method. It is possible to obtain the ‘Excellent’ or even the highest available rating – ‘Outstanding’.” [1] The building was named after Katowice-born Maria Goeppert-Mayer, a Nobel laureate in physics. She is the second female laureate in physics, after Maria Curie-Sklodowska. The building is located at 33 Konduktorska St. It was erected in 18 months by Budus (construction) and Spec Bau. The usable area of the building covers 7 800 sq. meters of which 6 800 sq. meters are designed for lease.

* The tri-generation system enables to produce the energy by a piston engine installed in the Goeppert-Mayer building and being powered with natural gas. The mechanical energy produced by the engine is transformed by a power generator into electric energy. The waste heat received during that process and rejected by the generator is used for water or office spaces heating. Cooling is achieved by passing the waste heat to an absorption chiller. As the network is local there is very little energy lost in transmission.”[4]

¹ Katowice is a city in Silesia in southern Poland. At the time of Maria’s Goeppert-Mayer birth in 1906 Katowice was Kattowitz, a city within the province of Silesia, Prussia - a German kingdom from 1701 to 1918. In 1922 it has become Polish territory. Since 1930 Goeppert-Mayer lived and worked in USA. She was awarded the Nobel Prize in Physics in 1963, shared with J. Hans D. Jensen and Eugene Paul Wigner. In 1967 came to Poland as a guest at the 100th anniversary of the birth of Maria Curie-Sklodowska but unfortunately she could not visit her hometown. Office complex GPP BUSINESS PARK, dedicated especially for companies in the BPO (Business Process Outsourcing) and SCC (Shared Service Center).

² September 1, 2012 For more details and to see photographs of the Goeppert-Mayer building, and especially of colorful effects of music and light show during the great opening go to <http://www.katowicethecity.com/gpp-opens-goeppert-mayer-green-building/>

Human interaction with the control system of the building takes place at different levels - active: design, technical control and use, and passive - the mere presence of a man associated with heat recovery and operating of other installations. Here are the details described by the chief architect of the building, Mr. MSc. Tomasz Tumas, in an interview with the author of the article, also a practicing architect what is a platform for understanding, choice of what is important and formulation of questions to which the answer are the following data:

The scope and levels of active influence on the systems: „An overriding level - the designer who took the assumptions of efficiency throughout. Based on the concept of the building computer simulations of thermal comfort were performed by PhD Andrzej Baranowski at Silesian University of Technology. The analysis was to confirm the assumptions of operation of the system with the assumed parameters of regulation. Next to that stage were made the exact analysis of the parameters of sources of heat and cold along with analysis of the merits of financial investing. Designs presupposed the possibility of obtaining a flexible increase or decrease the amount of air, heat and cold between floors, depending on the needs of the tenants, as their needs differ greatly from each other. Parameters of facade and roof insulation are of highest level, there are as well triple glazing windows and external blinds automatically controlled to reduce the impact of external climate on internal conditions. Second stage is the implementation of the arrangement of space by tenants and system programming according to the guidelines - in this stage parameters of operating of installation are defined and it is determined how an object will allow interventions in these parameters to individual users to achieve the assumed energy efficiency parameters. Some parameters are assumed as superior - which must be approved by environmentally conscious user - e.g. inability to raise the blinds completely in case of extreme temperature outside in the summer and full sun exposure of facades - the user can change the angle of slat blinds but the system is to completely block the possibility of raising - which would lead to overheating of rooms and excessive heat gains. Then the phase of exploitation - technical team is constantly analyzing parameters obtained in the premises of individual tenants and the entire building, and the regulation seeks to achieve the assumed minimum energy consumption. Training users in the operation of systems of the building and how to use them in a way that ensures sustainable use is also essential. Supervision of the institution awarding the BREEAM- 4 certificate checks to verify the scope of the implementation of the project and the actual performance achieved by object.”

Passive influence on the systems: “Number of people ensuring no need for heating is difficult to define without a practical knowledge of how they work, what equipment is used, etc. You can specify that number entirely theoretically by doing calculations, but they can only be done for reference rooms and not the entire building. Therefore, our monitoring of performance of the building in the future will tell what the resulting parameters in the various ways of the use of the building space would be. We will publish the results after the first full season.”³ Feedback effect on the users of systems applied: „The first effect is the awareness of the contractors and Investor that

³ The article was written in February 2013 In Poland so-called heating season due to weather conditions of autumn, winter and spring lasts from about middle September till middle April depending on temperatures. The length of it shows how important the energy efficiency is.

marketing activities are the easiest way to verify in the field of energy efficiency. Users, renting office space are also of higher consciousness and ability to control how changing of the conditions of the external and internal climate influences their way of working, comfort, efficiency and so on.” Moreover „The concept assumed to create a Class A office building, elaborated in every detail in terms of functionality and visually characterized by efficient energy management and also, and perhaps above all, creating a friendly environment for people to work therein. As demonstrated by recently published research by scientists from the UK efficiency of employees working in facilities like Green Buildings is 20% higher compared to conventional buildings. Meeting the assumptions of the sustainable and energy efficient building required the use of the highest quality, ecological building materials, high-performance insulation and installing specialized building systems such as: - Tri-generation system used for the production of electricity from natural gas, where the waste phenomenon in the production of electricity is the production of heat. This heat is then used for the preparation of hot water, heating the outside air in a ventilation system, as well as for the production of cold. - Intelligent lighting and external blinds control system, analyzing external and internal illumination, the direction of the sunlight, the sun dazzle and glare reflections from neighboring buildings. The entire installation maintains required light intensity, with a maximum of contribution of daylight from the outside, at the same time detecting presence of people in offices. - Highly efficient ventilation system with heat recovery, heating, cooling, dehumidification and humidification, with smooth regulation of efficiency. - system of heating and cooling beams and VAV flow controllers to maintain proper air change and performance comfort. - A number of temperature/ CO₂/humidity sensors - all to maintain high standards in the field of air quality and the optimal distribution. - High Efficiency system of lifts with energy recovery, and many other cooperating systems exchanging information, and all of this, on the one hand to make optimum use of available media, and on the other to be in line with the principles of respect for nature. As Mr. Lukasz Sajewicz, Viessmann Sp. z o.o. says, Tri-generation system is an innovative technology solution that is ideal for office buildings. With this system devices not only produce electricity and heat, but also cold, which in office buildings is required in large quantities, especially in summer, with high temperatures that often are burdensome. The interest in tri-generation shows the number of queries which the company Viessmann receives in recent times by the architectural practices. They believe that in the near future that type of solution will become common in Poland. The complexity of the systems that are in the tri-generation means that the user receives the best economic parameters of it. How many things are combined together determines the payback time. Analysis of the profitability of a tri-generation system used in the building of the Upper Silesian Industrial Park has been made very carefully. On this basis, Mr. Sajewicz says, they can conclude that the period of repayment of that investment should close during 4-6 years. Used by them in this building tri-generation system has another important advantage for all future users. The system can be powered not just an ordinary natural gas, but also other types of gases – biogases, liquid gas and gas mining, which in the case of Upper Silesia is of particular importance in view of the industrial character of the region. [5] This in the opinion of the author of this article has also an impact on

inhabitants of Upper Silesia region which is the aspect of interaction in a wider perspective on a larger scale.

Swegon Sp. z o.o. is the company that supplied the building of GPP in complete air-conditioning system, its control integrated with the Building Management System. Swegon GOLD air handling units with full equipment and instrumentation hardware AKPiA offers fully automatic operation of units integrated into the BMS system, with the functions of monitoring and control. The system contains integrated with each other, centrally located temperature and humidity sensors. This will enable the analysis of the level of CO₂ in each of the floors, cutting off fresh air and keeping the minimum temperature for rooms where there will be no work done. Central air humidification is achieved using a new generation of water humidifier Swegon, whose electricity consumption is four times less than traditional steam humidifiers, and the work of a system guarantees lack of formation of legionella. The system provides the minimum indoor air humidity of 40% and, if necessary, control of moisture can set drying of outside air supplied to rooms at the same time regulating the temperature of ventilation air and the refrigerant, to avoid vapor out dropping in the cooling beams. The system ensures no possibility of legionella bacteria in air duct systems and chilled beams. This allowed no necessity for condensation water drainage and pump systems and fan units in cooling beams which significantly reduces operating costs and reduces the risk of disease caused by too dry or too humid working environment. Air distribution takes place in single zones by induction fan coil units brand SWEGON (the so-called heating and cooling beam). According to Mr. Wojciech Machowski from Swegon Sp. z o.o. complete air conditioning system consisting of a GOLD air handling unit, cooling – heating induction beams, refrigerating unit and adiabatic humidification is a highly efficient system designed to provide optimum air quality while minimizing energy costs. It is known that thermal energy for buildings is the largest component of operating costs. If we used a heat recovery system and cooling of air in a building used more than 80%. [5]

Here we touch another important aspect of human – computer interaction, which is also very important in building industry. Any system applied in objects designed for people has to be not only efficient from the point of view of energy consumption and economic factors; first and foremost it has to be safe from the point of view of human health and ensure comfortable conditions of living or/and working.

3.3 Ergonomics and Aesthetics

As the author is also a practicing architect, ergonomic and aesthetic aspects are as important as the economic and technical. Ergonomic aspects in the case of this article are equal to efficiency of use in terms of comfort of a user - referring both to effects and the very act of adjusting – how one can operate it, and the comfort and easiness of it. What concerns aesthetics, it is vast topic that deserves a separate study from the point of industrial design and trends. What we can say in regard to MGM building in Katowice, it is interesting that light-show (mentioned earlier in footnote 2) was prepared for the opening of the building, but active systems of lighting facilities are now also being increasingly used, for example, active lighting changing color of surroundings. Furthermore, as mentioned in technical information on MGM building, supplied by architect Tomasz Tomus, another advantage is the flexibility in the arrangement of

the system of open plan or corridor arrangement of premises through the use of fire protection valves on the exhaust installation which allows tenants flexible arrangement of space and changes without having to rework ventilation installation in respect to fire hazard restrictions.

4 Future

Possible scenarios and questions about the future development of technology in the construction industry and its impact on human life take us to the world of science fiction books and films. On one hand, technology can become means of obtaining freedom to allow human to full disposal of one's time. In this case, the technology is hidden in the background of human activity. In the second scenario, a technology that has reached a high level of development (artificial intelligence) may become a human partner, be programmed to be a friend and guardian of man. In this case, the technology can play a very important, even a primary role in human life as a being of high autonomy.

5 Summary

Overview of influences and interactions between technology and its user in architecture, including aspect of the aesthetics of technology leads us to a conclusion, that the architect as a unique profession that combines many topics together - architect's responsibility covers both technical aspects as well as the appearance of the building and its installations and control systems. Architect sets the parameters and the corresponding industries provide the tools to achieve and control them, and once again selection of these tools lies in the hands of the architect who takes into account the aesthetics of them in the context of the building and its interior. As a result of a design, we expect that the technology in combination with the aesthetics will provide a good quality of life for the users of contemporary building.

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The Computed-Aided Judiciary – How the Contemporary Technologies Change the Courtroom Design?

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Abstract. The introduction of multimedia electronic systems changed the legal practice over the last decade. The presence of computer-aided techniques such as information booths, digitalized case lists and land registers, e-courts in selected case categories, and electronic registration of the proceedings have entered the courts. Juristic buildings are permeated by sophisticated technologies, some of them influence the spatial organization of the courts. Has this change impacted courthouse architecture and furnishings? In order to answer this question the paper presents some implications of the implementation of computer-aided jurisdiction. The paper concentrates on the problems of architectural and acoustic requirements for the courtroom in view of electronic registration of the court proceedings; spatial needs for new types of rooms ie. electronic land register reading rooms, e-courts, secure teleconference and hearing facilities, server rooms; spatial and ergonomic requirements for the location of electronic information devices such as secure info-booths and electronic case lists.

Keywords: architecture, IT in courtroom, spatial organization of courtroom.

1 Introduction

The image of the courthouse is one of the most traditional institutions conceivable. Law court is often depicted as a historic building, whose architecture conveys the concept of reliability, permanence, and venerability, whereas the institution itself has undergone a very serious change, largely due to the introduction of contemporary technologies. To quote F. L. Lederer: “the impact of technology on courtrooms and courthouses is, and will be, multifaceted. (...) A proper understanding of its effects on courtroom and courthouse design requires a review of contemporary courtroom technology. Courtroom technologies can be divided into the categories of administration, interpretation, court record, counsel communications, remote appearances, information/evidence presentation, jury room deliberations, assistive technologies, and infrastructure”[8].

The introduction of IT equipment does not only change the functioning of space, and bring new furnishings into existing rooms, it has broader implications, perceptible

to an architect. Traditional courtroom space was conceived without considering such architectural questions as: ergonomics of furniture and fixtures, acoustics, sightlines and light control. The functionality of existing space without any changes seems doubtful. In order to provide proper working conditions in a courtroom, adaptation of existing rooms for IT purposes should be associated with extensive refit. Conversely, the technological revolution did not to date, change the basic functional patterns, like access zones, functional clusters of rooms and like, some innovations, like emergence of e-courts, have no architectural impact at all.

2 Architectural, Lighting, and Acoustic Requirements for the Courtroom in View of Electronic Data Presentation and Registration of Court Proceedings

Until the dawn of the 21st century the courtroom was basically a traditional space, often in a historic building, with few technological improvements such as sound amplification systems. From the onset of the 21st century, many countries experimented with different tools for automation of the court records [14] in search of the most effective and least time-consuming procedures. For more than 10 years now the Research Center for Legal and Economy Issues of Electronic Communication at the Faculty of Law of Wroclaw University (later referred to as CBKE) has been developing IT solutions for Polish justice system. One of research fields of CBKE was electronic civil court procedures recording system, being now implemented throughout the country. Polish Ministry of Justice regulations as to the court records since 2010 instigated digital recording as the obligatory form of court record of all civil cases in appellate and district courts. The technology is put into operation in nearly 500 existing courts as well as in new ones [6], without any guidelines for architectural refit of adapted spaces as yet.

Architectural Considerations. The introduction of IT technologies in the juristic system is viewed by a vast majority as purely technological innovation, unrestrained by the architecture of courthouses. However, it is the comfort of work, not the access to technology, that is at stake while launching IT systems in the courtroom. To quote one of the court IT systems pioneers, hon. Justice Janis Graham Jack, US District Judge Southern District of Texas,: “technology (in court) can be very efficient, very exciting, it can also be very disruptive”[5]. Court electronic technologies and courtroom fittings have to match in order to form a working environment. This working environment cannot be properly designed without architectural refit, even if many faults of the surrounding space may be overcome by technological solutions.

Architecture has to accommodate the new requirements of the space by designing:

- ergonomic placement of permanent and movable equipment,
- adjustment of sightlines for better perception of projection screens and/or computer screens,
- corrections of room lighting,
- adjustments in building acoustics,
- aesthetic blend of the IT environment and justice facility interior design standards.

Architectural design determines the level of flexibility of the space of a courtroom by adding well chosen finishes and fittings, like raised access flooring, adaptive suspended ceiling elements, acoustic wainscoting, location of additional sockets, and movable furniture [12].

Adaptive Reuse Problems. Extensive use of IT equipment within historic buildings may cause serious problems with the hardware[12]. The most challenging, apart from the functional issues are: placing of ducts for HVAC and computer cables, furniture upgrades, window blinds, and acoustic adaptation. Any works, conducted within a listed building should be reversible, ie. allow the future generations to restore the original state of the building. This rule of conduct poses a very hard task for the designer and calls for very flexible solutions with as much movable elements, as possible.

Courtroom Acoustics. To design a functional courtroom one has to decide on its physical dimensions considering desirable sightlines and acoustics. These should be augmented by the choice of finishes and equipment as well as furniture. Courtrooms are considered by the acoustic science as small to moderately sized rooms, therefore their proportions can be derived from Bolt's conditions: a tool for dimensioning rooms with good acoustic characteristics [15], and furnished with so-called acoustic adaptation finishes.

Good quality of court acoustics can be achieved in courtrooms where reverberation times do not exceed 1 sec.(0,7 – 1), and background noise level at 20-25 dB [10], with RASTI index no less than 0,6 [15]. With the implementation of video recording of court proceedings, and the introduction of extensive amount of electronic equipment the requirements as to the courtroom size, finishes and their acoustic characteristics changed only slightly. The main considerations remain: reverberation time, speech transmission, and acoustic insulation of the justice building and its elements [2].

In a very small courtroom the main source of sound is direct sound propagation, but within room larger than 150 m³, the reverberated sound prevails. Acoustic conditions of hearing are associated with sound absorption, of which 90% is provided by the persons present [10]. Courtroom designer should take into account the problem of decreasing number of people attending court proceedings, and consequently, allow for a larger amount of absorbing surfaces in the room to attenuate this effect (see Fig 1).

Currently, the main design problem is the quality of the recording of court proceedings. Acoustics for the best hearing conditions is not the same as the proper acoustics for recording. To obtain the preferred recording conditions shorter reverberation time (RT factor lower than 0,6 sec) is desired, which may be considered in the architectural design of new premises; the undesirable effects of indistinct speech in existing buildings can be eliminated by the use of directional microphones for recording, and directional loudspeakers within the room.

High speech intelligibility seems to gain importance as well as the use of acoustic absorbers to exclude long reverberation times, and provide comfort zones for counsel. Although the judge, litigants, counsel and witness are located within the area of good direct sound propagation (up to 10-15 meters from each other), the recording of the proceedings may suffer from noise, long reverberation times, fluttering echoes within

the courtroom. Sense of privacy in consultation between the litigants and their legal counsel within the courtroom and for the judges should also be considered in the high-tech court. The principles of room acoustics require that the front part, containing the judges' bench and seating for litigants should be furnished with sound reflective surfaces for early reflections, esp. from above [1], while for obtaining the aforementioned privacy there should be overhead absorbers introduced [3]. Alternatively, acoustic comfort may be drawn from the introduction of sound screening noise, a solution, that has been lately put into practice in some US courtrooms.

Although Polish courtrooms are in general considerably smaller than US courts, because of great variety of their dimensions and finishes it was not attempted to draw guidelines for acoustic adaptations of courtrooms [3]. To avoid problems with acoustic refit, the in-situ experiments of CBKE, conducted in a historic courtroom in Wroclaw District Court were concluded with highly technological solutions. A method of recording separate sound tracks for 4 different zones of the courtroom: the judges, litigants and witness, electronic mixing and noise reduction, was chosen and later established as the official requirements of the Ministry of Justice for courtroom recording technology[4].

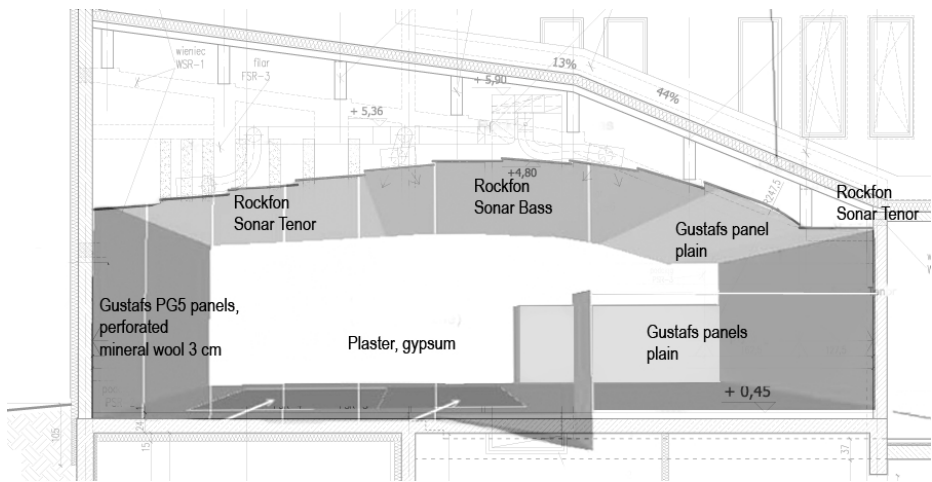


Fig. 1. Acoustic adaptation of a conference-type courtroom in Zabkowie Slaskie, architect: R2 Biuro Projektow Rubik L., G. Hryncewicz-Lamber et al., acoustics AVProjekt, P. Barczynski. Area; 124m², volume: ca. 550m³, RT-0,7, average RASTI-0,62 at 40% audience present, sound system to be provided by the user (author's own drawing).

Sightlines. The viewing range of the public, and litigants in the IT courtroom are different to the ones in traditional courts. While the role of the judge's and jury sightlines are still the most important issue, a new point of focus is added. The screen, or screens placed in the room play an important role, one of the exhibit / evidence presentation place, which has to be clearly perceived by all parties involved in the trial.

Technological inventions enable easy evidence observation for the participants with the use of scanners and document cameras focusing at exhibit tables, although the equipment employed may in itself be of quite large dimensions and require a location within the courtroom well, not obstructing the sightlines.

Real-time recording of the proceedings is a new concept in many countries, although not in the US. Video recording augmented by extensive use of computer technology will shortly be the main medium of court records, therefore a secure placement of cameras in the courtroom, providing the view from the judge's perspective is extremely important. Overhead cameras, installed in the majority of Polish courtrooms provide a composite view on the screens: wide view of the the room (recording a view comparable to the peripheral sight range of the judge) is complemented with a inlet of detailed view of witness or expert lectern [6].

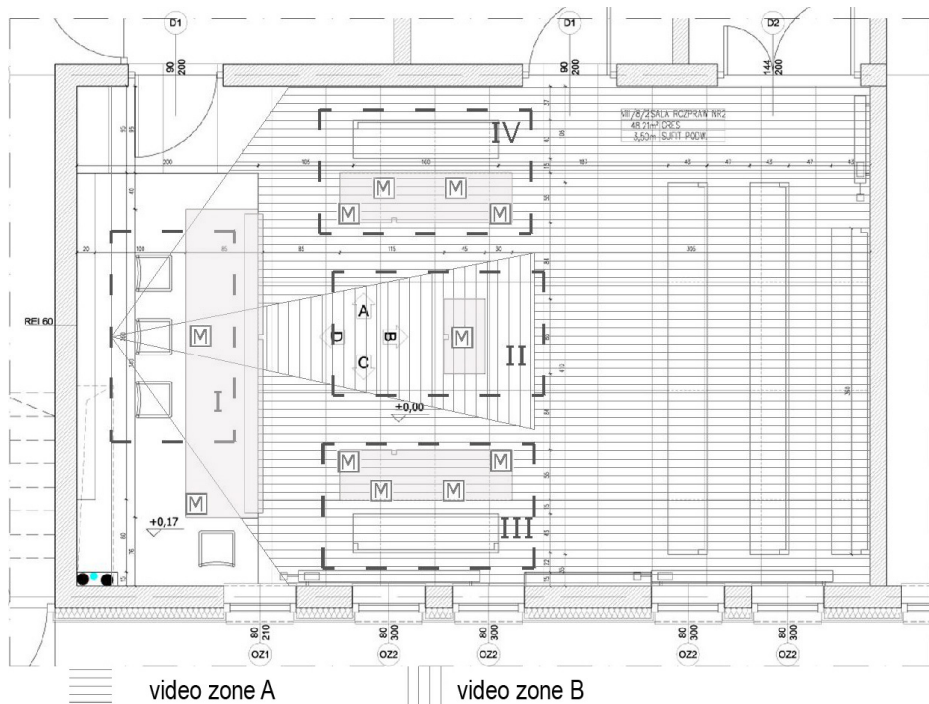


Fig. 2. An example of Polish audio-video court recording system technical requirements: I-IV audio recording zones, M – microphone locations, A- wide view camera range, B-camera focused on witness's range (author's own drawing).

Lighting. Introduction of IT technologies brought about two major changes in courtroom lighting: the increase in required light intensity and the need to control the amount of daylight.

The requirements concerning proper lighting for workspaces furnished with computers are more demanding than those for other workspaces (light intensity of 500 lx at table surface). Judge's bench and counsel tables, as well as jury seats should be

considered as computerized workspaces, which means that the lighting of many existing courtrooms may prove insufficient.

Moreover, the lighting should be operational to work with overhead projectors, turning off or dimming of selected light sources required, while watching exhibits or documents on screen. Courtrooms with natural light should be equipped with window shades, allowing for blackout, and partial screening of daylight.

With a large number of light sources, cameras, and projectors it is advisable to rethink the type of architectural lighting and finishes introduced to avoid glare and uncontrolled reflections. Surfaces with satin or matte effect are recommended [9].

3 Spatial Needs for Data Storage and Transfer, Remote Appearances and E-Courts

With the shift from paper data to the electronic ones, the courts face the same challenges, the libraries have undergone before. These are: the digitalization process, the change from paper to digital data storage requirements, server room within the building and remote location, remote appearances environment, spatial needs of e-courts.

Digital Data Storage. Change from one mode of collecting data to another, apart from procedural problems, is at the initial phase rather space-consuming. For instance, nowadays apart from digital recording at Polish courts, there still exist written records, and beside the server-hosted data, each case paper folders with essential information have an attached CD-ROM of the recorded files [4]. The shaft in data processing is neither absolute nor fast, transcriptions to paper being used in some cases. The digitalization is a lengthy procedure, with specific requirements for office space, and specialized equipment needed, some paper documents need conservation and repairs before digitalization. In Polish courts there are data migration offices, formed when switching from paper to electronic land registers. Contemporary architectural solutions should be as flexible as possible to allow for functional change and adaptability, as such temporary uses may take place in any digitalized court department.

Server and data storage require locations in separate rooms. These should be placed in different fire zones than the rest of the court administration, with separate HVAC system, independent electric energy sources (generators, batteries), advanced fire extinguishing systems (gas or water mist of high pressure). The same requirements apply to the local servers for different court departments or different storey, which should be located centrally for technological reasons.

Remote Appearances. New technologies in courthouses bring about dubious functional inference, namely the deliberations on dematerialization of the physical space of the adjudication facilities [11]. Although it may seem futuristic, the remote appearance technologies have already been used in court, which leads to opening of a discussion on the shape of the courthouse of near future. Teleconferencing can be performed in IT courtroom, as long as there is an appropriate space at the remote location, prepared for suspect interrogation, or expert appearance. Most of the courts

with video recording apparatus and large screens are properly equipped for remote appearances, and the technology allows for recording of teleconference data obtained via internet connections. The criteria for lighting and acoustics of IT courtroom apply, proper distribution of microphones and loudspeakers being a key issue.

E-Courts. For an architect, the electronic courtroom is one of the administrative rooms with workstations, and possibly, a larger allowance for data storage. The space for e-court does not require any special features, apart from IT equipment dedicated furniture.

4 Spatial Needs for the Reception Areas

Court Reception Areas. In the 20th century the justice facility with its luggage scanners, and electronic gates at the entrance gained the image of a fortress. Nowadays however we aim at different perception: the image of a more user-friendly institution is looked for [11]. To achieve this, a blend of architecture and IT is needed. Better orientation for the citizens in the courthouse is established by the introduction of automated information and electronic case lists in the building common areas. Above head location of electronic screens in the court's waiting areas and alongside the courtroom entrances should provide good viewing conditions: the size of screens in proportion to the viewing distances, studying their contents should not obstruct movement of other court customers.

Info-booths. Self-help information booths, connected to the court IT system are also a new feature in the courthouse circulation areas. These information points are often equipped with computer screens, and printers, sometimes they also provide the opportunity of court payments (cash or card). Location of these elements within the court's main hall, must not obstruct neither normal circulation nor fire evacuation, and be in monitored areas. [13].

Court Information Offices, Legal Help Offices, and Reading Rooms. Fully computerized information desks are transformed into front office areas with customer seating, comparable to spatial solutions found in banks and office buildings. These offices are in some countries accompanied with legal help offices. Since the range of legal help available at courts differs from country to country, the architecture may also vary, basically these rooms should offer privacy of counsel, augmented by the possibility use of computer and printer to fill and print court forms with assistance of a helper. Accessibility should be provided for all citizens to all rooms of the courthouse, providing comfortable workstations for the people with disabilities in front of help desk. Alongside with the opening of the court front offices, on-line communication between the court and its customers is being established, which enables litigants and attorneys to view information about current cases without entering the courts. [13]. Still there is a need to review the mode of data presentation in the court documentation reading rooms. At present every court is furnished with a typical reading room for browsing non-digitalized data in large folders under physical supervision of a court clerk. With the introduction of digitalized data this starts to be

insufficient. Not all the court recordings, and as for now in Poland - only the audio CD-s, are accessible to the litigants outside of the court. Consequently, these recordings have to be accessed in the reading room through the court computer system [4]. Court reading rooms should be equipped with furnishings and technology for the new media, and adapted acoustically to prevent buildup of noise from printers, audio systems and other apparatus.

5 Rooms Made Redundant in View of New Technologies

The children's hearing room, victims' room, and detention rooms for potentially aggressive criminals seem to be surplus in view of remote testimony possibilities. Bringing victims and small children to the court does not help in their psychological recovery after assault or crime. On the other hand transportation of criminals is inconvenient, dangerous, and costly [8]. Even though no courts are designed without detention areas, the victim and children hearing rooms could be in future conveniently transformed into citizen legal help areas if properly located within the building.

6 Conclusion

To an architect introduction of electronic tools into justice system seems a part of a larger whole, a societal change. For centuries justice facilities were held in the highest regard as unattainable institutions of power. Nowadays, in view of the emergence of the information society their role changed to that of civic buildings, where the information technologies bring about the sense of intelligibility of the space and procedures. This means not only mere transparency of glazed walls, and video registration of the trial. Introduction of audio and video recording in the courtroom was a step towards transparency of the proceedings [7] as well as a major factor of changes in the spatial patterns of the justice system [5]. The functioning of the courtroom space is nowadays affected by the use of new equipment, allowing for remote appearances of witnesses, counselors and experts, video presentations of evidence and 3D visualizations of crime scene documentation. With application of the above mentioned technologies, we will have to rethink the rationale of retaining such functional solutions as suspect in holding transportation to the court, victim hearings in the courtroom, data and evidence storage within the justice facility[8; 10]. New technologies of open society call for more flexible use of the courtroom space and for more user – friendly court interface, that is for easier access to data, with a different type of data in store: instead of paper records more and more digital data incl. videos are to be presented to litigants and their legal representatives. These changes will affect mostly courthouses of first instance – local courts with their confined space and those housed within historic locations, where preservation concerns may impede implementation of new technologies. Technological innovation should be housed in a physical environment conveniently adapted, or designed anew.

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Design Research of Augmented Realty Plant to Depressurize on Office Ladies

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Abstract. Melancholia is regarded as one of the three major diseases by World Hygiene Organization of United Nations. By using two stage questionnaires with virtual plant (named Green Point) design, research focuses on what is the office lady pressure comes from and what product could release her stress? The result reveals that career women have the positive evaluation in the aspect of degree of satisfaction of virtual plant. Being asked for which virtual planting tension-relieving product design style is more likeable, career women prefer pure fashion and lovely look, and have a deep impression on nature and creativity.

Keywords: Adaptive and augmented interaction, Augmented Realty, Depressurize, Office Ladies.

1 Introduction

With the advent of the 21st century, the social pattern changes, many of Psychiatry Branch confirmed the growing popularity of depression incidence. Research project of the National Science Council in suicide cases tracking study plan, proposed that Taiwan's suicide rate has been the highest people mortality rank 9 [1].

Depression is one of the risk factors for suicide attempts [2]. Depression incidence between the ages of 25 to 54 on women is higher than men. The probability to get it of a woman is lifetime rate of a quarter. Traditional family life as the main women, a lot of time in life was beginning to bet on the workplace. Female office workers at the same time play the role of multiple changes. The workplace, the family, and the social pressure is relatively derived with heavy physical and mental load pressure causes diseases of civilization. It causes a great negative impact in the daily life. Therefore, the working women living pressure control with physical and mental adaptation should not be ignored.

Based on the release pressure, the research focuses on:

1. What are female office workers diastolic pressure elements and expectations of demand for the use of the product?
2. Could virtual plant be the good product to release pressure for them?

2 Literature Review

Many researchers have proposed different angles for pressure [3, 4]. Working pressure is undue pressure or burden occupational, and seriously affects the work pressure by psychological and physiological condition due to the competitiveness of the too fast social rhythm [5]. In organizational behavior earliest practical use of scientific methods to verify the pressure by Seley put forward his earliest word "pressure" to introduce in the field of social sciences, that pressure is an unexpected reaction to any demand [6]. Working pressure is physically expected that workers to adapt to the working environment or psychological requirements triggered reaction [7].

Ivancevich and Matteson believe that stress is an adaptive response, and such a reaction is a result of the event for personal special psychological or physiological requirements, personal qualities as an intermediary [8]. By many scholars of different pressure angle, it is stated that the importance of the pressure relieve pressure response may be facing not suited, and we should avoid the pressure to produce the damage done.

By Japan's Hakuhodo Institute, for everyday life, the pursuit of small and possible changes desire in mood, men and women are different [9].

3 Methodology

Two-stage survey is applied. First stage of the investigation is to understand the emotional reaction as Norman did [10]. The second stage of the development is following with a design example to investigate female office worker satisfaction by using it.

The first phase of the questionnaire is divided into three parts, the first part of the basic information (age, education, marriage, income...). The second part of the survey of female office workers for the working pressure of the source of pressure on the workplace, emotional reaction (self-pressure work environment pressure ... and other items) and emotional response handling survey, the third part of female office workers for diastolic pressure demand (preference factors, functional requirements... and other projects .)

The second phase of diastolic pressure through a questionnaire for the appearance of the product design example, use the function, the overall feel, the three categories of satisfaction and massage surveys. On various topics in a very do not agree, do not agree, no opinion, agree, agree very much divided into five scales as Likert (Likert Scale). It is given in 1, 2, 3, 4, 5, as a follow-up assessment of satisfaction.

4 Implementation

Questionnaire of first stage is by sampling female office workers over the age of 18 have some spending power in convenience. Measuring a total of 39 qualified people,

the age of the majority of 20-30 year old, 7 married women, unmarried 32, the data are collected. At the second stage questionnaire experiment applied into female office workers, a total of 54 samples which age most between 20-35 years old with 40 bachelor degree.

Observational survey results of the first stage, various factors cause pressure ranked in descending order are helpless accounted for 66.2% of 258 votes, restless 157 votes accounted for 40.3%, angry 147 votes accounted for 37.7%, depressed 146 votes 37.4%, manic-depressive 139 votes accounted for 35.6%, tense 118 votes accounted for 30.3%, panic 117 votes accounted for 30%, followed by 100 votes or less is sad 97 votes accounted for 24.9%, wronged 89 votes accounted for 22.8%, unfair 83 votes accounted for 21.3%,The other 81 votes, 20.8%, the emptiness 65 votes accounted for 16.7%, fear of 55 votes accounted for 14.1%, fear the 26 votes accounted for 6.7%. According to the survey results show that the society women in the workplace work generally faced with the pressure. Most people cannot get a good reaction. In long-term pressure on the mood, if she failed to obtain the vent window or massage healing will generate negative emotions cause psychological anxiety, mood swings, and physical in the health damage. This stage concludes the emotional reaction (helpless 66.2%, anxiety 40.3%) to further investigation.

In order to obtain the diverse demand factors, an open-ended questions collect female office workers' needs and expectations of the diastolic pressure. Collected data to compare and remove too similar meaning factors, 20 demand expectations are summarized.

Observed diastolic pressure product functions and expectations diastolic pressure has most of the similarities, such as transfer bad mood lovely shape, fun, sense of humor, people immediately vent help to carry natural ecosystems, aromatherapy calms mind as other commercially available stress relief products such as relaxation, help sleep, continuity, humane.

In next step a developed virtual plant designs (named Green Point) for female office worker satisfaction assessment are as Fig.1-4. It comes with 3 groups and 15 questions.

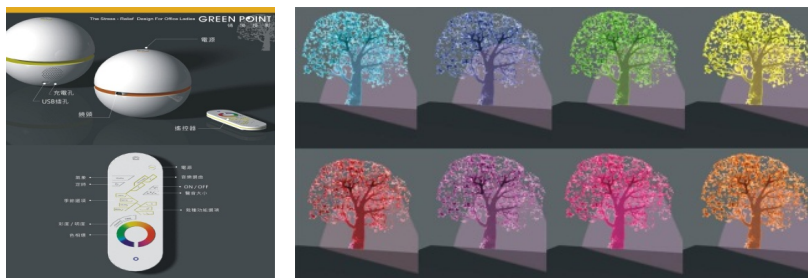


Fig. 1. Ball projectors (different colors match tree colors under)

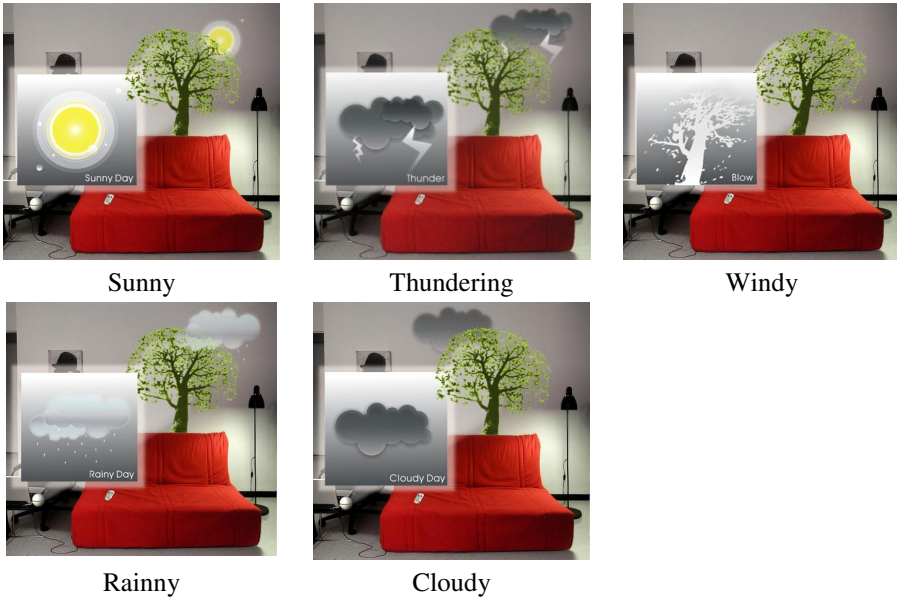
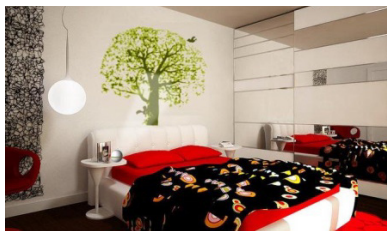


Fig. 2. Simulation of climate

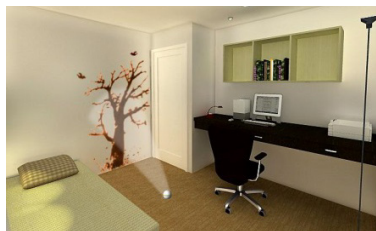


Fig. 3. Simulation of caring

The survey result is as Table 1. Try the practical design of the diastolic pressure, relax the body, mind and spirit, two kinds of healthy living concept as the planting class stress relief product design direction, combination of female office workers and the products they use on the diastolic pressure, the use of behavior, the use of needs of the design elements of the functional and situational settings presented. Through simulation, a questionnaire survey to understand the working women feeling on the diastolic pressure added.



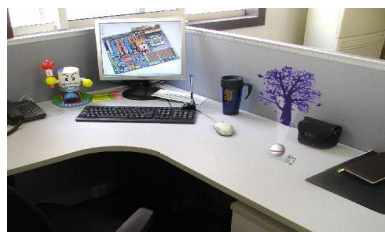
Top front of bed room



Beneath the working table



Living room corner



Office booth

Fig. 4. Simulation ambience

Table 1. Design satisfaction ratio

Question	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
Category	Overall appearance				Using function					Overall feeling					
Satisfaction	Fashion	Lovely	Vigor	Relieve	Humane	Technology	Continuity	Space	Relieve	Relax	Natural	Pleasure	Healthy	Creative	Relieve
Very satisfied	61%	52%	56%	65%	61%	56%	54%	65%	56%	54%	63%	59%	54%	63%	59%
Satisfied	31%	44%	35%	30%	28%	35%	35%	26%	33%	37%	30%	39%	39%	30%	39%
No opinion	6%	4%	9%	5%	11%	9%	11%	9%	11%	9%	7%	2%	7%	7%	2%
Not satisfied	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
High dissatisfied	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Busy working women can easily create a virtual planting to enjoy the sensual pleasure of the natural setting. To get rid of the high-rise buildings in the city and the cold cement, It is comfortable to create the overall space atmosphere by any projection of space and remote control. Planting interaction and situational select, season, weather, music, color etc., use function contains to select overall natural feel .It help the body and mind to relax. At the same time it enhances the sense of self-space, increase environmental decoration, and healing commodity special positioning. To summarize the concept of diastolic pressure, the body mind relaxation and healthy living are two directions fusion of any stress relief design. The interactive relationship from plants and natural context, the transfer of psychological comfort, create a whole space on scenarios to help the physical and psychological release of negative emotions are fun and can build confidence to avoid damage to the health threat to life in negative thoughts.

Different changes in the appropriate context to create a space environment more suited to their mood, enhance self-sense of space, so the atmosphere into which to relax the body, mind and spirit to meet the pressure relieve people more content.

Title of the evaluation to the appearance, use the function, overall satisfaction with the massage assessment experience three types of test items for a total of 15 questions, product appearance is part of the title, including the overall shape is a simple fashion, lovely, with vigor and sense of color matching, the overall appearance with relief pleasure of using 4 function topic contains humane sense of technology, continuity, and the space environment can change the application line the diastolic pressure unpleasant sensations of 5 questions, the overall feel part of the topics contain overall physical and mental relaxation, natural pleasant, healthy, creative, meet the diastolic pressure to help 6 questions.

Design sample assessment project satisfaction ratio as shown in Table 1, the observed design example the proportion of satisfaction found that The design paradigms Green Point planting situations diastolic pressure in the appearance of the shape up to 96% (satisfied or very satisfied) women office workers agree with the lovely feeling, diastolic pressure feeling 95%, 91% agree with the sense of science and technology in the use of functional part, with space applications, while 98% of the subjects agreed to achieve the pleasure of using the overall feel and comfortable pressure help. Evaluation of the above observations found that a majority of 93% of the subjects were given in the design example positive (satisfied to very satisfied), the proportion of 7%, and the evaluation of the negative (not satisfied to very dissatisfied) 0 %, the study based on literature survey results planting scenarios developed diastolic pressure product design examples can really help women office workers to relieve the pressure of self as well as the practical needs.

5 Conclusions and Recommendations

Following are the Conclusions and recommendations:

1. Female office workers under the long-term pressure with the emotions accumulated react mostly in helpless, restless status. Emotions did not get the vent window. Without compression capability, easily lead to negative emotions and mental health threat as Millenson found [11].
2. User needs and expectations are: relaxed, energetic, stylish, creative, space environment changes, natural ecological context and create a self-space stress-relief product.
3. Female office workers have a satisfactory evaluation of simple planting interactive features, the application of natural plant elements is very important for product development.
4. Virtual space environment variation opens a natural landscape window. For working women, not only help to transfer mood to relax, but also improve the atmosphere of tension space.
5. Female office workers prefer simple fashion, lovely sense of style, and natural-feeling creative feelings product. Natural elements, such as planting features can improve to attract women.

A lot of pressure on the formation not only in work, interpersonal relationships, affection relationships, family pressures, economic pressures as Rotter and Robbins mentioned have different types existed [12, 13]. Product demand is different for different sources of pressure on the follow-up study to explore the needs of different design strategies to meet consumer demand.

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Religious and Cultural Aspects in Shaping the Public Space of Hygiene and Sanitation Activities

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Abstract. All cultures and religions of the world, in all their branches and sects, have their own point of view and way of teaching when it comes to the human body, its purification and physiological needs. It was not only the result of social and cultural dimensions of the times, but also the then common medical knowledge shaping opinions and views on these matters. The paper discusses and analyzes the complex religious and cultural aspects affecting the reactions and attitudes towards water, bathing and hygiene practices and defining the range of the needs, requirements and preferences for public health, hygiene and sanitary environment, its form and equipment.

Keywords: public bathing, public hygiene practices, public hygiene facilities, religious and cultural aspects of public hygiene and sanitary spaces formation.

1 Introduction

Undoubtedly, the issue of public health and hygiene conditions was closely related to people anytime, anywhere. Ways of dealing with it was different, not only dictated by the difference of cultures and religions, but also different over the centuries. Available technology had an undeniable part in this, but social, cultural and religious aspects of shaping the public space of hygiene and sanitation activities were far more important determinants. These conditions not only determined the universal attitude to human existence and everything that was associated with it, but they were also deeply rooted in the rights of religious and social rules and norms, the violation of which caused certain legal sanctions.

In deliberations about religious and cultural aspects in shaping the public space of hygiene and sanitary activities a symbolism of water is playing the very important role. Water as a ritual symbol of purification plays a key role in almost all religions. From the first moment when man invented rituals and deities, which gave the cult, the notion of purification was attached to the act of ritual ablutions. Cultic washing was not only cleaning the dirt. It also freed from spiritual impurities and washed sins.

In addition to purification of body and soul, the water would also allow entry into another state of being. Since time immemorial, water has been regarded as a symbol of transition, by marking characteristic moments in human life. Water was also used

during the celebration of the rhythm of the seasons. The use of water was also essential during certain rituals and the ceremonies associated with the initiation.

Development of medicine caused, that religious and sacred significance of water was obscured its hygienic properties. However, the new reactions and attitudes towards bathing didn't smear the symbolic meanings of water. Even though hygiene rules result from scientific bases, the human contact with water and bath have actually cultural importance. Cultural aspects became crucial when it comes to bathing habits in different civilizations. They also influenced the form of public places of hygiene and sanitary activities in various cultures and they shaped the ways of using it.

2 Cleanness of a Body as a Religious Canon

Washing oneself in clear water before paying homage to the gods and deities became part of the ceremonial of every religion. In Egypt, people washed their faces and hands before offering up their prayers to the goddess Isis, while the priests bathed their bodies at least twice every night and twice during the day.

According to the records in the Old Testament, God demanded from Aaron and his sons that they washed legs and hands before liturgical activities. The water, however, was not the appropriate symbol of the spiritual life, until to the New Testament era, when Christianity properly understood bath commanded by Moses, in which the matter and spirituality coincided for the first time. St John the Baptist baptized the first Christians in the river Jordan. This act was replaced much later (around the seventh century AD) by the simple expedient treatment of pouring a few drops to the head. According to Tertullian, the famous Christian apologist of the second century of our era, the water had inherent natural cleansing properties. As a essence of holiness, it could remove all taint and dirt and open the way to the new state of existing.

All the prophets of the great religions - Manu, Buddha, Confucius, Moses and Muhammad - came to the essence of the moral attributes of water, ordering ablutions in their teachings, until finally the water came to be seen as "cleansing the souls" as well as the bodies.

In India, water had the power of giving life, strength and purity, both in the spiritual as well as material sphere. The followers of Brahma bathed once or twice a day, in the holy river or pool, and rinsed his face and hands several times a day. Hinduism imposed on his followers, who want to clean up the flaws, the duty of ritual bathing in the waters of the rivers, which are still regarded as sacred, the Ganges at the head.

In the Jewish religion, the ritual bath - *mikvah* (in the sense of the Hebrew - the concentration of water), was ordered by Moses. According to the Talmud, the Jews may not live in the city without a public baths. Although the *mikvah* is not a cleansing bath in point of fact, because one should be thoroughly washed before using it. It is mainly reserved for women and requires total immersion of the body in clean water at a specific and significant moments in a woman's life: before the wedding (a male analogue exists only for this bath), after childbirth, after a trip, and after touching a dead body. The basic principle of *mikvah* was exactly specified - the water could not be standing, but naturally flowing water. Therefore Jews tried to locate and use a sources or ground water. If this proved to be impossible, it was allowed to collect rainwater. The bath chamber was size about six square meters and it was filled with rose water. Inside of

the tank was available with the stairs leading from the upper level. A small room above the tub was designed for the woman supervising the proper conduct of the ritual acts. Changing room with stone benches against the walls and windows in the frame of precious stones overlooking the surface of water was an additional element.

Muslims, who require total physical cleansing for the celebration of Fridays prayers, have a similar canon, associated the Koran law with the practice of the *hammam* (Turkish public bath). As a sign of purity to Allah, Muslims wash their hands, faces and feet before each of the five obligatory prayers in a day. Ablutions in the fountain are executed when they pray along the way, because, as Sufi science says, "cleanliness is a part of faith." Not without reason, Islamic culture led to the development of the ancient idea of public baths. The *hammam* is compared by Muslims to the mosque, where ritual ablutions are a part of the preparation for the Friday prayers. But in addition to the rituals of purification, the *hammam* is a place serving meditation, spiritual exercises performed in the state intensified sensory awareness, for both physical and mental relaxation. According to the beliefs, the *hammam* had the power of healing seriously ill patients. Even today it is called the "silent doctor". The magical nature of the *hammam*, intelligible only to the followers of Islam, as dictated by their religion and culture, gives it the status of a holy place. But it is not surprising, because that purity in Islam has a rank of holiness.

In Japan, Buddhist rituals dating back to the sixth century AD, were entirely consistent with Shintoism, in which physical health and spiritual purity are inseparable bond. Like most other religions, Shintoism identifies the immorality with dirt, the morality with purity. Bathing in Shintoism is part of a whole sequence of purification rituals, even today in a place of pilgrimage one can hear the sound of the ancient rites. Prior to joining the indoor pool area one should draw water and rinse the mouth and hands. Gifted thousands of hot springs because of volcanic islands, the Japanese consider them to be a gift of the gods to Earth - some of the temples are built on such sources worshiped for thousands of years. The Japanese have one thousand hot springs because of volcanic origin of the islands and consider them a gift of the gods to Earth - some of the temples are built on such sources worshiped for thousands of years.

The water has been regarded as a symbol of passage, by marking specific moments in human life. Bath after birth is common to most civilizations, as well as a ritual bath before the wedding, and the washing of the dead body as a symbol of purity of soul before the journey to the next life.

It was also used during the celebration of the rhythm of the seasons. The Celts and Germanic tribes consisted their thanks to nature for the life-giving rain in the spring, by immersing themselves in a large vat of water brewed with herbs and spring flowers. This custom was known as May Day Bath and maintained today as part of the celebration of St. John. According to a proverb, bath made during this day was worth as much as the other nine baths. Amongst worshipped Slavic gods god of the bath - *Kupala* was especially adored. Old Slavic prototype of the modern bathroom was spacious separate room in the dugout and treated with religious reverence. All important feasts and ceremonies were held in this room. Christmas traditions were also celebrated in it. Slavs feasting on the benches strewn towels. The threshing floor was well compacted and inlaid with ceramics. Night dishes and a bathtub were basic instruments - tub in the form of burned trunk, by hand carved out of the lime tree, which gave the body a unique fragrance.

Water was also used in certain rituals of initiation. In the Middle Ages, before accolade, candidate for a knight having spent the previous three nights in prayer and fasting, then took a bath in a large tub of warm water and fragrant herbs. [2, 8, 9, 11]

3 The Symbols of Water in a Secular Context

Water is a symbol of purification and passage in a religious context. It is also a symbol of regeneration and renewal in the secular sphere. American Indian steam baths symbolized rebirth. They had ways of experiencing the changeable state of existing. Inside conical hut they built the hearth, covered them with stones, and then sprinkled the hot stones with water mixed with cleaning herbs - sage, lavender. Even the structure of the hut was symbolic. The roof was usually made of willow branches, because this tree had analgesic properties. Number of vertical beams, stones over a fire - all had a specific meaning. Before the ceremony the hut was covered with the fabric creating the semi-darkness what symbolized the return to the Mother Earth and denoted safety and protection. Hot steam caused the excretion of sweat - water returning to Mother Earth with gratitude for the food. After opening the door steam rose to the sky, home of the Great Spirit.

In Western civilizations, generally the total immersion of the body represents rebirth - notion the most protected in the symbolism of the bath. To go into water that is to return, completely literally, to the source of life, and even - from the time of the psychoanalysis - to life in the womb of the mother. Floating on the water is connected with a safety. The emergence from the bath gives you a sense of recovery, being a new person. The Demeter worship of ancient Greeks was also associated with plunging under waves in order next to emerge with a new name and with a new life.

Bathing in cold water, the French philosopher Gaston Bachelard, described as a dream of renewal, the "Fountain of Youth", which has the strength and power of rejuvenation. Dreams of restoring to health by water were often associated with hope for curing of ailments and diseases. Ancient Egyptians regarded the water treatment as an effective cure in case of many physical and psychological complaints. In Greece, the health-giving properties of water have been known and prescribed as a remedy since the time of Hippocrates. They were also supported by Galen. In the second century BC Asclepiades of Prusa founded the medical school in Rome, where he emphasized the therapeutic use of water. It was one of the reasons for building the Roman thermal baths and spas localized in areas of natural resources.

Warm springs - the thermal springs - were popular in all ages. However, they became particularly popular in the nineteenth century, when there was a development of medicine and a treatment hot springs and spas actually adopted. Then created balneotherapy and hydrotherapy centers, fashionable as excellent to spend holidays and vacations, a place for the elite. Over the nineteenth century, a strong conviction about the health qualities of water were partly rejected due to the development of science and technology. Religious and sacred importance of water was obscured its hygienic properties. The earlier gift from God and the nature was replaced with the industrial, standardized and sold product. However, new sense of water didn't smear its symbolic meanings. Even if hygiene rules result from scientific bases, the human relationship with water and purity criteria have actually cultural significance. [2, 3, 9, 11]

4 Cultural Influences on Bathing Habits in Different Civilizations

Not without reason, Islamic culture led to the development of the ancient idea of public baths. We are accustomed to call it simply, a Turkish bath. However, the *hammam*, although entered in the alleys of the Muslim cities, carries with itself more than just a bath. The *hammam* fit to the specific logic of the purity of Islam, understandable only to this culture. Practices of the *hammam* are an integral part of the Turkish and Arabic lifestyle. In this place is possible to clean the body, but also to relax and to recreate. Idea of the warm bath (in the Arabic "hamma" means "to warm") is referring to times of the Eastern Empire, but in contrast with the first Roman baths, *hammam* is a secluded place.

Moorish model of *hammam* usually takes the form of the complex of rooms inlaid with a marble facing, where from one is taking a walk to next. The whole structure is formed at the central plan, sometimes takes the shape of a cross. In the middle, the hot room *beit-al-harara* is located, around which smaller rooms are situated radially. The increased marble plate, called the "stone belly" is placed centrally. It is possible to sit it on, to lie down, to take treatments of massage. Dry heat is supplied here through the hot air pipes located under the floor. In the hall there is a twilight, only the a few delicate sun's rays, filtered by small colorful glass holes in the dome, flows into the interior. From here it is possible to go to the steam room where the hot water drips from the ceiling, saturating the atmosphere with water vapor. Here is also the central pool, the *maghtas*. After traditional treatments of massage, stretching out and scrubbing the body, one should wash itself with soap, and then rinse using the fountain. For drawing cold, refreshing water are used iron galvanized bowls. Finally, one should return to the room with the clothes left behind (*maslak*). There it is possible to relax, to drink the mint-flavoured tea, to savour oriental sweets. Religious considerations prohibit use of the *hammam* as the mixed bath. Days of using the bath are set individually for women and men. The *hammam* built in the sixteenth century in Istanbul by Sinan, the greatest Ottoman architect, caused a scandal. Never before it happened that under one roof was part of the masculine and feminine.

Another culture for which the bath is practically a religion it is Japanese culture. Ethics of the bath is rooted in the souls of the Japanese with the appropriate meaning of purity, nature and aesthetics. It is dominant in most areas of their life - art, architecture, literature, crafts. Is related to the preparation and consumption of food. The bath has also become a model indicator of family and social organization. The basis for its ethics, common to all areas, both now and in the past, is the philosophy of Shinto. In Japan, the water is a magical part of everyday life. The attention focused on the daily bath is one of those habits that every foreigner quickly notices. Soaking in hot water is regarded in Japan as one of the greatest pleasures, which it is possible to enjoy in countless places. Despite the fact that almost all the houses are equipped with bathrooms, every district of the Japanese city is retaining *senzo*, a public bath, which has a long tradition. Wealthy Japanese and monastic communities began to open public baths for the poor early in the seventh century. Development of the commercial bathing establishments occurred at the turn of the sixteenth and seventeenth century.

In the nineteenth century, in the capital of Japan there were 600 public baths, which were the most popular meeting place. Residents of the city were coming there not only to wash, but also relax, talk, have fun.

The Japanese often talk about "the brotherhood in the nudity," or bath experience that brings closer people together like no other. It is a way to meet new friends, but also to maintain a sense of community, the interaction of different social classes. Business partners and neighbors listening local gossip meet in the bath. Before the Meiji period (1868 - 1912), in which Japan opened to the world, the order of the day were shared baths for men and women. Suppression of coeducation was introduced only under the influence of Western culture and the Christian missionaries. The principle of separation of female and male parts of the bath is observed in most of these places even today. Only on some thermal water places, bath may be shared between the sexes. Thanks to the volcanic origin Japan has over 26 thousand geothermal springs, called *onsen*. The hot spring water has a minimum temperature of 25 degrees Celsius and the preferred concentration of minerals. It has a therapeutic effect. Bathing in the open air, surrounded by a beautiful landscape, it is a great passion of the people of Japan, deeply rooted in the tradition. Contact with nature has always been an important element of the Japanese bath.

Not important whether in a public place, or in their own home, immersion in the bath without earlier washing is unthinkable in Japan. In the public baths taps with cold and hot water, running at knee height, along the wall on which water drips, were used for this purpose. Public baths for this purpose are fitted with taps with cold and hot water, running at knee height, along the wall on which water drips. In order to use them it is necessary to sit on the prepared small wooden stool. Special bowls are used to pour the body. One should soap the body and rinse, and only then go to the evaporating bathtub. Next the bather should sit on the edge and pour the body with the bowl, in order to accustom the skin to the boiling water. Only after some time, the total immersion and dedication to a relaxing bath are taking place completely. Such a bath in Japan is a part of everyday life. The Japanese use it with great passion, satisfaction and respect, which is reserved for the highest values.

In Japan not only for mortals, but also for gods the bath is a matter of vital importance. Water in the Japanese tradition means not only a bodily purity, but also symbolic, spiritual purity. In the Buddhist tradition, Buddha's birthday is celebrated, bathing the statues in green tea, and main rituals of *shintō* religion are associated with cleaning and water. After escaping from the world of the dead the Izanagi god took a bath in the river, which was supposed to wash dirt of the death from his body. According to the tradition initiated by him, before the entrance to the *shintō* shrine one should wash their hands, getting water from the well. Purification rituals are accompanied not only all religious ceremonies in Japan, but also many secular customs. Dirt is an evil, so it is necessary to get rid of it, best with the help of water and the salt. Special "pyramids" of the salt are standing before the entry to many bars. Sumo wrestlers also fall salt onto the ring. Water, salt, washing, rinsing, cleaning - it is a Japanese secular and religious everyday life. Every meal in the restaurant, even in most second-rate, is preceded by wiping hands with the wet cloth (*oshibori*) delivered at the beginning.

Particular attention that the Japanese focus on *o-furo*, "respectable bath", is favouring them relating to other nations. Statistical Japanese spends every day in the water about half an hour, but also longer baths are not uncommon. Soaking in hot water, they consider to be one of the greatest pleasures, and even daily *o-furo* in your own bathroom usually is not enough. In spite of equipping flats with bathrooms, the Japanese people visit the public baths, continuing the old tradition. Many persons having their bathrooms visit *senjo* or spend their mini-break in one of thousands sources (*onsen*) scattered across Japanese islands. Some of them are ordinary holes in the ground or a rock with a modest guest house nearby, other these are famous luxury holiday complexes.

Interestingly, when it comes to aquatic delights of the Japanese, is the fact that even a bath in your own bathroom they feel for the pleasure especially sociable. It is obvious that they go to *onsen* or *senjo* in order to stay in a nice group, but also immersion in a bath at home in the company of spouse and children is their greatest pleasure. In the bathtub, the vat, or the pool the Japanese people willingly immerse themselves in the company of other the Japanese. People, who dressed, in particular avoid the physical contact, not allowing themselves even for the gesture of matey patting the friend on the shoulder, in *senjo*, whether in *onsen* without the resistance help him to wash the back. Here, all barriers of the status disappear. Japanese bath is an experience that approaches people together like no other. To *senjo* or *onsen* you can go with friends, colleagues from work or invite a business partner. The common bath is also a good opportunity for parents to play with their young children or have a serious talk with teenagers. Also pairs do not shun the common bath and often spend their first vacation at a resort with hot springs. Inviting the guest from foreign countries to the common bath together with Japanese friends is a great honor for him, and in addition unique opportunity in order to see the piece of the naked truth about Japan. Not in vain the Japanese people often talk about the special closeness that creates shared bath, or about the "brotherhood in nudity".

Great passion for the bath, and especially into a vapor bath, is also characterizing the Scandinavian culture. The Finnish proverb says: "when you have already built the sauna, you can build the house". In Finland alone saunas is more than in the remaining part of the world. Here one sauna falls on the one family. It is suggesting the rank of this ancient form of the bath which was brought to Finland from central Asia, through Russia, over two thousand years ago. Practices of the steam room were here closely associated with the fire worship, typical for the distant, north part of Europe, where the winter months, deprived of the sunlight, seem to be infinitely long. Steam bath which exactly warmed the whole body, took place in cells, built from wooden beams, sometimes partially buried in the ground. The most important element was a hearth, stove in later times. Stones from the river were placed on the hearth, even better if they were fragments of volcanic rocks which were being heated up to the redness. Next they were being poured with the cold water in order to release the steam.

In addition to its practical features, a sauna, alluded to many beliefs and predictions. Its name symbolized the maternal warmth and safety and, through its location on the edge of the forest, near a river or lake, harmony with nature. Sauna was the place of cleaning, but also relaxation and deep meditation. It was important to stay in

it with the whole family, or in the company of close friends. The invitation to the sauna still is regarded as a great honor. Using it during the evening symbolized the end of a working day. Particularly important was the bath at the end of the week, and before Christmas, at the Christmas Eve. Now of course, these customs are more fluid, but the tradition remained. According to it, entering the sauna it is necessary to be dry, although many persons today prefer earlier fast washing oneself in the shower. To stimulate circulation and force the body to sweat, the Finns use small bundles of birch twigs. They were once one of the basic accessories used in the sauna. When the body is already enough sweaty one should leave and rinse them with water. This process should be repeated several times. The most important is the last, most profuse sweating, which is the result of increasing the temperature and increasing the intensity of steam. Cold water must be drawn from a wooden bucket with a special ladle with a long, preventing the burn, wooden handle. Then water is poured on hot stones. According to likings it is possible to add to water a few drops of eucalyptus oil. A very important thing is lighting the sauna, which should be the weakest. Candles or lanterns are the best solution. As soon as you get the feeling of satisfaction (bath time depends on the preferences and physical condition), you should wash your body in a room for this purpose, using a natural sponge or brush and finish the process with a cold shower. In the countryside it is possible to use the lake or a direct contact with the snow. Next it is necessary to drain the skin with a rough towel. At the end, you can take one more trip to the sauna heat to keep warm. It is also the perfect time to satisfy hunger and thirst.

The Finns cannot live without a sauna and infinite pleasure of experiencing contact with heat, water and nature, shared with the family in an atmosphere of peace and safety. In order to understand what these few stones on the hearth means to them, it is necessary to see the precision of their gestures associated with bathing and to hear the memories of childhood, which indicate how their tradition is strong. [1, 2, 5, 6, 7, 10, 12, 13]

5 Summary

The bath in the water is a symbol of purification and transition in a religious context, as well as a symbol of regeneration and renewal in the secular sphere. Her strength and power of rejuvenation and health properties, effective in the treatment of many physical and mental ailments, were emphasized and appreciated for centuries.

The reactions and attitudes towards water, bathing and hygiene practices and the range of the needs, requirements and preferences for public health, have cultural significance to a large extent. Cultural influences shaping bathing customs over the centuries also determined the contemporary form of the public area of hygiene and sanitation in various civilizations and ways of using it.

Islamic culture has developed the idea of an ancient public baths. Practices of the *hammam*, for centuries associated with the law of the Koran, are an integral part of modern Turkey and the Arab way of life.

Other culture for which the bath is like a religion it is the Japanese culture. Ethics of the bath survived in the Japanese souls with proper meaning of purity, nature and aesthetics. The Japanese often talk about "the brotherhood in the nudity," or bath

experience that unites people together like no other. Bathing in public baths *sentō*, which is used regardless of their private bathroom, they still believe to be one of the greatest companionable pleasures.

Great passion for the bath, and especially into a steam bath, is also characterizing the Scandinavian culture. To this day, the Finns cannot live without a sauna and infinite pleasure of experiencing contact with heat, water and nature, shared with family and friends. It is estimated that nowadays about half of the two million saunas in Finland are public saunas (in hotels, holiday houses, by swimming pools). Undeniably it is a large number compared to the Finnish population, which amounts to about 5 million people. This number shows the important role of the sauna in the contemporary life of Finns. Indeed every Finn comes to the sauna once during the week, and in the holiday season even every day. [4]

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Touching Buildings – A Tangible Interface for Architecture Visualization

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Abstract. The process of architectural design and urban planning has been fundamentally transformed through digital media. While providing the opportunity to make the process more flexible and open to realize an extensive public participation, they also pose specific problems. *Touching Buildings* is a prototype for a multimodal, collaborative interface that integrates the various aspects of the planning and communication process through a platform for tangible interaction with an open communication system. This paper presents the results of a first implementation of this prototype.

Keywords: Urban planning, visualization, touch interfaces, natural user interface, tangible interaction.

1 Introduction

Contemporary architectural design and urban planning is fundamentally transformed through the impact of digital media. Not only the architectural form finding but also the planning and decision-making structures are significantly altered by digital tools and communication media. Less concerned with questions of form finding, this study analyses the role of new media in the process of urban planning and communication and proposes a new approach to utilize digital interactive media to facilitate these processes while at the same time avoiding some of the pitfalls that might arise from them. Urban planning has become an increasingly complex process having to take into account complex information layers. Digital media have both complicated this process and opened new ways of structuring it and achieving new and so far unprecedented degrees of flexibility and democratic involvement. After a brief analysis of some of the positive and negative aspects of digital media on the planning and communication process we will discuss a prototype for a new multimodal digital interface that can serve as an efficient tool for both planning as well as the communication of planned interventions.

1.1 Urban Planning and Digital Media

Historically urban planning is marked by increasing complexity and while until the mid 1960s it was mostly undertaken by centralized institutional bodies formulating a

master-plan based on surveys and analysis of the surveyed data it has grown to involve more stakeholders, participants and require a more complex and dynamic structure. The master-plan was a fixed goal to work towards, and once formulated it was intended to determine the future development over an extensive period of time. Since the late 1960s the planning methods have changed and become more flexible and open ended. As Hall and Tewdwr-Jones describe [1], in the late 1960s and early 1970s urban planning moved from the “blueprint to systems planning”. Inspired by cybernetics [2] and the notion of an ongoing feedback loop urban planning started to be conceived as an ongoing process that was open to revision and adjustment. The fixed blueprint gave way to an understanding of the urban space as a dynamic system. Equally in the late 1960s and early 1970s new theories of analyzing places such as those of Henri Lefebvre [3] introduced a more complex and layered understanding of space integrating a physical, mental and social perspective.

With online media the dynamism and complexity of urban planning processes has further increased. The influences of the internet on the development and our understanding of places are manifold. Through the creation of a communication and resource distribution structure that is largely independent from the geographic reality that it connects to, the internet has introduced a secondary layer that completely evades traditional methods of geographic surveying and observation. Nevertheless, it has a strong impact on the development and the active forces determining the dynamics of the geographic reality through the physical reality of cables as well as through the resource flows of this secondary information infrastructure, which alters traditional patterns of consumption, work and general social interaction [4]. On the other hand social media provide many opportunities to involve the public into the planning process and establish sustainable forms of participatory interaction to implement the public process, which in many states is called for by law [5]. An example of city planning employing participatory mechanisms is the Future Melbourne project, which used a wiki platform to establish open public engagement [6]. The online-enabled participatory process can become so active that it can pose obstacles to the decision making process as the mayor of New York City, Michael Bloomberg, states: “We are basically having a referendum on every single thing that we do every day, [...] And it’s very hard for people to stand up to that and say, ‘No, no, this is what we’re going to do,’ when there’s constant criticism, and an election process that you have to look forward to and face periodically.” [7].

1.2 Spatial Imagination

While the engagement enabled through online social media has great potential to establish a collaborative and democratic planning process, we also hear in concerns like the one of Bloomberg the fear that decision making gets prolonged with possible failure to make any decisions as they could go against the opinion of at least part of the constituents. Another related concern is that online media allow for comments and criticism to be formulated remotely and in dissociation from the actual geographic site and its immediate dynamics. This abstraction from the actual locality may be increased by the inability to fully anticipate the planned intervention, since being off-site the information flow in online participation has to rely foremost on maps, textual

descriptions, and visualizations. These are rather specialized communication tools specific to the domains of planning, architecture, statistics etc., which are not always readily understood by non-specialists. In general, in order to criticize and judge a planned intervention the commentator has to be able to gain a comprehensive understanding of it. This normally involves a mental representation of the planned and thus not yet existent structures integrating the various aspects of information available.

Various newspaper articles [8] and studies [9] suggest that it is exactly this ability to imagine spatial structures that is hampered by digital media. Our reliance on digital tools like GPS and navigation systems seem to have a negative effect on the ability to navigate space and to create mental maps. It is expected that this decrease in spatial ability will lead to a loss of cultural literacy, as the British Cartographic Society warns [10]. While some of the impacts on the spatial ability of users of navigation devices can be attributed to design issues of the device [11] it is important to note that direct experience of a space is most conducive for the formation of mental representations of the space.

The aid of navigation systems seems to reduce the exposure and the degree of mental processing of the space, thus hampering the creation of a mental map of the place. Meanwhile traditional maps, even though they provide a helpful overview knowledge of the space, introduce the problem of harmonizing the internal perspective (the overview knowledge provided by a map of by surveys) and the external perspective (the spatial knowledge gained from directly navigating the space). The task of harmonizing the two perspectives poses specific cognitive challenges [12]. Conclusively we can say that the direct experience of a space contributes most to the formation of mental representations and the understanding of the complex set of characteristics of this space. Even though digital representations such as 3d modeling and simulations can be efficient tools to support the understanding, direct experience is the most informative and efficient way to form mental representations of a space. In addition to purely visual information it also makes vestibular and kinesthetic information available to form a mental representation of the space traversed. This makes it easier to integrate the different aspects of the space and form a more coherent and rich representation [13].

2 Methodological Considerations

2.1 A Multimodal Approach to Planning Communication

The core question of our project was to find ways to realize the benefits of direct experience and digital media already in the planning communication while avoiding the potential problems associated with them. Obviously in the planning phase direct experience is limited to exploring the site where the intervention is planned, all other aspects need to be communicated through media representations. In the project Touching Buildings we are exploring technologies to integrate information visualization, documentary film, 3d computer-visualization, computer-based simulation, and haptic modeling into one system that is built around touch- and gesture based interaction with tangible objects. The development hypothesis for Touching Buildings is that within the framework of an interactive multimodal interface it will be possible to

integrate the main modalities of urban planning communication leading to a comprehensive understanding of the planned intervention and a platform of participatory communication.

The research for an urban planning project comprises a plethora of different layers of information, which all have their own ways or language of communication and which are not seamlessly integrated into a standard framework or generic methodology [14]. Wang and Groat identify seven groups of significantly different vantage points: interpretive-historical, qualitative, correlational, experimental and quasi-experimental research, simulation and modeling, logical argumentation and finally case studies. The results of these research layers can come in the form of texts, diagrams, plans and information visualization, audio-visual testimonies and observations, computer-generated 3d graphics and animated simulations. For the non-specialist observer these layers of information can create challenges in terms of understanding and readability as well as in terms of integration into a comprehensive and coherent picture. Our strategy to address these challenges is to create a framework using interactive digital media that can hold all of these layers and keep them in a structure grouped into understandable categories and in a coherent aesthetic treatment so that they can be easily related to each other. In order to keep the cognitive load of parsing the information in an accessible range we are using various categories and present specific details on demand, i.e. more detailed information is available upon active request (interface widgets that allow to call up the information) but does otherwise not clutter the display.

2.2 A Shared Tool for Planning and Communication

Touching Buildings is conceived as both a tool for planning and discussion among those involved into the planning process as well as a communication tool for a larger audience of non-specialist users. The requirements for these two usage scenarios are quite different and our aim is to integrate both processes in order to accommodate an open and ongoing planning process that does not hermetically seal the planning phase from the phase of communicating the planned results to the public. Adopting the notion of systems planning we are creating a framework that can access a flexible database with a growing information repository containing survey results, planning decisions, public feedback etc. This database can have an online interface to actively call for participation and thus make the public process an integral part of the system. Despite the online possibility the main notion of the Touching Buildings project is to work as an interactive installation which serves at the same time as an elaborate display as well as a meeting point and a location for discussion. It is meant to foster face to face discussion and the constructive interaction among the users and with the system through a multi-user interface. For the team of people involved into the planning process such a shared physical system fosters collaboration and active exchange for which the normal computer workplace is not conducive. Earlier studies have shown that such multi-user systems can enable collaboration and can be helpful in particular for the domain of urban planning [15]. For the participant in the public process the installation-type system functions similar to an information kiosk but with an open two-way communication, in the future potentially removing the boundary between

on-site and off-site online interaction. For both scenarios the physical situatedness of the system provides a physical and tangible context in relation to the planned intervention. In this way it roots both the content and the interaction in a shared discursive context. Our hypothesis is that this rooting within a shared discursive context with a physical location and tangible interactions with discourse-partners will foster a sustainable and problem oriented decision-making process rather than the prolonged and unfocused exchange criticized by Bloomberg.

In the current state Touching Buildings is realized as a prototype that implements a subset of the possible functionality as a lab-version, and currently does not implement a structure for online interaction.

3 Realization of the *Touching Buildings* Project

3.1 Architectural Model as Tangible Interface Device

The prototype implementation of Touching Buildings examines a part of Downtown Los Angeles which will be the location of a planned transit-hub of the Los Angeles Metro system. The core of the project is a physical model that represents the area in question. The model is touch sensitive and allows users to interact with it by touching its different parts. The model itself is made of laser-cut multiplex and thus sufficiently robust so that it can withstand the interactions of a larger audience. The represented area measures several blocks around the metro station including major landmarks such as LA-Live and the Staples Center and focuses more on the overall city layout rather than on realistic details which would make the model too fragile to be interacted with. The model is plain white and serves as the surface for a projection. In this way the model itself becomes one of two screens that can function as interactive displays. The projection on the model uses projection mapping to display various layers of information ranging from satellite images delivering an aerial perspective of the area all the way to animated traffic simulations.

The interaction is tracked with a Microsoft Kinect depth camera that can locate the hands of the viewers in various positions. This set-up allows us to not only implement a direct touch sensitivity of the model surface, but the hands can also be tracked while floating above certain parts of the model, effectively implementing a “hover”-state in the touch interface. Pointing gestures are one of the basic categories of spatial communication and direction assessment plays generally an important role in the formation of mental representations of space and the testing of spatial ability. We intuitively communicate by pointing to things and integrating this aspect of gestural expression into our interface concept seemed vital. Normally touch interfaces can only react to physical contact and are thus missing the “hover” or “roll-over”-state that traditional mouse-based interfaces have. Adding this layer in its full significance as a form of spatial communication is an important aspect of the creation of an intuitive and natural user experience in the Touching Buildings project. Different layers of information can thus be accessed through “hover”-states and through touching.

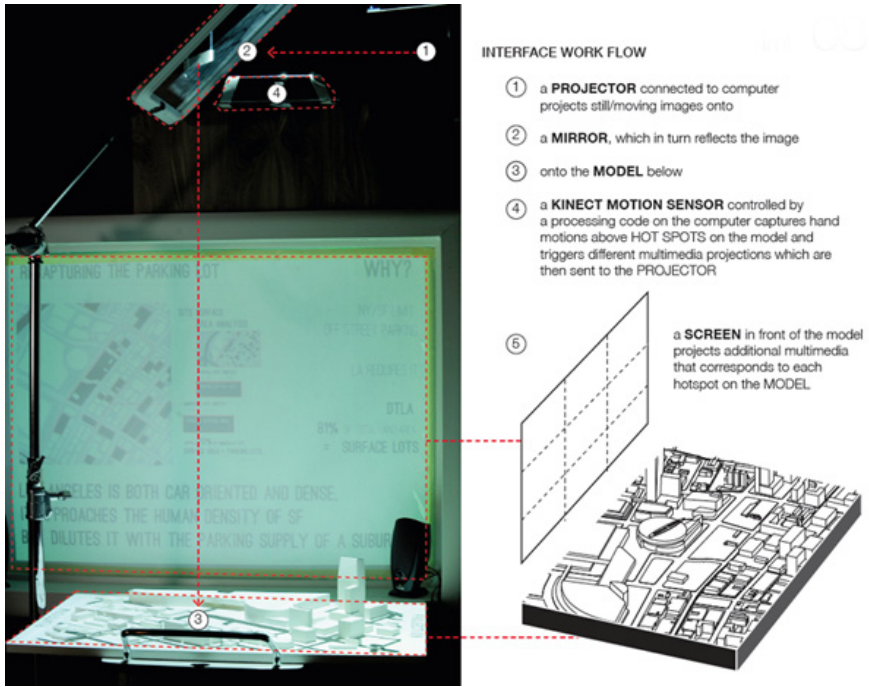


Fig. 1. Key elements of the *Touching Buildings* installation set-up

This kind of physical involvement with the model makes a contribution to establishing some of the benefits of direct experience for the formation of a cognitive map of the area. The added modalities of tactile and kinesthetic sensation contribute to the formation of a more nuanced mental representation of the planned intervention even though they are taking place in a scale model. Pointing to certain aspects of the area and quasi-exploring it with a finger delivers a stronger experience quality than what could be achieved through audio-visual information delivery alone.

3.2 Video-Mapping to Reduce Cognitive Load of Information Integration

The scale model serves in conjunction with a calibrated projection system as the center piece of the installation where all the information layers come together. The projection mapping allows to “skin” the model in different ways and thus display current states and planned states in a compelling way. It can also serve to localize survey data, simulation data and other information directly in the corresponding place of the model. This centralized approach makes it easier for the viewer to relate the different information layers to each other and to integrate them into a comprehensive understanding and mental representation of the planned intervention. The information layers projected onto the model are always connected through their geographic relationship. Rather than looking at visualizations, charts and diagrams the viewer can see the data attached to the localities that they refer to.

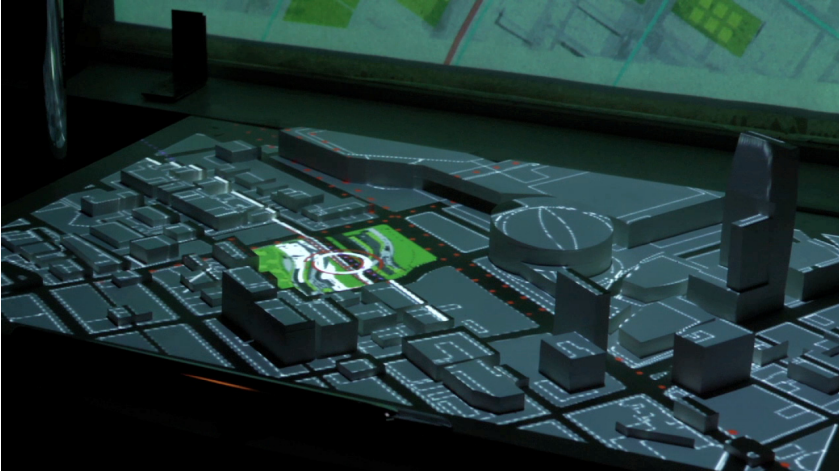


Fig. 2. Animated traffic simulation projected onto the architectural model

The model-screen is one of a set of two screens arranged perpendicular to each other. The second screen can be used to show information that is not pertaining to exact spots on the model, such as interviews and documentary sequences, historical and other background information. We use the second screen further to display information that would be obscured by the pointing gestures or that would be overloading the display capacity of the model-screen. The two screens can also be used in conjunction with each other to give large format overview information similar to the high resolution display of traditional maps. The close relationship of the two screens allows also to support the integration of internal (overview) and external perspective (stemming from direct experience). The flat vertical screen delivers overview information, which can be directly linked to the detailed and quasi-on-the-ground information displayed on the model screen.



Fig. 3. Double screen projection with a combination of overview and detail information (left) and with documentary film and locational information (right)

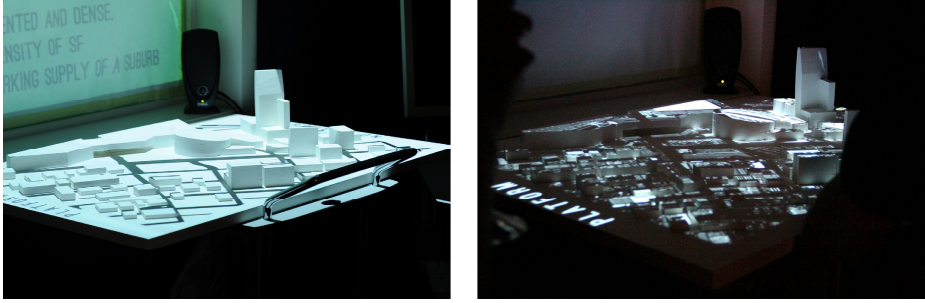


Fig. 4. Images projected onto the architectural model

4 Conclusions

Touching Buildings is a prototype that implements the core functionalities of our concept. The installation was shown to a group of approximately 50 people both female and male, in an age group ranging from 20 to ca. 65. Our aim in this first presentation was to get a general feeling for how the concepts and technologies work with a mixed audience and how well they are accepted. With varying subsets of the group members we conducted exit interviews and think-aloud observations; all members were part of a general observational study. We looked at criteria such as ease of use and the accessibility of the interface, as well as the efficiency of the communication flow. Further we looked at time spent in the installation, which was conceived without any restrictions on the extent of a session, users could walk away whenever they wanted. Another area of interest for us was the level of enjoyability of the experience.

We found that most of the participants judged the experience engaging and spent enough time in it to go through all major aspects. The majority of the participants lived in Los Angeles and was able to get a good understanding of the general setting of the planned intervention that was presented in the project. A few occasional textual prompts on the screens were used to invite people to touch the surface of the model and most of the users had no problem engaging into the touch interaction. A small number of participants stood back without directly operating the interface, instead observing others use the system. Through the large format double projection the appearance of the system had an informative and pleasurable quality from a distance as we understood from those participants. This behavior was mostly observed when a group of people such as a family or a group of friends was using the system and only one member of the group was the one to operate it while the others stood by.

In general people were not hesitant to touch the model, which was perceived as solid enough to not be concerned about its fragility. The possibility to directly touch buildings, blocks and streets was perceived as entertaining and pleasurable. The ease of acceptance is related to the widespread familiarity with touch interfaces combined with a novelty aspect of the fact that the touched surface is modeled. Participants easily discovered and used the “hover”-states resulting in a two-layer exploration consisting of the direct touch and the “hover”-states. Finding what kind of information was attached to “the air” above the model seemed to be an engaging activity.

All audience members showed and expressed an appreciation for the displayed materials and their aesthetic appearance.

In the current set-up we used just one depth camera to track the model, which worked well with the structure of the model. The particular area of Los Angeles has mainly low buildings and large open spaces such as parking lots etc., resulting in a rather flat model. For other model types we anticipate problems with occlusion in the tracking system where high buildings create ‘shadows’ in which the interaction cannot be tracked. For such cases probably a second depth camera would need to be used.

As in this first prototype we only observed high-level aspects of the interaction and communication associated with the system, a series of more specific and quantitative evaluation will be necessary to determine the actual degree of influence of the implemented physical interaction on the formation of a mental image of the site and the understanding of the planned intervention as well as the influence on the planning process as a whole. The system therefore should also to be tested with an audience of people less familiar with the general setting of the area.

Further research will have to explore different ways of model making and touch integration and the online participatory component will have to be tested with a larger audience. After having had a rather positive outcome of the first feasibility study it is now the task to build the system out into a solid and flexible platform for collaborative planning.

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Photography as a Research Method in Collecting Information from Elderly Respondents in Senior Housing Design

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Abstract. This study is concerned with acquiring knowledge of elderly peoples' perceptions toward senior housing design by using "photographic technique" based on participant design theory. The researchers asked 78 participants to choose 5 important areas of their own home and to take pictures of these. This was followed by a semi-structured interview. From those meaningful dialogues during the interview process the best insight into the elderly persons' experience is revealed and, therefore, offers an understanding of the elderly persons' perceptions and their spatial design preferences.

The results reveal four very important issues for the elderly participants in their everyday life. First, is concerning the items connected to or from the past. The second relates to family or social life. Third, concerns their hobbies or interests. Fourth, is in regards to where they spend most of their time. Moreover, the results show that by using a "photo taking" method this could possibly make the elderly participant feel themselves as contributing more to the project. Potentially this could improve the effectiveness of data gathered from the elderly respondents.

Keywords: Senior housing Design, Ethnographic method, User experience, Photographic method.

1 Introduction

The aging population has become an important issue during the twentieth century. There has been increased public concern about welfare policy and the quality of physical environment provided for elderly people through both government and local authority. Furthermore, research relating to spatial design for the elderly has been subject to significant growth in recent times.

However, elderly people seem to like having and expressing their own opinions and perceptions about living spaces (Lee 2011). Most design and research is mainly focused on facilities, safety issues and fire prevention equipment etc. In particular, those studies have emphasized the application of interior ergonomics to meet the special needs of the elderly, but without adequately addressing their psychological needs. (Green 1975, Valines 1988). Moreover, in most research, the elderly person has been viewed as a

customer but not a participant and, therefore, their feelings and opinions have been generally ignored. Besides, recent research shows that involving elderly people as participants at all levels of the design and development of their own living environment, is extremely beneficial (Sanoff 2000, Black 2006, Carter and Beresford 2000).

Because of those reasons, then, this study is concerned with acquiring knowledge of elderly peoples' perceptions toward senior housing design by using a "photographic technique" method followed by an in-depth interview, based on participant design theory to understanding of elderly persons' perceptions of recent senior housing design and their spatial design preferences. From those meaningful dialogues during the interview process best insight is revealed into the elderly persons' experience and therefore to a greater understanding of the elderly persons' perceptions of recent housing design and their spatial design preferences. Importantly, this forms a design protocol for the design or modification of environments for the elderly.

2 Research Methodology and Process

2.1 Participants

There are 78 participants in total who are 65 years old and over. These comprise 37% (29 people) males and 63% (49 people) females, with 45% aged between 65-74 years old, 27% aged between 55-64 years old, 26% aged between 75-84 years old and 2% 85 years and over. Furthermore, the top 3 ranked occupations that the participants were engaged in before retirement are as follows: 38% housewives, 14% engineers and 13% working in an industrial service related job.

2.2 Research Procedure

There are 2 phases within the data gathering stages, namely, "photo taking" and semi-structured interview. In the first stage, we asked participants to take 5 pictures of the areas or things they think are important to them in their house and document these by using a digital camera. In addition, a standard operation procedure (S.O.P) was made before the research commenced, to ensure each interviewer received the same type of information.

Following the photo taking procedure, the researcher asked each participant to introduce their own house, including a description of the space arrangement and functions. More specifically, the participants were asked the reasons why they chose those spaces. Further, they were asked about which space they spend most of their time in their daily life. From those dialogues during the interview process, it reveals insight into the elderly persons' experience with their everyday living space and, therefore, helps the researcher to have an understanding of their perceptions and their spatial design preferences.

3 Analysis

Two different types of data were gathered from this research both in quantitative and qualitative format. These include the photographs of spaces the participants took and the Narrative information from the individual interviews.

The results obtained from the quantitative assessment will provide the information on which spaces or items in the house are important to the elderly people. And the results gained from the qualitative assessment will provide more detail on the elderly participants' perceptions of the spatial design.

To analyze the narrative information from the 78 subjects, each interview discussion was reviewed, simplified and summarized in relation to the subjects' perceptions and preferences, regarding spatial design issues of their homes.

4 Findings

The results show that from a total of 390 pictures taken by the 78 elderly participants (Fig.7), the top 10 aspects/areas people selected were as follows: personal collections, travel souvenir/display or family pictures (80 pictures); living room (60 pictures), garden or balcony (34 pictures) kitchen (33 pictures), bedroom (27 pictures), sofa (25 pictures), dining room (23 pictures), Buddhist prayer room (22 pictures), computer (20 pictures) and study room (17 pictures). These were followed, respectively by, bathroom (15 pictures), massage or sports equipment (8 pictures) and second bedroom (4 pictures). Other areas or items with less than 4 pictures included: outlook of the house, stairs, mirror, reception area etc.

After the picture taking process, in depth interviews were undertaken individually with the participants to try and better understand the reasons why they think those areas or items are important to them. The results of this are as follows:

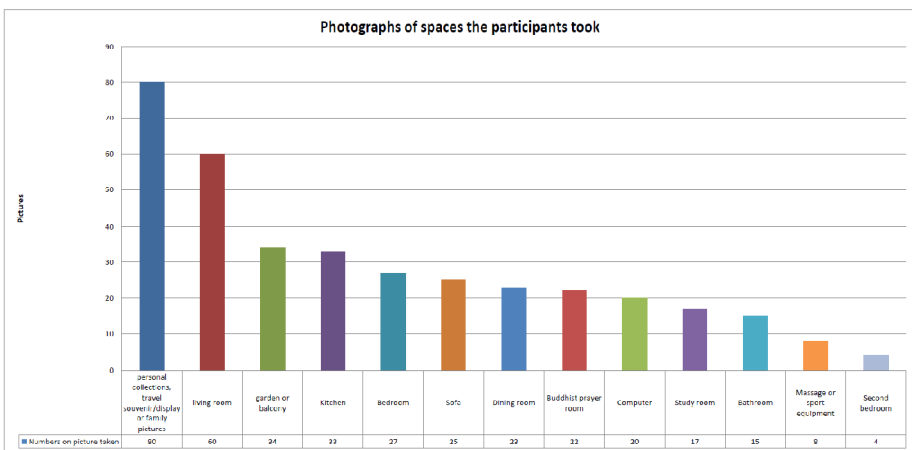


Fig. 1. Photographs of spaces the participants took

Collection/Souvenir or Photo (80 Pictures)

There are 80 pictures in this category, including: medals awarded for their achievements; personal collections such as painting, marbling etc; decorative items given by family or friends; family photos or photos from their vacations and drawings from their grandchildren etc. From the interview, most people explained that the reason they chose those items is because each individual item had its own individual meaning for them, and its own story. Due to this, the participants were able to speak at length about these items.

Living Room (60 Pictures)

The main reason the elderly participants chose the living room is because of the location of the T.V. Indeed, most said that they spend a lot of time watching the news or dramas when they are at home. The second reason is because the living room is usually the place where family and friends meet together and chat etc. Moreover, some participants said that they use part of the living room for reading or to go online. Others explained that they like to use the living room as a display area to show and share with friends their collections.

Balcony or Garden (34 Pictures)

There are 34 pictures taken of balconies or gardens. The main reason given by the participants is because they like plants and flowers and think these can make the environment look more pretty and feel more comfortable, particularly if they live in the city. Therefore, most participants arranged flowers around the house (if living on the first floor) or at the front balcony. Additionally, some of the elderly participants grow vegetables such as sweet potato leaves, by using plastic boxes. In particular, they believe that growing their own vegetables and planting flowers everyday can greatly benefit their health, as it involves a degree of physical exercise and the consumption of natural healthy food.

Also, other than planting, balconies are a convenient place for them to keep pets, such as dogs or birds etc.

Kitchen (33 Pictures)

There are 33 participants who chose to take pictures of their own kitchen, for 2 main reasons. First, they prefer to cook everyday meals on their own, because they think home cooking is more healthy than eating in a restaurant. Second, is because they enjoy cooking and love to make a variety of dishes to share with their friends or neighbors, especially at Chinese New Year or on other special occasions. From the interviews, participants made statements such as, "when people enjoy my food, it makes me feel so proud and joyful" and, so, the kitchen is seen not only as a functional space, but also one that has personal meaning for the individual.

Bedroom (27 Pictures)

Most participants see the bedroom as a private space. Apart from sleep, some participants like to read or rest in the bedroom, as it is normally quieter than other spaces.

Besides, some people prefer to stay in their own room as they don't want to disturb other family members' activities. In this space they enjoy watching their favorite T.V. programmes or being engaged in other activities. Also, in some cases, the bedroom is the only room in the house that has air conditioning. Therefore, during the summer-time, they would prefer to stay in the bedroom all day, as this makes them feel more comfortable.

Sofa (25 Pictures)

The sofa is only one of a few items, other than the space/areas, which have been highlighted from the picture taking process. From the interview, the participants explained that the sofa is the place for them to relax, whether watching T.V. chatting with friends or even taking a nap. Thus, the sofa is regarded as a very functional item for them.

Dining Room (23 Pictures)

The reasons the participants chose the dining room as an important place in their house are similar to those expressed about the living room. For them, the dining room is the place where family and friends eat and chat together. Most of them say that they look forward to mealtimes or special events such as birthdays or Chinese New Year etc. as they love the atmosphere when family and friends meet together.

Buddhist Prayer Room (Hall) (22 Pictures)

Religion and spiritual sustenance are the main reasons for the participants choosing the Buddhist prayer room as one of the important spaces for them. A Buddhist praying room is usually a specific area which is separated from other rooms. It is used to show respect to Buddha and to make him offerings, like fruit, incense and candles. Normally, they use these spaces in the early morning and late evening to pray. This room is also used for small group meetings to discuss the Buddhist teachings. Further, as most prayer rooms will pay attention to feng-shui, the participants believe that having a Buddhist prayer room in the house can purify the house space as a whole.

Computer or Laptop (20 Pictures)

Most surprising in the survey is that there are many senior citizens who have a habit of using the computer. Nearly all of them use computers to store and organize the photos they have taken on vacations, or they search for news or health information etc. More commonly, some of the participants use the internet to contact their family or friends abroad. And a few people use the computer to play games.

Study Room (17 Pictures)

Usually, only those in a larger house (over 130 m²) are able to have space for a separate study room. It is typically a multi-functional space used for reading, going online, chatting with friends, writing or even drawing.

Bathroom (15 Pictures)

For the interviewees, they view the bathroom as a functional place in a home, where they can ‘wash away’ their daily stresses. Some people even prefer to take a bath rather than having a shower, as they think it will help them to relax at the end of the day. In addition, some participants mentioned that they helped with some of the child-care in the home, particularly assisting their grandchildren to take a bath each day.

Massage or Sports Equipment (8 Pictures)

For some participants, physical degradation forces them to stay in the house most of the time, as they cannot participate in outdoor activities. Therefore, simple home equipment such as exercise bicycles, for example, is very important to help the elderly participants in maintaining some basic fitness.

Second Bedroom (4 Pictures)

The main reason participants chose the second bedroom is because they want to keep a vacant room in the house in the event of their son/daughter or grandchildren coming back to visit them. For the elderly participants this room is not only seen as a multi-functional space but also it has special meaning for them.

5 Conclusions and Recommendations

The results demonstrate, firstly, that items connected with or from the past (family pictures, travel souvenirs or displays) are very important for the participants in their everyday life. Secondly, areas related to family or social life is expressed as another key issue for them. Specifically, the reasons for choosing living room, dining room, kitchen, computer and sofa were because these are the places or functions related to family or friends meeting/connecting. Thirdly, importance is attached to aspects related to the participants’ hobbies/interests. For example: garden or balcony for planting the flowers or vegetables; computer for typing articles etc; Buddhist prayer room for chanting Buddhist scripts and the study room for reading or engagement in other activities. Fourthly, is the significance the participants give to those areas where they spend most of their time, such as bedrooms etc.

In addition, the methodologies implemented within this research offer insight into the perceptions of elderly people and provide us with relevant information concerning their requirements. It also shows that by using a “photo taking” method, instead of traditional methods such as direct interview or questionnaires during the design process, could possibly make the elderly participant feel more interested and engaged with what, otherwise, may be regarded as an unfamiliar topic. Indeed, this may make them feel that they are contributing more to the project and, so, potentially improve the effectiveness of data gathered from elderly respondents and achieve more accurate and reliable results. If these findings can be adapted to the field of interior design then they may assist building providers in more fully understanding the experience of elderly residents and, thus, enhance their satisfaction and quality of life.

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The Role of Woman and Man on Shaping the Old and Modern Households

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Abstract. Owning a house or a flat is closely related to the necessity of maintaining it. Housework requires various skills and abilities, as well as both physical and mental effort, overcoming weariness caused by the repetition of activities while experiencing lack of lasting effects, financial difficulties, and sometimes shortages of supplies and services. Moreover, the housework sometimes has to be done in poor living conditions. The primary goal of housework is creating, for each of the household members, the conditions in which one can develop, regenerate and relax. Modern households, especially the kitchenware, reflect the technological advancement of our digitalized contemporary world. The declining role of people in housework reflects grave social and cultural problems in the developed countries, such as: disintegration and atomization of family, anonymity and unification of behavior. The paper presents: the models of housework organization and their evolution in history, the role of women and men in housework, historically changing specificity of housework (including kitchen chores), as well as contemporary tendencies in domestic life in industrialized countries.

Keywords: Ergonomics, households, housework.

1 Introduction

Having a house or a flat is closely related to the necessity of maintaining it. Owning or renting a real estate and having an access to public utilities (electricity, water, gas etc.) is connected with fixed charges and, sometimes considerable, expenses from the household budget. What is more, maintaining, and improving the technical quality of the flat requires repairs and renovations. Fulfilling the housing needs, as well as keeping the living conditions on a satisfying level is connected with the necessity of repeating routine activities – housework. Those actions encompass a lot of activities, such as: chores (including cleaning) and shopping, as well as doing the washing or repairing clothing. Another important duty is supporting and raising children and taking care of their education.

Throughout the centuries those chores were closely related to the position of a woman in the society. The householder is a person who is able to run the household and bring up children despite the professional activity. Running a house and raising

children have always been women's responsibility [11]. Despite numerous initiatives to free the women from the hardships of being a homemaker, this is still true even today. Such initiatives were proposed by women's organizations and movements and socialist theoreticians even in the second half of 19th century. Currently, thanks to numerous appliances and technical conveniences the men's share in household chores has increased. The chores connected with cleaning the house, preparing meals and raising children are still mainly the responsibilities of women.

2 Distinction of the Household Chores

Household economics in the past encompassed the whole scope of human activities. In the past people worked in the areas adjacent to households. Even the farmlands and craft workshops were assigned to particular owners and households. Maintaining and supporting the house and gainful employment intertwined with each other. The work places (also those connected with gainful employment) such as: looms, pottery workshops, blacksmith workshops etc., and the places of livestock husbandry (poultry, cattle and swine) were often located in the same places where people lived. Usually all the household members, even women and children, were involved in gainful activities. The working time and the scope of duties were not standardized but they depended on the laws of nature and the local authorities. Therefore the households from the preindustrial times were strictly tied to the production processes. All the members of households took part in those processes – adults, children, members of the family and people who were not related to the family but who were involved in the household (servants, helpers, hired workers etc.). The activities performed by the members of the household (also those connected with gainful employment) were mainly focused on food obtaining and processing. Other chores, such as: cleaning, children's education or accommodation of goods had a secondary meaning.

The households in feudal times had a strong social and economic structure. Very often not only a married couple with their children, but also a lot of other people lived together under the same roof. In those times it was typical for the extended family and unrelated people (servants, labourers, journeymen etc.) to live together. Agriculture and craft production ensured to a certain extent a dose of independence and self-sufficiency in the access to the consumption goods. The shortages in goods and the high prices of services limited the development of trade exchange and opening the households to external influences [12].

The time of industrial revolution was the beginning of separation of household and gainful activities. The popularization of industrial production has led to both spatial and organizational separation of the working and dwelling environment. The living environment was still spatially dispersed (house, farm buildings, workshop, fields, etc.), while the working environment began to be spatially merged (factories), which was caused by the development of the rules of production organization. Together with the spatial distinction of places of gainful employment and transferring them to manufacturing plants, also the character and functions of the living environment changed. The "production zones" successively disappeared and the typical activities connected

with maintaining households ceased to be perceived as work in the sense of production organization. Therefore, the household became a place of: reception of industrially produced goods, consumption and development of next generations of employees. The removal of gainful employment from the living environment has increased the role of household chores in everyday life. This trend was also caused by gradually growing housing needs (including hygiene-sanitary needs, which firstly aimed at eliminating the diseases and epidemics), increasing living space, social advancement, etc. [5].

Gainful employment and the access to consumption goods and services have led to creating a network between the household environment and production and service environments. As a result of the division of work the households ceased to be independent and self-sufficient. It was necessary to do a lot of everyday chores in different places. The supplying functions were taken over by shops and markets, while the eating places supplied their clients with food. First public laundries and tailor's shops etc., as well as schools and kindergartens (which helped and sometimes substituted for home upbringing) were opened [12].

3 The Tradition of Division of Household Chores

Over the centuries in the western world the patriarchal model of household organization together with the hierarchical division of duties between men and women was prevailing. Especially during the feudal times women had to be subordinated to men. It was only after the industrial revolution when many of the previous dependencies were revoked. Occupational development of women in 19th century enabled them to become independent in case of obtaining the rights to properties, taking up a job, etc.. The women's social activities (including gaining the voting rights during the interwar period) have their origins in 19th century. During the postwar period the equal rights of men and women were legally guaranteed.

The hierarchical division of genders, since the ancient times, was based on the model of social distinction of the men's and women's roles and on perceiving women as "the weaker sex", which was based on the apparent biological differences. According to the old stereotypes men were perceived as those who are strong, wise, active and resourceful, while women as emotional, sensitive and passive [13]. Men were supposed to obtain the means of support (by hunting, cultivating the soil and finally by gainful employment), while women were demanded to focus their activities on upbringing the children and taking care of the house and the garden. The spatial area of activity throughout the centuries was substantially bigger for men than for women. Even in the craft production the most important tasks were given to men; women and children were given secondary tasks [8]. The industrialization of production solidified the former division of activities – gainful employment of men and doing household chores by women. The division of the work and living environment has led to the isolation of women in the households.

4 The Role of Homemaker in the Society and Family

The old, bourgeois model of family portrayed a woman as a housewife and a mother, while a man as a founder, breadwinner and family's helper. The household was perceived as "the place of rest" from work for the man surrounded by his family, run by a disciplined and modest woman. Such a model was consolidated thanks to numerous literary works and paintings, especially those created in 19th century. Continuously growing demand for employees in manufacturing plants has led to considerable gainful employment activation of women. Non-profitmaking housework (such as: cooking, cleaning, doing the washing, taking care of children, etc.) had to give way to the professional activity in the newly built manufactures. A significant number of women started gainful employment mainly in 19th century. Taking up gainful employment by women had various causes. For the wealthy women it was a means of emancipation and gaining independence, for those less fortunate it was an economic necessity [1].

Another factor which contributed to the professional activation of women was the introduction of compulsory education and education of girls in the beginning of 19th century. Girls' schools firstly were mainly focused on educating the young women how to be good housewives. However, the education resulted in strengthening the social position of women and resulted in their more active participation in the world dominated by men [2].

As a consequence, the role of women in the household chores has diminished, also in case of using the service of servants and housekeepers. Many of the chores started to be done with the help of modern appliances, which were becoming more popular and accessible thanks to the massive production. With time the social attitude towards housework has changed too. The housework started to be perceived as a necessary activity parallel to gainful employment and became reduced to the minimum [10]. The traditional role of a man as "the only breadwinner" has been undermined when the gainful employment of women has become necessary. Nevertheless, the role of women in maintaining the households still has not changed, which in the 20th century resulted in burdening them with a double workload. In the interwar period more than 30% of women were working professionally, and since 1950s the percentage of women working professionally has increased to 45% [12]. However, during that period, mainly the single women took up jobs; married women were still taking care of the house and children. Combining professional work and upbringing children was especially difficult for women. This trend changed only in 1960s when taking care of children by such institutions as nurseries and kindergartens enabled mothers to take up gainful employment. Through the decades the main reason why women worked professionally was a need to ameliorate the economic status of the family; non-material reasons had a minor meaning.

The late 1960s was the period of questioning of the traditional model of family, consolidated in bourgeois tradition of 19th century, in which the primary role of women was maintaining the household. It was also the period of the escalation of emancipation movements which exhorted women to total liberation from housework and family ties. The will to take part in social life and to be acknowledged was more vigorously undertaken. The last half of 20th century was the period of evident social expansion of women in the work environment. Taking the managerial positions by women was commonly acknowledged, and making a career by them did not surprise

anybody anymore. At that time women started to appreciate non-material aspects connected with gainful employment, such as: social benefits, as well as social independence. At that time it was a common belief that a woman who works professionally enjoyed more respect than a housewife [7].

The problem of reconciling the obligations connected with work and family causing the overburdening of women still remains unsolved. The choice between a career and family life is still a difficult compromise. The contemporary social and technological advancements (including the mechanization of housework) enable women to focus on raising children apart from concentrating on their career. Therefore, the role of “a housewife” has become secondary to the role of “a mother”. On the other hand, the technological improvements reduce the dirtiest and most monotonous chores. Maintaining the household has become therefore more attractive. In the last years a lot of women are leaving their careers which is caused by the hardships on the job market and a high level of unemployment. Those who are particularly facing these difficulties are young women, who give birth to children, and women over 50 years old, who are less flexible in improving their skills.

5 The Role of Men in Households

Women are still responsible for organizing and doing the housework. Maintaining the household and taking care of children are very intensive activities and they take many hours every day. Women work at homes more than 4.5 hours every day. Additionally, taking care of children takes them, on average, approximately 2 hours a day [3]. The percentage share of the main housework is as follows: chores (cleaning, making beds, doing the washing-up, etc.) – about 40%; preparing meals – 25%, doing the washing and ironing – 15%, shopping – 10%, others (including gardening, taking care of pets, and maintenance of the house and cars) – 10%. In comparison, the involvement of men amounts to less than 2.5 hours a day, despite of the professional activity of women (unemployment, part-time or full-time job) and in spite of the number of children. It is also estimated, that children (depending on their age) spend around 1 hour a day on housework. The majority of housework is done therefore by women. However, it is usually both of the parents who take care of children, especially if the woman is professionally active.

The involvement of men in housework is short-term and selective. There are numerous chores which men never do; doing the washing, ironing, operating the washing machine, dusting (except vacuuming), cleaning the windows, sewing and darning are the activities which men almost never do and in which they lack experience. About half of men is involved in cooking and preparing meals, and doing (especially big) shopping. Men, on the other hand, specialize in repairing and renovating. Avoiding various routine chores is often justified by men with being overburdened with the professional work. It is usually true, but is it contradictory with the necessity to work at home by women, also those who are professionally active. Moreover, the statistical research shows that if a man does not work, for instance due to unemployment, the division of duties between men and women is not changed [3].

The aforementioned results indicate that the model of household organization has not changed notably over the centuries; it has just been modified to a certain extent.

Men still perceive themselves as breadwinners, hence their actual and emotional involvement in gainful employment, even if it means neglecting the housework. That is why men, less than women, are willing to seek unemployment benefits when they lose their jobs. The traditional, patriarchal model of household, with the dominant role of a woman as a homemaker and mother is supported by over 80% of men. Almost half of households actually functions basing on this model. The alternative is so called partnership model, which implies a more even division of duties. This model is accepted by less than a half of men, while only 15% of men live in such a model [3]. Moreover, other 15% of men live in households where both adults are strongly involved in their professional careers and they delegate taking care of their children to the third parties.

6 The Conditions of Keeping a Modern Household

High technical standard is typical for the modern households. The housework has been mechanized or even automatized to a certain extend. The appliances were designed in order to make keeping a household easier and more efficient. They were supposed to simplify, shorten the time and even eliminate some routine chores. The total time devoted to the housework was supposed to be reduced. However, as the matter of fact, the effort and time spent on housework did not diminish. This situation is caused by numerous additional duties, hygienic requirements and continuous growth of property, which requires an organized stockpiling on the limited space of the apartment. The main advantages of technological conveniences are: shortening the time needed to do particular chores, lowering the physical work load, increasing the independence from the surroundings and external services, increasing productivity, and the improving the work quality. The negative phenomena connected with using appliances include: increasing the intensity of work, the necessity of doing additional preparatory and work and chores, disappointment with the results, additional costs, using of the resources and appliances, endangering the environment, etc.. Running the household, especially the kitchen, requires a more complicated organizational process than it used to. Shortening the duration of chores, reducing the effort and simplifying the chores by using the appliances require substantial intellectual effort [9]. Dividing the housework between the members of the household, apart from emotional load, entails the necessity to take up effort to organize all the undertakings. The consumptive lifestyle and the access to various services substantially complicate and prolong the housework. Nowadays, a lot of time is devoted to the organization and division of duties, planning different types of relaxation or vacations, shopping, driving the members of family to various extracurricular activities, etc.. Also other duties, which sometimes have to be done simultaneously, cause the weariness and the rush. Moreover, the stressful situations are intensified by: the isolation of the living environment, monotony, repetition of chores and seeming “senselessness” of work (the lack of lasting effects of the work) and a low social status of a homemaker. This status was solidified by education and media, which emphasized the advantages of the independence of women from the households (especially from husbands and children). Those tendencies coincided with important demographic changes taking place in industrialized countries. Since the second half of 20th century the multigenerational family model has started to be less popular, and big families in which the man is the “head of the

family” and the woman “the guardian of the household” began to disappear. The common model of “nuclear family” forces young people to become independent and to start households very quickly. According to the statistics, in the second half of 19th century only 5% of adults lived alone. Currently, depending on the country of the research, the number of people living alone varies from 25% to 35%; the majority of them are young people, especially women [6]. More than 30% of households consist of two adults without children [4]. This tendency is continuously growing. Single people have to maintain a household on their own, without sharing the housework with other members of the house. Those people are often strongly committed to their careers, which shortens the time spent in empty houses. Therefore, the activities connected with eating, doing the washing and spending free time (sport, entertainment and recreation) are realized by those people outside the house.

7 The Probable Evolution of Households in the Future

The quality of life and the living conditions have improved over the last couple of dozen years. This situation is particularly visible in industrialized countries. The technological improvement has changed all areas of life. The whole human activity has been connected with numerous civilizational achievements. The harder chores are now done with the assistance of different appliances; some chores are performed entirely by proper appliances. The growing pace of life, involvement in gainful employment and fear of losing the job are the reasons of stress which has a negative impact on human relations, both in the work and living environment. That is why the living space becomes an individual sphere of privacy. The access to various services and numerous opportunities of spending free time with acquaintances outside the house leads to treating the household as a space reserved only for the closest family. At the same time, the supply of flats increases and the households become fragmented. As it was mentioned above, in the industrialized countries the multigenerational households are being replaced with a one-generation family model. There is also a dynamic increase in the number of one-person households.

The sociological research conducted among Swiss youth indicates that the patriarchal model of family will still be predominant in the near future. Both young men and women perceive the division of roles in a household in a traditional way: women should take care of the house while men should be involved in gainful employment. At the same time, both groups of respondents indicated that men have certain predispositions to protect the family, to succeed in professional life, to be assertive and persistent when facing the obstacles, while women possess the qualities of sensitivity, delicateness and care towards children. Few respondents (less than 5%) accept a possibility of changing the roles of men and women in the future. A vast majority of young people appreciates the institution of marriage and wants to be a spouse or a parent in the future. Merely 15% of interviewed youth rules out a possibility of getting married and becoming a parent [1].

However, the research conducted in Poland indicates that women expect partnership and equal division of duties in the family. According to the survey, almost 90% of women wants an equal involvement of men and women in keeping a house and raising the children. Women, therefore, do not accept the traditional division of roles

and expect cooperation in the household chores. This can imply that the traditional division of duties according to the gender may also undergo some changes in the future. The changes in the division of roles in the household and a bigger involvement of men in housework, especially in the area of upbringing children, slowly gains understanding. The institutional manifestation of this trend is, for instance, a possibility of taking a paternity leave and devoting by them time to raise children, which incrementally gains acceptance in modern societies and among men themselves [7].

Thus it is to be expected that the traditional, patriarchal model of family will slowly evolve towards the partnership model, in which men's share in housework is going to be increased.

8 Summary

The increase in wealth, the amelioration of living conditions and consumptive lifestyle significantly influence the household models. The households become less numerous; the multi-generation and large families are rare. The social diversity and stress connected with working lead to the individualization of home life. The technical progress has significantly influenced the housework. Thanks to numerous appliances hard and routine chores can be done easier and more efficiently. However, having a diversified lifestyle, as well as using civilizational conveniences, demands doing numerous time-consuming organizational activities. As a result, maintaining a household still is a complicated undertaking, which remains in a conflict with a professional career.

The tendency to live alone in one-person households, and a decreasing birth rate in the industrialized countries are unsettling. The consumptive lifestyle, fear of losing one's job and lack of access to flats of sufficient size remain the major reasons of the decrease in population in the developed countries.

Despite various temptations and modern trends, marriage still enjoys a good reputation in the society. Also young people see themselves in marriage and family in the future. The traditional division of roles and duties in the family is also still accepted. Commonly acknowledged various predispositions of men and women may, in favourable conditions, become a fundament of an equal division of housework. Not to be overestimated is also the role of a woman as a mother raising the children and taking care of the household. The economic situation (including the job market situation, and the structure and amount of earnings) and increasing standard of living already allows in many countries to temporarily and voluntarily stop the gainful employment and career by one of the adults (still mainly women) in order to fully involve in the home life.

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Optimum Building Shape in View of Energy Saving

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Abstract. In most highly developed countries there are standards applied to define the requirements for the insulation coefficient of outer partitions, as well as adequate computer programs to both measure the heat loss in the buildings designed and calculate the amount of electrical and thermal energy needed for heating and ventilating the building. Although these programs are able to calculate the heat loss in the designed buildings, they cannot define their optimum shape. Apart from other numerous factors which influence the ecological and ergonomic value of the architectural project the building shape itself may significantly reduce the construction and maintenance costs of the object. An optimum shape of the building is very important for energy effectiveness, as well as keeping ecological and ergonomic standards applied to solve the space of the building. These factors should be analyzed by the architect as early as in the initial design stage, i.e. while the visual concept of the object is being developed. For different shapes of the object, with the same area of the plan and the same insulation quality of outer partitions, the area of these partitions can be very different, so the amount of the building materials necessary for the constructing, as well as the heat loss resulting from its maintenance can also differ significantly.

Keywords: architecture, ecology, ergonomics, economy.

1 Introduction

For several years now, the political demand for limiting carbon dioxide emissions to the atmosphere has changed the attitude to the shape of buildings designed. The need to reduce the consumption of energy obtained from non-renewable sources, such as gas, crude oil or coal, and rather use the renewables, such as solar, wind and water power or geothermal energy, is becoming more and more important for contemporary economy and indirectly affects the architecture of buildings.

The systems for using alternative sources of energy have now appeared on the market as a mass product and gradually become cheaper. It is said that due to the extensive designer's explorations, whose effectiveness have been examined for a few years now, some stable principles concerning the shape of building - in view of energy saving and the renewables used - have been formulated in contemporary architecture. The aim of this paper is to collect those basic rules so that the optimum shape of the building could be developed as early as at the design phase of the whole building process.

2 Design Principles of Energy- Saving Buildings

When it comes to a typical building in which solar energy is used, one can formulate a few basic principles concerning the designing process. Some of them do not significantly influence the shape of the building and refer to the situation when:

- The object is built from eco-friendly materials that can be easily bio-degraded or recycled;
- The object is built from the materials available in the neighbouring area, which reduces the cost of transport;
- The object is built from materials consuming only little energy, which helps reduce the cost of manufacturing;
- The insulation coefficient of the outer partitions is very high, which reduces the heat loss to a minimum.

The other principles define the shape of the building, such as:

- Geometry of the building;
- Functions of the building distributed according to the exposition to the sunlight;
- Glazed spaces, such as winter gardens, directed to the south;
- Appropriate size of windows in the elevations— according to the amount of sunlight;
- Protection of elevations and rooms from excessive sunlight;
- Appropriate selection of solar systems.

3 Geometry of the Building Shape

It is obvious that for the same building area it is observed that: the smaller the periphery of the building and the area of the external partitions are, the cheaper the construction and the maintenance of the building. If a one-level building is to be built, the possibly smallest periphery would be achieved if the building is based on a circular plan. Every time when the circle has been extended into the ellipsis of the same area, we will end up with the periphery of the ellipsis bigger as compared to the periphery of the circle.

When it comes to a regular octagon of the same area, its periphery would grow by merely 2.5%- as compared with the periphery of the circle. The fewer sides of the polygon, the bigger its periphery, whereas more sides, which make the polygon look more like a circle, result in its smaller external periphery. The building of the same area which has been based on a square plan will have the total length of external walls bigger by 12.5% than the circle. If this building is to be more and more transformed into a rectangle, the length of external walls will grow bigger and bigger.

When it comes to a building designed on a regular triangular plan, the periphery of its external walls will be longer by 28% in relation to the circle periphery. If one of angles grows, the periphery of the walls grows as well. When we reach the form of the right-angled, isosceles triangle, the length of the external walls will be bigger by 36% than the periphery of the circle.

Theoretically, the circle is an ideal figure as it has the smallest periphery of the external walls compared with other geometrical figures of the same area. The advantages of the circle have been confirmed throughout the many years of the buildings activity in many different cultures and on different continents. This can be exemplified by the residential homes of Inuits – the igloo, or the homes like the yurt in Asia and the Indian wigwam in America.

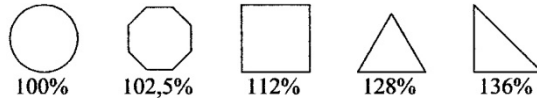


Fig. 1. External periphery growing for basic geometrical figures of the same area (Source: Author's drawing of December 2012)

In contemporary civilization houses are usually built on rectangular plans. This mainly results from industrialized manufacturing as it is easy to execute a mass production of simple, repeated and equal building elements, as well as the interior furnishings. Making a rectangular load-bearing beam, as well as a rectangular bed or wardrobe is much cheaper than making an untypical round bed, a moulded wardrobe or a bent steel construction beam. Moreover, it is easier to combine rectangular elements and compose more complicated functional structures from them. Besides, it is not possible to design every building on a circular plan – due to the dimensions and shape of the building lot, as well as the functional and usable qualities of residential buildings in which rooms are rather small and adapted to being furnished with mass-produced rectangular elements.

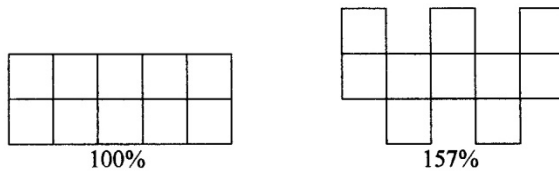


Fig. 2. Geometrical defect of rectangular projection (Source: Author's drawing of December 2012)

Comparing two rectangular buildings of the same area, one can easily observe the influence of the more and more sculptured plan on the growing length of the external elevation and – consequently – the growing cost of the construction and energy loss in the object built. In two rectangles of the same area projected (Fig. 2), with 3 protruding or dented elements designed, the length of the external walls grows bigger by 57%. This causes the effect of the external periphery growing, which mathematically could be regarded as “geometrical defect of the rectangular projection” and described by appropriate mathematical formulas [1].

How the area of external partitions grows can be very well illustrated with another example of 8 cubic modules. In relation to the arrangement of those cubes, the area of walls, floors and ceilings, as well as the cost of the investment itself and later the heating cost of the object can grow even two times bigger in the situation when the modules have been arranged as single, detached objects.

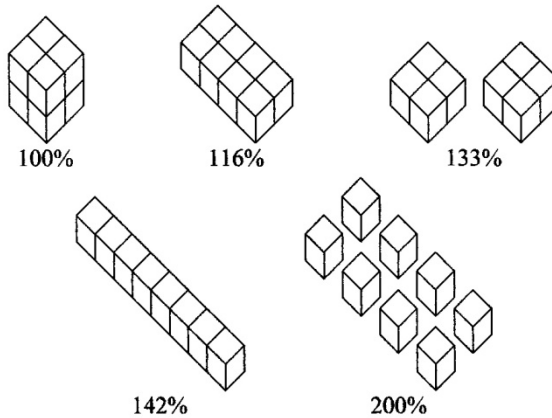


Fig. 3. How the area of external partitions grows in relation to the arrangement of the building modules (Source: Author's drawing of December 2012)

Summing up, it should be admitted that in order to reduce the cost of energy needed for constructing the building and later throughout the years of its maintenance until the recycling stage when it has been worn out, the optimum shape of the building should be understood as a simple and compact form, which possibly looks like a hemisphere (dome) or a rectangular box whose proportions resemble a cube, with no dents or protruding parts. It is obvious that the reflections above concern only such problems, as energy consumption while the building is being built and energy saving while it is maintained. Some other architectural aspects, however, have not been discussed, such as functional and aesthetic value, and the satisfaction of the users living in a unique and beautiful place. Anyway, it seems that the acting inspired by the idea that “simple is beautiful” should be appreciated and there is no need to complicate the form of the building or make it look strange as this may result in the growing costs and, paradoxically, an aesthetic loss as well.

4 Distribution of Functions in the Building

When it comes to designing energy-saving buildings, it is very important to develop a proper arrangement of usable areas according to the geographical directions. To achieve that the following tips should be considered:

- The rooms where people stay for the longest time, so the highest comfort of warmth is required, ought to be situated on the south, east and west sides with the biggest amount of sunlight (in case of a detached house these are: the dwelling rooms, as well as a kitchen and bathrooms);
- On the north side ancillary rooms, in which the temperature can be lower, should be located serving as a kind of thermal buffer (in a detached house these are: the basement garage, pantry, dressing room, boiler room, washing room etc.).

The group of experts preparing a study for the company Mostostal Warszawa S.A. [2], defined the optimum sizes of dwelling rooms in relation to their geographical direction:

- From the south, east and west sides the dwelling rooms should not be deeper than 5.5m;
- From the north side – not deeper than 3.5m.

5 Glazed Cubic Spaces on the South Side

One of characteristic features of energy-saving buildings are winter gardens– or greenhouses, which are situated on the side where there is the biggest amount of sunlight.

In the existing buildings these are mostly cubic spaces added to the original building form, whereas in newly-designed buildings the winter-garden function can become an integral part of the whole building. The greenhouse function can bring some advantages, such as:

- Thermal buffer for the south elevation which is most exposed to the sunlight;
- In the winter time, especially on sunny days it catches and collects the solar energy.

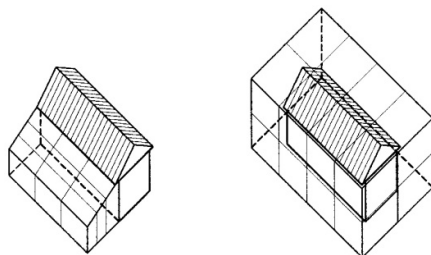


Fig. 4. From the house with a winter garden to the idea of “house in a house”

Yet, in the summer winter gardens can be heated more than it is needed, so it would be necessary to provide an appropriate system for shadowing and ventilation.

The greenhouse idea is very close to the idea of the “house in a house”. This interesting solution can be described by an example taken from Lithuania, where a medieval building, along with the land around it, is owned by a bank holder and is situated not far from Vilnius. The architects of the company G. Naktevičius & Partners restored the old building and covered it with glass cubes [3].

6 Size of Windows in Elevations

Poland has a temperate climate where the difference between the summer and winter temperatures can be as high as 60°C and the amount of sunlight is about 4500 hours a year. In the summer for about 8 weeks the temperatures reaches up to +32°C, while in the winter at night goes down to minus 30°C. For approximately 6 weeks in the

daytime extensive clouds can be observed which practically make it impossible to catch and collect any solar energy. Having analysed the results of the research study done by the group of experts mentioned before for a building company in Warsaw, one may conclude that for the climate like this the optimum size of windows are the following [2]:

- In the south elevation: up to 50% of the elevation area;
- In the east and west elevations: up to 30% ;
- In the north elevation: up to 25% .

Other suggestions concerning windows are:

- The obligation to install shadow-systems from the south, east and west;
- Minimum coefficient of heat penetration for the window: $U = 1.0 \text{ W/m}^2\text{K}$.

7 Protection from Too Much Sunlight

Apart from catching solar energy in the winter, the building ought to be protected from excessive sunlight in the summertime. In order to reduce the amount of sunlight one should consider the biological partitions as a natural and ecological solution. It would often be enough to plant a tree on the southern side and a creeper that would grow up the wall. They will shadow the building in the summer but when the leaves fall down in the autumn, the sunlight will have an easy access to it. The protection of the elevation from excessive heating may be done by means of various blinds more or less automatized– from permanent external blinds installed on the building elevation up to complicated automatically steered movable blinds or roller blinds. Those automatized movable systems for shadowing elevations should be classified as the active type. Yet, they are just a technical addition to the whole building form which itself does not provide this kind of protection.

In order to protect the building from overheating naturally, the architect can design a protruding roof, arcades or balconies from the south, east and west, which would be classified as a passive solution. The angle of the sun's rays is different in the winter than in the summer. Therefore, the shape of the elevation which is exposed to the sun should be predicted while the building is being designed. Protruding eaves or a deep balcony designed give a kind of passive protection from the excessive sunlight in the summer, whereas in the winter make it possible for the sun's rays to get through.

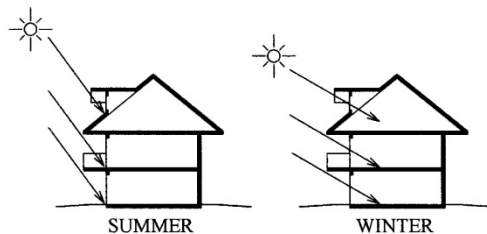


Fig. 5. Passive protection of the building from excessive sunlight (Source: Author's drawing of December 2012)

The excessive energy observed in the glazed buildings may result in the situation that more energy is used for cooling the buildings in the summer than for heating in the winter. In this case, a kind of the greenhouse effect can be limited by the use of a double glass facade, as well as by low-emission glass applied. This, however, has a negative effect, i.e. the noise resulting from the hot air speeding up. In very high buildings there are special systems used for reducing the speed of air, which is achieved mostly by having the elevation divided into sectors. Theoretically, the natural flow of hot air between the panes of glass in the double facade can be employed to drive the wind turbines which would produce electricity.

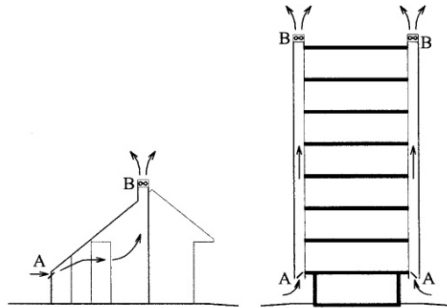


Fig. 6. In a greenhouse and a high building one can use a flow of hot air between the glass panels (Source: Author's drawing of December 2012)

8 Solar Systems

When it comes, for example, to the assembly method used, the solar systems can be divided into [4]:

- Additive, i.e. those which can be assembled to the existing buildings being the modularized liquid-based or photovoltaic collectors;
- Active, i.e. rotating after the Sun— mainly photovoltaic collectors to be installed on roofs or on the ground near the building;
- Integrated with the building form, mainly as photovoltaic cell built into glazed facades and roofs of the buildings— these collectors perform the protective function having replaced the external partitions.

Each of the types mentioned to some extent influences the appearance of the building, the additive and active collectors being the most visible. The collectors integrated with the elevation fit in the divisions made and may create interesting visual compositions.

When it comes to the systems for collecting geothermal energy, those do not influence the building shape. What the ground-source heat pumps require is the area big

enough to install the system of pipes in the ground. As for the air source heat pumps the influence of those on the appearance of the building is limited as the air from the outside is taken through the louvred elevation.

The situation changes when energy is taken from the wind. For this case in Poland there are a lot of restrictions due to the law demanding the preservation of the natural environment which, indeed, do not permit any turbines installed even if they are of little power on fairly low poles. Therefore, the wind power stations are permitted only in the open areas that are free of buildings as the noise and the wind mills themselves may negatively influence the landscape.

9 Conclusion

Contemporary knowledge of the energy saving methods makes it possible to design buildings in a rational way - in view of their cost-effectiveness and the energy necessary for the object to be built and maintained. Unfortunately, it often happens that this factor is not examined before the final stage of the designing process when the building has been almost completely designed. Consequently, to reduce the maintenance cost, especially the cost of winter heating and summer cooling, some very expensive technical solutions must be applied. Yet, it often turns out that in order to reduce these costs one should have defined the optimum shape and function earlier - while the architectural concept was being created. At the beginning of the design process the following issues ought to be analyzed:

- Geometry of the building;
- Appropriate distribution of the functions in the building according to the direction: due East, South, etc.;
- Making it possible to design the glazed spaces directed due South;
- Appropriate size of windows in each of the elevations;
- Protection of the south, east and west elevations from excessive sunlight;
- Appropriate selection of solar systems.

Having considered energy crisis and general economic decline, as well as the growing consciousness of the society, the investors and users of buildings now pay more and more attention to ergonomic, ecological and economical aspects of the building objects. The quality of architecture results from more factors than just the external form of buildings. What seems fortunate, however, is the fact that no one can definitely classify the influence of individual factors on the quality of architecture and decide which one for the given solution is the most important: the form, function, economy or ecology. What can be done, however, is to appeal to architects and discourage them from making the space model of the building too much complicated unless it is strongly and reasonably justified.

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Spatial Transformations of Architect's Workplace Due to Development of Computer Aided Design

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Abstract. Architects, among other professional groups, are especially involved in the technical development of their occupation at three different levels: designed objects, ways of performing investment processes and methods of current communication. The usage of stationary and mobile computers, graphical tablets, smart phones and other multimedia equipment are currently influencing not only the way of work, but the space of workplaces as well. This paper is aimed at researching this transformation and development. A comparison between two approaches towards a design process will be made, i.e. classical – based on a drawing board and modern – with implementation of Computer Aided Design, graphical stations, virtual modeling and multimedia presentations. There will be a discussion on proper measurements and parameters of the workplace in relation to human needs and limitations tested in case studies and in literature examples. Based on conclusions, the guidelines concerning designer's work with the modern electronic equipment will be formulated.

Keywords: architect's workplace, workplace with computer, work with multimedia equipment.

1 Introduction

From the early conceptual stage of a design to the stage of choosing proper finishing materials a designer comes across varied electronic devices which are involved in his work to a different extent at particular steps. Also methods of presenting and executing each documentation stage have drastically changed in the last decade. The usage of stationary and mobile computers, graphical tablets, smart phones, etc. forces architects not only to pursue their profession in a different way, but also to transform their everyday work environment. However, due to the low ergonomic research development there is a severe misuse of digital appliances which can be inconvenient, harmful and dangerous to the quality of life and work as well as to physical and mental health in the long term. According to literature sources [1, pp. 92, 93], among various threats the following ones can be mentioned: Carpal Tunnel Syndrome, the ulnar nerve groove syndrome, de Guyon canal syndrome, Chronic shoulder peri-arthritis. Despite the fact that there are some satisfactory guidelines implemented by the European and Polish law concerning human-computer relations, they usually take into account only basic technical solutions. The influence of other electronic appliances should be still

researched, especially in a narrower field which is architect's work. According to Glegoła [2, p. 28], only 1% of workplaces equipped with computers are prepared according to requirements as well as rules of ergonomic design.

2 Aim and Method

This paper presents a transformation and development by analytical and comparative studies on architect's workplace. A comparison will be made between classical methods of performing designing processes based on a drawing board, hand drawing and a traditional space model execution used in the former decade and modern ways of the project elaboration with implementation of Computer Aided Design, graphical stations, virtual modeling and multimedia presentations. A part of the research will cover the transformation of methods of the building inventory from the measuring tape use towards a laser rangefinder and 3d scanner. The investigation will also include architects themselves with a focus on the equipment they mostly use or prefer and how it affects their everyday work. All the three aforementioned aspects will be related to an individual workplace commonly understood as one consisting of a desk, a chair, a telephone and a stationary computer. This definition will be updated to the current standards and expanded on other multimedia equipment necessary to perform professional duties with an additional consideration of managing the investment process. There will also be a focus on threats and inconveniences connected with fast and usually ergonomically unsupervised development of designer tools. Following this aspect and drawing on conclusions, some important guidelines will be formulated concerning designer's work with modern electronic appliances. For each part of the study different methods were used, i.e. for the initial stage and definition formulation – literature research, interviews with professionals, comparative analysis; for case study – photographic documentation, graphical analysis; for final conclusions and future guidelines: analysis, synthesis and comparative analysis.

The issues connected with natural and artificial lighting, microclimate of rooms, psychological factors, acoustical environment, etc. were omitted on purpose in order to focus on material matters which seem to be most neglected in local architectural offices. Moreover, in the light of the executive regulation of the construction law in Poland, the requirements of proper thermal protection of buildings, inner temperature, natural and artificial lighting are commonly respected. Due to the fact that this field of study is so vast and the number of digital equipment available is countless, the presented work has an initial character. The research and measurements were carried out on chosen devices in the field of micro-ergonomics, which was recalled by Nowakowski and Charytonowicz [3, p. 78] as a form of interaction between man and machine. The studies were focused on Polish architectural offices and professionals as well as the available equipment and used in local design studios. Due to this assumption, national regulations were mainly taken into account. It should be stressed that also human measurements may differ due to a nationality and region of origin.

3 Discussion

3.1 Definition

A crucial element of the whole studies was to define what should be understood by the architect's material place of work. According to Charytonowicz [4, p. 23], there are three main aspects of factors influencing any type of the workplace: technological, organizational and ergonomic. The first one is connected mainly with the technology and equipment involved, the second one takes into account organization and external factors, while the third one includes adjustments to human needs and physical requirements. It is needless to say that a great transformation can be observed in all of these groups. At present, the main drawing tool of an architect is a computer equipped not only with a keyboard and a mouse, but also with a graphical tablet. It is really important to notice that in the specific work typing takes only a part of the whole time and much more common is drawing with the usage of a mouse, a graphical tablet and very rarely a touchpad. As a part of the discussed definition, an appropriate Polish document was taken into account, namely, 'Regulation of the Minister of Labour and Social Policy of 1 December 1998 on health and safety at workplaces equipped with a display screen' because it refers to a computer as the main device used in modern offices. The above mentioned document [5, p. 5392] describes a workplace as divided into the following elements: basic equipment, additional utensils and service elements. The first one includes a display screen, a keyboard or another input appliance, a central unit or a disk drive (the last one is outdated). For the architect's workplace we should add a graphical tablet. In an additional tool group there are the following devices: a printer, scanner, mouse, trackball, and in this group there should be included a 3d scanner and a 3d printer (still unpopular on the Polish market) as well as a plotter. According to this regulation, the last group includes service equipment such as a table, chair, footrest and paper holder. The document also mentions software as a part of the work place and other elements that are less relevant to this article. Much more crucial would be to include other work tools which not necessarily have to be plugged into a computer, but they constitute everyday use of electronic appliances such as a mobile phone, laser rangefinder, GPS, etc.

In order to confirm the above mentioned data, several interviews were conducted with individual professional architects of the young generation, i.e. 25-35 years old, working in architectural offices, owning design studios and freelancing. The first question concerned a type of the computer used. Most of the responders emphasized that a unit with a display screen, keyboard and mouse constitute a basic tool in the stationary office work. However, a laptop was mentioned in almost all interviews and there were also declarations that it was the basic equipment at least for additional tasks prepared at home. In the group of everyday use devices, the following were mentioned (listed in order of appearance): printers, plotters, scanners and phones. Apart from these, also the following objects were mentioned: traditional measuring tapes, laser rangefinders, a total station, a tachometer, a leveler, a theodolite, a 3d-scanner, digital cameras, digital SLR and digital phone cameras. As for traditional techniques of the architect's work, they are believed to be very useful at an early stage of a design in the form of hand drawing, sketches performed with pencils and markers. Painting techniques such as aquarelle are very rarely used for visualization. As far as a

drafting table is concerned, only few of the interviewed persons mentioned that they had them; however, were not used in accordance with purpose.

Taking into consideration the aforementioned listings and the individual research, the definition of a modern material architect's workplace is understood as furniture and electronic and digital tools which are fixed as well as mobile used to create a full building-architectural documentation prepared in an investment process. Due to a change of the basic definition, also ergonomic factors have been modified and they will be discussed later on.

3.2 General Requirements

According to the previously formulated definition, analysis of the ergonomic aspect of the architects' workplace started from the basic elements and then shifted to minor, yet also important tools. According to the research conducted by Glegoła [2, p. 28], the best way to provide each user with a good solution for his anthropometric characteristics while keeping the furniture in the same style is to use adjustable equipment. The basic parameters which should be regulated are as follows: height of a chair, an armrest and a desk, a tilt of a seat recline, a seat angle and protrusion and the monitor's position. To meet these requirements, manipulation of localization of the keyboard in parameters of height and protrusion should be combined with an operational footrest. The next element would be the possibility of adjusting a distance between recline and seat, a space between armrests and their angles towards the level, together with a modifiable recline curvature supporting the spine, e.g. with the use of a special air pillow [6, p. 55]. Depending on a literature source, the height of the desk should be regulated in a range of 85-60 cm (top edge) allowing placing its surface on an elbow level of a sitting user. The chair height is ranging from 40-51 to 36-50 cm (top edge), tilt of seat recline – 5° to front and min. 15° to 30° to back from a vertical position, the surface of a seat should be movable at an angle with the range of 2-7° from the level. The armrests in typical chairs are usually situated 20 cm from the seat surface and should be moved up in a range of 5 cm while the distance between them should be regulated in a range of 46-51 cm. A seating wideness ought to be between 35-40 cm and 38-40 cm deep. The space under the desk should have minimum dimensions of 65 cm – height, 70 cm – depth, 70-80 cm – width. Footrests should be fixed on the floor and their inclination must be regulated in a range of 0-15°. [2, p. 28, 6, p. 55, 5, pp. 5393-5395, 7, p. 122] According to Grandjean [7, p. 118], the space between the bottom of a desk and the surface of a seating is also important, which should range between 27-30 cm. The author drew attention to the profile of a seating and presented a lot of research with contradictive results. It must be emphasized that the seating parameters must be chosen for each individual separately, however, there are chairs with manually regulated seats in the range of inclination towards back and front. Moreover, some systems flexibly follow the body position adjusting dynamically to each situation, i.e. leaning towards a computer, reclining during a phone conversation, etc.

The next issue involves the proper localization of the computer elements such as a keyboard and a monitor. The former should be placed in a distance of at least 10 cm from the desk edge and the latter in a distance of 40-75 cm from the user's eyes. The angle of inclination of a monitor from the vertical position should be 20° to back and

5° to front, and rotate around its axis at least 120° to 60° at each side. The screen upper edge should be placed below the user's sight line. The aforementioned regulation [5, pp. 5393-5394] recommends adjusting localization parameters for individual anthropometric features. Glegoła [2, p. 29] further discusses the work with screens of the size equal or larger than 18'' with the observation angle in a range between 20-50°. Hands working on a keyboard are usually placed below the working desk plane on a special shelf and they should be underneath or at an angle of 90° to elbows on armrests of the chair [6, p. 55] The angle of the aforementioned device ought to be regulated in a range of 0-15° and its total height in at least one position must not exceed 3 cm. [5, p. 5393]

3.3 Case Studies

The first case study was carried out on the basis of historical and literature examples of work with the use of a drafting table. Grandjean [7, pp. 30-31] presented different positions of three men of diverse heights working on drafting tables of variety of wideness. The work in a standing position on the improperly regulated board caused a need of 'head to back' relation inclination up to 76°, while in a sitting position it was about 16°. Analyses of drawings show that the regulation was a crucial element of a proper drawing board solution enabling comfortable work in standing and sitting positions along with a recommended foot rest.

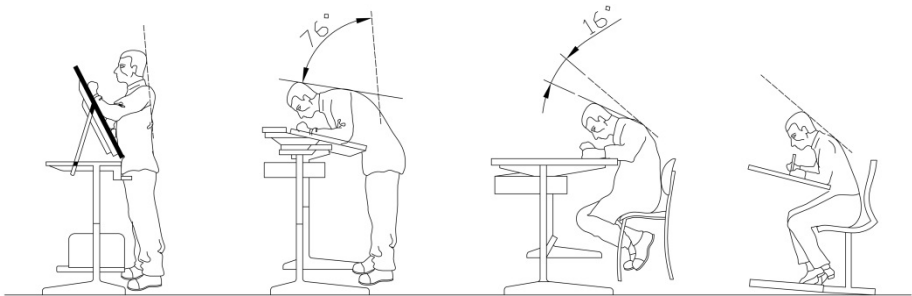


Fig. 1. Work with the use of a drawing board in standing and sitting position. (Elaborated on the basis of [7, p. 31]).

Together with the technological growth, requirements of clients in relation to architects have also changed. Lack of time-consuming hand-drawing needed for preparation of each documentation and easiness in communication – constant availability through mobile phones and the Internet – caused shortening of the documentation execution phase. Another substantial difference would be reduction of paper records to final printing for an administration office or a construction site. Also a form of presentation through rendered visualization forced a designer to use minor mobile electronic devices in order to achieve better communication with a client. Mobility of a designer has also exceeded and it is hard to determine whether portable computers enabled this process or a change in the work organization forced engineers

to use new technologies. Despite this fact, laptops, notebooks and even tablets have been slowly replacing the aforementioned stationary computers. This process is especially strong when we take into account owners and managers of architectural offices who are less oriented towards drawing work for the benefit of frequent meetings with clients, building and structural engineers or spent a lot of time in administration offices. It is observed that an architect's relation to the technology becomes stronger and has serious implication on all aspects of life as Frejtak [8, p. 13] implies. According to Wachowiak [6, p. 56], mobile computers if used as permanent work devices should be placed as monitors and other parameters must be fulfilled with the use of additional utensils such as a keyboard and a mouse, which is demanded by the aforementioned regulation [5, p. 5393]. However, field studies show that in practice it is hard to find such examples. The aforementioned interviews show that it is crucial to provide architects with the additional space for work with notebooks, net books and laptops at least for the time of presentation, preparation and so on.

Two mobile computers and a stationary one were tested. In all of the three cases the user was observed in the starting consciously straight position and in an unconscious situation after 5-10 minutes of work. The first one was a large laptop with a display screen of 17.3" and general measurements of 28,5x42 cm with a regular keyboard (standard and numeric) placed 10,7 cm from the edge and with the height of 3,1 cm measured at the position of "A" key. The monitor of this equipment in the open position is located at least 28,5 cm from the edge of the device. With the appropriate placement of the computer on the table, the screen can be distanced in a range of 40-55 cm from the user's eyes and these parameters fit in the aforementioned requirements. Within this setting, a comfortable position of hands on a keyboard can be maintained. This element will be placed in the required minimum distance of 10 cm from the desk edge. During the test, the monitor observation angle was from 31-47° in a starting position and 33-51° in the final posture. This data are slightly worse from the recommended ones. Moreover, in the final position a strong and improper inclination of 16° 'head towards back' relation in comparison with the initial situation was observed. This phenomenon can be related to the lack of monitor's height regulation which forced the screen surface observation at an angle different from 90° at desirable inclination as set by the user. Moreover, in this case there is no possibility to turn a monitor around its axis. On the tested computer the distance between a monitor and a keyboard cannot be controlled and localization of the unit is always dependable upon the placement of furniture. If the inclination of the keyboard is necessary, the computer supporting pads may be used. Equipping the workplace only with a large laptop may be suitable for a small group of people with certain anthropomorphic characteristic; however, it will not be adjustable for all workers. But even for them limitations of this arrangement may become unbearable during a longer period of time. An additional test was performed with a laptop placed on the user's lap. The 'head towards back' relation changed from the beginning to the finishing position by 25° and screen's observation angle varied from 49-74° and all these numbers are far from the recommended ones. The second tested device was a small net book with a display screen of 10.1" and overall measurements of 18,8x26,5 cm and a minor keyboard distanced at 5,5 cm from the equipment's edge and 2,1 cm height at the 'A' key position with the display of 18,3 cm. While working on the desk it is possible to provide the keyboard position of 10 cm from the surface edge and a

display will be distanced about 40-50 cm from the user's eyes, however, the screen observation angle is $40-51^\circ$. Due to a display limitation and small keyboard sizes, longer work on this equipment is not recommended. The results were compared with an analysis conducted with the use of a typical stationary computer with a separate monitor of 19", a standardized keyboard and a mouse. The position of the monitor and the keyboard unconsciously chosen by the user was analogical with recommended values and the screen observation angle was $16-28^\circ$. The 'head towards back' relation shifted from the starting to end position only by 7° .

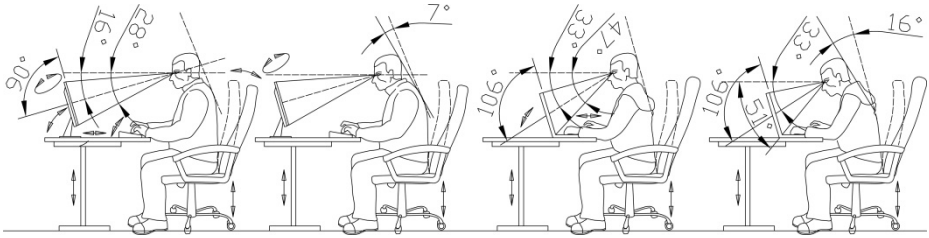


Fig. 2. Stationary computer and laptop comparison of starting and finishing positions of user. Regulation options were marked with arrows.

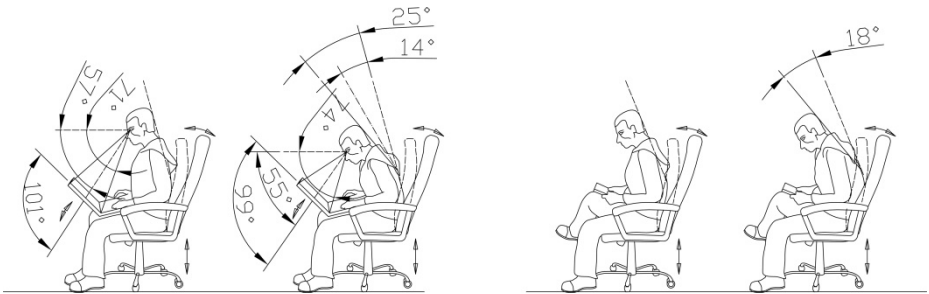


Fig. 3. Head and back inclination during work on laptop and tablet placed on user's thighs. Regulation options were marked with arrows.

In the group of minor equipment the following devices were tested: a laser rangefinder 60x100x28 mm, Smartphone 115x62x7 mm, tablet 246x170x11 mm, graphical tablet (measurements in format of x, y, z). The analysis of graphical documentation of work with a laser rangefinder did not show any dangerous spine positions. During a longer period of time it is possible that an extended forearm may expose worker's body to hazards. However, in regular architect's activities such on-site measurements constitute only a small part of all assignments. Most of the positions assumed by a worker during work with a laser rangefinder are more comfortable than with measuring tapes. Smartphones, tablets and graphical tablets are operated with hands and due to their size they are kept on the lap. As we can see, the 'head to back' relation inclination changed during the work with Smartphone by 21° , while with a graphical tablet by 22° from a starting position. This position may be hazardous for health of the spine and back muscles and the amount of time spent on

activities involving minor digital devices has been on the increase each day. In order to establish a proper position for longer work on a tablet and Smartphone, recommendations for laboratory workplaces with small equipment may become relevant as described by Charytonowicz [4, p. 25]: feet must be resting on the floor or a footrest with their whole surface, a shank and a feet ought to form an angle not less than 90° , a shank and a thigh are located relatively to each other at an angle not less than 90° , the head is slightly inclined to the front, an object is placed at a distance of 30-40 cm from the eyes. In this position the author mentions three possible hand placements: elbows and forearms are resting on the table, half of the forearm is resting on the work surface or wrists or hands are resting on the table. The last test examined the fingers' position while manipulating minor devices. It showed an unfavorable thumb position while operating bottom left corner keys of both laser rangefinder and Smartphone.

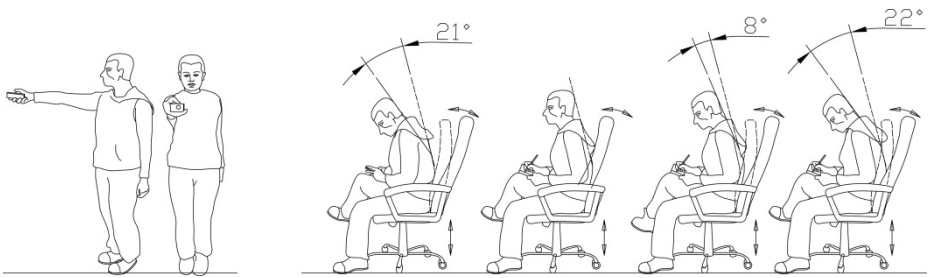


Fig. 4. Work on small devices, from the right: laser rangefinder, Smartphone, graphical tablet – starting, middle and final position

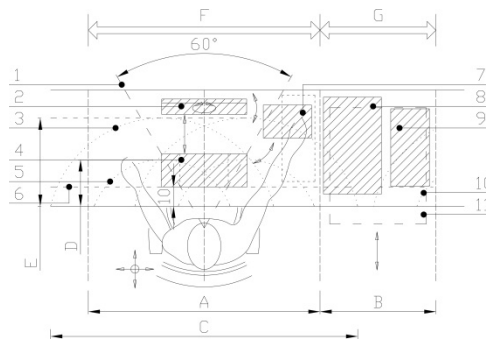


Fig. 5. Workplace recommendation scheme for a drawing architect. (elaborated on the basis of the scheme by Ramsey presented in [4, p. 24]) A – minimal recommended work surface: 120 cm, B – minimal recommended common surface: 60 cm, C – men: 159 cm / woman: 145 cm, D – men: 24 cm / woman: 21,5 cm, E – men: 45,5 cm / woman: 40,5 cm, F – individual workplace, G – common workplace, 1 – convenient visual range, 2 – standard monitor area, 3 – maximum hand range, 4 – standard keyboard or graphical tablet area, 5 – normal work hand range, 6 – minimum keyboard from desk edge distance, 7 – standard keyboard or graphical tablet storage area, 8 – typical A4 scanner area, 9 – phones, small equipment, 10 – next work place ranges, 11 – document/paper movable container (on wheels).

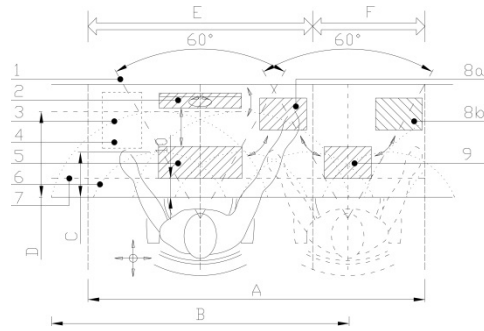


Fig. 6. Workplace recommendation scheme for a managing architect. (elaborated on the basis of the scheme by Ramsey presented in [4, p. 24]) A – recommended work surface: 180 cm, B – men: 159 cm / woman: 145 cm, C – men: 24 cm / woman: 21,5 cm, D – men: 45,5 cm / woman: 40,5 cm, E – basic workplace, F – additional workplace, 1 – convenient visual range, 2 – standard monitor area, 3 – maximum hand range, 4 – additional document space, 5 – standard keyboard area, 6 – normal hand range, 7 – minimum keyboard from desk edge distance, 8 a, b – storage space for notebook/net book/tablet, etc., 9 – small equipment workspace tablet/net book /Smartphone, etc.

4 Conclusions

In order to design an appropriate place for each architect in the office, we must divide the designers into two groups. The first one includes managers – directors and group leaders whose work is connected with contacting clients and contractors, coordination of office work and project supervision, correction of documentation while preparing concepts and drawing as an additional activity. The second one includes designers and assistants whose responsibility is to prepare all the drawings in documentation with technical descriptions and elaboration of concepts. Concluding, a manager-architect desk should be long (ca. 180 cm) and enabling work with a lot of small pieces of equipment such as a tablet, a net book, a notebook, a laptop, a Smartphone and other devices placed next to the stationary computer. If the usage of a mobile computer is necessary for a longer period of time, its measurements must be sufficient (minimum 17” screen) and work place furniture must enable regulation. The computer supporting pads are recommended. A very important element would be to provide possibilities of proper work with all the available equipment. A longer desk would enable moving along the equipment, providing proper hand and elbow positioning on the desk while using a Smartphone and a tablet.

For drawing architects there should be an additional storage space enabling quick changes between a graphical tablet and the keyboard. Peripheral appliances placed on desks such as scanners, stationary phones, etc. may occupy a common space assigned to two adjacent employees. Desk printers, faxes and free-standing plotters or 3d-printers should be placed in a separate room with good ventilation due to a harmful impact of printing media such as inks, toners and others. In both of the described situations a stationary unit should be placed below the desk, on a dedicated shelf on the left desk corner.

Architects' workplaces have changed a lot since the drawing-board period as well as the specificity of work which is done mainly in a sitting position with the use of digital and electronic equipment. Nowadays it requires various types of computers and constant communication via e-mails, the social media, communicators and telephones. These factors made the architects' workplaces similar to the office ones, however, with one significant difference, namely, a need to use peripheral devices assigned to graphics. Each design and refurbishment process must include these novelties equally in order to select proper furnishing which should be ergonomic and adjustable to varied anthropometrical types. Summing up, health hazards that nowadays can affect architects are greater than they used to be during hand drawing processes and are mainly related to the new minor equipment.

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Design of Modern Hotels – Humanization of the Residential Environment

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Abstract. After the hotel building boom before Euro 2012, the Polish tourist branch is currently experiencing a period of stabilization. Current investments are prepared with more consideration as regards the ways of gaining and attracting new customers to the proposed services. Small and very economical buildings like hostels and motels that are erected nowadays are attracting a young part of the society, while elegant and more expensive buildings gain customers from constantly aging people. Attempts to provide better and well-adjusted functions evolve along the demand to meet different needs of people with various disabilities. Humanization and individualization of service for the benefit of various customers should be based on appropriate ergonomic solutions and novel technologies. Analyses will be carried out on recommendations for hotels designed for people with disabilities, different medical conditions and representative case studies of German examples.

Keywords: ergonomics in architecture, hotels for the disabled, hotels for the elderly, ergonomics of the disabled.

1 Introduction

The Polish hotel branch has gone through significant changes during the last five years. Transformations started with the announcement of the list of countries organizing Euro 2012 and many investors noticed this as an opportunity to expand their capital. Buildings with a variety of residential opportunities were put up within a short period of time without much thought about long-term policies and their future functioning. A process of decreasing birth rate, which is generally observed in Europe, combined with a constant increase of longevity together with very active lifestyles of the elderly contribute to the creation of a new type of a hotel user. This person is more demanding and may suffer from usually minor disabilities, however at the same time such customers are also able to pay larger amounts of money for their comfort and realization of needs than young globetrotters. The elderly not only travel in order to deepen their knowledge, but also to use a hotel as a place for doing business or as a target leisure, relaxation or beauty centre. Along with a need to provide perfectly suited environment and functions, there evolves a demand for adjusting services to various disabilities such as vision and hearing disorders, movement dysfunctions or disorientations. In the light of these assumptions, it seems necessary that a modern

hotel design should be focused not only on providing original interiors with technological novelties, but also on humanization and individualization of the public and private space in order to improve safety and well-being of users.

1.1 Purpose and Method of Research

The main purpose of the paper was to study a current state of knowledge on modern hotels and solutions implemented in working units in order to establish possible adjustments and amenities for the elderly and people with various physical and mental disabilities and dysfunctions. Attention was focused not only on major problems but also on minor disorders that impede and lower the comfort of a stay beyond a usual dwelling place on a temporary basis because it may affect any member of the population. All these solutions were compared with anthropometric human features and equipment measurements in order to describe the best suited standards. The literature studies were carried out on a number of examples and already existing recommendations. They were analyzed in the light of case studies researched in the form of field studies in Windmühle Seifhennersdorf – a complex including workshops, a hotel and green surroundings adapted for the needs of people with disabilities. A detailed focus was on components such as the main hall and reception hall, public horizontal and vertical communication, rooms with bathrooms and sports and leisure zones as they are closely connected with guest service and their design has a direct influence on the customers' comfort. An ergonomic and aesthetic standard of those spaces is constantly changing due to the development of new building and industrial technologies, materials, human expectations and a need for concurrency. The main methods used in the presented studies were graphical, comparative analysis, case and literature studies as well as field studies along with a synthesis.

2 Discussion – Hotels in Poland

In Poland in the 1970s the problem of architectural adjustment was widely harnessed by the legislation system and later in the 1980s it was described in technical conditions for buildings. However, realizations of these times did not take into account the suggested solutions. [1, p. 11] This situation has significantly changed and nowadays the problem of the disabled in architecture is widely recognized and discussed. In the case of hotels, however, solutions are limited to one or two adjusted units while the rest of the design is subordinate to aesthetical design. Lobbies, restaurants, sport areas, bars, clubs and cafes are usually planned as if they were meant only for fully healthy people. Complicated spatial plans, 'designer' solutions and sophisticated technological equipment can create hazards to all users. An important part of discussion is to define who should be included in a group with disabilities and what activities should be expected. Błądek [2, p. 19] elaborated a list of incapacities that each hotel should be prepared for, e.g. movement supported with different medical devices such as canes, crutches, balconies, wheelchairs, prosthesis, the blind and visually impaired, the deaf and hard of hearing, temporary manual, movement or perception disorders, allergies, phobias typical of the elderly, children strollers, pregnant women

and others. According to the statistical data presented in 'National Census of Population and Housing 2011. Report of the results' of Polish Central Statistical Office (Pol. Główny Urząd Statystyczny GUS) for the year 2011 (initial result), 12,2% of the population suffers from different forms of disability. The responders voluntarily declared or presented a valid document confirming their health status, which allows us to believe that this data is yet underestimated. [3, pp. 64] The overall number of people with dysfunctions, elderly and persons with temporary incapability reaches 30% and is similar to other European countries. [1, p. 13]

There are several general references that can be used for each hotel design. Cars and buses should be able to drive up directly to the front of the main entrance. The surface of the driveway must be hard, even and leveled with the interior floor. If a threshold is necessary it cannot be higher than 0,02 cm. Available space should be sufficient for wheelchair accommodation, an accompanying person and free passage for other users. It must be remembered that the minimum operational space for a person on a wheelchair is set at 150x150 cm and must be provided in front of any doors, slopes, stairs, etc. In the interiors it is crucial to keep the main communication path clear of permanent impediments and movable items that could block movement or create hazards. Lack of level changes or thresholds is advisable as well as avoidance of intersections between transportation and service paths with movement of people. A clear, understandable spatial layout with significant landmarks and without small vestibules, sluices or unnecessary door multiplication should be designed. The main entrance ought to be leading into the hall with information and reception that is clearly marked and contain places for service of people on wheelchairs. Surfaces of desks and tables ought to be placed on a certain height and have width that can be reached from a wheelchair or by a person who uses a cane (for the usually elevated reception desks the recommended height is 90 cm). [2, pp. 21-22, 53-54, 4, pp. 46, 5, p. 27, 6, p. 40]

Form and arrangement of furniture, appliances and utensils must be safe for all users and rounded angles are recommended. Due to a number of different disabilities and their character, workplaces should be adapted to individual needs. All movement areas and work surfaces ought to be well lit with light of constant frequency, providing proper color perception. It is also important that monochromatic colors and uniform textures for people whose sight is partially impaired may create additional problems in movement and orientation, although aggressive patterns and tones may turn out to be tiring. Attention must be drawn to floors which ought to have an even and non-slippery surface on which any level or function changes should be highlighted in contrast colors. For this purpose, also special bumps are used that can be sensed by the blind with a cane, however the material and form of those marks must not pose additional dangers, for example tripping or slipping. Stairs and slopes should have rugged surfaces in order to ensure better adhesion and must be protected with balustrades from both sides. Each country has its own set of rules concerning these elements; however, there is a common need for balustrades to have easy-grasping handles which are extended towards movement surfaces by 30 cm. Also spatial maps of a hotel and its recreation surroundings may be used which will help the guest to get to know a new space. [5, p. 27, 6, p. 40, 4, pp. 46, 2, pp. 21-22, 53-54] The most comfortable solutions of vertical communication are elevators and in a hotel they may be installed in spite of a number of floors because they will serve all guests and luggage transportation. It is important to keep operating tables (preferably in a horizontal

position) on an accessible height which nowadays seems to be a standard. Another popular solution is also the use of the public address system (PA) in elevators and other characteristic orientation points which helps blind people and partially sighted to navigate. The recommended [2, p. 63] minimum measurements for a hotel elevator adjusted for the disabled is 140x140 cm with doors not smaller than 90 cm, additional handles and symbols in Braille.

2.1 Measurement Recommendations

Wheelchairs have a number of measurements depending on their type and driving gear. The typical manual utility dimensions vary within width of 60-75 cm (i.e. 31 cm in a closed position), length 78-83 cm with sitting of 35-52 cm of width with the main wheel diameter at around 60 cm. For electrical carts and scooters used usually for exteriors these data are: width 58-72 cm, length 94-122 cm with turn radius about 70-80 cm. According to ISO standards these data are as follows: width 70 cm, length 120 cm which seems to be average and can be taken into consideration as typical. [4, p. 51, 8-11]. Width of the minimum passage for a person: with a cane or balcony – 70 cm, with two crutches – 80-90 cm or 68-96 cm (depending on a literature source), on a wheelchair 70-85 cm, with a guide-dog: 75-80 cm, with a white cane: 85-90 cm (175-185 cm in longitudinal section), 90 cm – through the door, for two people: on a wheelchair with another person beside – 1,50 or 1,60 m (depending on a literature source). The minimum standard corridor width vary depending on a country from 105 to 150 cm, in Poland 1,20 m and 180 cm for two lanes. The minimum working space for an operator sitting in a wheelchair has 80 cm of width, 60 cm of depth and minimum 1,2 m of depth for overall space (longitudinal section) – desk with floor. The height of operation level – 80 cm and 1,10, 1,30 m for shelves that can be reached above the workspace. As far as a general vertical hand-reach range is concerned for a person on a wheelchair, it is from 40-150 cm or 65-150 cm (depending on a literature source) and optimal for activities: 90-125 cm, side reach 0-60 cm (80 cm maximum) and on a working plane about 65 cm (front, maximum 80 cm) – 80 cm (side, maximum 90 cm). A standard sight level of a person on a wheelchair was set on 1,25 m from the floor surface. The vertical reach-range for a person moving with the support of a cane, crutches or a balcony is up to 155 cm, but a lower range varies at 50-65 cm. [7, p. 39, 4, pp. 44-45, 50, 70, 2, pp. 31-32] It is important to note that the suggested dimensions are standardized and they will vary depending on each individual and what is particularly visible in a hotel situation, each nation and race will have different anthropometric features.

2.2 Room Recommendations

Apart from general guidelines, there are several additional rules that will help guests with disabilities spend quality time in a hotel. First of all, user-friendly materials should be employed, i.e. natural, biologically safe and not emitting harmful particles or radiation. Instead of classically opening doors, disabled people are more comfortable with using sliding systems that can be manually or automatically operated with the use of buttons, touch sensors or photocells. [6, p. 40] The requirements prepared for

residential architecture assume that for one elderly person room surface should amount to 20 m², for two 22 m² and for one disabled person this value ought to reach 23 m². [6, p. 40] On the other hand, Jasiak, Swerda [4, p. 71] maintain that it should not be less than 16 m². The operational space in front of the main facilities should have the size of 150x150 cm. Most disabled people use different wheelchairs for exteriors, i.e. electrical scooter and other types for interiors, therefore each individual room ought to have some free space for wheelchair parking which is minimum 4 m². [6, p. 61] For people traveling with a guide-dog, a special place for an animal is required.

Windows and doors as well as sunshades must have opening handles on a reachable height. The same requirement refers to electrical plots, switches, touchpad, control panels and remote controls. This parameter is usually set on 80 cm or 85-110 cm (depending on a source) for door knobs and 90-110 cm for others. There must be an opportunity to turn off and on all the appliances and lights from the bed position. The arrangement of furniture, especially chairs, armchairs and beds should take into account ergonomics of changing positions from a wheelchair and enable approaching a given facility from at least one side. The minimum width of such a space is 80 cm. Although wheeled utilities enable an easy space change and arrangement, there is a possibility to block them, therefore they will not move while sitting. Shelves, sections of wardrobes and hangers have to be placed on the aforementioned comfortable access ranges. The doors of furniture ought to be sliding and in the case of traditional ways of opening, a person should not be forced to drive too far away from the equipment. A supporting structure of utilities cannot interfere with movement based on a wheelchair, cane of crutches. The space under desks and tables must be minimum 0,8 cm wide and 0,67 high to allow driving underneath. The fittings with changeable, adjustable surface heights will allow different users to work comfortably. A phone connected with the reception and emergency numbers is necessary in each unit. [2, p. 53, 69, 73], [4, p. 156]

Each adjusted unit should be fitted with a private bathroom and an outdoor resting space to provide the disabled with maximum intimacy if necessary. The space for outdoor relaxation on a terrace, balcony, loggia or in a garden for each elderly or disabled person is minimum 4,5 m². [6, p. 61] This sort of place allows a person to use it any time without any obligation to find an adjacent recreation green area in a foreign city. It is important to enable the bathroom usage without a need to ask for help of another person. The minimum standard dimensions of this room are as follows: width may vary depending on a country, i.e. 137-225 cm and length 150-300 cm. [4, p. 70] It is very important that an alarm switch can be accessible from this place as well in order to call for help from the reception. This option may be used by all guests. In Hotel 'Puro' in Wroclaw a bathroom is hidden in a glass cabin automatically delicately lit in the night, so it is easily accessible at any time. This sort of solution helps to avoid disorientation caused by a stay in unusual conditions. Another popular solution that can be found, e.g. in 'Monopol' Hotel in Wroclaw is a shower that is leveled with the floor surface – formed in marble – and is accessible without having to overcome any thresholds. If a movable or still seat is installed on the wall, it must be on the same level as a wheelchair and must be connected to a set of handrails enabling easy change. If bathtubs are used, it is necessary that they are equipped with special railings and additional facilities protecting from slipping and permitting a sitting position. There are also several producers offering bathtubs opened from one side which makes

entering and changing positions from a wheelchair more comfortable. They are deep with a barrel-like form and bathing takes place usually in a sitting position.

Measurement recommendations in reference to sinks/basins are as follows: width 60-70 cm, depth 50-60 cm, height of installation 80-90 cm. Some producers offer basins of flat and wide shapes with a convex curvature in the middle of the front edge that enables supporting the body. A gentle inclination of the device prevents from wetting clothes which is possible while washing hands or the face in a sitting position. The handles on both sides help to pull towards and push back from the washbasin. If for aesthetical reasons a decorative blade is installed and the basin is placed in it, there must be an additional space underneath in order to enable driving under and the front edge should provide an easy grip for users like in Kipriotis Panorama Hotel & Suites in Kos. It is recommended that for the needs of people on wheelchairs a mirror over a basin is inclined from the vertical position towards the user at about 10°. Shelves for cosmetics and toilet accessories should be installed at reachable heights providing a good observation angle and their shape should protect objects from falling. They can also be a part of the basin blade which seems to be a very comfortable solution. The toilet may be preferably accessible from the side with the minimum space of 115 cm between its side and the wall. It should be fixed on the compartment on the height of 50-54 cm and extended towards the front 75 cm from the back wall. [4, p. 72, 2, p., 73, 80, 91]

2.3 Common Spaces and Leisure Activities

All food courts, bars, restaurants, cafes should ensure easy access for the disabled, which is not sufficiently respected in small coffee bars and clubs usually situated in basements. Tables and chairs must also follow the relevant regulations. In large rooms such as halls, conference halls and spacious restaurant lounges the problem of excessive reverberation time causes the main sound waves to fade and makes speech incomprehensible. For this kind of interiors, inductive loops supporting individual hearing aids are used that help to strengthen the original sound. For translations and guided tours, radio systems with individual headphones may be used. In this group also infrared systems can be employed. The seats in assembly halls should be arranged possibly close to the speaker and performed presentations because such an arrangement will provide a better view for people with sight disabilities as well as preferable loudness for those with hearing disorders. The depth of space for the disabled sitting in a row arrangement is 155 cm. [2, pp. 23, 98] There is also a need for enabling access to hotel SPAs, sport zones, fitness centers, swimming pools and so on. If a lot of guests with special needs are expected to arrive in a hotel, it is advisable to equip a sport center with adjusted devices. The changing rooms should have separate cabins for people undressing in a sitting position (measurements 1,5 m x 1,9 m) or lying position (2,00 x 2,20 m) and showers which enable driving into cabins. Both areas must be equipped with handles and balustrades. In sport areas, wheelchairs designated for these zones should be used. This equipment needs the space not only for parking and storing, but also for cleaning and disinfection. For pools, special lifters or movable chairs are used that enable slow descending of a person into the water, however this sort of facility may be negatively perceived for psychological reasons. In this range, pools with movable bottoms that allow driving with a pool's wheelchair on

them and then slow lowering into the water are recommended. In these areas, adjusted barriers and handles should be used enabling movement for people with disabilities and orientation disorders. Also anti-slipping floors are indispensable in these areas. [2, p. 110, 4, pp. 139-145]

3 Case Study – References

Field studies were conducted in Windmühle Seifhennersdorf, Germany. The complex of buildings of a training center (designed by Architekturbüro Gustavs + Lungwitz Dresden [12]) includes two hotels, restaurant and a regional house as well as workshops, all situated on a hill in a place of an old windmill. The entire site despite its varied landscape is adjusted to people with disabilities, especially for those moving on wheelchairs, i.e. with the use of slopes, footbridges, bridges and terraces made of stone, wood, granite paving or concrete. This diversification also comprises an interestingly shaped green area offering recreation, leisure and open-air games (e.g. terrain chess) and it is accessible for everyone.



Fig. 1. Windmühle Seifhennersdorf – from the left: situation (site plan), large hotel, small hotel, adjusted terrain – wheelchair slope and bridge (on the plan: 1 – service building: restaurants, library, meeting halls; 2– large hotel with rooms for the disabled; 3 – small hotel, with rooms for the disabled, 4 – elevator leading to the lower level with workshops 5 – regional house – reception, meeting rooms [Elaborated on the basis of evacuation plans [13]).

Buildings have simple forms inspired by architecture of the region and historical object of the complex. Their shape harmonically blends in with the surroundings, which facilitates relaxation and creative activities that are held in workshops. Natural materials such as wood, ceramic and glass enable taking care of guests' health, with their colors that are toned but recognizable. The slope roofs referring to the local architecture were fitted with solar panels in order to gain renewable energy and keep air as clean as possible. Two hotels are comfortable to use and are relatively low – only two floors with wide corridors. Rooms for people with disabilities were situated only on the ground floor of the buildings on external sides of buildings in order to omit unnecessary movement and keep the way towards them straight and simple. The information placed near each entrance makes navigating through the structure even easier.



Fig. 2. Windmühle Seifhennersdorf – from the left: regional building with terrain adjustment, slopes and level (regional building in the background), car access – rondo

Due to the fact that this scheme was duplicated in each object, guests can easily find their way each time they visit the complex. The corridors are well illuminated with daylight seeping through large windows located on one longer side. Contrasting but calm colors – yellow walls, blue floors, white ceilings – create a sort of frame for the passage designating the main directions for moving

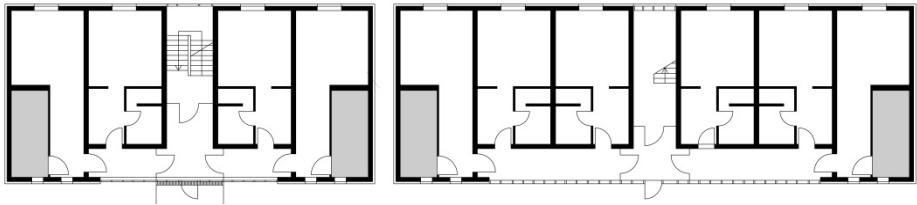


Fig. 3. Windmühle Seifhennersdorf – plans from the left: small hotel, large hotel (in gray adjusted bathrooms for disabled). (Elaborated on the basis of evacuation plans [13])



Fig. 4. Windmühle Seifhennersdorf – adjusted bathrooms for disabled users (from the left – in a large hotel, in a restaurant, details of a sink/basin installation)

In the adjusted rooms beds have been fitted with additional sides protecting from falling which can be also used as handles while sitting. Night cupboards are easy to reach, i.e. for turning on handy lighting. More furniture can be moved in order to arrange more free space in a room. Also an analysis of the building details has shown special thought put towards the proper adjustment of space. Also all elements which are important for orientation and moving such as handles, frames, balustrades as well as objects that can be hazardous like parts of the supporting construction were painted red in order to make them more visible.



Fig. 5. Windmühle Seiffhennersdorf – from the left: adjusted rooms, sliding doors to the bathroom, corridor

In the bathrooms sliding doors were installed and the passage was made wide. All facilities and equipment are placed in accessible spots for people on wheelchairs or with canes, furnished with basic and additional handles that have ribbed surfaces so they will never be slippery even when moist. The flush buttons were installed on side walls and dustbins are hung above the floor on a reachable height. An additional floor space for moving, turning, etc. provides disabled people with a comfortable environment.



Fig. 6. Windmühle Seiffhennersdorf – from the left: vertical communication building leading to workshops below, adjusted elevator, workshop's interior

4 Conclusion

Even a small disability can cause certain problems in movement, orientation as well as a physical and psychological health status. This is why an important part of each hotel design should be their adjustment for special needs understood in a broad spectrum. As field and literature studies have shown, each element of a common building structure can cause hazards or be planned in an adjusted manner. Also some “designer” solutions (lack of balustrades, small differences in tones of colors, vast polished surfaces) which are very popular nowadays in hotels can be inaccessible for some groups of users. Although written sources show that a lot of knowledge has been gained, we can see that in practical terms these recommendations are not commonly

used in buildings. Almost each modern Polish hotel contains an adjusted room; however, communication leading to it, its spatial plan of the main entrance vestibule, hall and reception may be confusing. Also level changes, slopes and stairs constitute architectural barriers as well as finishing materials of floors, while room furniture is sometimes not ergonomic at all and can be uncomfortable for users.

In the light of the aforementioned arguments, the main conclusion that can be drawn is that the issue of ergonomics in hotels should be studied further with a special focus on new technologies that employ natural materials which are safe for health and renewable, clean energy sources. A special emphasis ought to be placed on construction elements and environment parameters such as floors, stairs, slopes, level changes, elevators, natural and artificial lightings, colors and textures, furniture, orientation points (landmarks), balustrades and handles. Examples of good practice like the presented case study of Windmühle Seifhennersdorf complex must be broadly promoted in order to encourage architects and investors to focus closely on problems of people with disabilities and the elderly due to a great change and transformation in the European society structure in the nearest future.

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Evaluation of Guideline System and Sign Design of Public Space in Taiwan Emergency Department

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Abstract. In order to prevent the man-made error under stressful environment in the Emergency Department (ED), it is important to design the clear guidance of the sign. The anticipated goal of this study is to evaluate the emergency service in three major hospitals of southern Taiwan, especially to compare the strengths and weakness of guidance sign and the medical flow. By the focus groups with design professional and twice questionnaires, this study not only indicates the common problem of ED, but also redesigns the guideline system. The researchers consulted the strength in current emergency system and integrated color-coding to signal redesign. Guiding Line, Banner Design and Color Coding Integration were shown in the design stage. In the end, three factors (Guidance, Identification and Comprehension) were estimated the usability by Likert scale in questionnaire II. The design improvement might increase the efficiency and efficacy care of S.O.P in hospital emergency service, as well as quality of patient in future ED.

Keywords: Sign, Emergency Department, Public Area, Color Coding.

1 Introduction

In order to improve the patient safety and comfort, guideline system and sign design in medical field is very important, especially in the high-pressure Emergency Department (ED). In order to estimate and prevent the man-made error under fast and stressful environment in the ED of the hospital [1], the design of clear guidance of the sign to be easily allowing the patients to follow is extraordinarily important. A useful medical guideline system should allow for reliable and accurate interaction between system and the users in ED [2] [3]. Encoding, visualization and decoding is the process of information transmission [4]. According to the recently research [5] are three key points of sign design; (1) Arouse the reading motivation of user, (2) Attract the attention of users, (3) Increase the users' comprehension (See Fig 1). The successful sign design should base on the human-center standard, and stand on the viewpoint of user.

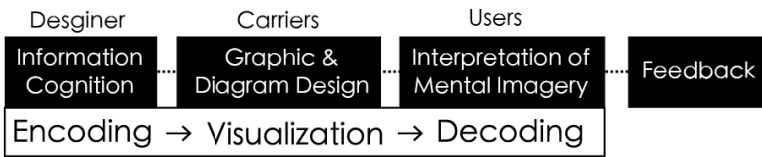


Fig. 1. Information Transmission [4]

Generally speaking, the medical flow of ED in Taiwan is working as Fig 2, when the patients arrive, the nurse or volunteer staff will start to triage the state of illness, and patient will ensure their triage station before the register. Then, the nurse will show the way for the appropriate consulting room and give the treatment. After seeing the doctor to decide receive the surgery, hold for continual observation or hospitalized for further treatment. The final stage is go to cashier and pharmacy and then discharge from the hospital.

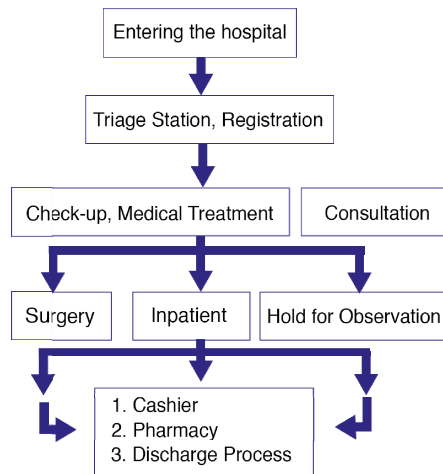


Fig. 2. Flow Chart

This study aims to evaluate the guidance sign of emergency service in three major hospitals of southern Taiwan and compare their strengths and weakness of the working flow. On the other hand, the study points out the common problems found in Taiwan ED, and conclude the opinion from experts and user to redesign the guideline system.

2 Methods and Data Collation

This study aims to evaluate the emergency service in three major hospitals of southern Taiwan; we collect the basic profiles of three hospitals by observing the daily flows in National Cheng Kung University Hospital (NCKUH), Chi Mei Hospital (CMH) and

Sin Lau Hospital (SLH) respectively. Through literature review and observational techniques to verify the key elements of the guidance design; then, the researchers precede the first focus group and questionnaire to integrate the experts' opinions and the core issue.

2.1 Observational Techniques

Observational techniques are one of the important aspects of action research and case studies whether undertaken by participants or outsiders. This study took the unstructured-participant observation [6] to data collection. The main idea is that researchers only do observation but not attend any activities of target. We use photography to collect the floor plan, path of the patient, sign and guideline system in three major hospitals in Tainan, the city of southern Taiwan.

2.2 Focus Group and Questionnaires

The focus group held in this study for twice, one took place after the observation to differentiate the study goal. The second focus group aims for the possible design directions. The participants who join the focus group have the professional background of medical or design. During the discussion, the researcher will ask the participants to share their personal experience of visiting the ED, introduced our observation outcomes and discussing the possibility of redesign the sign and guideline system.

Questionnaire I expects to confirm the problems found from first focus group applicable or not. Next, the second focus group will aim to refine the design concepts. When the researchers achieve the probable guideline system and sign design in ED by previous data collection, Questionnaire II will purpose the evaluation of new types of sign.

3 Results

3.1 Observation

Compare the three floor plans and the observation in NCKUH, CMH and SLH. We found that SLH has the smallest ED, as the result, the whole medical flow is easily understood by the patients. On the other hand, NCKUH is the largest among all EDs, in which had the most patients, and it was under the process of rebuild construction.

In term of the sign design and guideline system, there are only few guiding signs hang on NCKUH, but many temporary icons. The type of guideline system in CMH is really simple and clear, which won the good comments by users. Its medical flow collocated with number marks and single color-coding. SLH used two colors (light green and skin tone) to differentiate different use, one for index the road sign and other is target the destination in their public area of ED.

3.2 Focus Group I

Six participants were asked to join the Focus Group I, one has medical background, and others are industrial design experts. Based on previous observation, the main purpose of Focus Group I is to aid the inadequate information of ED and share the medical experiences as well.

There are some viewpoints found in the first Focus Group;

1. Many kinds of problem happened in ED, usually cause by the error that nursing staff didn't hand over the patients' condition completely.
2. Triage station is not clear that makes patient to ignore, and sometime nurse didn't ask patient's condition actively; therefore, the patient will miss the triage desk and jump to the registration stage.
3. Patient's family or accompanier paid more attention on problem of the sign seeking and guideline system.
4. Recently, the design concept of caring center often applied the "Central Island".
5. It needs to be considered the other livelihood service; such as public telephone, convenient store, restroom, and ATM.

3.3 Questionnaire Survey I

Questionnaire I confirmed the result and problem of Focus Group I. The participants of Questionnaire I required to have the medical experience in ED or had accompanied other to use the emergency service. There is 70.91% of participants face the neglect of nurse in the ED, and 60% of participants didn't know where to register. The reason is that 58% of them couldn't find the guiding sign.

According to the Questionnaire I, more than half of the participants (56%) used the assistant sign to find their way; however, interfering with many other signs or couldn't find the right sign were the major issues of confusion. The patients and their families often use the sign of restroom, information counter, registration desk and pharmacy. It was found that more than 80% of participants think the hospital should propagate the serious injury patient's priority while they on waiting list of emergency medical service.

3.4 Focus Group II

Seven participants attended Focus Group II, there are two major in nursing and three have design professional. Focus Group II aims to share the existing sign design to experts and discussing the potential design ideas to refine the concepts.

The researcher noted that the guiding system marked with numerical reminders made the whole proceeding easier. In addition, to encourage user's comprehension, the guiding line on the ground, which pilots different functions, was adopted. Nevertheless, these lines stick on ground will cause attrition problem. Besides, the arrow-head pattern probably caused the direction misunderstanding. The experts agreed that sign should overlook systematic design, and the concept of "Color-Coding" could be

a direction of farther approach. The experts also mentioned that it should shift the color of information to avoid causing visual tiredness on the long banner. Different purpose of use also addressed as a great ideas to distinguish the guideline system.

3.5 Design Stage

After reformulating the rough design concepts, the research team consulted the strength in current emergency system and experts’ point of views. Then integrated color-coding to redesign guideline system. Guiding Line, Banner Design & Color Coding Integration was following the discussing session, and we separated them to two categories, “Line” and “Banner”. (Table 1)

Guiding Line provided guiding information and direction on the ground of ED. Banner included more then three information or icons on the long board suspend from ceiling. Color Coding Integration, based on different colors and different uses to display the sign; for example, using colors to differentiate the medical or administrative signs.

Table 1. Design Items and Category

Category	Sign Design
Line 1	
Line 2	
Line 3	
Banner 1	
Banner 2	
Banner 3	
Banner 4	
Banner 5	

3.6 Questionnaire II and Usability Evaluation

In the last stage, the researchers appraised the potential designs’ usability by the Questionnaire II. 55 questionnaires were done by the participants who have the experience visiting ED. Three factors: Guidance, Identification and Comprehension were estimated the usability by Likert Scale [7] in Questionnaire II.

Guidance is the factor that brings the definite guiding effect to the users. Identification aims for users to see the sign clearly or not. The third factor is Comprehension, which determines the understanding of information given. Questionnaire II was compiled statistics by repeated measure ANOVA, the comparison of different design items are given in Fig 3.1 & Fig 3.2.

Through repeated measures ANOVA, it was discovered that all the factors of three lines had significant differences. Guidance ($F_{2, 108} = 48.106, p < 0.001$); Comprehension ($F_{2, 108} = 14.928, p < 0.001$); Identification ($F_{2, 108} = 3.609, p < 0.05$).

It's feasible to use the ground line of guiding ways; yet, the pattern types should be choosing carefully. To figure the means of different items from Fig3.1, Line 1 gained the best Usability. Although monochromatic and solid Line2 got the good performance of Identification and Comprehension, its Guidance is weaker among others.

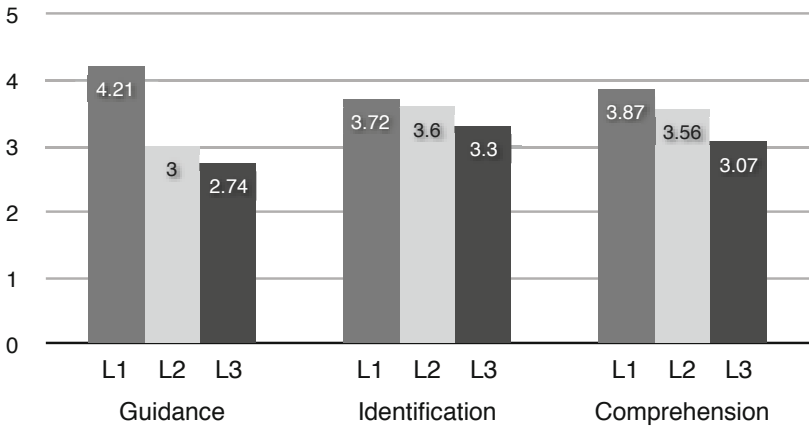


Fig. 3.1. Comparison of Usability of different Lines

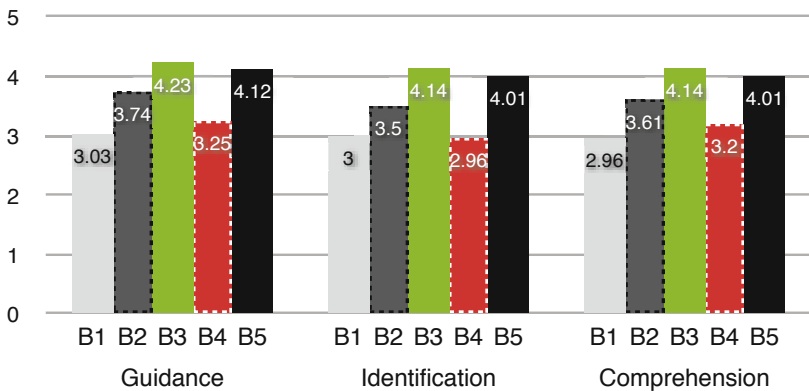


Fig. 3.2. Comparison of usability of different Banners

According to ANOVA, all the factors of five banners showed the significant differences. Comprehension ($F_{4,216} = 23.737$, $p < 0.001$); Identification ($F_{4,216} = 28.704$, $p < 0.001$), Guidance ($F_{4,216} = 28.156$, $p < 0.001$).

By inference of paired comparisons, Banner 2, 3 & 5 are in the high-performance group, while Banner 1 & 4 are in the lower one. Banner 3 with monochromatic obvious contrast got the highest Guidance. The color differentiate Banner 5 took the second place. Monochromatic Banner 4 and Banner 1, which are low contrast, achieved poor Identification among five items. The outcomes demonstrated that color separate with strong contrast or with different colors is a better choice for signs provided multi-information.

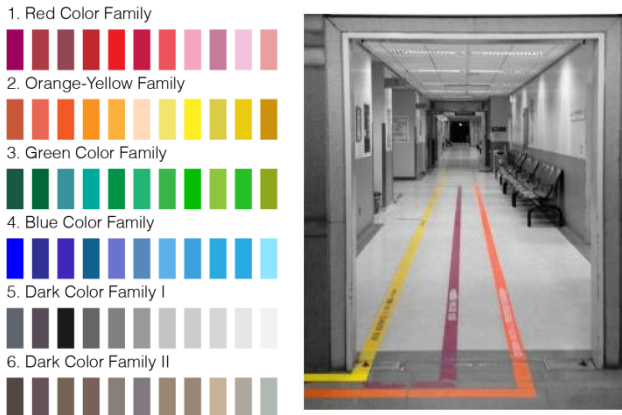


Fig. 3.3. Example of Color-Coding families and ground lining

Questionnaire II investigated the subjective preference of color-coding at the same time, most of participants (47.46%) prefer the analogous blue colors to use of administrative relevant signs, the green family (28.81%) stood on the secondary support level. On the other hand, preferences of medical relevant signs tend to the orange-yellow family (45%), and then the analogous red colors (28.33%). It was found that using the colorful lining guide-system practicable.

4 Discussion

Although the medical flow is completed in ED, but due to the specific status in the hospital, there were a few differences from other departments. For instance, the individual triage station, and variation of the registration. In addition, the interior configuration affects whole flow most. Some problems, such as containing the huge amount of patients or hospital beds obstructed the public area, caused by the interior design. It is discovered that visual guideline designs give few influence. The core-guiding problem is the crowded and disorder situation when lots of patients suddenly appeared in ED. Hence, the further study might focus on the guideline system of whole hospital environment and combined interior configuration.

Questionnaire Survey II demonstrated that colorful indicator sign and guiding line, which point out destination, are easier accepted by general. However, the patters

designed of Guiding Line should not be too complicated; and the color separation is the better choice for the banner provided multi-information.

The arrowhead emphasized the direction of Line 1, which won the higher Identification of users. In spite of other Lines also use stripe pattern to increase the degree of identify, they didn't obtain the users' confidence. The result confirmed that using color-coding to differentiate the medical or administrative relevant sign had high feasibility. Furthermore, colorful Guiding Lines on the ground are more obvious and directly for its usability, which could catch patients' attention. The items of lining also showed the higher degree of preference form Questionnaire II.

The study only evaluation the subjective preference, and it was limited by online survey. Studying in practical field of ED should be thinking about in the further research, the results might be different. In addition, graphic layout is the other important variables of sign design; for instance, the direction of the word or information on the banner might also affect the user' attitude.

5 Conclusion

The study found that it's hard for patients to seek the specific sign in ED; the identification might be confused if there are many icons provided. The researchers consulted the advantages and color plan of guideline system in public area of Taiwan hospitals, and redesign two main types of sign form experts' advices.

Line 1, with the pattern of arrowhead, got the good performance of Identification in questionnaire evaluation; the researchers discovered that banner with strong contrast or with different colors is the better choice of guide system of ED.

We anticipate our study to be a starting point for more sophisticated for efficacy care of S.O.P in hospital emergency service, as well as quality of patient in future ED. The other relevant studies will be benefit from such design developments.

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Dwelling Houses of Building Cooperative Schlesische Heimstätte in Wrocław (Former Breslau) and in Silesia in 1919-1941 as a Precursor of Modern Ergonomics in Architecture

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Abstract. Wrocław should be regarded as the most important amongst German cities in developing and promoting modern domestic architecture in interwar period. The influx of refugees fleeing the territories of Germany had lost as a result of the war and massive migration to other cities exacerbated the housing shortages. With its economy ruined by the war and burdened with huge reparations imposed on Germany, the country undertook considerable efforts to develop and present model solutions. New building cooperatives and societies were established to develop modern housing estates. In Wrocław, with the financial back up of the state, a housing cooperative – “Schlesische Heimstätte” was founded in 1919. Between 1919-1925 it was managed by Ernst May and it specialized in building cheap and functional houses for the people of modest means. It worked out the catalogue of ready-made designs and published a magazine called „Schlesisches Heim”. It built housing estates with small flats and functional gardens in sub-Wrocław districts and towns in Lower Silesia. It existed till 1941. In new housing estates not only a new form but also or may be first of all, new construction solutions, new, promoted at that time, materials, new colors, new layouts of flats, new interior arrangement, new way of living in modern houses and new urban planning were presented.

Keywords: interwar period, “Schlesische Heimstätte”, dwelling houses.

1 Introduction

In Germany after World War I in years 1918-1923 inflation was a decisive negative economic factor. Since 1923 the inflation process started to increase suddenly. Since July 1923 German currency lost its function of means of payment. Cash was changed into valuables as quickly as possible. Economic development was totally crippled. Unemployment had increased till 1923. Thanks to introduction of Rentenmark in October 1923 and stabilization of money as well as Charles Gage's scheme regulating reparations claims and loan connected with it, an upturn in economy in unknown, up till that time, degree started in Germany in 1924. Since 1924 a lot of credits, mainly from American investors, came in to Germany. They had long-term

impact on German economy. Between 1924-1929 German economy was relatively stable. Introduction of a tenement house tax in spring 1924 even improved it and made development of mass housing construction with the smallest two and three room flats in 1925-1930 possible.

In Wrocław need for flats was enormous. It was much bigger than in other German cities. Although a number of flats built here was as large as in, for example, Berlin, it was still not enough. Wrocław municipality gave an account of the worst housing conditions.

This enormous lack of flats was caused by division of Upper Silesia between Germany and Poland in 1922. It led to a great number of refugees. In 1919-1928 13.206 new flats were built with state money, where about 70 million marks came from city funds. Taking into consideration shortage of flats, minimal year demand for them was three thousand.

The 1920's and early 1930's were an exceptional period in the Wrocław development stimulated by a fruitful collaboration between the local group of innovative architects and municipal authorities. The first master plan was prepared in 1924, new planning regulations were implemented in 1926 and the city's administrative area was greatly extended in 1928 through the incorporation of suburban communes. The city was perceived as a unique place on the map of Europe, a hub for new solutions to the housing problem.

In June 1919 building cooperative "Schlesische Heimstätte", provinzielle Wohnungsfürsorgegesellschaft m.b.H (Silesian Homestead, provincial company supporting housing construction, Ltd.), was founded in Wrocław as part of Prussian housing act. It acted under the aegis of Ministry of Social Care. [1-5] It existed till 1941.

The partners of this company were: Prussian state, Silesian province, almost all country second levels of local government administration, a lot of districts and building cooperatives as well as Schlesische Landgesellschaft. In 1925 construction office employed about 40 people and had its branches in Jelenia Góra (former Hirschberg), Legnica (former Liegnitz) and Wałbrzych (former Waldenburg).

It specialized in building small and functional houses for people of modest means and worked out a catalogue of ready designs. It built estates with small flats and functional gardens in sub-Wrocław districts and towns in Silesia. The company dealt with organizational, financial, technical issues as well as making out estate plans and building designs. It also helped to supply with building materials.

In 1920-1930 the company published, together with Oberschlesische Siedlungs- u. Wohnungsfürsorgegesellschaft m.b.H. (Upper Silesian Company supporting housing estates and flats construction Ltd.) "Schlesisches Heim" magazine in which it propagated new- cheap building materials, constructions, house shapes and gardens as well as interior fittings and colours.

2 Types of Houses, Constructions and Materials

In the first years after WWI, at the time of great postwar crisis, Ernst May - a young architect beginning his career, was appointed as a manager of "Schlesische Heimstätte". May was under big influence of work of Theodor Fischer and Raymond

Unwin as well as movement for protection of native lands (Heimatschutzbewegung). He simply paid attention to traditional architecture. [4] The company was to supply people of modest means with healthy and properly furnished flats at low prices. Own house with a garden, often with an outbuilding for small livestock, was the long-awaited ideal and was connected with a possibility of growing own food. In hard economic times occupants - to - be quite often helped to build their future houses.

Ernst May's motto for construction design office concerned craft tradition, accuracy in outer shaping of a building block and architecture adjustment to a given surrounding. [4]

Architectural and urban planning concepts were to draw inspirations on Silesian countryside buildings. The buildings were to remind old houses and agricultural homestead.

After 1918, in order to lower construction costs, standardization and streamlining of construction processes were propagated. Standardization turned out to be a superior feature of "Schlesische Heimstätte" company's construction despite its traditional, often rural look.

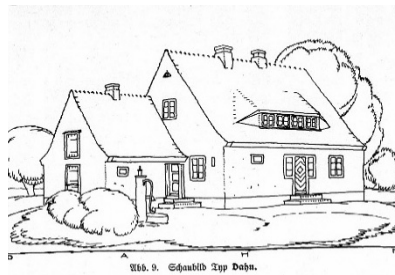


Fig. 1. "Schlesische Heimstätte" detached house, Dahn type (Source: Schlesisches Heim, 5, no.3, p.74)

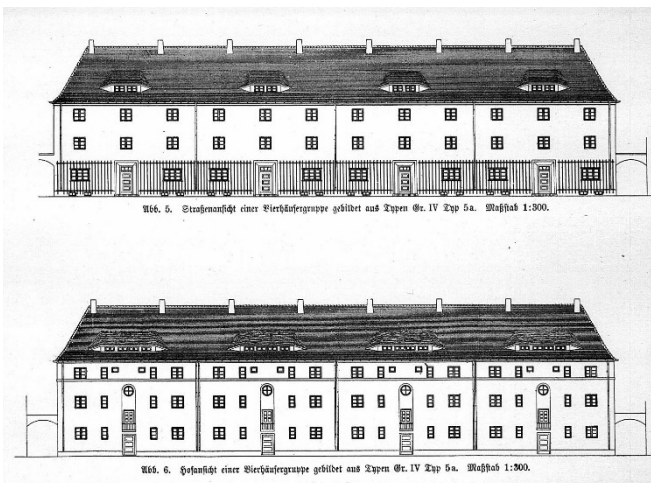


Fig. 2. "Schlesische Heimstätte" multi family house, group IV, type 5a (Source: Schlesisches Heim, 1, no.4, p.10)

In construction office of “Schlesische Heimstätte”, a catalogue of 16 types of one - and multi - family houses were worked out. First they were numbered but later on they were named after important personages of Silesian culture – reformers, architects, writers, poets, industrialists, philosophers, painters (e.g. Opitz, Schleiermacher, Gerhart Hauptmann, Karl Hauptmann, Damaschke, Langhans ojciec, Langhans syn, Freitag, Borsig, Boehme, Menzel, Ulitz, Dahn, Willmann, Logau, Neisser itd. [1], [4], [6 - 12] While standardizing window and door forms, “Schlesische Heimstätte” cooperated with German industry committee for standardization. [4] Flats with a floor area from 52 m² to 76 m² were offered. Only “Menzel” terraced house as well as “Felix Dahn” detached house for moderately rich with a floor area of 144 m² were larger. The propositions of the smallest houses were introduced in 1919-1920. They were crisis houses (dwelling summer houses) with a room, small barn and toilet. They were to be enlarged or replaced with new buildings after the economic situation would have improved. However, they were never mass-produced. [4]

May put emphasis on rational, functional and economic lay out of a flat where kitchen consisting of a dwelling part and cooking niche, was a central place. This type of flat was very common in Silesia.

Houses designed by “Schlesische Heimstätte” were inspired by native style propagated earlier by Heinrich Tessenow. Traditional gable roofs, among the others centring roof, for example, in 1921-1922 in Ołtaszyn (former Ołtaschin) estate for agricultural workers in Wrocław. Sloping roof of this construction not only let use the attic area better but also lowered the construction cost of the house.

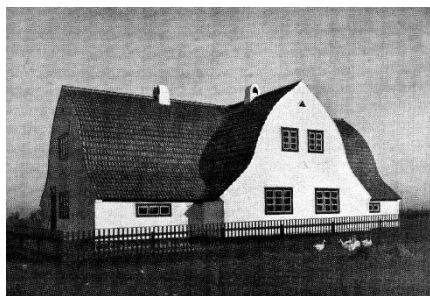


Fig. 3. Dwelling house with centring roof in Ołtaszyn (former Ołtaschin) (Source: Schlesisches Heim, 5, no.12)

Because of the lack of building materials after WWI, building cooperatives used substitute materials. “Schlesische Heimstätte” company presented a house with centring roof covered with clay shingle at Wrocław building fairs in 1921. [15 - 16] Three walls of the house were erected in “Schima” construction from fired airbrick which, because of larger size and smaller weight, allowed to build faster than from traditional brick. [4] The fourth wall was made from clay hollow bricks produced by “Schlesische Heimstätte” company. The company constructed a machine to produce such bricks. With its help it was possible to make use of the clay being on side. [4]

Traditional natural materials were recommended in all designs – walls built from bricks and plastered, wooden truss and roof covered with tile. [17] In order to find cheap solutions old local building materials were used. Walls could be built from dried clay blocks, limestone, calcareous slag or wood. Shingled or even thatched roof houses were suggested. [18]

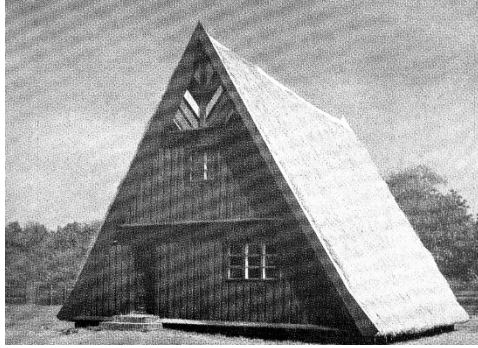


Fig. 4. Model House presented at Wrocław building fairs in 1922 (Source: Schlesisches Heim, 4, no.1)

“Schlesische Heimstätte” from the very beginning of its activity based on mass - production, used standardized building elements of houses – beams, rafters, windows, doors, stairs, stoves etc.

3 Interior Fittings and Colours

Ernst May took advantage of colour as an important artistic means. Colour was to decrease the monotony of complexes of average houses. The use of colour by “Schlesische Heimstätte” became part of all - German trend concerning colourful construction of interwar period.

Architects aspired to preserve originality of their works. Colour had become an excellent means to achieve individual character of the particular estates. It was used on house elevations and interiors.

In pages of “Schlesisches Heim” articles propagating the use of colour as well as those showing carried out examples and technical problems were published. [19 - 20] It was written that no other means adds, at such a little cost, peculiar character to rooms. “Schlesische Heimstätte” designs were accompanied by colour cards showing designed colours of separate building parts both outside and inside. Paul Baumann’s, from Aue in Sachsen, pattern book of 1350 different shades of colours was used. [21] Attention was paid to the impact of colour on men and possibility of the intensification of light and the sun in rooms. [20] Colours were chosen in accordance with the purpose of the rooms. Colours of the furnishings - furniture, stoves, lamps etc., were also taken into consideration. Two ways of obtaining elevation colour were pointed out – plaster coloured in a mass and plaster painted in paint. The first way gave small

possibilities to get diverse colours. In “Schlesische Heimstätte” only 5-6 distinctive colours were obtained. The other way gave much bigger possibilities. “Keim” mineral paints were promoted. [21]

“Movement for colour” had its peak between 1926-1929. It revived thanks to the growth in economy. Colour was used in mass - housing construction not only by radical, avant-garde Neues Bauen architects (Bruno Taut, Otto Haesler) but also members of “Bund zur Forderung Farbe im Stadtbild e.V. ” (BFFS) founded in 1926. That second term was supported by craftsmen and industry producing paints. [22]

Bruno Taut was a pioneer of “movement for colour” (Farbenbewegung) in Germany. His love for colour was already noticeable in early garden estates built before WW I. Since 1913 together with Paul Scheerbart, he developed an idea of architecture and fine arts synthesis (Gesamtkunstwerk), placing colour equally with a building shape. His constructions inspired, among the others, Ernst May and encouraged to “fight for colour”. “Farbiges Magdeburg” campaign ran since 1921 stimulated “movement for colour” in Germany in the next few years. They used bright colours such as: red, orange, blue, green, ochre, brown, purple, pink, grey and black. They also used vivid value and colour contrasts.

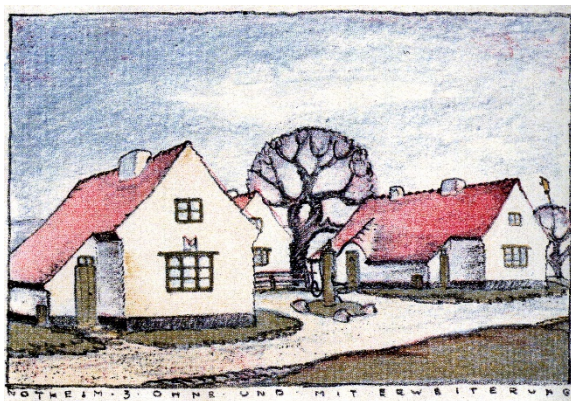


Fig. 5. Dwelling houses, Wrocław Złotniki (former Goldschmieden) (Source: Schlesisches Heim, 2, no.2)

After his visit to Magdeburg, Ernst May became convinced that the use of colour in architecture was a must. [23] In 1922 he published in “Schlesisches Heim” an article entitled “Fear of colour” (Angst vor der Farbe), in which he enthused about Magdeburg experiment and called for using colour. In 1919-1925 he built in Wrocław and its vicinity a lot of colourful estates (Klecina, Ołtaszyn, Prudnik, Bolesławiec – former Klettendorf, Oltaschin, Neustadt, Bunzlau). He designed buildings in the form of barracks where colour (red, blue, green) was the only decoration. May used, as he claimed himself, the cheapest and most decorative means to add life to simple architecture.

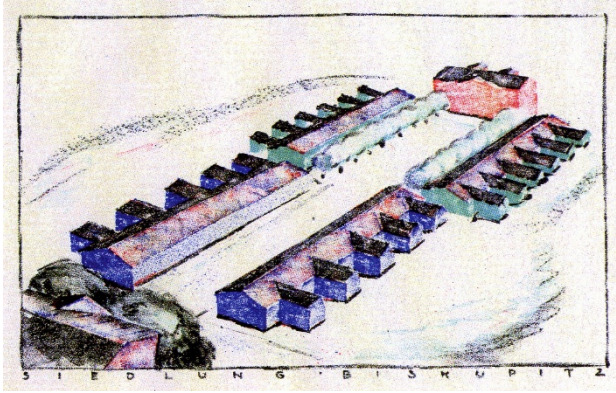


Fig. 6. “Schlesische Heimstätte” estate, Zabrze – Biskupice (former Hindenburg – Biskupitz) (Source: Schlesisches Heim, 4, no.5)

In new housing estates, colour had an important task to do. It was to create an impression of secure estate space. Involvement of city building authorities who supported “movement for colour”, played an important role in shaping colours of German cities of the time. Two methods were used - “colour dictatorship” according to Ernst May’s concept which he initiated in Frankfurt on the Main (municipal officials who supervised painting works done according to designs made earlier were appointed) and consultancy based on freedom which was introduced in Wrocław. An independent organization enabling arrangement of colour designing according to identical criteria was founded here. Municipal Council for Visual Arts and “Colourful City” society were founded. A function of local visual artists who worked under four department managers: Theo Effenberger, Moritz Hadda, Hans Scharoun and Hermann Wählich, was introduced. [24]

Interior fittings were also standardized. The dimensions of furniture designed by “Schlesische Heimstätte” was adjusted to small flats. [25 - 26]

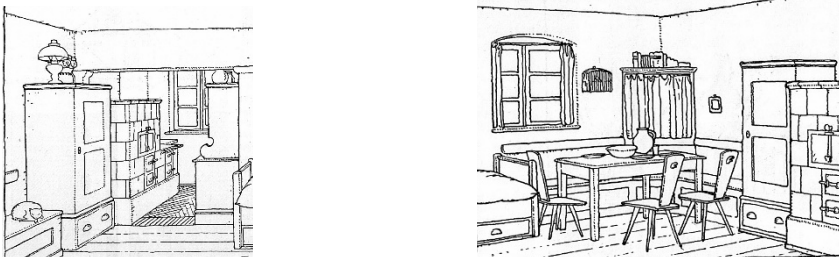


Fig. 7. Standardized furniture in small houses (Source: Schlesisches Heim, 1, no.2, p.4)

4 Gardens

Interest in landscaping was connected with cooperation with Leberecht Migge that started in 1922. The manifestation of it was Niederschlesische Gartenfürsorgegesellschaft m.b.H. (Lower Silesia Company for Supporting Gardening, Ltd.) founded in 1923 in Wrocław by “Schlesische Heimstätte” and landscaping architect Leberecht Migge from Worpswede. The company signed a contract for an unlimited period and its aim was to make gardens as well as to support intensification of agriculture, especially small home gardens. Garden appliances were sold. The company was to realize its tasks in very close cooperation with “Schlesische Heimstätte” and institutions called to support laying small gardens. Information on company’s activities was published in “Siedlungs-Wirtschaft”, a magazine edited by Leberecht Migge and Max Schemmel, since 1923 as a supplement of “Schlesisches Heim”. The magazine popularized knowledge about agriculture, especially in small, functional home gardens and showed model gardens and estates. [27 - 28]

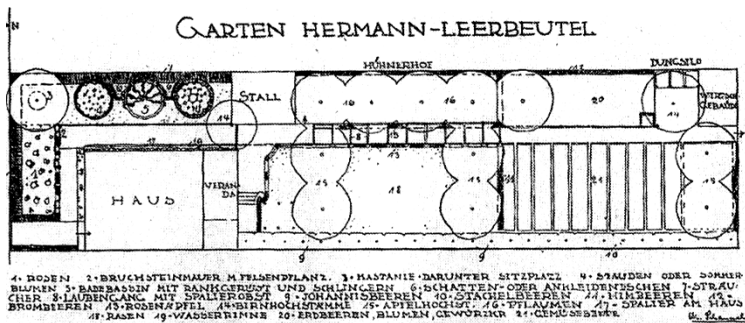


Fig. 8. Garden of “Schlesisches Heim” dwelling house in Wrocław, Zalesie (Former Leerbeutel) (Source: Siedlung – Wirtschaft, 3, no.12, p.437)

Allotments were also propagated. For example, in western part of Wrocław, in the vicinity of the road to Leśnica (former Deutsch lissa), on the Ługowina stream (former Schöngartener Flossgraben) in 1931, 300 modern common gardens “Am Flossgraben” were made by “Schlesische Heimstätte”. Gardens of area of 500 m², 600 m², 750 m² and 1000 m² were, first of all, to supply food. A lot of roads, playgrounds for children and numerous wells were built in that area. Garden owners had to build summer house in precisely marked places and according to types allowed by “Schlesische Heimstätte”. All the gardens had trees and fruit plants. Small Garden Union (Kleingartenverein) made out a decision that let people raise small animals in their gardens. The results of growing and raising were to support home budgets in hard times of crisis.

5 Conclusions

Activity of “Schlesische Heimstätte” shows the changes concerning shaping of social housing estates after the First World War according to the social situation in Germany.

The main task of “Schlesische Heimstätte”, in compliance with its status was building of rural and suburban estates, that’s why most of typical houses was of rural character what was very well accepted by future dwellers. Building form, interior’ size, ergonomic furniture became a success of “Schlesische Heimstätte” activity in Silesia.

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The Discussion of Innovative Concept for Icon Display on Elevator's Indicator

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Abstract. In this paper, we focus on the researching innovation of open-close button of elevator by questionnaire. The text of native language is found the best cognition for button indicator of open-close on the attributes of observability and relative advantage in elevator. The conclusions are: (1) Chinese glyphss “開 (open)” and “關 (close)” are the most easily observable and the highest relative advantage. So the text of native language could be the best for open-close button in elevators. (2) The complex symbols are the thick stroke with multi-element. (3) Important indicators of elevators could not only need thick black and slender arrows, but also it is non-highlighted.

Keywords: elevator, button indicator, caring concept, diffusion of Innovations.

1 Introduction

An elevator (or lift in the Commonwealth excluding Canada) is a type of vertical transport equipment that efficiently moves people or goods between floors (levels, decks) of a building [1]. After 150 years, a set of doors kept locked on each floor to prevent unintentional access into the elevator shaft by the unsuspecting passenger when the lift working, the safety and control has great promotion. There is innovation in the manipulation control, some button controls, which are generally inaccessible to the public, include: Fireman's service, Switch to enable or disable the elevator. Especially, there is a pair of open and close switches or buttons to control the doors for passengers.

There is evidence that arrows are special over learned stimuli which are processed in a favorable way. Several studies have provided evidence supporting the notion that gaze acts as a special attention cue that reflexively triggers attentional shifts [2, 3]. These studies applied a spatial cueing paradigm, first introduced by [4] and reviewed by [5]. There is a issue to discuss the gaze acts to utilize in efficient control. [6] found indicate that predictive arrows produce attention effects that greatly exceed the individual or summed effects of reflexive orienting to nonpredictive arrows and volitional orienting to predictive numbers.

[7] proposed diffusion of innovations is a theory that seeks to explain how, why, and at what rate new ideas and technology spread through cultures. It is a adequate

proposal to search a new design from several attributes. Diffusion of an innovation occurs through a five-step process. This process is a type of decision-making. It occurs through a series of communication channels over a period of time among the members of a similar social system. Ryan and Gross first indicated the identification of adoption as a process in 1943 [7]. Rogers defines several intrinsic characteristics of innovations that influence an individual's decision to adopt or reject an innovation. In the diffusion of innovation, Rogers' 5 factors which cognitive attributes of the innovation are different importance, can be divided into: (1) Relative advantage: How improve an innovation is over the previous generation; (2) Compatibility: The level of compatibility that an innovation has to be assimilated into an individual's life. The innovations and value system of past experience; (3) Complexity: the degree of difficulty of the understanding and use of an innovation, If the innovation is perceived as complicated or difficult to use, an individual is unlikely to adopt it. (4) Trialability: How easily an innovation may be experimented. If a user is able to test an innovation, the individual will be more likely to adopt it. (5) Observability: The extent that an innovation is visible to others. The consequences of the innovation can let others observe [8].

The elevator has become necessary machine for high-rise building, the most frequent operation is selecting floor button, next is open or close button, conveying a significant switch button can be accurately operated by passengers. The door will automatically close after 6-10 seconds when passengers entered elevator. If the passengers find outside ones who are galloping, they always hastily reflex to push open button, unfortunately, they occasionally and mistakenly push the close button, getting a disservice. We can distinguish that it is a instantaneous error judgment, causing from unclear enough key indicator icon display, leading to identify problem of open and close button. Simple and obvious icon design conveys clear meaning become importance of passengers. If the passengers can not properly recognize the icon display of "open or close" key button, they will miss action from hesitation, even mistakenly push the opposite switch, causing to embarrassment. The appropriate icon display can convey proper meaning to avoid misunderstanding.

Although, the mistakenly push open button to close door, it did not hurt passenger but also enough to scare them. To avoid mistaken open-close button is a main issue of taking elevator, so trying to focus on researching icon display of open-close button to recognize more innovative display of indication icon which has become the research purpose.

2 Methodology

In order to search innovative concept, two factors determine what type a particular decision is: Whether the decision is made freely and implemented voluntarily, and who makes the decision. Based on these considerations, three types of innovation-decisions have been identified within diffusion of innovations. The collective Innovation-Decision: This decision is made collectively by all individuals of a social system.

We tried to collect Innovation-Decision, used Rogers' 5 factors of diffusion of innovation. According to the characteristics of icon display, the triability attribute is not suitable for researching innovation of button indicators. Therefore, we choosed 4 factors as questionnaire items; (1) Relative advantage, (2) Compatibility, (3) Complexity, and (4) Observability, with the Likert 7 scale.

Accepted a high degree of innovation, is recognized as a high relative advantage, compatibility, observability, low complexity [9]. We Depended on this innovation theory to research indicator of "open and close", followed three steps to find the innovative concept of icon display on elevator's key button.

2.1 Collecting Samples

(1) Collecting photos: to collect photos of open-close buttons of elevator, taking pictures from several Asian countries such as Taiwan, mainland China, Malaysia, Hong Kong from 2009-2012. Then to discuss groups of their characteristics from collected photos.

(2) Selecting representative samples: Take representative samples from the collected photos, and then excluding similar ones.

(3) Depicting contour of indication icon: In order to have clear image of button key indication icon for investigation, each indicator will ignore material and light to concentrate on contour display. The collected photos were depicted into Bezier curve as icon display by drawing from CorelDraw13.

2.2 Sample Evaluation

(1) Descriptive statistics of key indication icon display: The value of each sample of open-close buttons is verified by descriptive statistics.

(2) Innovation description: Cognitive attributes of the innovation is recognized as a high observability, relative advantage, compatibility, and low complexity. We can discuss which indicator is adaptive value of 4 attributes.

3 Result

There were 113 questionnaires from Internet survey, and were statistical analyzed by SPSS PASW 18.0. Through descriptive statistics has 48 males (42.5%) and 65 females (57.5%), and reliability test found that the survey showed significance of gender and background.

3.1 Collected Testing Samples

Collected Photos. There are 103 photos of open-close key indication icons from Asian countries such as Malaysia, China, Hong Kong, Taiwan travel, then deleting the same or similar ones, and 56 photos were left.

Material of Key Indication Icon. After finishing found a relationship between the buttons and icons, can be divided into two categories: the separation of buttons and icons, and the synthetic one, a total of two forms, as the main way to synthesize one.

Selecting Representative Samples and Depicting Contour of Samples. In order to simplify forms and ignoring material, the kept photos were depicted to be white-black key indicator by software of CorelDraw, then removed the similar one, 18 kinds of key indication icon (see table 1) are left to proceed the following study.

Table 1. Diagram of key indicator of open-close button

	Open	Close	Open	Close	
1			10		
2			11		
3			12		
4			13		
5			14		
6			15		
7			16		
8			17		
9			18		

3.2 Creativity Evaluation

One participants were deleted from the data set because of excessive missing data, resulting in a final data set of 117 participants. Female comprised 56.8% (n= 67) of the sample (male, n=50). Participants' Educational level comprised from senior high school (5.1%, n=6), undergraduate (65.8%, n=77) and graduate (29.1%, n=34). The majority of field of education were Design (38.5%, n=45), and the other were seven fields as table 2.

Analysis progressed from 4 attributes for evaluation: relative advantage, compatibility, complexity, observability. According to descriptive stastics, the button icons of open and close have been evaluated as below, and recognize which is the better or worse disply of indication design. They are significance of all key indication icon of open-close with 4 attributes from one sample T-test, therefore they are reliable to discuss.

Table 2. Participant's background

Basic information	Description	No (n)	Percentage (%)	Cumulative percentage (%)
Gender	male	50	42.7	42.7
	female	67	57.3	100.0
Educational level	Senior high school	6	5.1	5.1
	undergraduate	77	65.8	70.9
	graduate	34	29.1	100.0
Field of education	Humanities and Social	13	11.1	11.1
	Design	45	38.5	49.6
	Art	7	6.0	55.6
	Management	18	15.4	70.9
	Science	4	3.4	74.4
	Engineering science	16	13.7	88.0
	Medical science	3	2.6	90.6
	Natural science	2	1.7	92.3
	other	9	7.7	100.0

Indicators Evaluation on Relative Advantage. In this section, we discuss the relative advantage, it means that the old things as opposed to being replaced, the extent of the advantages of innovations.

1. *Indicators evaluation of open icons on relative advantage.* The old things as opposed to being replaced, the Chinese glyphs “開 (kai)” (Fig. 1) is the first place of relative advantage. The second place indicator is the no.11 which has obviously opposite direction and 粗黑 arrow. The last place is the no.2 which has opposite arrow and two vertical lines to represent a door but feel complex. The second last one is white opposite arrow and on black background.
2. *Indicators evaluation of close icons on relative advantage.* In this attribute, the first place is no.11 which has obviously same direction and thick black arrow (Fig. 2). The second place indicator is Chinese glyphs “關 (kuan)”. The last place is no.9 which has white opposite arrow and on black background.
3. *Indicators evaluation between open and close icons on relative advantage.* The Chinese glyphs ‘開 (kai) and 關 (kuan)’ own the highest relative advantage (Fig. 3). It means that the native language character owns advantage of innovative cognition from mental image. We can obviously find out the icon display of open and close button that they own near cognition.

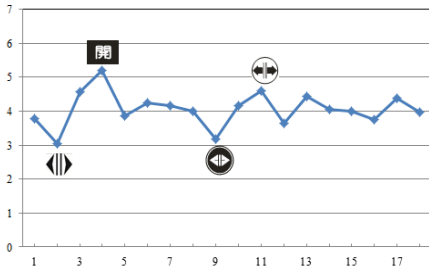


Fig. 1. The evaluation of relative advantage in open button

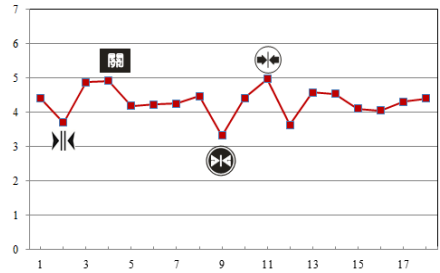


Fig. 2. The evaluation of relative advantage in close button

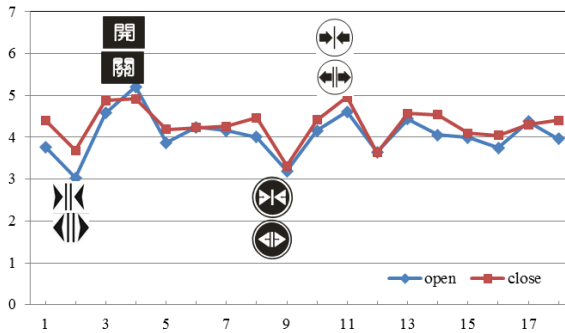


Fig. 3. The evaluation of relative advantage between open and close button

Indicators Evaluation on Compatibility. Compatibility means that the innovations and value system of past experience in diffusion of innovation. In this section, we can recognize the compatibility to win innovation.

1. *Indicators evaluation of open icons on compatibility.* All key indication icons are high compatibility (Fig. 4), it could know that they are well designed and selected from company, and have been verified by marketing research, but also appear fitnest difference in diffrenet country. The first place of compatibility is no.3 which has simple triangle white arrow, square black background and vertical thin line to display starting location, it has a clear opening image. The second place is the Chinese glyphs ‘開 (kai)’. The last two places of compatibility are same as the attribute of relative advantage.
2. *Indicators evaluation of close icons on compatibility.* The first place os close-button is no.11 (Fig 5), thick and black arrow have higher attraction which could be important symbol of directional icon. The simple triangle arrow (no.3) has the second place. However, no. 9 has thick arrow, owns the worst compatibility, it may have highlight to affect sense of sight.
3. *Indicators evaluation between open and close icons on compatibility.* The pair of no.2 wins high evaluation of open and close icon in this attribute (Fig 6), it could cause from the squre shape to match the elevator's space image. The pair of no.9 has lowest, it could cause from the fragments to lose evaluation.

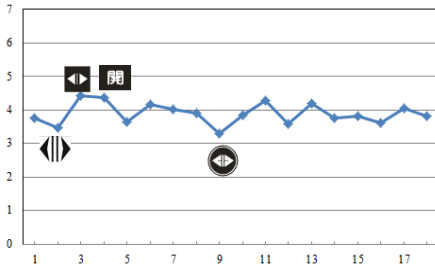


Fig. 4. The evaluation of compatibility attribute in open button

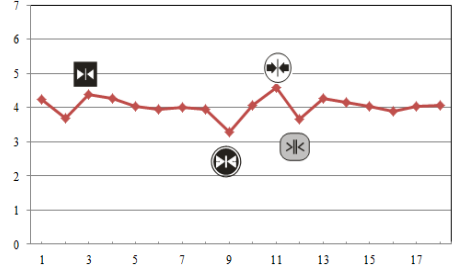


Fig. 5. The evaluation of compatibility attribute in close button

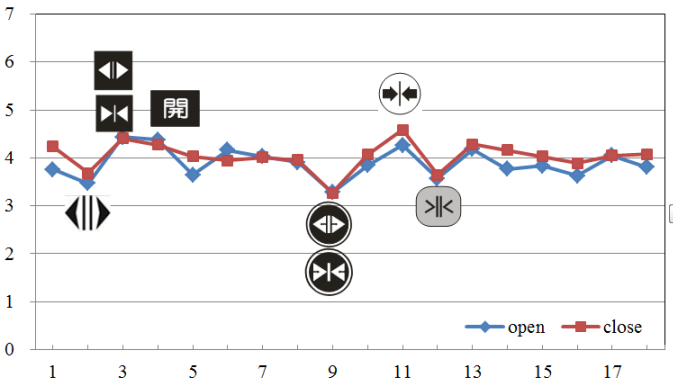


Fig. 6. The evaluation of compatibility attribute between open and close button

Indicators Evaluation on Complexity. In this section, we discuss the degree of difficulty of the understanding and use to recognize the innovation.

1. *Indicators evaluation of open icons on complexity.* The most complex key indicator of open button has a humanoid between a pair of reverse arrow (no. 5) in Fig. 7 the little less complex is no.3. On the contrary, simple and reverse arrow is recognized lower complex direction icon display.
2. *Indicators evaluation of close icons on complexity.* The no.9 (Fig 8) is the same as open-button that this pairs is the most complex indicator, the Chinese glyphs “關門 (guan-men)” (door close) in Fig. 8 is the second complex. It can be said that the thick stroke arrow, and two small Chinese glyphs are congonized to be complex.
3. *Indicators evaluation between open and close icons on complexity.* The no. 9 pair is the most complex icon, it could cause from the conflicts between circle and triangle. The no.3 pair and no. 13 pair have the least complex, they have simple triangle arrow to win the better reputation (Fig 9).

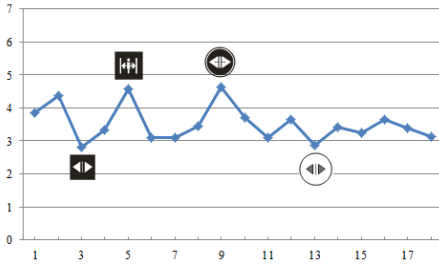


Fig. 7. The evaluation of complexity attribute in open button

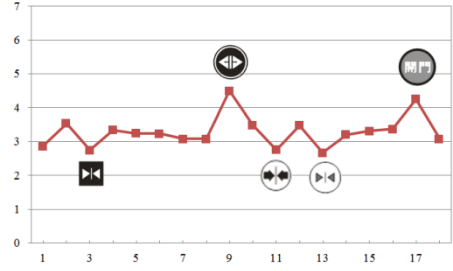


Fig. 8. The evaluation of complexity attribute in close button

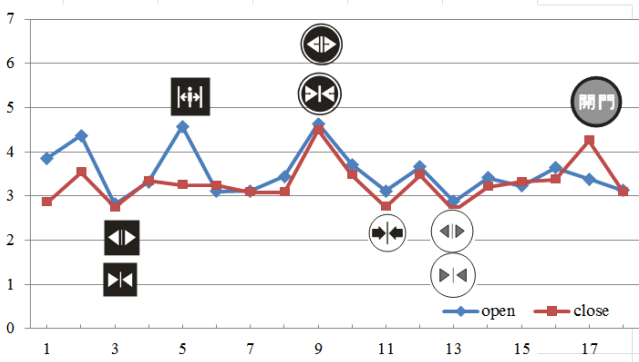


Fig. 9. The evaluation of complexity attribute between open and close button

Indicators Evaluation on Observability. In this section, we judge the consequences of the innovation of icon display can let others observe.

1. *Indicators evaluation of open icon on observability.* Although the common indicators of opening are the reverse arrow, but the no.4 “開 (kai)” (Chinese glyphs) (Fig. 10) is the most easily observable. Although the Chinese indicator is not suitable for Non-Chinese-speaking countries, but it can be said that open button with the native language text is the most easily observed in elevator.
2. *Indicators evaluation of close icon on observability.* The no.11 (thick arrow) (Fig. 11) is the most observable in close button icon, the Chinese glyphs “關 (guan)” (close door) is also the second observable place. Although, the Chinese glyphs is not easily observable for none-Chinese, but it is popular and recognizable.
3. *Indicators evaluation between open and close icons on observability.* From this section discussion, we can find out the better pair (no.4, no.11) and worse pair (no.2, no.9) for open and close button icon (Fig. 12). The icon display has obvious perception with native language text and thick directional arrow which are better, the other are multi-turn and crushing the arrow which cannot be easily observed.

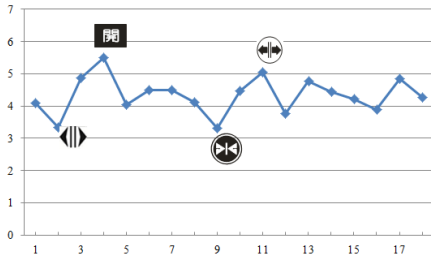


Fig. 10. The evaluation of observability attribute in close button

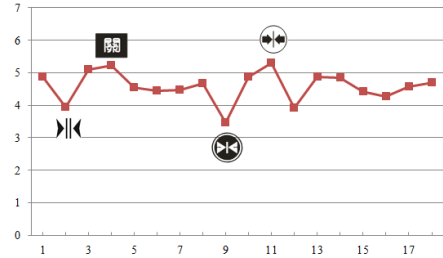


Fig. 11. The evaluation of observability attribute in close button

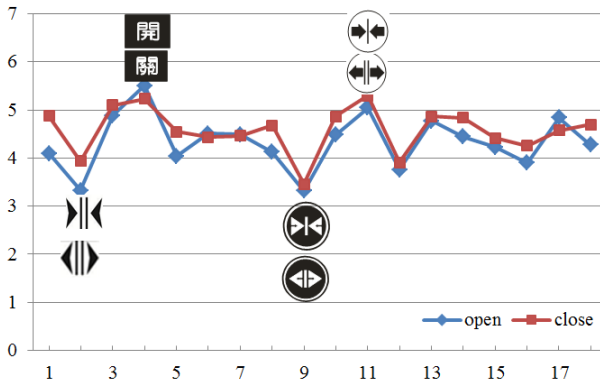


Fig. 12. The evaluation of observability attribute between open and close button

4 Conclusion

From the discussion, one may conclude that the button indicator has several important recommendations to care users. (1) Chinese glyphs “開(open)” and “關(close)” are the most easily observable and the highest relative advantage, so the text of native language could be the best for open-close button in elevator. (2) The complex symbols are the thick stroke of arrow indicator, small and many strokes of Chinese glyphs. (3) Important indicator of elevator could not need thick black obvious arrow, but also it is non-highlighted.

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A Map Guidance System by Multiple Dialog Robots Cooperation

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Abstract. The purpose of this study is to release user's feeling of unease and loneliness, which occur in people's mind while heading for the destination, by appropriate encouragement by multiple robots. In our development, we combined the robot technology with "good old-fashioned guidance know-how" and employed five concepts: Manual less, Operation free, Device free, corporeality of robot and Advantage of network robot. A comparative experiment was conducted. It proved the effectiveness of robot giving ease and joy to user. At the same time, we have found that the user come to feel uneasy with increasing distance from the robot. Therefore, measures for improving this problem have been studied. Those are the quantification of psychic distance concerning unease and the introduction of mobile robot.

Keywords: multiple dialog robots, guidance, networks, cooperation, encouragement.

1 Introduction

Nowadays, the navigation system of smart-phone has been getting popular. However, we have found that it causes some new problems especially with people who are not good at using smart-phone. It is a little dangerous while walking on the street because users are forced to look at the map in it again and again until they arrive at the destination. It causes the distraction around a user such as the obstacle near feet, passerby and so on, and it makes users feel at "unease" and "burdened" to head for the destination. Moreover, users are compelled to become accustomed to use smart-phones, taking much time. Naturally, it also inspires the feeling of "burden" to users. Furthermore, users feel lonely because of such a cool device which is totally different from general companion who can talk together freely. As a result, we focus on how to solve such problems of the guidance system.

It was proposed that by using the RFID tags and ubiquitous sensors, information of visitor's experiences at the science museum is obtained and the robot autonomously interacts with visitors based on such information [1]. It revealed that the combination of free-play interaction and exhibit-guiding contributed to promote visitor's interests at the museum. Also, there is a study that the guidance robot in shopping mall makes

a conversation with sophisticated dialogue strategy in order to try to be familiar with customers more in the long term [2]. It showed that it can be intimate customers by remembering them one by one and talk to customer about the individual topic. Also, under the background it's difficult to guide a lot of audiences at once in the museum, the method of how to decide an appropriate person to ask the question about exhibit to guide was proposed [3]. It is based on user's nod and direction of eyes and it revealed that to choose a person having prior knowledge about the question can attract interest of audience and facilitate talk.

In these prior studies, although the guidances in indoor environment such as in museum and in shopping mall were studied, the questions of guidance in outdoor environment are still open. To develop such a guidance system, we had to face the unsolved problems. There is the typical problem for heading for the destination through the unfamiliar streets. It is to occur the feeling of "unease" and "loneliness" in people's mind. Therefore, we considered releasing such negative feelings by the robot dialogue. Moreover, there are obviously the users who have long distance to the destination in outdoor environment. However, the systems in previous studies didn't mention such a condition. It's almost impossible for an only robot to lead such a user to the destination. Therefore, we considered multiple robots cooperation to lead user to the destination. In order to do those, we developed the guidance system which multiple robots appropriately encourage the user again and again, sharing user's information via networks: face, destination and route, so that user can easily get to the destination even if the distance from the user to the destination is too far.

We have been proceeding the research about the behavior of robot in the era there are a lot of robots in daily life to help people. We adapt the robot technology to guidance system to achieve following purposes.

- (a) So that the user can enjoy heading for the destination, multiple robots along the way encourage the user to reduce the "burden" and "unease".
- (b) So that the user can easily head for the destination, the system reduce the "burden" by forcing neither the memorization nor the manipulation to use the system.
- (c) So that the user can feel like being with companion, multiple robots make a conversation and encourage the user to reduce the "loneliness".

2 The Map Guidance System Which Multiple Robots Cooperate

2.1 Concept of the System

There was "good old-fashioned guidance know-how" that people simply catch a person who is walking by and ask how to get to the destination repeatedly until getting there. The era there are a lot of robots deployed in almost all street corners (like Japanese police box) is being expected. Therefore, we reached a notion combining the robot technology with such "good old-fashioned guidance know-how", shown in Fig.1. Moreover, such guidance know-how was improved more by the robot technology. We have found out five concepts in our system ("Manual less", "Operation free", "Device free", "Corporeality of robot" and "Advantage of network robot").

As for “Manual less”, there’s no necessity for memorization on how to use the system since it’s only necessary to make a conversation with robot to take directions so users can easily and immediately use the system.

As for “Operation free”, actually, there are the users, especially elderly people who complain about navigation system because they can’t easily manipulate the device such as smart-phone because of size of it although they sufficiently understand how to use the system. However, by virtue of dialogue robot, users aren’t compelled to manipulate complicated operation since having a dialogue is the most natural and the easiest behavior of human-beings.

As for “Device free”, the situation that a user has the device to get directions causes unpredictable dangerous situation for him/her. That’s why, not making users use a device while heading for the destination was needed. However, because of proposed system, since asking robot is only needed, users don’t need to have a device so it can allow users to pay attention to their surroundings while heading for the destination in order not to face such situations.

As for “Corporeality of robot”, In comparison with CG and the other devices which don’t have appearance of creature, people can naturally talk to a robot and feel like that I’m actually talking to it. Furthermore, even if a user gets lost on the way, another robot can be easily found. Therefore, users never feel lonely.

As for “Advantage of network robot”, by sharing information of user with the other robots via networks, they can cooperate with each other. As a result, it can realize that talking and encouragement based on user’s progress and smoothly lead the user to the destination.



Fig. 1. Appearance of guidance by robot

2.2 Outline of the System

The dialog robot which is used for our study is “Phyno” made in Yuvizoukei. This robot has 34 cm in height, 21 cm in length, and 26cm in width, and can move 3 degrees of freedom (DOF) in head, 1 DOF in arms, and 1 DOF in body. This robot can speak words by a voice of a mature woman with gestures. It works with camera, speaker, and microphone. In order to detect and distinguish the person, it’s programmed by being used OpenCV, and in order to recognize the voice the user speaks, we used Julius. Then, we used Dijkstra’s Algorithm as the short path problem to extract the best route to the destination. Finally, this system can share information of the

users via networks with multiple robots by using Winsock. A picture illustrating the multiple robots cooperation, which includes a range of robots considered for future works in the 6 Paragraphs, is shown in Fig.2. By sharing user's information (face, destination and route which the user passed) with the other robots, it can distinguish users and smoothly tell directions without asking his/her destination again. In addition, the robot can talk to a user depending on the user's progress circumstance and choose a suitable dialogue (e.g., "Welcome, I was looking forward to your visit. You are in the right place") and encouragement (e.g., "You can do it. You are almost there") in order to evoke a feeling of joy. The procedure of proposed system is listed below.

When a user approaches the robot, the user's face is detected by camera and sent to the server. And then, it's distinguished whether it's the first time for him/her to call on the robot or not. As a result of that, if this is the first time, the user will be asked the destination by the robot and take not only directions but also the nearest location of the robot from the user in order to reduce the burden to remember the route. After that, information of the user will be sent to the server to stockpile. On the other hand, if not the first time, the user will get directions without asking the destination again by reason of information in the server. Furthermore, appropriate conversation according to user's progress will be conducted by referring to stockpiled information in the server. And then, also revised information will be stockpiled everytime a user meets robot. A picture illustrating above procedure is shown in Fig.3.

As a result, proposed system can provide the following effects.

- Users can easily use the system because of using only dialog
- Users can enjoy heading for the destination and reduce the feeling of loneliness by being encouraged appropriately by multiple robots
- The burden of memorization of the route can be reduced by reason of no necessity to memorize all routes to the destination
- Users can feel at ease and reduce the feeling of loneliness by being remembered by the robot and talking to them as many as a user meets them

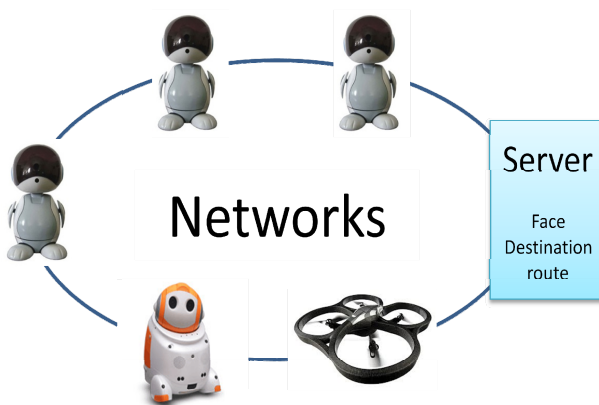


Fig. 2. Multiple robots cooperation via networks

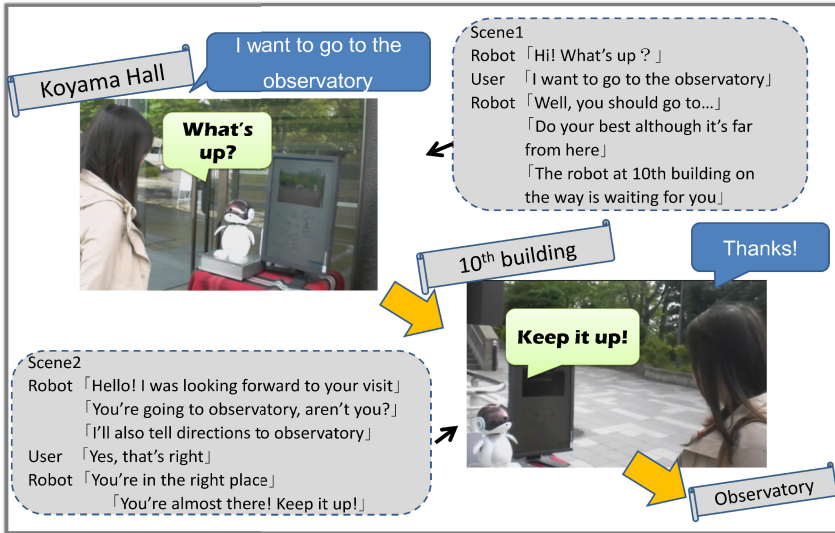


Fig. 3. Procedure of the proposed system

3 Experiment

We conducted an experiment under the following purpose.

“The route which easily enhances the feeling of unease about whether to be able to get to the destination because there are dimness, many corners and stairs is prepared. Even if users walk such a route, users don't feel uneasy because of talking to robot, and feel joy and easy.”

Twenty undergraduate students at Kyoto Sangyo University who had never visited at the building conducted our experiment, participated in experiment as subject. The reason why we chose such people is to eliminate people who can get to the destination without guidance. The subjects were required to get to the destination given by experimenter through the complicated route, shown in Fig.4 and 5, taught by the guidance system. In Fig.4, the left figure is the 3rd Floor (3F) map, and the star represents the departure point, and the (X) represents the robot (display). Subjects walk along the arrow. The right figure is the 1st Floor (1F) map. The triangle represents the arrival point and the (Y) represents the robot (display). We conducted a comparative experiment, and used a between-subjects design, and prepared two conditions for experiment, shown in Fig.6.

Outline of both conditions are listed below.

(a) Proposed guidance system

The robots were deployed at the departure point and at the stopover point. The subject tells the destination, which was given by experimenter, to the robot at the departure point and takes directions. And then, s/he smoothly gets the guidance again from the robot at the stopover point without telling the destination.

(b)Conventional guidance system

The displays were deployed at the same points as proposed system. The subject manipulates it with mouse to choose the destination among 6 places to get the guidance at the departure point. And then, s/he manipulates it again at the stopover point.



Fig. 4. Floor plan of the experiment

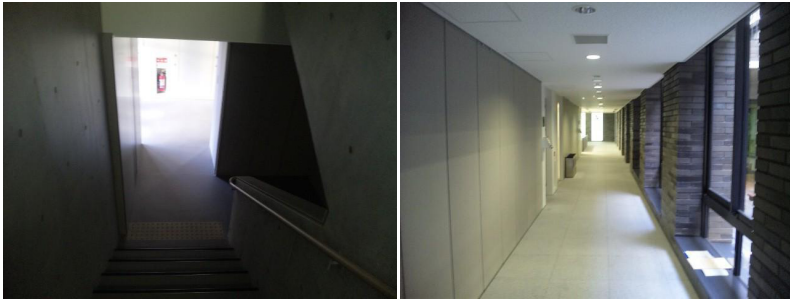


Fig. 5. Complexity of the route; stairs (left) and corridor (right)



Fig. 6. Snapshots of experiments; robot (left) and display (right)

In the questionnaire for the subjects, three bipolar words (“Ease”, ”Isolation” and ”Joy” and the scale of 1 to 7) were used in order to evaluate the individual impressions in both conditions. In addition, four bipolar words (“Natural”, “Persuadable”, “Humanly” and “Joy”) were also used in order to evaluate the individual impression for robot in only condition of the proposed system.

4 Results

As shown in Fig.7, the evaluated value in the proposed system (with robots) is on the whole greater than the conventional system as we expected. We could find that the difference of “Ease” and “Joy” between both conditions is statistically significant although the words used in experiment in both conditions were same. The reason is that there were existence and encouragements of robots, according to free description in questionnaires. That is to say, the robot can have an appreciable effect on enhancement of those feeling. On the other hand, as for “Isolation”, it could not be found although it seems that the value in the proposed condition is greater. The reason why the evaluated value of “Isolation” could not show a significant difference is that although talking to robot, the users felt happy and didn’t feel lonely, after departing from the robot, they started feeling lonely and at unease. As shown in Fig.8, the evaluated value of “Persuadable” and “Joy” are relatively higher. In addition, we found the significantly different rate between both conditions that the subjects could get to the destination without getting lost during experiment from the observation. In the proposed system, the number of such subjects was 8 out of 10, whereas as for the conventional system, it was 2 out of 10. It shows that the robot’s intimate behaviors that gaze at user and encourage user could evoke the motivation to try to remember the route more than one-sided navigation in the conventional system.

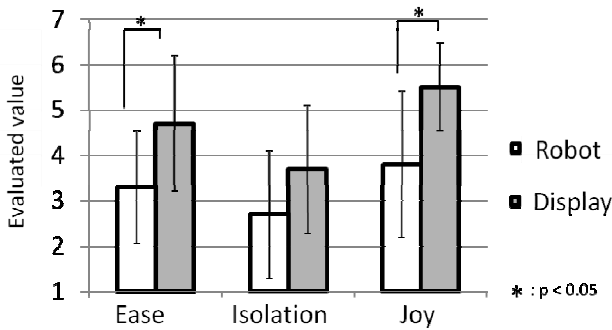


Fig. 7. Comparison of the robot and terminal

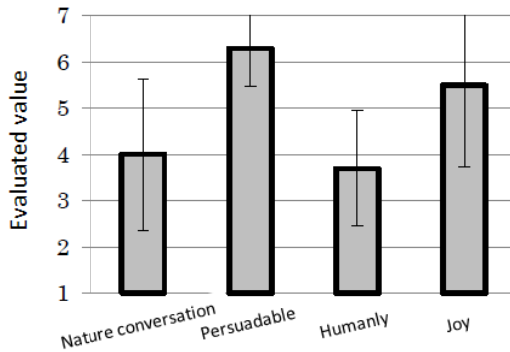


Fig. 8. Impressions of the robot

5 Discussion

We confirmed that users can easily use our system without learning how to use it. We also noticed the question seen in human conversation between the subject and the robot in order to take directions again. It shows that the subjects used the proposed system as if they talk to someone, which is to say it can decrease the burden of users as effect of “Manual less” and “Operation free”. Moreover, the users using the proposed system got to the destination without facing dangerous situation, paying attention to their surroundings during experiment. It shows that the proposed system can allow users to afford to pay attention for security as effect of “Device free”. Also the opinions that the subjects delighted to see the robot on the way were seen so it shows that the appearance like creature enhances the feeling of delight on meeting as effect of “Corporeality of robot”. Also obviously the conversation and the encouragement based on user’s progress could contribute to enhance the feeling of joy as effect of “Network robot”.

We found that the synthetic voice was stereotyped and monotone so it gave weird feeling to subjects. However, we found also the remarks that “because the robot was beside me, I surely had consciousness to talk to the robot”, which is to say the robot was regarded as conversational partner. That’s why, we are convinced that the evaluated value of “Humanly” didn’t plummet and kept intermediate value. It shows that the synthetic voice has to be improved by putting intonation and cadence. By doing this the feeling like being with robot will be given to users potently.

We found also the incidents that all subjects didn’t keep an eye on the robot while taking directions. After experiment, we asked them the reason and figured it out. It was that they concentrated on not the behavior of robot but listening to the guidance. Therefore, we figured out that our dialogue design was not sufficient so the dialogue design of study in Saitama University that make a decision about person whom the robot talk to based on person’s nod and direction of eyes will provide a clue to solve our problem. At least the behavior while giving directions and the behavior while greeting user should be made into different one.

6 Future Works

6.1 Quantifying of Psychic Distance Concerning Unease

According to some remarks from the free descriptions, we realized that the necessity for deploying the robot in appropriate place where users don’t feel at unease while heading for the destination. In order to do that, we have to figure out how long the distance between robots is suitable not to make users feel at unease. In addition, it’s involved in not only physical distance but also the number of corners, stairs and so on. Moreover, since the degree of feeling of unease caused by the distance depends on a person, if that psychic distance becomes obvious basically, the guidance and the notice depending on each people will be able to be given to them.

6.2 Introduction of Mobile Robot in the Proposed System

Even if we figure out the psychic distance, whether the robot can be deployed in appropriate place or not is not reliable and so we have an additional idea to diminish the feeling of unease. By introducing mobile robot in our system, all the user who is about to depart to the destination through the route which has a possibility to evoke a feeling of unease have to do is just to follow mobile robot. Two styles of robot (fixed, mobile) have each role. Giving directions compactly, the fixed robot can equally guide to every user, and engaging in a user, taking time, the mobile robot can dependently guide to specific users.

We found that there is the compatibility between these styles. Since the fixed robots are deployed in given place, the user just calls on the robot, which gave directions before, again whenever the user feels like visiting another place. It can give the feeling of ease that “going to a place where I took directions, I can meet the robot again” to user. It’s difficult to imagine that all users prefer following the robot all the way even if the robot has great performance of ambulation. Most people must prefer heading for the destination at their own pace. Therefore, typically, fixed robot is used as a kind of landmark and asked directions again and again, and mobile robot is used when needed. We think it is the most suitable role. Moreover, we have come up with flying robot as one kind of mobile robot. As the advantage of flying robot, it can easily lead users to the destination even if the surface of streets is not flat such as unpaved road, stairs and so on. Therefore, in the indoor environment, it is appropriate that mobile robot using wheel is used, while in the outdoor environment, it is appropriate that flying robot is used. The point is that various robots are cooperated to appropriately lead users to the destination, depending on each condition.

7 Conclusion

We proposed the guidance system combining robot technology with good old-fashioned guidance know-how. In our system multiple robots are deployed in almost all streets. This system solves the problems of the common navigation system which make users feel uneasy and lonely.

The proposed system is based on five concepts: Manual less, Operation free, Device free, Corporeality of robot, and Advantage of network robot. Thus, the burden to become familiar is removed. Danger caused by walking while watching the mobile phone is reduced. Feeling of loneliness is also reduced. Robots can encourage and entertain the user. We proposed a new approach that multiple robots cooperate mutually via networks to tell directions with appropriate dialogue and encouragement based on user’s progress circumstance. An experiment for comparing with proposed and conventional guidance system was conducted to prove the effectiveness of robot. As a result, it revealed that the difference of the evaluated values of “Ease” and “Joy” between both conditions is statistically significant. The result also shows that user can enjoy heading for the destination, and feel easy. The evaluated value of “Persuadable” and “Joy” as impression against the robot got much higher. It shows that the guidance by the robot can inspire the consciousness to listen to directions more than the

guidance by the display and is more enjoyable. Moreover, we have found the problems to be solved. Those are the inappropriate part of the dialogue strategy of robot guidance, artificiality of synthetic voice, and the fact that user get to feel uneasy and lonely after departing from robot. We also proposed the methods of solution. Those are quantifying of psychic distance concerning unease and introduction of mobile robot. We are expecting that the knowledge obtained by this study will adapt to the various systems employing robot, and contribute to the development on symbiotic society of human beings and robots.

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Part IV
Multi-sensory and Multimodal
Interfaces

Towards Designing Audio Assistance for Comprehending Haptic Graphs: A Multimodal Perspective

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Abstract. Statistical graphs, such as line graphs are widely used in multimodal communication settings. Language accompanies graphs and humans produce gestures during the course of communication. For visually impaired people, haptic-audio interfaces provide perceptual access to graphical representations. The local and sequential character of haptic perception introduces limitations in haptic perception of hard-to-encode information, which can be resolved by providing audio assistance. In this article we first present a review of multimodal interactions between gesture, language and graphical representations. We then focus on methodologies for investigating hard-to-encode information in graph comprehension. Finally, we present a case study to provide insight for designing audio assistance.

Keywords: Haptic Graph Comprehension, Audio-Verbal Assistance.

1 Graph Perception and Graph Comprehension

1.1 Presenting Graphs in Different Modalities: Visual vs. Haptic

The primary goal of visualizing data is to (re-)present them in a pictorial format more suitable for using them in thinking, problem solving and communication, namely in the representational modality of graphs [1, 2, 3, 4, 5]. Graphs are successful means to present data, both in tasks of analyzing data and in tasks of communicating data. Communicating visualized data using graphs is used extensively in different types of publications, from scientific journals and textbooks to magazines and newspapers. Line graphs and bar graphs are the dominant, i.e. most frequently used, types of graphs in addressing non-experts in communication through graphs [6]. In addition to text-graphics documents, in many professional communication and classroom settings, graphs, language, and often gestures, accompany each other forming multimodal communication.

Since for blind and visually impaired people the advantages of graphs are not directly accessible, haptic-audio interfaces to graphical representations have been proposed for—partially—substituting vision in the use of graphs [7, 2, 8] and other types of graphics, such as maps, floorplans etc. [9, 10]. Whereas visual perception

supports comprehension processes which switch between global and local aspects of a graphical representation, haptic perception has a more local and in particular a more sequential character. Thus, compared to visual graphs, one drawback of haptic graphs is the restriction of the haptic sense regarding the possibility of simultaneous perception of information [11]. Comprehension of haptic line graphs is based on exploration processes, i.e. hand movements following the lines with the goal to summarize information of geometrical properties of the line explored; in particular, the detection of shape properties—as concavities and convexities, as well as maxima and minima—are of major importance, see Fig. 1 depicting the Phantom Omni® Haptic Device we use in our studies, as well as an exemplifying haptic line graph and its visual counterpart.

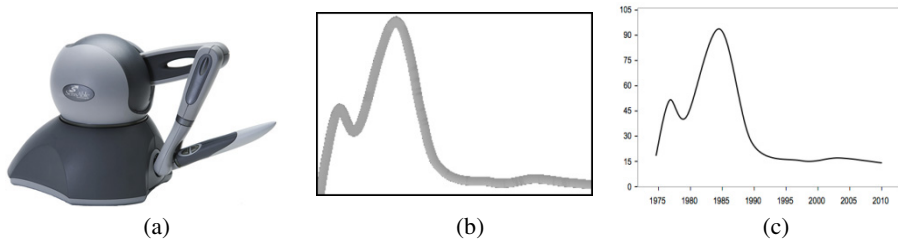


Fig. 1. (a) Phantom Omni® Haptic Device, sample (b) haptic graph and (c) visual graph

Whereas it is relatively unproblematic to detect haptically the shape of simple graph line with only a single global maximum, graphs with several local maxima require—depending on their complexity—additional assistance for most users of haptic graphs. For resolving some difficulties in haptic exploration of graphs, providing additional information, such as auditory assistance through the auditory channel, has been proved to be helpful [8]. Sonification or speech can support—for example—the detection of local and global extrema of graph lines. The usage of these alternative modalities with the haptic modality arises new research questions, namely, which pieces of content to be presented should be made accessible through the haptic modality, and which pieces should be communicated using language (speech) or sounds (sonification).

1.2 Data Visualization: Visual vs. Haptic

A standard starting point for generating graphs are tables or their computer-science counterpart, relational data-bases [12]. But, visualizing exclusively data points is suitable only in certain cases (see Fig. 2(a), depicting “average daily maximal temperature at San Francisco”, data from [13]). Under specific conditions, e.g., if some Gestalt principles are satisfied, human visual processing, leads pre-attentively, to the visual impression of a linear whole, namely a line. Fig. 2(b) depicts a line graph that relieves the perceptual and cognitive load by making the line explicit. This line-graph— independent of whether data points are visually depicted or not—contains elements of the line, which have no origin in the data. The contrast between data-point

graphs and line graphs exemplifies how substantially the human perceptual system determines the comprehension of data visualizations. Blind and visually impaired people who can use some types of haptic graphs successfully would have critically more problems in exploring data-point graphs—as depicted in Fig. 1(a)—haptically using an Omni device, since in this case Gestalt constitution is not supported.

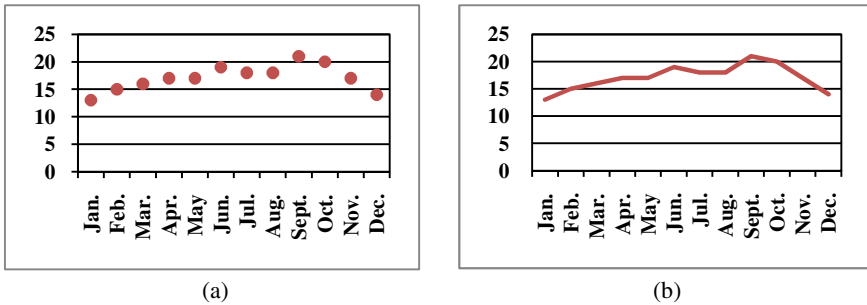


Fig. 2. Average daily maximal temp at San Francisco (a) Data-point graph (b) Line graph

Line graphs, for example, present not only data points explicitly, but in addition, second-order entities, such as *trends*, *local* and *global maxima*, second order properties (e.g., *strength of an upward trend*) and second-order relations (*crossing of lines*) can be also easily detected due to preattentive processes of the human visual system [2]. To design audio-haptic interfaces to graphs, it is important to know, which concepts depicted in graphs, are most relevant to people during graph comprehension. In prior studies we used successfully three empirical paradigms to get insights in human’s conceptualizing of graphs: (1) eye tracking in exploring language-graph co-comprehension [1, 14], (2) sketching of graphical cues on graphs under linguistic guidance of written verbal descriptions [15], and (3) combined analyses of gesture patterns and of eye movements during producing spoken descriptions of graphs to investigate the role of gestures in graphical communication [16].

2 Graph Comprehension in Multimodal Contexts

2.1 Language - Graph Comprehension

Graphs are usually accompanied by language in communication settings, either in spoken form, as in presentations or lectures or in written form, as in newspapers, magazine articles and web blogs. In all those settings, a successful communication through graphs and language usually requires the integration of information contributed by both modalities. The pivot of this integration is the construction of reference and co-reference relations between text, the elements of the graph and the entities in the domain of discourse that are referred to by text and the graph [17]. For instance, a specific linguistic constituent, such as “the peak” in the text may refer to a peak in the domain of discourse (e.g., a peak in temperature), which is also referred to by a peak as a graphical entity in the graph. We have investigated various aspects of

such integrated conceptual and spatial representations both from a theoretical perspective and in empirical studies [1, 14, 20, 33].

Text and graphical constituents appear in various forms in text-graphics documents. In most cases, the graph and the text are placed side-by-side on the page, thus leading to a separate layout of graph and text. To facilitate the construction of referential links between the text and the figure, different types of cross-reference link are used in the text to provide a link to the graphical material, thus providing a specific type of signaling in verbal form. Figure captions are usually referred to by those explicit cross-reference links, such as “see Figure 1” in the text, thus facilitating the integration of information contributed by the text and the figure [18]. The use of graphical cues on the graph frame, such as an arrow to emphasize an increase or a point-like marker to emphasize a peak, provide another signaling technique that aims to attract the attention of the reader and facilitate the construction of thematic relevance between the information contributed by the text and the information represented by the graphical entities [19]. In addition to those signaling methods, verbal elements, such as verbal annotations on the graph frame may have a facilitating role in comprehension of the text-graphics document [20]. An appropriate methodology for investigating the construction of referential links between language and graphs is the eye-tracking methodology. Eye tracking has been one of the techniques that provide comprehensive information about online cognitive processes of a graph reader since it lets to trace the allocation of attention. The previous empirical studies showed that eye movement parameters such as gaze pattern, transition matrix entropy and fixation rates are useful tools to investigate graph-language comprehension [21].

2.2 Gesture – Graph Comprehension

The studies on language-gesture interaction from the embodied cognition viewpoint are mainly based on the assumption that concepts are sensorimotor, emphasizing that they are based on perceptual experience [26, 27]. If the concepts are concrete and easy to visualize the speaker gestures more; even abstract concepts are grounded in physical terms [25]. There are several frameworks that investigate gestures from various perspectives, but all of them agree on that gestures rely on spatial representations. According to the GSA (Gesture as simulated action) framework [25], one of the frameworks that focus on how gestures are produced, gestures are byproduct of speech. In particular, linguistic planning involves simulation of visuo-spatial events; this activation during articulation is considered as a source of speech accompanying gestures. Another framework, that is closely aligned with the GSA framework and that focuses on how gesture and language production are integrated is the “Interface Hypothesis” [28]. The preparation for language production requires organization of rich and comprehensive information into small packages that contain appropriate amount of informational complexity within a processing unit. According to the “Interface Hypothesis”, this processing unit may correspond to a clause for speech production, and the contents of a representational gesture are affected by the organization of these information-processing units, which are prepared for speech

production. Therefore this close relationship between gestures and language makes gestures an effective tool in the assessment of the reader's conceptualizations by means of the analysis of verbal descriptions [29].

Although the interaction between language and gesture has been investigated for the past several decades in a variety of domains [22, 23, 24, 25], specific investigations of graph comprehension—be it based on the visual or the haptic modality—in interaction with language and gesture, has been one of the scarce topics in HCI and relevant disciplines. Gestures provide additional information that enhance comprehension and resolve ambiguities during the course of communication. They are convenient tools to carry spatio-temporal information. Besides, they highlight the information presented by the other modality and convey additional information that is not expressed by the other modality. For instance, within the context of communication through graphs, a fluctuating increase in a line graph may be verbally described by the term “increase” and it may be simultaneously accompanied by a gesture that represents the fluctuation in the increase [16]. Based on these similarities, Tversky [30] proposed that the vocabularies between these three modalities (graphs, language and gesture) can be considered as parallel. One of the studies focused on communication through line graphs [16] showed that the perceptual features of the graphical cues that highlight certain aspects of the visualization (e.g., a graphical cue such as an arrow) influence conceptualization of presented information, and this effect is observable in the gestures produced by graph readers. The results of that study indicated that in order to emphasize process concepts (e.g., *increase*, *decrease*) more vertical and diagonal gestures were produced by humans, whereas more pointing gestures were produced for emphasizing punctual state concepts (e.g., a *peak*). Similar findings were obtained from a comprehension perspective, in the sense that vertical and diagonal gestures were efficient in conveying information about processes. The findings also revealed a low efficiency of non-directional gestures in conveying punctual state information, possibly due to ambiguities between pointing-as-representational gesture and pointing-as-deictic gesture. Analysis on eye movements showed that participants also exhibit back and forth eye movement between the gestures and the face of the narrator, indicating potential source of attention split during the course of comprehension.

To sum up, gestures can be considered as a tool to assess how the graph reader interprets the graph and conceptualizes the processes, events and states represented by the graph, because gestures provide additional information, which is aligned with the visuo-spatial aspects of communication through graphs. Therefore gesture analysis helps to detect the hard-to-encode information and disambiguates, that are generally highlighted with the presence of accompanying gestures.

3 A Case Study on Haptic Graphs and Design Guidelines

Comprehension of haptic graphs is still one of the topics, which has not been comprehensively investigated so far [9, 31]. A systematic investigation of the interaction between modalities in communication through graphs has the potential to

contribute to identifying design principles for multimodal communication settings that facilitate efficient and effective communication of information since experiments give evidence about the content relevant to the conveyed information (in particular the question what should be communicated by language). Our particular research focus in the case study [31] is the investigation of the characteristics of hard-to-encode information in graphical communication through gesture and language production. The motivation for analyzing hard-to-encode information is to identify the types of assistance that should be provided to ease comprehension by visually impaired users.

Participants, Materials and Design. The experiment was conducted in two conditions in a within subject design employing a total of twenty participants. In the first condition, the participants (N=9) explored line graphs haptically (see Fig. 1b). In the second condition, the graphs were presented on the computer screen and the participants (N=11) had visual access to the graphs (see Fig. 1c). In both conditions, after the participants explored the graph, they were asked to produce single sentence summaries of bird population graph to the hypothetical audience. As a result of this experimental paradigm, two different types of gesture production occurs; exploration gestures and communicative gestures [32]. The gestures produced during the haptic exploration of the graph are categorized as exploration gestures while the gestures produced during verbal description of the graph are classified as communicative gestures. In this study, Phantom Omni® Haptic Device (Fig. 1a) is used to represent the haptic line graphs. Haptic graph exploration with this device is performed by moving the handle of the haptic device, which can be moved in all three spatial dimensions (with six degree-of-freedom). In haptic graph representation, the graph proper (the line of the line graph) is represented by engraved concavities on a horizontal plane; therefore the graph readers perceive the line as deeper with respect to other area on the surface and trace the line haptically by moving the pen (Fig. 1b).

McNeill's [23] semantic gesture classification and then syntactic classification were used as a coding scheme. In the first classification, the gestures were categorized according to their semantic classifications, such as beat gestures and representational gestures. Then each representational gesture was classified in terms of its directionality: non-directional, and directional. According to this classification, the hand movements conducted in small space without having any directed trajectory were categorized as non-directional gesture, whereas the hand movements with aimed trajectory on the air were classified as directional gestures. Directional gestures were also classified into two categories; (i) single direction, and (ii) multiple directions. The gestures that contained movement in only one direction (such as upward) were classified under the "single direction" category, while category of "multiple directions" covers the gestures formed with the combinations of one-directional gestures (such as movement consisting of upward, downward and upward movements).

Findings. The results—focusing on the communicative gestures—revealed that the gestures produced during the course of verbal description were influenced by the modality (haptic versus visual) of the graphical representation. The results also

indicated that graph readers tend to produce multiple directional gestures, as well as one-directional gesture when they explored the graph haptically. On the other hand, the exploration of visual graphs resulted in the production of more one directional gestures compared to multiple directional gestures. This alignment between the psychical properties of the haptic graph (Fig 1b) and communicative gestures produced during verbal description of the graph (see Table 1) is remarkable and the resemblance may be the possible source of this effect that we named as “multimodal carry-over effect”. In addition to analysis of communicative gestures (Fig. 3a), the analysis of the relationship between communicative gestures and explorative gestures (Fig. 3b) is considered as another method that can reveal the underlying mechanisms of this effect. While the haptic exploration gestures (most focused regions, back and forth movements) provide evidence for the online cognitive processes in the course of graph comprehension, verbal descriptions and communicative gestures give valuable information about how the graph reader conceptualizes the events represented by the haptic graph. In Table 1 and Fig. 3, the sample verbal description and accompanying gestures for the bird population graph given in Figure 1 were presented in addition to heatmap representation for explorative gestures produced during haptic exploration.

Table 1. Sample Verbal Description produced in one of the protocols

Verbal Description (<i>translated from German</i>)
It had a small peak, than a large peak and somewhere in the midfield it levels off.

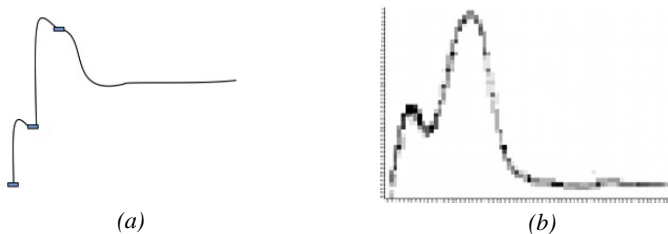


Fig. 3. (a) Trajectories of the gestures accompany to this description (the rectangles indicate pauses on the gestural movement) (b) Heatmap for Haptic Exploration Gestures in Grayscale (darker areas represents more focused areas)

In addition to providing insight about how graph readers perceive and interpret the haptic graphs, the findings of the case study also give clues about how to utilize these results in the haptic graph design. In the current state of art of haptic line graph design, providing haptic information on the graph axes, such as information for numerical labels and axis title, is hard to implement. This is a potential source of difficulty in haptic comprehension, because the lack of axis information may lead to difficulties in comprehension. As can be seen from Fig. 3a and 3b, although the trend of the trajectory of produced gesture and the graph proper (the line) have quite

resemblance, there existed misinterpretation about value, the number of bird population probably due to not having any reference to real values. Such difficulties are good candidates for substitution by other modalities such as verbal or audio assistance. Furthermore, since the visual perception of the graph lets the graph reader to access both local and global information, the information about the start and end point of the graph or steepness/amplitude of the peaks are already accessible to them. However, this information, not provided by haptic modality, is crucial for the haptic graph reader in order to create appropriate mental representation of the graph and content represented by it. The haptic exploration gestures are also used to obtain insight about how the graph reader perceives and comprehend these critical parts of the graphs.

4 Conclusion

To conclude, various modalities are intertwined in communication settings, including communication through line graphs. The investigation of gestures, eye movements, language and haptic exploration in interaction has the potential to provide insights for human interpretation of the represented information that has a direct contribution to multimedia design. One of the fields, profited by these researches, is multimedia design for blind and visually impaired people. The graphical representations are wide spread in both print and electronic media, and they are used as a basic material to elaborate the information, which is hard to express within text only. Therefore, to provide access to graphical representations for blind people is one of the important topics of this field. Haptic graphs are considered as an efficient medium that provides access to the visual representations presented through haptic modality. However haptic representation has lower bandwidth compared to visual modalities, since the haptic exploration is sequential, while visual perception allows the perception of both local and global information about graph at one glance. Therefore, visual representations can be considered as superior in the amount of conveyed information. In order to bridge this gap and present coherent information to the haptic graph readers, haptic graphs should be accompanied by alternative modalities such as verbal/audio modalities. In this study, we aimed to emphasize the multimodal method to be used in the investigation of haptic graph comprehension and detect the content to be provided by haptic modality and to be assisted using alternative modalities. The findings provide insight for the implementation of user interaction design for visually impaired people, by providing guidelines for the design of audiovisual assistance during the course of communication.

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User Target Intention Recognition from Cursor Position Using Kalman Filter

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Abstract. This paper discusses user target intention recognition algorithms for pointing – clicking tasks to reduce users' pointing time and difficulty. Predicting targets by comparing the bearing angles to targets proposed as one of the first algorithms [1] is compared with a Kalman Filter prediction algorithm. Accuracy and sensitivity of prediction are used as performance criteria. The outcomes of a standard point and click experiment are used for performance comparison, collected from both able-bodied and impaired users.

Keywords: Intention Recognition, cursor movement, tracking, Kalman Filter.

1 Introduction

Human - computer interaction has become an every-day aspect of lives as technological devices make their ways out of the laboratory. New input devices are being introduced to the market not only in the form of computers and smart phones, but televisions, kiosks in hospitals, even advertisement screens in airports. The availability of these devices to ordinary people increased the diversity of the population using them, which include impaired and elderly users as well as able bodied, expert and non-expert users. Most of the input devices require a pointing task which can be difficult to some users, especially users with motor impairments which can become an overwhelming activity that they want to avoid.

Characteristics of cursor movement have been examined by HCI researchers in the recent years [2]. Algorithms to reduce the movement time and distance to target were suggested considering cursor movement characteristics of able-bodied users. Fitts' Law has been used as the basis in determining difficulty of a task depending on the target size and distance. It has been shown that it is possible to reduce this difficulty by increasing the target size [3-4], employing larger cursor activation areas, moving targets closer to cursor location, dragging cursor to nearest target or changing CD ratio [5]. However interactive systems employ more than several targets at a time and they are becoming more complex everyday. Hence, it is not trivial to decide on which target to expand or drag the cursor to. In addition,

pointing tasks could become more overwhelming for users if wrong targets are altered one after another. In the vicinity of a target prediction algorithm, dynamical alterations will become more meaningful and successful. Several algorithms have been proposed so far for target prediction.

However, cursor movement vary in characteristics for motor impaired users since they experience tremor, muscular spasms and weakness [8]. The velocity profile includes several stops and jerky movements. This needs to be taken into account when applying target prediction. State space filtering techniques are promising [9-9] in estimating intended targets as well as smoothing cursor trajectories since it is possible to model the movement, fine-tune or adapt the parameters for different users.

In this paper we compare a Kalman Filter framework with another algorithm suggested by Murata [1]. The accuracy and sensitivity of Murata's algorithm and a basic Kalman Filter framework will be investigated and compared using point-click task data from able-bodied and impaired users.

2 Method

Cursor data was collected from able bodied and motor impaired users, utilizing a standard point and click ISO task. Collection of start and end points were available for over 400 tasks. The user starts the task by clicking on a button at the centre of the screen and ends it by clicking at a target appearing on the screen. To evaluate the performance of intention recognition, 12 targets are located artificially around the starting point, comprising a circle and the end point being one of the targets. Intended target is indicated as target number 1 throughout this paper. The algorithms were run offline for comparison.

3 Target Intention Recognition from Bearing Angle

One of the first algorithms to be suggested was by Murata. The angle deviations towards all possible targets are calculated and the target with minimum deviation is determined. The results show that the pointing time is reduced by 25%. [1]. Asano et.al. point out that having more than one target on a particular movement direction results in poor performances of the afore mentioned algorithm, especially when dealing with target located far away. They used previous research results about kinematics of pointing tasks and showed that peak velocity and target distance have a linear relationship. They predict the endpoint with linear regression using the relationship between peak velocity and total distance to endpoint [6]. Lank et.al also employ motion kinematics where they assume minimum jerk law for pointing motion and fit a quadratic function to partial trajectory to predict endpoint [7].

However, Murata’s method can provide a suitable starting point for target prediction since linear the motion assumption holds for especially able-bodied users and it is still one of the few and reasonably effective algorithms.

The idea is based on the assumption that a cursor should travel the shortest path, which is a line from the starting point to the intended target. This means that the angle from the current position to a possible end point should stay constant. The algorithm looks for a minimum change in angle calculated cumulatively.

The angle between two vectors, first being current cursor position – previous cursor position and second being current cursor position – target location is calculated (Fig.1). Target with minimum cumulative angle is determined as the prediction. This cumulative approach is important for impaired user cursor traces since cursor characteristics include a lot of deviations and a history should be available. It is also possible to apply weighing to buffer elements as discussed in Wobbrock’s angle based CD Ratio adjustment methodology[5].

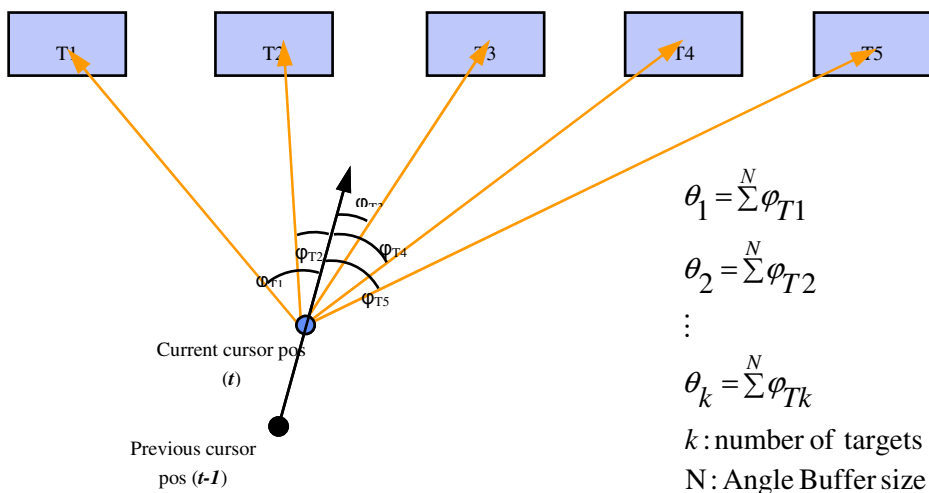


Fig. 1. Angles to targets are used to predict user’s intention in Murata’s algorithm

Figure 2 shows a cursor trace from a task completed by an able-bodied user. Correct prediction was made at the third data point since the trace is a straight line from the origin towards the target.

However, for more extreme cases such as overshooting targets and more complicated layouts with targets along the same direction, the performance is reduced. Comparative results are presented in the conclusion section. It is possible to increase the buffer size for disabled users to keep a longer history if the movement and increase accuracy at the cost of memory and computational complexity.

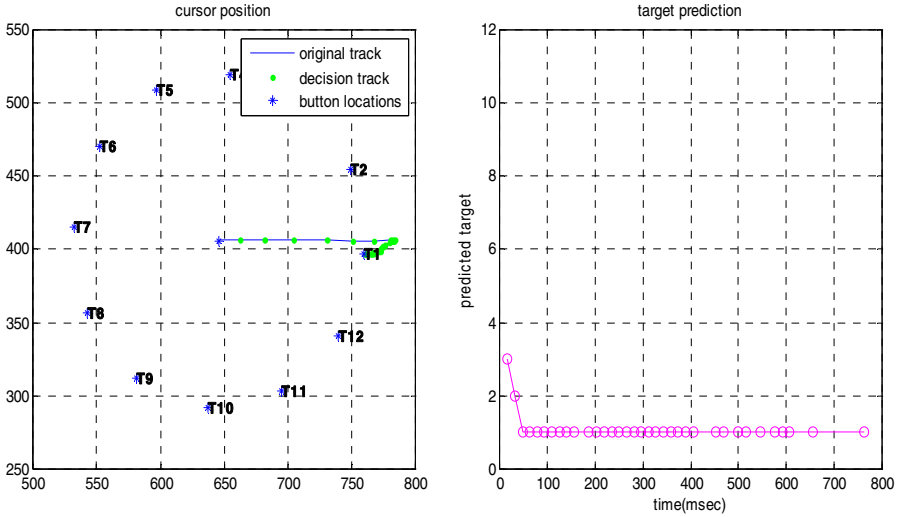


Fig. 2. Cursor coordinates collected from an able-bodied user and target prediction obtained by Murata’s algorithm

4 Target Intention Recognition with Kalman Filter

Cursor trajectories of impaired motion have been shown to consist of sub-movements where the user stops and starts moving again with a different velocity and heading angle [10]. If this motion can be modeled in state-space, a Bayesian framework, such as a Kalman Filter, can be used for state space estimation, which can also work as a smoothing filter to aid the user visually [11]. In this paper, a basic Kalman Filter is proposed to estimate the cursor position and use the estimates to update a probability distribution for possible targets.

Looking at the velocity profiles of motor-impaired cursor trajectories, it could be a reasonable starting point to model the process as a “*nearly constant velocity*” process. The velocity is modeled as a Brownian motion and process equations are given in Equation (1) below.

Process model:

$$\begin{aligned}
 x[k+1] &= x[k] + \Delta t * v_x[k] + v_x[k] \\
 y[k+1] &= y[k] + \Delta t * v_y[k] + v_y[k] \\
 v_x[k] &= dB \\
 v_y[k] &= dB
 \end{aligned} \tag{1}$$

Cursor position in horizontal and vertical directions is taken as measurements with white noise (Eqn.2). The noise characteristics can be personalized depending on the motion-impairment level of the user to account for jittery movements.

$$\mathbf{z}[k] = (x[k] \ y[k])' + \omega[k] \tag{2}$$

It is possible to assume that all targets are equally probable at the beginning of any pointing task and update the probabilities. For N targets, the probability of target i will be:

$$p_i = 1/N \tag{3}$$

These probabilities can be updated according to the angle, distance and both angle and distance to targets at every measurement as given in Equation (4).

$$\begin{aligned}
 p_i[k+1] &= p_i[k] * (1/\text{distance_to_target}) \\
 p_i[k+1] &= p_i[k] * (1/\text{angle_to_target}) \\
 p_i[k+1] &= p_i[k] * (1/\text{distance_to_target}) * (1/\text{angle_to_target})
 \end{aligned} \tag{4}$$

For the following sections KA will be used to indicate prediction using only angle to target, KD to indicate prediction using only distance to target and KAD to indicate prediction using them together.

Experiment results show that using both distance and angle to target to update the target probabilities can handle different cases more robustly. Figure 3 shows the cursor coordinate estimates and measurements on the left and the target predictions from a task using Kalman Filter. It can be seen from the graph that KA and KD can result in wrong predictions more often whereas using KAD provides the correct prediction at a reasonable time and distance. Figure 4 shows the cursor trace in 3d, z-axis being the time. The instance of first correct prediction from KAD is marked with a data tip.

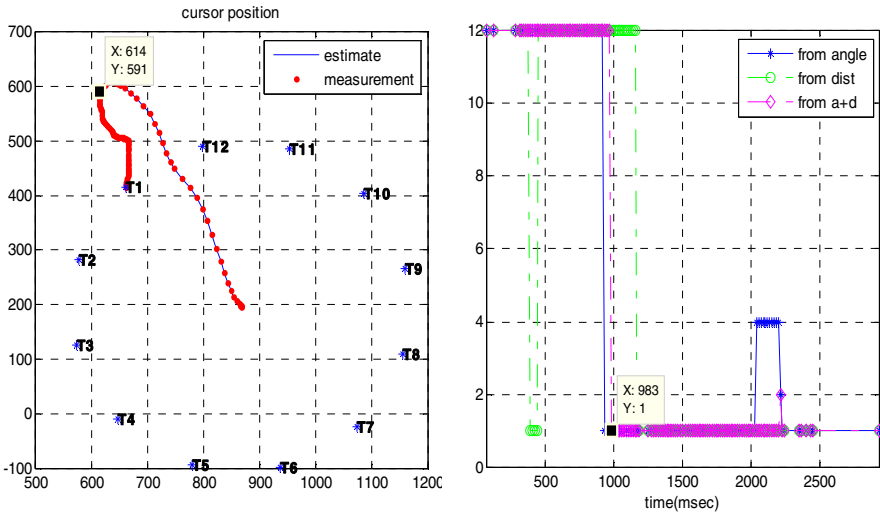


Fig. 3. Cursor trace and target predictions. Using angle and distance to target together produces a more robust result.

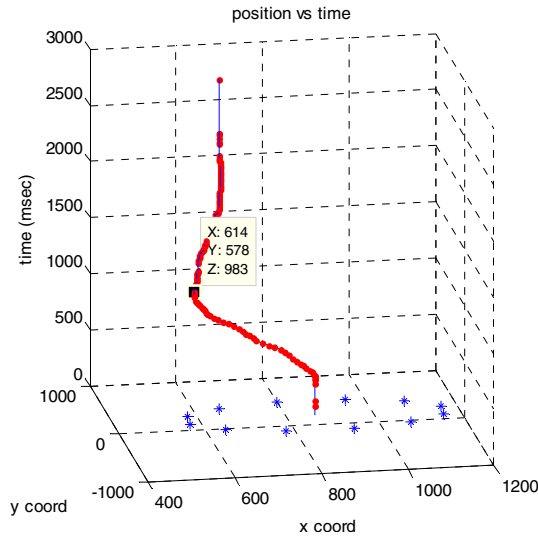


Fig. 4. Cursor trace shown in 3d with time on the z-axis. The location and timing of the correct decision is marked with a data tip.

5 Comparison

Target prediction with Murata's bearing algorithm and Kalman Filter perform similarly for able bodied users since the cursor trajectory follows a relatively simple path. Here Kalman Filter is more advantageous since keeping a history of data points is unnecessary. In addition, Kalman Filter also smoothes the cursor trajectories which is especially important for users with tremor. The noise characteristics can be personalized to specific users or can be adaptively updated.

For this paper, a total of 471 cases were processed. Both able-bodied and disabled users were present among subjects. Bearing algorithm failed to stay on correct target prediction at the end of the task in 35 cases whereas KA and KD failed in 2 and 1 cases respectively. KAD was able provide the correct prediction at the end of all tasks.

2 performance measures were considered for comparison: accuracy and sensitivity.

- Accuracy : ratio of correct predictions to all predictions
- Sensitivity: percent time or distance of correct prediction to indicate how quickly a decision was made

Prediction accuracy is obtained as 64% for Murata's algorithm and 65% for KAD. However it is possible to provide first correct prediction quicker with Kalman Filter and accuracy is increased for non-standard cursor traces. Kalman Filter framework does not provide better prediction for able-bodied users but requires less memory.

A decision firing mechanism can also be used for real-time systems in order to avoid target prediction update at every iteration as well as avoiding instant false detections. An easy choice is to look at consecutive decisions and check if the decision remains the same for several time instants. This could result in a no decision case in highly distorted cursor traces. Table 1 shows the availability of prediction in case of prediction at all iterations and firing mechanism where the same target was prediction at 3 consecutive time instants.

Table 1. Availability of prediction for bearing angle algorithm and Kalman Filter Framework

	bearing	KA	KD	KAD
prediction	471	470	470	471
Firing Mech.	446	455	459	469

6 Conclusion and Discussion

In this paper the possibility to use a simple process model and a Kalman Filter to predict a user's intended target was investigated. The results are promising to be used as target suggestions when a user is interacting with a system. However, the investigation was carried out in a restricted environment as an initial study. The performances should be investigated using more complex layouts and different input devices such as pointing devices. Process model could be developed as well as adaptive noise recognition. It is also possible to model the system such that the probabilities of targets will be directly obtained from Kalman Filter probability updates which will benefit more from process modeling.

The algorithms being developed will also benefit from analysis of the user interaction and acceptability where user has visual feedback of the intended target.

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The Effects of Mirroring in a Playful Virtual Environment: A Comparative Study with Children and Adults Having Impairments

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Abstract. This study explored the effects of a projected self-image in a game situation created for people with different impairments and ages, to question life quality and social cognition. A simple video capture game utilizing the Microsoft Kinect enabling embodied interaction was created. Test sessions consisting of two test conditions, a mirrored self-image condition and a silhouette condition, were conducted with repeated measurement and an interval of one week between each condition. The participants were from four special needs daycare centers and selected by caregivers. They consisted of 20 children (10 male, 10 female) and nine adults (three male, six female), all with various impairments. Video recordings were analyzed with a qualitative case study approach, and a follow up semi-structured "in-situ" interview with the caregivers was held to support the interpretations. Overall findings indicate that the system has a variety of possibilities and the participants used it in their own way e.g. for rough-and-tumble play, creative expression, and as a medium for cooperation. However there was no visible difference between the mirrored condition and the silhouette condition.

1 Introduction

Previously, according to Lanier [1], there was an overlap between the research in Virtual Reality (VR) and the research into tools for supporting disabilities. There were no distinctions between these two areas of research because their goals are almost the same; to use technology on the terms of the people and not the other way around. This is still a trend. It is underlined that the exploration of mirroring in virtual systems is a promising development toward future methods of treatment [2, 3, 4]. In line with this strategy, the way of working with children and adults having special needs has evolved from inclusion [5] and accessibility [6], to a dynamic strategy that includes "quality of life" (QoL) aspects and transfers to everyday life. The basic idea in this body of work is to use engaging play to create an expressive and stimulating environment to supplement traditional intervention approaches to generate this quality of life approach for people with impairments.

This paper reports on a study where the effects of a projected self-image in a game situation were investigated to question life quality and social cognition. A QoL framework in line with Flanagan [7] was utilized focusing on the use of engaging play to create an expressive environment to supplement traditional intervention approaches. This approach contrasts an “Activities in Daily Living” (ADL) approach focusing on training of everyday tasks [2, 3].

The core of this research is self-recognition and mirroring relating to the concept of self-presence where a link is created between the person and a virtual self. Ulrike [8] defines self-presence as when a person identifies him- or herself with an avatar and the connection transcends mere control; the avatar becomes an extension of the person. In this way, self-presence represents a feeling of agency where the person becomes the avatar [9]. Mirroring is defined as the personal experience when looking in a mirror or as defined in this paper, when seeing a projection of the self in a digital game designed for the motion sensing input device; the Microsoft Kinect. Mirroring influences self-perception such that “empathic behavior cannot emerge until the child has a concept of self and is capable of taking the role of another or being influenced by someone ‘like me’” [10, p. 235].

2 Methods

In order to investigate the effects of mirroring and self-recognition, a game with two different visual outputs was designed through a ‘Rapid Applications Development’ (RAD) life cycle process that involved the participants in the design process. The test was conducted through repeated sessions over a period of five weeks. Each participant took part in two sessions with at least one week between the sessions.

The setup of the test was different in each of the four special needs daycare centers. All setups consisted of the Microsoft Kinect placed so that it was able to record the participant in an area where the participant, dependent on ability, could either lie or sit while watching the projection of the game e.g. on a screen or a nearby wall. If the color of the area was not suited for chroma keying it was covered with a piece of green or blue cloth. During the session the participant played the game with either a caregiver, project group member, or another participant. Each session was video recorded.

A case study approach [11] was applied as the sample from the special needs daycare centers contained children and adults with different impairments and different challenges. Furthermore there was little control over the events in the test. The video recordings of the participants were detailed and full of amassed thick data for analysis on the individual participants, which made the data ideal to analyze as a case study. Generalizations can be difficult as each case study was a detailed description of each individual’s experience of the system based on his or her specific impairment.

Based on a set of sample requirements, six out of 29 participants were selected as individual case study subjects after viewing the video material from an Interaction Analysis approach [12]. These requirements included that the participants had to have been exposed to both conditions with more than seven days between exposures, they should experience the conditions without influence from other participants, the footage of their faces had to be available, and the case study analysis had to be based on both children and adults. Footage from the rest of the participants was used to support or discard tendencies seen in the case studies.

2.1 The Joint Application Development

During the development process in the RAD life cycle, caregivers from the different special needs daycare centers were involved. They defined each of the participants' profiles via their weaknesses, likes and dislikes and clarified the participants' expectations to the process and the system. In addition the caregivers participated and contributed with reflections regarding the system. These steps also contributed to the evaluation and review phases. Based on the input from 'Joint Application Development' meetings as a part of a participatory design approach, a series of basic design goals were developed.

The study included two separate test sessions; one session with a mirrored projection of the participant and the other session with a silhouette projection. The sessions were video captured and a comparative analysis between the mirroring and silhouette imaging outputs was conducted. Following the test sessions, semi-structured in-situ interviews were held with the caregivers. These included a form of co-editing of the video material in order to question the interpretations and to evaluate the findings in line with Buur and Ylirisku [13].

2.2 Participants

A total of 29 participants took part in the experiment: 20 children (10 male, 10 female) and nine adults (three male, six female). The participants came from four different special care special needs daycare centers and were selected by their caregivers and the criterion was whether the children or adults would be interested in playing the game.

2.3 The Game

During project initiation, a series of goals and rules were decided to guide the design process. The system should be adaptive and mobile in order to function within a range of different environments to address variance in user needs [14].

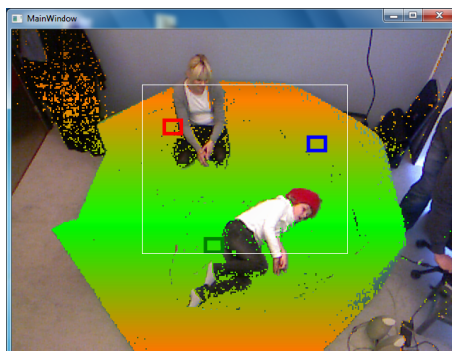


Fig. 1. A screenshot from the game

As the game was intended for a wide audience of children and adults with different impairments, users with limited motion range and physical disabilities had to be taken into consideration. This was addressed by implementing an adjustable activity zone to achieve the 'Zone of Optimized Motivation' (ZOOM) [15], supporting people with impairments to have playful experiences. The open-ended goal of the game was to activate three differently colored boxes that then colored the virtual setting around the participant, enabling the participants to also use the game as medium for creative expression.



Fig. 2. The setup consisted of a laptop, which was running the game, a projector, a Kinect and the green cloth covering the play area

3 Results

3.1 Case Studies

In follow-up interviews, information about the participants' diagnosis and profile were received from the caregivers. This information was outlined for the six participants in the case studies as follows:

Participant 1 is a five-years-of-age female with no diagnosed impairment, but considered mildly disabled mentally. She needs long time to adapt and prefers playing alone.

Participant 2 is a five-years-of-age female with no clear diagnosis. Her development is stunted and not corresponding to age. She needs a clear structure and gets distracted easily, and if so, she reacts with distress, crying and sometimes aggressive behavior.

Participant 3 is a four-years-of-age male with very impulsive behavior. His actions are controlled by his impulses, and this often inhibits him playing with others. He mainly uses simple sounds as his utterances.

Participant 4 is a four-years-of-age male with cerebral palsy. He does not have any verbal language and have difficulties communicating. He likes to observe other children playing but finds crowds uncomfortable.

Participant 5 is a four-years-of-age male, diagnosed with AMC (Arthrogryposis Multiplex Congenita). He is wheelchair bound and unable to use his legs and his arms

can only be used to a certain degree. His cognitive abilities are those of a traditionally developed child.

Participant 6 is a young adult male having a physical age approximating 20 years but a mental condition of a child around three-to-four-years-of-age. He easily gets distracted. He is an active young man who enjoys visual entertainment. He lives at a special needs daycare center.

3.2 Area of Analysis

During the analysis of the children and adults interacting with the game, it was evident that two topics repeatedly occurred as the main tendencies. The terms for the two themes, which emerged after processing the video material with data triangulation and Interaction Analysis [12], were created by the project group. The focus for the case study analysis was: Self-Recognition and Shared Experience.

4 Discussion

4.1 Self-recognition

This study has analyzed self-recognition, differentiating between direct indication and indirect indication. Within these two structures, inspired by Brooks-Gunn and Lewis' six behavioral categories [10], actions that indicate self-recognition have been analyzed.

Indirect Self-recognition

Indirect self-recognition is defined as performing actions that indirectly indicate mirroring. This includes actions such as performing active gestures while observing the screen and performing intentional gestures within the context of the game.

Participant 1, 3 and 6 showed a combination of indirect and direct self-recognition. Participant 1 and 3 were both highly active under the test, standing up and walking around. In comparison, Participant 6 is similarly physically able to be active but chose to lie on his back throughout the test. The tendency observed from the participants from the children-aimed special needs daycare centers, was that they (Participants 1-5) were as active as they were physically able to be; the children who could stand preferred to stand. The occurrence of indirect self-recognition seems constant over the two tests, with the exception of participant 5 who more than doubles his indirect expressions in his second test; silhouette projection. Participants 4 and 5 exclusively showed signs of indirect self-recognitions. They are both profoundly physically disabled and their motoric skills severely limit their ability to express themselves explicitly.

Direct Self-recognition

Direct Self-Recognition is defined as performing actions, which clearly shows mirroring such as pointing at oneself, or rearranging one's clothing or hair as a reaction to the captured self-image.

Interestingly, participants 1 and 6 both showed no signs of direct self-recognition in their silhouette test in comparison to their mirrored test where they had many of such expressions. This might indicate that the condition showing the mirrored embodiment is easier to understand than the silhouette projection. This is in line with the work of Brooks-Gunn and Lewis [10].

Rearranging one's clothing or hair was observed in the cases of participants 1 and 6 but both only in the mirror version. While this is a clear sign of mirroring, it is not a sign of a higher understanding other than being able to identify oneself. The fact that it only happened in the mirror projection should not be interpreted as the participants having a better experience of this condition as it can be attributed to the representation of them being more visually detailed and interested.



Fig. 3. Participants showing signs of direct self-recognition

4.2 Shared Experience

The importance of social interaction, hereunder the role of the facilitator and the role of peer-learning, as a determinant of learning and development is emphasized by Vygotsky [16]. This has been an inspiration for this work to generalize on the subject and analyze for shared experiences in the sessions. Shared Experience is considered as the times where a child or adult playing the game interacts with others while playing. This includes showing and acting together to complete a task. In the case of participant 5 and participant 4, participant 5 helps participant 4 to reach the boxes, by leading his hand towards the active areas in the game. They both seem to react with enjoyment to the peer experience. Participant 1 used the caregiver as an extended tool in the game; identifying the caregiver in the game, and trying to control how and what the caregiver does. Participant 3 is at one point playing together with several other children while interacting with the game. There is no caregiver guiding this play and even when they play rough it is directed towards the game and not the other players. This indicates that throughout the game, he was able to play with others without guidance from caregivers. How the participants interacted with the game was deemed dependent on their impairment and their ability to focus, but there is indication towards the game enabling social interaction.

4.3 The Role of the Facilitator

The caregivers' influence on the test is twofold: Firstly they dictate and guide the participants in the play session, and in some cases function as the primary mediator between the participant and the game. The caregiver's personal engagement and ability to facilitate the participants during the play session, dictates the interaction. Secondly by assisting in interpreting the video data. The caregivers' personal opinion of the game is a potential influence to their feedback when interpreting data.

An example on the former is when a female child is interacting with caregivers while being in the game in one of the sessions. The facilitator and the child create a play where the child rolls her whole body across the floor of the play area to activate the sounds from the game. After a while the caregiver leaves the session and another newly arrived caregiver enters. The child tries to continue the movements, but fails to do so because the new caregiver, unaware of the child's self-invented play, wants the child to interact with the game in a different way. Here the influence of the caregivers is obvious as the child, at first is a bit frustrated but then ends up changing behavior with the second caregiver and creates a new play accordingly. The degree of learning and development is highly influenced by the caregiver: The first caregiver and the child in this case quickly find a good way of interacting with the game, which results in the child moving and laughing. As the child is physically limited, movement is a part of her daily training. The second caregiver does not seem to obtain the same level of interaction with the child and the game, and the child never reaches the same level of enjoyment and movements as when being in the session with the first caregiver.



Fig. 4. On the left an example of the facilitator guiding the experience. On the right an example of a shared experience between the participants.

In the case of participant 4 and participant 5, where they interact with each other in a session, the caregiver and participant 4 is alone in the start of the session. The caregiver helps the participant to move his arms as he is unable to do so alone. Participant 5 observes their session and is suggested to participate, which he accepts. When he enters, participant 4 reacts with joy (noises indicating laugh), participant 5 helps participant 4 move his arms and this increases the indications of joy from participant 4. The caregiver encouraged peer-experience by inviting the other participant, and the caregiver's role shifted from being the one helping participant 4 to facilitating peer-experience and hence the reactions from participant 4 changed.

Participant 5, though motorically limited, is guiding the interactions and it is believed that this can influence his feeling of empowerment, as he is able to help others.

4.4 Mirroring

The effects of mirroring have been difficult to determine, but it has been observed that the reactions were increased direct self-recognition when using the game with a mirrored self-image. According to the caregivers from the special needs daycare centers, the participants seemed more engaged when they could see their mirrored self-image within the game. The participants often expressed joy when identifying themselves as a part of the game, and in the case of e.g. participant 6, the caregivers replied that there was a noticeable change in the attention span when he was able to see himself in the game. In some cases, especially when the participants were severely disabled both physically and mentally, there was no change in their reactions while interacting with the game with mirroring compared to their interactions with the game with silhouette.

4.5 The Adjustable Activity Zone

The adjustable activity zone proved sufficiently adaptable to a wide range of physical impairment, e.g. a paraplegic wheelchair user could use his head to participate and get a playful experience. For future studies the adjustable activity zone could be moved during the sessions to challenge the participants' range of motion. This could also help to distinguish intentional activation of colored boxes from coincidental interaction when analyzing results.

5 Conclusion

This study focused on the effects of a projected self-image in a game situation. A case study was carried out in order to investigate if there was a difference between a mirrored self-image condition and a silhouette condition. The results showed two emerging themes namely that firstly, in the mirroring condition, the participants showed tendencies toward increased enjoyment in the virtual environment, as the self-recognition often evoked joy, laughter and pointing behavior toward the projection. Secondly, that the sessions were highly affected by the mood of the participants, their mental model of the room and their degree of impairment, how much they enjoyed the system (or if they enjoyed it at all) and their ability to keep their concentration during the tests. However, even for the participants with problems concentrating, they were able to concentrate at some point during the tests. It was concluded that the social aspects with regards to both mirroring and enjoyment, seem to have an impact on the experience. Children used the system as a tool for enabling play with others, and children and adults working together with either caregivers or other participants to activate the system, but this is not representative for all cases.

The physical position of the setup is very important, as the participants seem to have a need for identifying the setup before entering the room in order to be comfortable with it, and the possibility of repeatedly being in the system.

It can be concluded that the system has a variety of possibilities, and the participants are using the system in different ways, which opens up the possibility for further development.

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Designing Accessible Visualizations: The Case of Designing a Weather Map for Blind Users

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Abstract. Major strides have been made to improve the accessibility of text-based documents for blind users, however, visualizations still remain largely inaccessible. The AISP framework represents an attempt to streamline the design process by aligning the information seeking behaviors of a blind user with those of a sighted user utilizing auditory feedback. With the recent popularity of touch-based devices, and the overwhelming success of the talking tactile tablet, we therefore suggest that the AISP framework be extended to include the sense of touch. This research-in-progress paper proposes such an extended design framework, MISD. In addition, the article also presents the preliminary work done in designing an accessible weather map based on our theory-driven design. A discussion and an outline of future work conclude the manuscript.

Keywords: Accessibility, Universal Usability, Auditory Information Seeking Principle, Multi-Sensory, Sonification, Spatial Sound, Visualizations, Weather.

1 Introduction

Modern computing, with its easily available text-to-speech applications, has improved a blind user's access to textual and graphical information by creating an experience that is comparable to that of a sighted user. However, text-to-speech techniques remain limited in their use at providing meaningful information about complex visual representations. These visual depictions of data, better known as information visualizations, still remain inaccessible to the blind. Data visualizations are typically used to improve comprehension of large quantities of data [1]. A central challenge in accessibility is devising alternative modes of representing such visual data for blind users, which frequently does not easily translate into textual equivalents.

A common method, to develop accessible visualizations, is to provide a reading of the data table upon which the visual representation is based [2]. In theory, the data presented to a sighted and non-sighted user is equivalent; however, it does not allow the blind user to obtain a high-level overview of the data and identify points of interest, which is the strength of information visualization [3]. Accessibility researchers have proposed that equivalencies may be accomplished through approaches such as haptic visualization, force feedback, and/or sonification, ([1], [4]) however, such research has typically been theoretical and also somewhat fragmented. This ongoing

research attempts to fill the gap by exploring the possibility of developing a theory driven, integrative design framework for generating accessible visualizations. Specifically, we use the guidelines proposed by Walls et. al. [5] to develop a design theory. In addition, we also report on the preliminary steps for applying the design theory to develop an accessible weather map for blind users.

2 Research Background

Sonification represents the technique that has found significant resonance in the efforts to develop accessible visualizations. This technique is characterized by “the use of non-speech audio to convey information about data” [6]. The general concept of sonification is to provide feedback on the dataset through sound, allowing the user to develop “nominal, qualitative, or quantitative judgments” about the underlying information [7]. Unlike the static reading of a data table or pie chart, the exploration of a sonified visualization is more interactive, allowing the user to experience the dataset on a deeper and more meaningful level. [8]

Research has provided evidence regarding the usefulness of sonification in developing accessible visualizations, particularly in the context of graphs, scattergrams, and tables [2]. There is indication that sonification is useful in conveying a value measure. Pitch is the most commonly used auditory property for providing a distinction between values. In the most extreme cases, finding the lowest bass note or the highest treble note is a relatively simple activity for the average user.

However, at the same time there are indications from research that sonification by itself is not completely adequate for the visualization of complex data sets. In fact there are significant challenges in using only sound to provide feedback to a user [6]. Precision is a concern because the user must be able to interpret data values and value differences between data points. Research has shown that users have had trouble making such comparisons [6], as it becomes more difficult to judge the magnitude of difference between the notes of A and C as compared to A and D.

Another challenge for sonification is that certain visualizations of data are essentially spatial in nature. A particular challenge is that spatial data must be approximated within the azimuth plane since “users are unable to accurately locate the position of the sound source as accurately as they could locate the information in an equivalent graphical visualization” [7]. Duraiswami et al. [9] found that while pitch is acceptable for conveying the east to west location, or north to south locations, it is problematic to try and denote both at the same time. There is an indication that attempts to represent spatial and value data simultaneously using sound, tend to overwhelm the user as the cognitive effort shifts from mere perception to that of remembering the exact interpretation of the sound sequences.

The above discussion provides some indication about the necessity for the development of an integrative, multi-modal approach to visualization.

2.1 Developing the Theory Driven Design Theory

Our approach toward developing a design theory has been guided by the framework proposed by Walls et al [5]. Walls et al [5] propose four important components for the development of a design theory artifact: *kernel theories*, *meta-requirement*, *meta-design*, *testable design product hypotheses*. In this framework, kernel theories represent theories from natural and social sciences that provide governing principles for the design theory. These theories inform and facilitate the formulation of meta-requirements - global goals that the design theory needs to satisfy. The meta-requirements in turn lead to the development of a meta-design framework which meets the needs specified in these requirements. Finally, the testable hypotheses allow for the explicit testing of the appropriateness of the meta-design. As this research does not extend to the evaluation of the design, we have stopped at the development of the meta-design.

2.2 Kernel Theory

The Auditory Information Seeking Principle (AISP) [9] lends itself as an appropriate theoretical framework for informing our design theory. The goal of this principle is to provide a blind user with the same strategy that a sighted user would take to gather information using auditory clues. The underlying principle of AISP is to model the auditory seeking behaviors on that of the visual seeking behavior [9]. The model uses four activities to highlight the mental process related to interpreting visualizations: *gist*, *navigates*, *filter*, and *details on demand*. The first two of these processes model the cognitive behavior of a user as he/she begins with the development of a high level overview of the data and then navigates through it to gain a deeper understanding. *Filter* and *Detail on demand* on the other hand describes the users need to focus on relevant information to reduce information overload and also to access specific parts of the data as and when necessary. The AISP then suggests the use of auditory techniques of information presentation that would enable the user to emulate each of these activities. Space limitations constrain us from a broader discussion of AISP and we refer interested readers to Duraiswami et al. [9] for a more detailed discussion of this framework.

The benefits of AISP include the matching of the visual and non-visual information seeking behaviors to maintain one user experience and providing a consistency for sonification of information visualizations. However, while AISP represents a significant step for developing accessible visualizations, it remains limited because it implicitly proposes a unimodal sonification based approach. Therefore, application of AISP is challenging for the visualization of data that has intrinsic spatial characteristics. There is an imperative to extend AISP into a multi-modal domain. In this endeavor, the components of AISP: *gist*, *navigation*, *filter* and *details-on-demand*, and their underlying principles represent the *meta-requirements* that inform and constrain the development of our design theory.

2.3 The Meta-design - Multi-Modal Information Seeking Design

The development of the design theory is predicated by the rationale that additional modalities are essential to provide a more equivalent information seeking process for the blind. By designing the visualization using multiple channels of feedback, such as sound, tactile, and haptic, we would be to provide the user with more information simultaneously and therefore more closely approach the experience of a sighted user. We therefore propose that a multi-modal approach should be taken, and in this section present our preliminary conceptual development, the Multi-Modal Information Seeking Design Approach (MISD).

In the initial implementation of the AISP, there are allusions to the incorporation of touch into their sonification [9]. They suggested, however, that a goal of their approach was to minimize the requirement of specialized hardware, such as external haptic and tactile devices [9]. However the need for such specialized hardware has reduced with the advent of tablet-based computers and touchscreen phones. These devices are now available to the public at a lower cost than standard PCs, which moves the inclusion of haptic and tactile features back into the realm of mainstream possibilities.

Research indicates that touchscreen exploration is the preferable method of interaction as it allows for a “direct interaction of haptic-spatial cues and sonification” and that “a combination of sound and touch will work better than a single modality for non-visual display of spatial information” [10]. In addition this also conforms to the premise that users should interact with spatial data by means of a spatial interface [7]. There is also empirical evidence that touchscreens and tablets are tools that may supplement comprehension of data through supplementary sensory perceptions, and that the usability of visualizations depicting spatial data would be vastly increased by a more multi-modal approach [11]. Belardinelli et al., [10] suggests that there are immense possibilities in the dynamic integration of auditory and haptic capabilities, and that it may usher in new frontiers for the study of new effective non-visual displays.

The MISD is an extension of the AISP which strongly incorporates the sense of touch as the user’s primary method of interaction with the system. The purpose of extending this principle is to take advantage of existing research which has proven the AISP to be a reliable design approach which maps the behavior of a visual user onto that of an auditory feedback strategy. The incorporation of touch incorporates a familiar form factor which can be used to provide additional information in a consistent and simultaneous manner for all visualizations.

The integration of auditory feedback with touch based navigation is done based on the following principle. The design framework suggests that a) magnitude or value based information be provided using auditory feedback, b) spatial information be provided using incorporation of touch based interaction, and c) spatial points of interest be identified through haptic feedback. We describe the main elements of MISD in the table below. One should note that the multi-modal aspect does not extend to all the components of AISP, but only to those where it represents a significant design benefit. For example, we believe that auditory feedback would remain appropriately useful for providing the *gist* of the visualization to the user, on the other hand an explicit multimodal approach would benefit the requirements of *navigation*, *filter* and *details-on-demand*.

Table 1. MISD tactics for multi-modal equivalency of visualization

	Multi-Modal Information Seeking Design (MISD)
Gist	Gist of information may be provided primarily through Auditory feedback mechanisms (e.g. pitch of sound, stereophonic sound production) that provide the user an overview or summary of the data
Navigate	Navigation should be implemented using touch-based interaction designed to allow the user a sense of the spatial information underlying the data
Filter	Filtering mechanisms may be implemented through use of device-based control mechanisms (e.g. volume rocker of phones/tablets) to allow user to choose specific information presentation modes. In addition, filtering mechanisms could also be implemented through allowing user variations of auditory feedback. Finally, filtering may also be implemented through haptic feedback intimating the user of points of interest.
Details -on- Demand	Details on demand may be achieved through the synchronization of touch based interaction and auditory feedback, such that the user can select points of interest and demand additional information. Selection would be enabled by the tactile interaction, and the demanded information would be conveyed through the mechanisms of auditory feedback

3 Applying MISD – The Accessible Weather Map Project

In this section, we discuss the details of the accessible weather map project that has been undertaken to apply and evaluate MISD. Weather maps are a very common visualization which can be relatively simple or incredibly complex. Casual users are familiar with simple maps that illustrate temperature and precipitation, but weather maps can also include lesser known attributes, such as humidity, isobars, and dew point. This data can be shown individually, but it is more common to appear in a single view. Weather maps are often animated to describe the movement of storm systems, but they can also portray a static context. In addition to discrete information, it is also possible to display more complex information such as trends on maps in a static context.

Weather is a domain in which visualizations are readily used. In large part, the weather information is summarized and then presented with visuals to give meaning to the user. This domain is overly complicated because it is an intersection of many areas including geography, territorial boundaries, and atmospheric data. Therefore, the weather map represents a very suitable domain within which to apply MISD. The assumption being that if an accessible data visualization could be prepared for this complicated domain using an inherently multi-modal approach, it could be generalized to other complex domains and provide initial support for MISD.

Below, we provide the design and implementation details of the prototype weather map. This implementation of the weather map is the extension of an earlier prototype of a desktop PC-based sonified weather map is described in [11]. Figure 1 denotes a high level architecture of the application

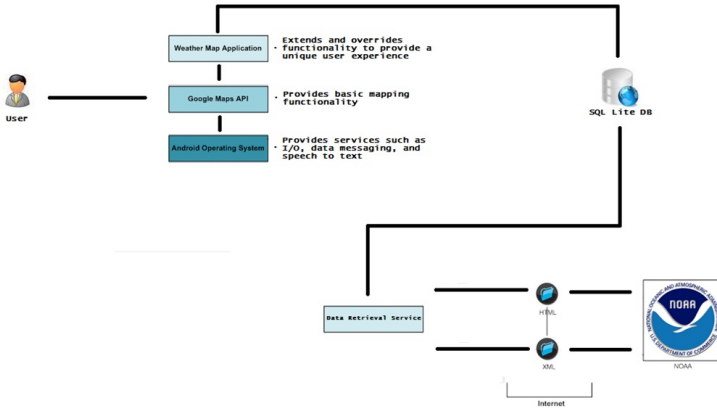


Fig. 1. Application Architecture of the Weather Map Visualization

3.1 Application Stack

The system was designed using a layered architecture approach. This allows for modularity of design and allows for collaboration through various levels of abstraction. We discuss below the different components of this layered architecture.

The basis of this application is the Android operating system (AOS). The AOS supports an application-based environment. Typically these are compiled Java byte-code developed using the Android SDK. The weather map application uses a number of services that are native to AOS, e.g.

- text-to-speech engine for voice output
- message handling and bundling services for communication
- input and output through a touch-based user interface

The second layer of the architecture is the Google Maps application. This is a closed-source application written by Google, Inc. however Google exposes the mapping functionality through an API, which provides basic services such as access to Google Maps servers, map display, and response to map gestures. The application utilized the Google API to generate the map, to allocate pixels to GPS coordinate mapping required to position the weather station data, and to map the user input into the global positioning system. In addition, weather map application overloads the interaction methods to include additional or modified behavior. For example, the standard gestures including drag, zoom, and fling have been ignored and substituted with alternative actions. Another such important change was the modification of the application

I/O to make it compatible with the usability enabled mode of the AOS. Android devices now offer an accessibility mode which allows usage of the devices by all users. Blind users touch the screen and the data is read to them. Further selection of choice may be done by a double tap of the appropriate option. The UI for map application incorporates such interaction behavior. Finally, unlike the standard Google Map application, the weather map has its location fixed at a point in the center of the United States.

To create this behavior, transparent overlays were placed over the map. There are two overlays used in the application. The first is the state, or territory, overlay which responds to the user input as they move their finger across the map. This overlay is created from XML files which describe each of the United States and their boundaries. The overlay responds to the user's touch by announcing the state names as they cross the state boundaries. If the user double taps on a location, the application zooms into the state, to focus on an area of interest. The state overlay contains a list of state objects which are used to represent the United States. As the user touches the overlay, a polygon algorithm is used to detect if the user touches within the state or not. If they do, the Android text-to-speech engine speaks the name of the state to the user.

The second overlay represents the weather data. This overlay is created from weather data stored in the application database (we describe the nature of our data service in the next section). The weather overlay contains a list of weather station objects which hold the weather data values. When a station is pressed, the station is identified and the data value is extracted for the specific weather mode. The tone is chosen from the predefined scale and the media player is used to play the tone to the user. The separation of these two overlays introduces flexibility to the design by allowing us to modularize spatial information and the weather data.

Figure 2 shows the communication structure used when interacting with the weather application. The Google map is the underlying component which is providing the GPS to pixel conversion and the background map images. The overlays lay on top of the map to prevent the user from interacting directly with it. These contain new and overloaded functionality to accomplish the goals of the application. Between the overlay and the data, is a gesture handler which detects new behaviors.

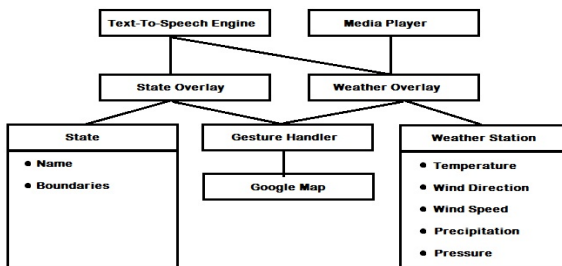


Fig. 2. Map Component Hierarchy

3.2 Data Service

In addition to the application, a data service has also been created as a background process. During the initial load of the application, an initial data fetch will occur, however, during subsequent loads of the application, the data will be fetched directly from the SQLite database. The use of a background process, allows the application to load quickly while retaining currency of weather conditions. Figure 1 displays the data retrieval process in graphical form.

Each of the weather stations serves as a data point within the map. The data is provided 3rd party from the National Oceanic and Atmospheric Administration (NOAA). NOAA maintains and allows access to the readings of their weather stations throughout the country. The data retrieval is accomplished using the data handling and message bundling services of the AOS. These can be identified using unique ids, which are packaged and sent via an HTML request to NOAA. The data is returned to the message handler in XML form. The data is then processed in the database, where it can be retrieved as a station object to place on the map as a marker as part of the weather station overlay.

3.3 Application Usage - User Story

After the application has loaded, a user can initiate touch based navigation of the map in geography mode or press the volume rockers on the phone/tablet to navigate between the weather modes. After selection of the desired mode (e.g. temperature see Figure 3 for temperature screen), the user can begin to explore the map with their finger. As the user traverses the map they can hear state names announced via the text-to-speech engine. This allows the user to take note of their location as they explore the map. If the user drags their finger over a weather station a tone will be played based on the magnitude of the weather value. For example, the coldest temperature will play a deep bass note, while the hottest temperature will play a high treble note. This sonification of the data allows the user to listen to the data set as they explore the map with their finger. The notes are spaced evenly across the musical scale to prevent confusion when comparing values. This technique allows for an easy selection of the statistical outliers. The device also vibrates if the user selects or passes geographical locations containing minimum and maximum values. As the user listens to the sounds played, they will notice that the left and right speakers are playing sounds based on the side of the screen that the user's finger is positioned. This is the technique of spatial sound, using the origination point of the sound to provide additional feedback to the user. This directionality is intended to provide positive reinforcement of the data being transmitted through the sound and touch. The application speaks the state name only once until they press on a different state. This allows the user to explore the shape of the states and their neighboring territories. If the user is specifically interested in a state, they may elect to double click on it which forces the map to reposition to a closer view of the state. When the map is finished the transition, the application will alert the user and they will be free to explore in closer detail the desired area. When satisfied, the user can double-click the state once again to return to the full view of the United States.



Fig. 3. Weather Map – Temperature Mode

4 Future Directions and Contribution

The next step of this research will involve conducting a formal usability test of this prototype. The usability testing will be designed to explicitly evaluate hypotheses derived from the propositions formulated in the earlier section of this paper and will compare the performance of the prototype to an accessible weather map developed using a uni-modal sonification approach.

Data visualization remains an area that has faced significant challenges in developing equivalent presentations for blind users. This research in progress contributes to this area by proposing MISD, an integrative multi-modal design framework. While significant work remains in terms of formally evaluating MISD, we feel that it represents a small, but important step, towards developing truly equivalent accessible data visualizations for the blind.

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Modified Control-Response Ratio for Move and Rotation Operations on a Large Multi-touch Interface

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Abstract. This study focused on the effect of the control-response ratio (C/R ratio) of a multi-touch interface for move and rotation operations. The experiments were conducted to collect data on user performance and subjective evaluation to analyze the effects of five levels of the C/R ratio. Forty-five participants, 15 male and 30 female, were given tasks to complete. The results showed that in overall operations, subjective satisfaction was highest with the C/R ratio 1/1, but in the usability analysis among the C/R ratios 1/1, 1/2, and 2/1, there was no significant difference. Specific operations that analyzed the effects of the C/R ratio showed in the move operations the best C/R ratio was located between 1/1 and 1/2, and in the rotation operations, the difference among the C/R ratios 2/1, 1/1, and 1/2 was not significant. The best C/R ratio might be located among the three values. The results show that on a mid-size multi-touch screen, a modified C/R ratio may help users in pan and rotation operations to improve performance and satisfaction.

Keywords: C/R ratio, multi-touch, large touchscreen.

1 Introduction

Multi-touch interfaces are becoming an important part of consumer information products. The control/response ratio (C/R ratio) is a main factor in the design of these positioning devices. This study examined user performance and satisfaction to understand the appropriate C/R ratio of a multi-touch interface.

This study focused on the effect of the C/R ratio of a multi-touch interface for move and rotation operations. Multi-touch is defined as operating on the screen with two or more fingers, and it is a type of direct control with the screen as the input device. The C/R ratio is a ratio of the movements of the control and system response. For a direct manipulation interface such a multi-touch touchscreen, a C/R ratio of 1/1 seems to be natural. It is intuitive to use and learn for natural mapping. However, on a large-size touchscreen, the long travel distance may result in poor efficiency and muscle fatigue [1]. A modified C/R ratio may help users extend the range beyond the physical limitation. At first, users will find the response of the direct operation does not coincide with control. They may learn a new mental model similar to that of indirect operation. The purpose of this study was to investigate whether different C/R ratios are necessary for various tasks.

Sanders and McCormick [2] extended the human-machine interface C/R ratio concept and general application. The original term display was replaced by system response. The C/R ratio is the reciprocal of gain. Low gain is low sensitivity. High gain is high sensitivity. It is explained by the knob interface, and the concept can be applied to the mouse's sensitivity.

Stevenson et al. [3] adjusted the C/R ratio of the mouse to compare user performance. The result showed a high C/R ratio provided an advantage in accuracy. When the input interface is replaced with a multi-touch one, the C/R ratio is not an obvious factor to investigate. North et al. [4] mentioned that the single-touch operation was developed in the original one-click mouse operation. Multi-touch operation may require a different concept model. Perhaps in different tasks, the required sensitivity is different.

Literature related to multi-touch is mostly about the performance and satisfaction of task-based operations. For example, Fiorella, Sanna, and Lamberti [5], Yee [1], and Esenther and Wittenburg [6] used various multi-touch control modes to analyze user performance and satisfaction. In the literature, the three most commonly used multi-touch control modes are moving, rotation, and scaling. A previous pilot study tested the C/R ratio with 1/2, 3/4, 1/1, 4/3, and 2/1 and found the best C/R ratio was not the same for the efficiency of different operating tasks. However, the appropriate C/R ratio cannot be found in the range 1/2 to 2/1. And user satisfaction was affected by the participants' previous experience [7].

2 Experimental Design

The principal aim of the study was to gain insight into the influences of the control-response ratio in the multi-touch interface for move and rotation tasks. Performance and satisfaction were the main issues explored.

Forty-five subjects participated in the study, 15 male and 30 female. The age ranged from 20 to 26 years (Mean = 21.53, SD = 1.38), and they spend an average of 6.73 hours (SD = 2.33) using a computer every day.

The previous pilot study tested the C/R ratio from 2/1 to 1/2 but did not find significant differences in performance [7]. This study extends the range of the C/R ratio from 4/1 to 1/4 so that the sensitivity ranges from the lowest to the highest. The five levels of the C/R ratio, gain value, and sensitivity are shown in Table 1.

Table 1. Five C/R ratio levels and the related gain and sensibility

C/R Ratio	4/1	2/1	1/1	1/2	1/4
Gain	1/4	1/2	1/1	2/1	4/1
Sensitivity	Lowest	Low	Standard	High	Highest

For evaluating the performance, three performance indexes and subject satisfaction data were collected. The variables are defined as follows:

- Time: the time participants spent completing each task.
- Errors: the number of tasks the user did not complete correctly.
- Touch number: the number of times that the user put his (her) finger on the screen.
- Satisfaction: the satisfaction was evaluated after the participant completed each task using a Likert scale with five levels ranging from “very difficult to use (1 point)” to “very easy to use (5 points).”

2.1 Apparatus

The experiment was designed to compare performance and satisfaction in difference C/R ratios for a multi-touch interface. The configuration of the experiment environment is shown in Fig. 1. A computer with Microsoft Windows 7 operating system that supported multi-touch and a 23-inch Acer T231H infrared optical multi-touch screen with the highest resolution 1920x1080 (pixel) and viewable size 509.76x286.74 (mm) were used in the experiment.

The experiment system was designed with Adobe Flash CS5 that supported multi-touch function. The objects used in the tasks were set in 320x240 pixels with a poker pattern. The poker pattern can reduce a participant’s cognitive problems for image direction. Five percent of the target boundary was set as the tolerance (Fig. 2). Only when participants did not put the object in this area was counted as an error. The participants operated the two multi-touch modes on the objects to complete all the tasks.



Fig. 1. The configuration of the experiment environment

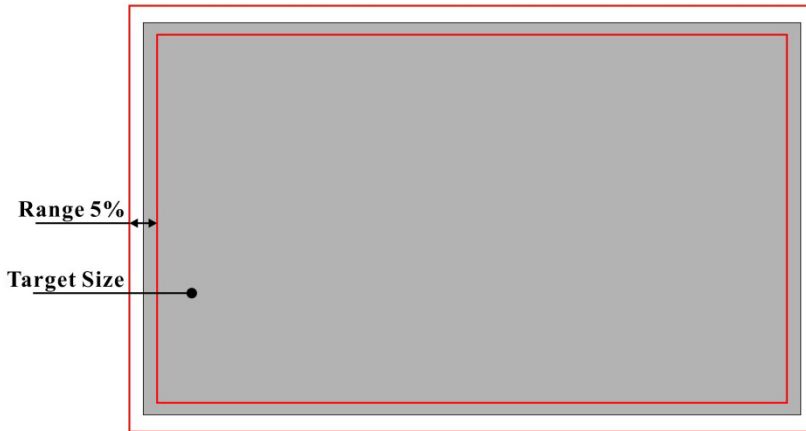


Fig. 2. The inside and outside error range of the targets was limited to 5%

2.2 Tasks

Two tasks were used in this experiment. All the tasks should have been completed with a single hand. The move task was set as the participant using two fingers to drag the object from the start point to the target area, as shown in Fig. 3. The rotation task used two fingers to drag the object from the horizon to the vertical, as shown in Fig. 4.

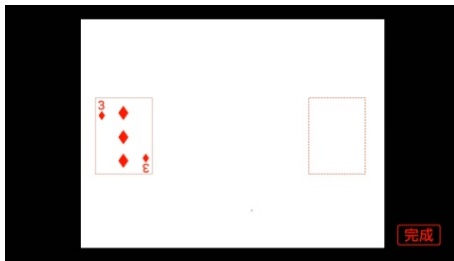


Fig. 3. Move task

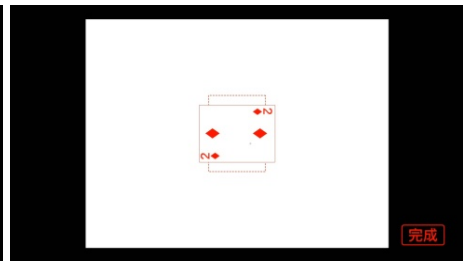


Fig. 4. Rotation task

2.3 Procedure

The experiment asked the participants to follow the instructions for performing the move and rotate tasks using one hand. The tasks with different C/R ratios were arranged with the Latin matrix to avoid the participants' learning effect.

The participants operated the two multi-touch modes on the objects to complete all the tasks. The error range of the target size was set at 5%. If the object was not moved or rotated within the error range and the participants clicked the "Finish" button, the system logged an error record. The system popped up a window to alert participants to continue the experiment until they had correctly placed the target within the error range. Participants were asked to rank their satisfaction with each task on the pop-up screen (see Fig. 5) after completing each task.



Fig. 5. The satisfaction evaluation screenshot

The study was a within-subject design. Each participant was tested with all ten tasks of two modes and five C/R ratio levels. Satisfaction was evaluated upon completion of each task.

3 Results

Table 2 presents the mean and standard deviation (SD) of each variable with a different C/R ratio in the rotate and move tasks. The C/R ratio values are set in descending order, that is, from low sensitivity to high sensitivity.

Table 2. Satisfaction, error, touch numbers, and the completion time with the C/R ratio

C/R Ratio	Task	4/1	2/1	1/1	1/2	1/4
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Satisfaction	Rotation	2.02 (1.00)	2.82 (0.84)	3.01 (0.97)	2.66 (1.04)	2.06 (1.01)
	Move	2.48 (1.08)	2.97 (0.88)	3.92 (0.90)	2.89 (0.88)	2.17 (0.94)
Error	Rotation	0.07 (0.29)	0.00 (0.00)	0.03 (0.18)	0.03 (0.18)	0.23 (0.52)
	Move	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.03 (0.18)	0.13 (0.37)
Touch Num.	Rotation	10.58 (10.82)	4.23 (1.91)	3.66 (1.70)	4.79 (3.29)	6.69 (4.80)
	Move	8.62 (2.46)	4.46 (1.73)	2.50 (1.00)	3.29 (1.49)	4.79 (2.80)
Time	Rotation	49.64 (56.82)	18.16 (10.08)	19.72 (15.03)	26.26 (21.55)	44.86 (39.58)
	Move	19.68 (9.98)	14.52 (6.78)	10.92 (7.09)	19.27 (20.37)	29.19 (21.05)

The C/R ratio with the highest satisfaction scores for the rotation task was 1/1 (Mean = 3.02, SD = 0.97); the lowest error was 2/1 (Mean = 0.00, SD = 0.00); the lowest touch number was 1/1 (Mean = 3.66, SD = 1.70); and the lowest completion time was 2/1 (Mean = 18.16, SD = 10.8). For the moving task, the highest satisfaction

score was 1/1 (Mean = 3.92, SD = 0.90); the lowest number of error was 1/1, 2/1, and 4/1 (Mean = 0.00, SD = 0.00); the lowest touch number was 1/1 (Mean = 2.50, SD = 1.00); and the lowest completion time was 1/1 (Mean = 10.92, SD = 7.09).

The analysis of variance (ANOVA) and Duncan post hoc test were conducted to compare the differences among the C/R ratios in each variable. The results of the ANOVA and Duncan test are presented in Table 3. All the variables had significant differences among the C/R ratios ($p < .000$). The rotation and moving task satisfaction scores of the C/R ratio 1/1 were significantly higher than the others. The number of errors for the C/R ratio 4/1 was significantly higher than the others in the rotation and moving tasks. There were no significant differences between the C/R ratios 1/1, 1/2, 2/1, and 1/4. The moving task touch numbers in the C/R ratio 1/1 were significantly lower than the others. The touch numbers for the rotation task for the C/R ratios 1/1, 1/2, and 2/1 were similar, there were no significant differences between them, and they were significantly lower than those for 4/1 and 1/4. The shortest completion time of the C/R ratios were for 1/2, 1/1, and 2/1 in the rotation task, which were significantly shorter than for 4/1 and 1/4. The moving task completion time for the C/R ratios 1/1 and 1/2 was the fastest, which was significantly faster than others.

Table 3. The ANOVA analysis and Duncan post hoc analysis. (***) $p < .001$

C/R Ratio	Task	ANOVA		Post Hoc Test
		F	P	Duncan
Satisfaction	Rotation	19.625	.000 ***	(1/1, 1/2) ≥ (1/2, 2/1) > (4/1, 1/4)
	Move	44.928	.000 ***	(1/1) > (1/2, 2/1) > (1/4) > (4/1)
Error	Rotation	9.137	.000 ***	(4/1) > (1/4, 2/1, 1/1, 1/2)
	Move	8.725	.000 ***	(4/1) > (2/1, 1/1, 1/2, 1/4)
Touch Num.	Rotation	22.508	.000 ***	(1/4) > (4/1) > (2/1, 1/2, 1/1)
	Move	124.234	.000 ***	(1/4) > (4/1, 1/2) > (2/1) > (1/1)
Time	Rotation	17.136	.000 ***	(1/4, 4/1) > (2/1, 1/1, 1/2)
	Move	20.262	.000 ***	(4/1) > (1/4, 2/1) > (1/2, 1/1)

4 Discussion

4.1 C/R Ratio in the Moving Task

Moving is a general operation, and the most frequently used in touch interface. The results have shown that the C/R ratio 1/1 had the highest subjective satisfaction score. The C/R ratio 4/1 had highest number of errors, and there was no significant difference among the others. The touch numbers for the C/R ratio 1/1 were significantly lower than for the other ratios. The completion time for the C/R ratios 1/1 and 1/2 was significantly faster than for the others. All the evidence demonstrates that in the move operation the best C/R ratio was located between 1/1 and 1/2.

The results are similar to those for a previous pilot study [7] that found there was no significant difference in completion time, number of errors, and touch numbers

among the C/R ratios 2/1, 4/3, 1/1, 3/4, and 1/2 in the moving task. However, the subjective satisfaction of the C/R ratio 1/1 was significantly higher than for the others.

4.2 C/R Ratio in the Rotation Task

In the rotation task, the C/R ratios 1/1 and 1/2 had higher subjective satisfaction scores than the others. The number of errors for the C/R ratio 4/1 was higher than for the others, and the difference among the C/R ratios 1/2, 1/1, 2/1, and 1/4 was not significant. The touch numbers among the C/R ratios 1/1, 1/2, and 2/1 were similar but significantly lower than the others. The completion times among the C/R ratios 1/2, 1/1, and 2/1 also were similar and significantly lower than those for the C/R ratios 4/1 and 1/4. These results illustrated that the performance among the C/R ratios 2/1, 1/1, and 1/2 was not significantly different. The best C/R ratio might be located from 2/1 to 1/2.

Similar results were also found in a previous pilot study [7]. There were no significant differences in subject satisfaction and objective performance among the C/R ratios 2/1, 4/3, 1/1, 3/4, and 1/2.

4.3 C/R Ratio and Operation

The C/R ratio is one of the factors influencing the interface design that affect the performance of the task operation. The optimal C/R ratio is related to the task attributes with the travel and adjusts the time. The ratio is also related the controller and the display [2].

The C/R ratio has been discussed for computer pointer devices, such as the mouse. For example, Stevenson et al. [3] adjusted the C/R ratio of the mouse to compare user performance. The result showed a high C/R ratio provided an advantage in accuracy. The mouse is an indirect pointer device; thus, the proportion of the control area size and display size affect the C/R ratio. However, when the input interface is replaced by a direct multi-touch interface, the proportion of the control and display is the same, and the C/R ratio is not an obvious factor to investigate. North et al. [4] mentioned that single-touch operation was developed in the original one-click mouse operation. Multi-touch operation may require a different concept model. Perhaps in different tasks, the required sensitivity is different.

The results of this study demonstrated that the optimal C/R ratio for different operation tasks in the multi-touch interface should be different. Especially in the mid-size multi-touch screen, a modified C/R ratio may help users in pan and rotation operations to improve performance and satisfaction.

5 Conclusion

The purpose of this study was to explore the C/R ratio with move and rotation operations on a mid-size multi-touch screen. The experiment was conducted to collect data. The experiment found that the best C/R ratio for the move operation was located

between 1/1 and 1/2, and for the rotation operation was located between 2/1 and 1/2. The results illustrated that on a mid-size multi-touch screen, the best C/R ratio for different operation tasks may be different.

The results provide a reference for multi-touch interface design, but future research and data need to be verified. The experiment was limited to hardware and software. In future research, the experiment and device need more revision. More operation tasks and levels of the C/R ratio should be added to obtain more accurate data to validate the findings, and to provide more relevant results for design and research reference.

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Gesture-Based Interaction for Cultural Exhibitions

The Effect of Discrete Visual Feedback on the Usability of In-Air Gesture-Based User Interfaces

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Abstract. The study aims to reveal the effect of in-air gesture interaction using the depth camera technology on complex human performance and to identify possible design failures and its implementation to the digital shadow play. Since in-air coordinate system of body kinematics shares the same directional vector with on-screen coordinate of the visual character, a systematic approach “directional vector transformation” has been proposed for transforming the in-air coordinate into the on-screen coordinate. A comprehensive literature review of human computer interaction, digital shadow play and gesture interfaces is given. Finally, identification of design failures and design guideline for further study are made for the design of in-air gesture interfaces.

Keywords: Gesture Interfaces, Depth Camera, Fitts’ law, FLG, Usability.

1 Introduction

Among recent studies toward the digital shadow play, it was claimed that shadow play is one of the intangible cultural heritages in China and was popular in most areas of the country but only few people watch the play now because of the increasing popularity of new media [3]. In order to attract more people’s attention, a new digitized performance method needs to be designed based on multi-touch technology which the method maps transforms of a small group of controlling points to character controlling points accordingly, with innovative mapping rules that decrease the complexity of controlling with fingers [3]. In Malaysia, shadow puppet plays is a traditional Malaysian theater art, which slowly loses its appeal to adolescents, who prefer computer games. In order to help reverse this decline, a 3D Seri Rama prototype was developed incorporating the traditional Seri Rama character into the Street Fighter video game, using modeling, texturing, and animation [4]. The prototype allows users to control

Seri Rama with a PlayStation game controller. This approach is mainly more towards the signs of awareness especially towards the younger generation that shadow play puppet is still an influential performing arts master piece heritage. Indirectly, this will help to open more opportunities for businesses and marketing plans including the tourism sector as more visitors will visit Malaysia in future [4].

In Taiwan, the Kaohsiung County is known as the homeland of puppet arts, digital shadow play has been developing and exhibiting to installing new energy into Taiwan's traditional puppet theatres [1][2]. (Fig. 1 and Fig. 2).

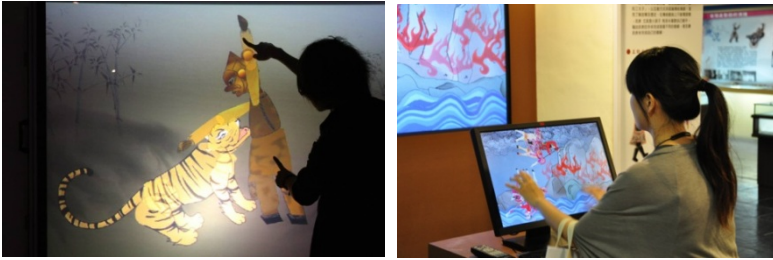


Fig. 1. and **Fig. 2.** The photo at left hand side demonstrates the first version of the digital shadow show “Wu-Song and Tiger”, developed based on the 80" infrared-based multi-touch technology and the open source software library that allows the touch sensitivity of the wall to be modified. Furthermore, the photo at the right hand side shows the second version of the digital shadow show based on Multi-Touch Surface Capacitive Touch Display.

To sum up, this study aims to reveal the effect of in-air gesture interaction using depth camera technology on complex human performance and to identify possible design failures and its implementation to the digital shadow play. The remaining of the paper is organized as follows: In Section 2, the background review of related areas is surveyed. In Section 3, the proposed experimental approach is demonstrated. The result analysis is given in Section 4. Section 5 provides a detailed discusses based on the results. Finally, conclusions and future work are highlighted in Section 6.

2 Related Works

2.1 Directional Vector Transformation

Depth camera technology observes users through a video camera and recognizes gestures they make with different body parts, including hands, arms, legs, and general posture. It presents a far more advanced gesture-based user experience than any previous input devices.

In order to utilize the gesture data in the air for the design of 2D GUI, the gesture data needs to be transformed into on-screen coordinates. For instance, the relation between both coordinate systems is illustrated in Fig. 3(a) and 3(b). In Fig. 3(a), the right palm moves from in-air coordinate A (X_1, Y_1) to B (X_2, Y_2). Following by Figure 3(b), the on-screen coordinate known as A (x_1, y_1) is the right palm of the visual character on the screen, it tends to move to unknown B (x_2, y_2) with the same directional vector based on the in-air palm movement from A to B.

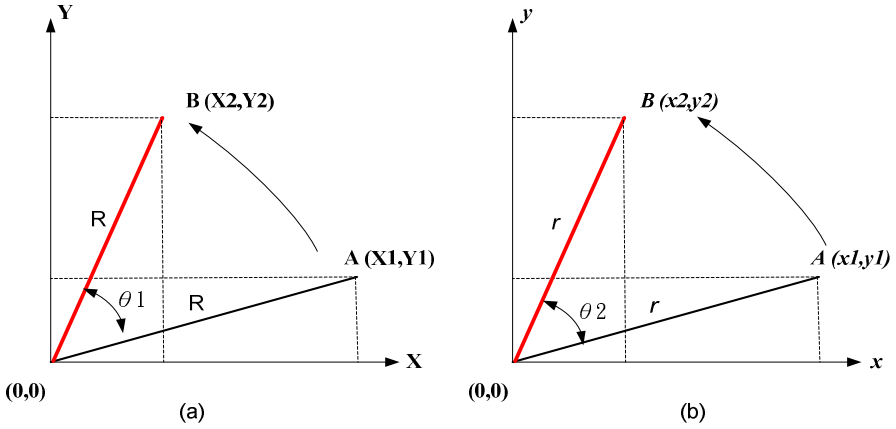


Fig. 3. (a) in-air coordinate system of the gesture in the real world and (b) on-screen coordinate system of visual gesture

This study proposes a systematic approach “directional vector transformation” for transforming the in-air coordinates into on-screen coordinate. It refers to two difference coordinates sharing the same directional vector, i.e. in-air coordinate of body kinematics, and on-screen coordinate of the visual character.

The followings are the procedure of the directional vector transformation based on the right palm movement; Firstly, the right palm moves from in-air coordinate A (X1,Y1) to B (X2,Y2), the directional vector for on-screen movement of the palm of the visual character can be expressed by a simple directional vector equation shown in Equation (1):

$$\overline{AB} = (X1 - X2, Y1 - Y2) \tag{1}$$

where (X1-X2) and (Y1-Y2) represent the direction of the movement of the related body kinematics in terms of x and y coordinate system. Since there is a coordinate difference between of in-air and on-screen, the value of the directional vector needs to be normalized by the displacement between A (X1,Y1) and B (X2,Y2), namely *AB normalized* , shown in Equation (3):

$$Displacement = \sqrt{(X1 - X2)^2 + (Y1 - Y2)^2} \tag{2}$$

$$\overline{AB} \text{ normalized} = \left(\frac{(X1-X2)}{Displacement}, \frac{(Y1-Y2)}{Displacement} \right) \tag{3}$$

In this case, the on-screen coordinate known as A (x1,y1) indicates the right palm of the visual character, it needs to move to unknown B (x2,y2), which the unknown B (x2,y2) can be obtained via the Equation (4):

$$B(x2,y2) = A(x1,y1) \times \overline{AB} \text{ normalized} \times Constant \tag{4}$$

Based on the directional vector transformation, the digital shadow play based on in-air gesture interface using Kinect sensor was developed using Adobe AIR, show in Fig. 4. Essentially, there is a difference coordinate between of the coordinate mapping from the body kinematics captured by Kinect sensor, and of the inverse kinematics (IK) on the screen. Even through, the direction between of those is the same. In this study, Constant is the length of the lower limb on the screen, i.e. Constant = 200 dot. Although the $B(x_2, y_2)$ will be never the same as $B(x_2, y_2)$, but movement direction is the same since the angle between B and B is 0° .



Fig. 4. The picture shows the difference coordinate between of the coordinate mapping from the gesture in the real world (i.e. colour dots on the screen), and of the visual character on the screen. Even through, the direction movement between two coordinate systems is the same.

2.2 Kinect Cursor Emulator

It is difficult to measure the objective human performance of the prototype demonstrated in Fig. 4. Instead, this study designed a simulated programme based on Equation (4) to emulate the mouse cursor movement mapping from the right palm in the air, namely Kinect Mouse Emulator. The programme uses the Kinect for Windows SDK and its skeletal tracking features to allow a user to use their hands to control the Windows mouse cursor, modified from a demo application (Source: <http://kinectmouse.codeplex.com/>). It demonstrates how to use the Kinect skeletal tracking feature to move the mouse cursor with a user's hands based on.

2.3 Human Performance Model

Regarding measurement of human performance, there have been many practices in the field of Human-Computer Interaction (HCI). One of famous practices is Fitts' law. [5] The mathematical relationship among speed, accuracy, amplitude of movement, and target size for upper extremity tasks, which can be expressed by a simple liner regression equation shown in Equation (5):

$$MT = a + b \times ID \tag{5}$$

where ID is index of difficulty proposed by Fitts, D is distance between targets, W is target width, MT is movement time, and parameters a and b are calculated on the

basis of simple linear regression. As expected, movement time for hard tasks is longer. Furthermore, MacKenzie [7] recommended the use of effective target width W_e instead of nominal target width W to measure actual performance of either devices or tasks:

$$W_e = 4.133 \times S.D \quad (6)$$

$$ID_e = \log_2(D/W_e + 1) \quad (7)$$

where $S.D.$ is standard deviation of endpoint over target region, and ID_e is effective index of difficulty. Recently, the ID_e model in Equation (7) had been standardized in ISO 9241 [8] as a design and testing guideline, and specification of non-keyboard input devices (NKIDs). In this study, Fitts' law was expanded into two-dimensional description in a polar coordinate system.

3 Method

3.1 Subject Selection

A total of ten Taiwanese undergraduate students in the Department of Animation and Game Design, Shu-Te University volunteered. The participants consisted of five males, i.e. age range from 20 to 21 years, and five females, i.e. age range from 20 to 21 years. All participants used their preferred right hand to perform the tasks, and reported over 6 years' experience with PCs.

3.2 Testing Apparatus

The laboratory used for the experiment is a computer laboratory in Room DB105-3 in Department of Animation and Game Design, Shu-Te University. The experiment was conducted based on following equipment:

- PC with a Intel i5 2.67 GHz CPU, 4 GB of RAM;
- 60" projector screen showing targets.
- A standard two-button optic mouse with 800 dpi, manufactured by Logitech®.
- A 'Kinect Sensor', manufactured by Microsoft®.
- Fitts' Law Generator (FLG) [1][2][13][16]. It can be used for multidirectional human performance measurement of Non-Keyboard Input Devices (NKIDs)
- Subjective assessment based on five-scale subjective questionnaire.
- A digital camera used to capture awkward postures of participants' performance during the experiment.
- A standard operation procedure (SOP).
- The data analysis is performed using SPSS version 17.



Fig. 5. Experiment condition in the computer laboratory in Room DB105-3

3.3 Experimental Procedure

The triangulation mixed method was implemented, it is a $2 \times 2 \times 2 \times 8$ within-subjects repeated measurement laboratory-based experiment, as shown in Table 1.

Totally, there were $n = 10 \text{ subjects} \times 2 \text{ devices} \times 3 \text{ blocks} \times 32 \text{ target conditions} = 1,920$ pairs of dependent variables being observed by a measurement platform Fitts' Law Generator (FLG). Therefore, quantitative analysis method can be applied. Those dependent variables and related methods are shown in Table 2.

Table 1. $2 \times 2 \times 2 \times 8$ factorial conditions

Factors	Levels
Devices (2)	Mouse, Kinect Sensor
Target distance (mm) (2)	100, 300
Width/Height (mm) (2)	300, 500
Angle of Approach (degree) (8)	$0^\circ, 45^\circ, 90^\circ, 135^\circ, 180^\circ, 225^\circ, 270^\circ, 315^\circ$

Table 2. Objective Dependent Variables

Factors	Description
De	Cursor movement distance (mm)
AT	Time of aiming target (ms)
PT	Time of decision making (ms)
MT	Time of movement (ms)
$Error$	Error (%)
TRE	Target-re-entrance (%)
W_{sd}	Standard deviation of pointing x by conditions (mm)
H_{sd}	Standard deviation of pointing y by conditions (mm)
W_e	$4.133 \times W_{sd}$ (mm)
H_e	$4.133 \times H_{sd}$ (mm)

3.4 Research Limitation

Kinect Cursor Emulator and the digital shadow play are both the in-air gesture interface using Kinect Sensor, sharing the same concept expressed in Equation (4). Since the digital shadow play does not require button activation, thus the result analysis regarding the pointing time is only recommended for further study.

4 Result Analysis

4.1 Data Adjustment

An error occurred when a participant registered a target acquisition while the cursor was outside the target.[13] Therefore, error cases are analyzed separately. Since there are two pointing device being tested, a total of 15 errors occurred out of 960 total trials with the mouse (1.6% error rate) and a total of 65 errors occurred out of 960 total trials with the Kinect sensor (6.8% error rate).

As for the mouse, the mean *MT* for all trials is 625 ms, and the removal of the error trials reduces the mean *MT* to 604 ms. With regards to the Kinect sensor, the mean *MT* for all trials is 2,689 ms, and the removal of the error trials reduces the mean *MT* to 2,528 ms.

4.2 Fitness-of-Models

As can be seen in Table 3, comparing with the result done by Chen and Chen [13] who reported an adjusted $R^2 = 0.44$ with a mouse, this study obtain higher adjusted R^2 values across the *ID* model. Therefore, our study is consistent with current study.

Table 3. The prediction of the total movement time (*MT*) (ms) across models (*ID*, *ID_e*, *ID_{e2}*)

Device	N*	Model	
		<i>ID</i>	<i>ID_e</i>
Mouse	945	0.479	0.396
Kinect Sensor	895	0.613	0.436

* The error trials were excluded for the analysis.

** The linear regression analysis was applied on the adjusted data for the prediction of the movement time *MT* across models (*ID* and *ID_e*). The adjusted R^2 value was used since the sample size was difference among these studies.

4.3 Device Difference

As shown in Table 2, Independent T test indicates that the mean of movement time, i.e. 1,941 mm, is significantly longer than for the mouse, i.e. 456 mm, $p < 0.000$. Moreover, the approaching time, the pointing time and the total movement time

for Kinect sensor are all significant longer than the mouse, i.e. $p < 0.05$. However, the result analysis reveals that there is no difference of cursor movement distance between of the mouse and of the Kinect sensor, $p = 0.212$, Hence, it is necessary to explore the design failures that cause similar cursor movement distance and longer movement time via the posture analysis and the subjective assessment.

Table 4. Objective data

Dependent Variable	Device	N	Average	S.D.
Error Rate*	mouse	960	1.6%	.065
	Kinect	960	6.8%	.111
Target-Re-Entrance*	mouse	945	3%	.161
	Kinect	895	9%	.323
Movement Time (ms)**	mouse	945	456.14	1449
	Kinect	895	1940.58	830
Pointing Time (ms)**	mouse	945	148.56	152
	Kinect	895	587.21	218
Approaching Time (ms)**	mouse	945	604.71	227
	Kinect	895	2527.78	868
Cursor Movement Distance (mm)	mouse	945	437	119
	Kinect	895	419	153

Remark: *: $p < 0.05$. **: $p < 0.001$. Except of the error rate, error cases are excluded for analysis.

4.4 Direct Observation

When using the Kinect Cursor Emulator, various arm and body postures of those with a preference for right handed working can be categorized in terms of the shoulder flexion angle θ_1 and the back flexion angle θ_2 :

- Angle θ_1 : shoulder flexion
- Angle θ_2 : back (spine) flexion

Based on the reviewed literature, the awkward working posture is defined as the posture having the joint range apart from the neutral posture.[15]. The observation reveals that there were two operational postures being defined, shown as follows:

- Type I: It is the neutral position where θ_1 and θ_2 are approaching to 0° .
- Type II: It is the awkward position where θ_1 and θ_2 apart from 0° .

As can be seen in Fig. 6, it is a selected pictures taken from the experiment, where the awkward postures are identified among the pointing task with in-air gesture interface using Kinect sensor.



Fig. 6. Type II operational posture, where the subject's back flexion is 25° approximately

5 Discussion

By the implementation of the triangulation mixed method, two possible issues that caused awkward working posture whilst using the in-air gesture interface, were highlighted: Firstly, based on the human performance study, it reveals that end-users tend to maintain the same joint range of particular body regions in order to take control of the cursor movement, especially where the angle of approach appears from the middle to bottom of the screen, i.e. 135° , 180° , 225° , 270° and 315° :

- Kinect sensor is not suitable for rapid and accuracy pointing activity. It was highlighted that the scenario related with Kinect application is not focused on productivity, speed, and precision, but enables an interaction that other input devices cannot [17].
- The position of the visual target must be designed over the middle of the screen.
- The cursor movement speed should be adjusted based on a repetitive design process with user test to achieve better quality-in-use.

6 Conclusion

The study has achieved its aims by revealing the effect of in-air gesture interaction using the depth camera technology on complex human performance and to identify possible design failures and its implementation to the digital shadow play.

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Including Uncertainty Treatment on the Accessibility Assessment of DOSVOX System

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Abstract. The speech interface development *per se* is not a guarantee of quality for the accessibility to visually impaired users either to as much of a website as possible where it can be achieved or to as much of functions a stand-alone product can provide. In this paper, a methodological approach for assessing accessibility problems in voice user interfaces (VUI) is proposed, which includes uncertainty treatment by using Bayesian networks. A case study is discussed, in which the proposed approach has provided encouraging results, and seems to have a potential to be successfully applied to other similar speech stand-alone software applications.

Keywords: Accessibility, Conformance Inspection, Bayesian Networks, Vocal User Interfaces, VUI.

1 Introduction

Accessibility can be defined as the result of a set of actions performed by software researchers and developers with the aim of making software usable for people with the widest range of user categories, including those with physical, sensory, visual and cognitive disabilities [4]. With respect to people with disabilities, the use of computer systems means a big challenge, because most of software applications are developed for people with no disabilities. Thus, aiming to allow disabled people accessing software systems and executing their tasks with a good performance, accessible user interfaces play a vital role.

Among people with disabilities, there are those with visual disabilities (i.e., blindness and low vision). These people access priority software using vocal user interfaces (VUI). VUI allows human to interact with computer by speech/voice [11-12]. However, the speech interface development *per se* is not a guarantee of quality for the accessibility to visually disabled users and computer systems. Therefore, accessibility assessment processes are inserted in the software development lifecycle for purposes of: (i) verifying of facility of access to product functionalities; (ii) analyzing user experience; and (iii) identifying accessibility problems.

One strategy commonly used to evaluate software accessibility is systematically inspecting a user interface for compliance with some set of recommendations [13], [16], with the aim of determining whether the evaluated interface is in conformance with the requirements of that standard. However, many subjective factors are inherent to this assessment strategy (e.g., evaluator experience, degree of product adherence to the standard), which can impact on the inspection results.

In order to evidence the uncertainty related with the conformity inspection process as well as to reflect the subjectivity of the evaluator judgment, the inclusion of a strategy based on uncertainty modeling to aid experts for decision-making and formulating diagnosis processes is proposed. Studies on conformity inspections of VUI, which includes uncertainty treatment to support expert decision-makings, were not found in the reviewed literature. The proposed approach was validated by a case study involving the conformity inspection of the user interface of the DOSVOX system to the Part 171 of ISO standard 9241. Furthermore, it included uncertainty treatment by using Bayesian Networks [10], [14].

2 Theoretical Background and Related Work

2.1 Usability and Accessibility

According to Petrie and Bevan [13], a wide range of definitions to accessibility and usability are found in literature. Usability is related with specific users, aims and contexts of use, defined from a particular set of circumstances (e.g., a system for creating, editing and reading text for people with visual disabilities has usability requirements different from a system with the same functionalities for users with physical disabilities). On the other hand, accessibility does not specify users, aims or context of users, (e.g., an accessible computer system must meet the requirements of all user groups, independent of disability).

Unlike usability, the main aim of accessibility is to provide access of a product for the largest possible number of user groups, including elderly and people with disabilities. Since accessibility and usability are not synonyms, it is important to include both of them as part of the specification and design processes [1], [5].

The part 11 of ISO standard 9241 [7] defines usability as the extent of a product, service or environment that can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use. On the other hand, the part 171 of ISO standard 9241 [8] defines accessibility as the usability of a product, service or environment for people with the widest range of capabilities. In other words, providing accessibility for a product implies on enhancing effectiveness, efficiency and satisfaction for a wider range of individual capabilities and preferences. On this basis, Sousa and Freitas [15] inferred accessibility as the conjugation of effectiveness, efficiency and satisfaction by any people, without a specific context of use.

Providing accessibility means removing barriers which prevent people with disabilities from participating of daily tasks, including services, products and information [16]. At this point, it is important to highlight that the inclusion of accessibility in early stages of system developments can bring benefits not only to users, but also to companies, because it can increase the number of potential users.

2.2 Conformity Inspection

A number of software usability and accessibility assessment methods have arisen in the past decades, and many authors have suggested forms to differentiate them [1], [13], [16].

According to [13], assessment methods can be divided into two broad categories: (i) formative or (ii) summative. Formative assessments aim to expose problems of an unfinished interface, in order to improve the interface since the beginning of the design process. On the other hand, summative assessments are performed on a done interface to draw a global diagnosis, based on fixed criteria, at the end of different steps of the interface development.

Usability inspection is a summative study, which is not user-based and includes a set of methods based on investigation of a product by evaluators, with the aim of identifying usability problems and enhancing the usability of an interface design by checking it against established standards (e.g., heuristic evaluation, cognitive walk-through and conformity inspection) [6], [10]. Conformity inspection of a product is a type of systematic usability inspection. It is performed by a specialist to inspect whether an interface is in conformance with the recommendations of a standard (e.g., ISO 9241 [9]).

2.3 International Standard ISO 9241

International standard ISO 9241 was designed at the end of the 80s as a standard with 17 parts, originally called as *Ergonomic requirements for office work with visual display terminals*. Over two decades, it has become globally influential as a reference to standards from many countries (e.g., Brazil, via ABNT¹).

Major advances on hardware and software technologies have been seen since the past two decades. It drove revisions and updates in ISO 9241. Actually, many parts are in update state. The new standard title – *The Ergonomics of Human-system Interaction* – includes the original content and also reflects a wider scope.

Among 17 parts from the original structure, only three parts were kept after reviewing and titles altering, with the aim of focusing on topics which apply to other parts: (i) Part 1 (*Introduction*); (ii) Part 2 (*Job design*); and (iii) Part 11 (*Hardware and software usability*). Based on the idea of applicable parts, in a greater or a lesser degree, for all other parts, there is the Part 20 (*Accessibility and human-system interaction*). The other parts are structured in series: (i) 100 Series (*Software ergonomics*); (ii) 200 Series (*Process guidance for human-centered design*); (iii) 300 Series (*Displays and display related hardware*); (iv) 400 Series (*Physical input devices*); (v) 500 Series (*Workplace ergonomics*); (vi) 600 Series (*Environment ergonomics*); (vii) 700 Series (*Control rooms*); and (viii) 900 Series (*Tactile and haptic interactions*).

With respect to software ergonomics, the 100 Series contains five parts: (i) Part 100 (*Introduction to standards related to software ergonomics*), (ii) Part 110 (*Dialogue principles*), (iii) Part 129 (*Guidance on software individualization*), (iv) Part 151 (*Guidance on World Wide Web user interfaces*); and (v) Part 171 (*Guidance on software accessibility*). Part 171 provides a guide on ergonomics and specifications

¹ Brazilian Association of Technical Standards: <http://www.abnt.org.br/>

related to the accessible software project at any context. Besides, this part includes aspects related to the accessible software project for subjects with visual, physical, cognitive or sensorial disabilities [8].

At the end of each ISO 9241 part, there is a checklist containing the recommendations to be inspect. In order to inspect a product according to Part 171, the evaluator needs to verify two aspects of development process for each recommendation. The first one is related to the applicability of recommendation to the interface project considered. For this aspect, there are two available fields - YES (Y) and NO (N).

When the assessment focuses on a product prototype of product, a second aspect called *Adherence* (or *Conformance* at reviewed and new parts of ISO 9241) should be verified. Since a recommendation is applicable to an evaluated prototype or product, if the product or prototype adheres to recommendation, it will be in conformance with that recommendation. For this purpose, two or three cells are available: PASS (P) or, FAILED (F) (unreviewed parts), or YES, PARTIALLY and NO (reviewed and new parts).

Lastly, for each inspected recommendation, the evaluator must comment on the reason of the non-applicability of a recommendation or about his/her judgment on the conformance of the product with a recommendation.

An excerpt of the checklist of Part 171 is given in Fig. 1 [8].

Clause/subclause of this part of ISO 9241		Applicability		Conformance			
		Yes/No	Reason not applicable	Yes	Partially	No	Comments
8	General guidelines and requirements						
8.1	Names and labels for each user-interface elements						
8.1.1	Provide a name for each user interface element	Y					
8.1.2	Provide meaningful names						

Fig. 1. Checklist excerpt for assessing applicability and conformity with Part 171 of ISO 9241

After completing the checklist, the summarization of results from calculus of adherence rate (or conformance rate) is recommended by ISO. With respect to Part 171 [8], ISO classifies adherence rate as (i) total and (ii) partial. The *Total Adherence Rate* (AR_t) is defined as the percent ratio of the number of applicable recommendations totally incorporated by the product (t) and the number of recommendations judged applicable to the context of the project (a). On the other hand, the *Partial Adherence Rate* (AR_p) is defined as the percent ratio of the number of recommendations applicable partially incorporated by the product (p) and the number of recommendations judged applicable to the project context (a) (see Eqs. 1 and 2).

$$AR_t = \frac{t}{a} \times 100\% \tag{1}$$

$$AR_p = \frac{p}{a} \times 100\% \tag{2}$$

Although these ratios are able to show the percent of recommendations totally (1) and partially (2) incorporated to Part 171 of ISO standard 9241, it encompasses with a

high degree of subjectivity. AR_t and AR_p can vary according to expert responsible for the assessment. Besides, ISO warns that the adherence rate is only an arithmetic indicator, which cannot be used as a reliable measurement without considering the importance of the respective items of context of use [9-10].

The completion of the checklist at the end of an inspection encompasses issues inherent to the evaluator (e.g., experience, knowledge on the product). Therefore, each judgment on the applicability of the recommendation and the adherence product to recommendation are related with a subjectivity degree.

The high subjectivity degree inherent to the conformance inspection, consequence of the large number of evaluator profile, is one of the main drawbacks of this procedure [10]. The inclusion of a modeling to evidence the uncertainty associated for evaluator decision-making is important because it can aid experts to express the uncertainty of their decisions.

2.4 Uncertainty Treatment

In order to overcome the uncertainty inherent to the conformity inspection to ISO standard 9241, Menezes et al. [10] suggested assigning certainty degrees for ISO standard 9241 recommendations.

Assigning certainty degrees (g_c) means to infer a certainty degree for each recommendation (r) of inspection list (LI), especially at ambiguous situations or when the evaluator is not able to infer a secure diagnosis on a recommendation [10].

The certainty degree for each recommendation (g_c) can be modeled from two aspects: (i) Applicability; and (ii) Conformance. In Part 171 of ISO 9241 [8], all recommendations are expressed by a conditional relationship, wherein the occurrence of a event B (consequence, i.e., the product is (or not) in conformance with a recommendation) is conditioned to the occurrence of a event A (cause, i.e., the recommendation is applicable to the product project interface). Therefore, the Bayes Theorem [14] can model this relationship, with the aim to express the occurrence of event B (degree of certainty of conformance - g_{con}) conditioned to the probability of occurrence of event A (degree of certainty of applicability - g_{apl}) (See Fig. 2).

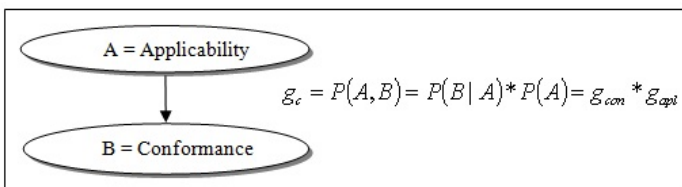


Fig. 2. Bayesian network model of recommendations of Part 171 of ISO standard 9241

The Bayesian Network shows the influence of A on B, i.e., the applicability of each recommendation influences on the product conformance with the standard. The degree of certainty of each recommendation is calculated from probabilities of A and B, i.e., $P(A,B)$. Thus, it is possible to calculate the mean degree of certainty of

evaluation. If the probability of certainty covers the set of all recommendations totally incorporated by the product (E), since they are all applicable, the mean probability of certainty is called Mean Total Certainty (MTC) (see Eq. 3).

$$MTC = \frac{\sum_{i=1}^{|E|} g_c}{|E|}, \quad (3)$$

The approach described here is based on the study developed by [10], which resulted in a development of the specialist system called X-SCI (Expert System for Supporting Conformity Inspections). It was designed to aid evaluators to perform usability conformance inspections of user interfaces according to the Part 16 of ISO standard 9241 [9]. Actually, conformance inspection to the Part 171 of ISO standard 171 is done manually, since it was not found at review literature other computational system to aid software practitioners to perform conformance inspections to the ISO standard.

3 Case Study

Here it will be detailed a case study involving the use of DOSVOX, a computer system developed for helping people with visual disabilities to use the computer.

3.1 DOSVOX

The DOSVOX is a computational system to aid blind and low vision people to perform tasks in the computer as the same way as people without disabilities. DOSVOX system was created at 1993, by the Tércio Pacitti Institute of Applications and Computational Research² (iNCE), at the Federal University of Rio de Janeiro (UFRJ). At first, it was developed to aid blind students to perform their academic tasks (e.g., writing and reading texts, browsing the web and using email). Today, statistics shows that it is largely used by people with disabilities in Brazil and others countries in Latin America [3].

This computational system is used at personal computers and has a multimodal vocal interface, since there is another mode of interaction between user and computer in addition to voice interaction (i.e., text) [2]. The data input is via keyboard. On the other hand, the data output is textual (*Text User Interface* – TUI) and vocal (*Voice User Interface* – VUI).

Actually, the DOSVOX system is in version 4.4 [3]. Besides having many functionalities for creating, editing and reading files, it has application for a wide range of daily tasks (e.g., keyboard testing, games, e-mail, web browser, sound recorder, text to mp3 converter, screen reader, vocal calculator, telephone book, vocal chat) (See Figs. 3 and 4).

² <http://portal.nce.ufrj.br/>

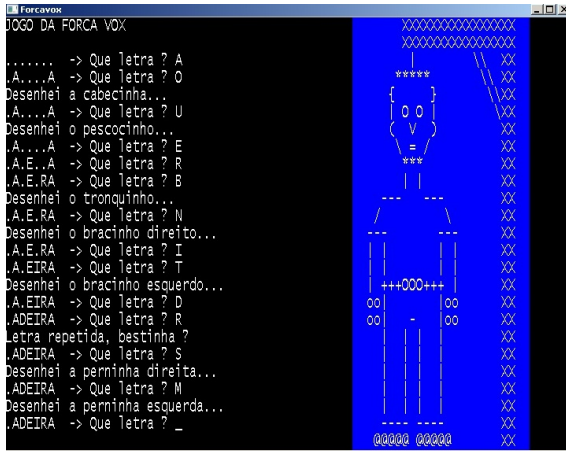


Fig. 3. Forcavox (Hangman) – A DOSVOX game



Fig. 4. Edivox – DOSVOX file editor

3.2 Conformity Inspection of DOSVOX to the Part 171 of ISO Standard 9241

As can be seen in Fig. 1, the third column of that checklist is used to indicate whether the requirement or recommendation in each clause/subclause is applicable or no [8]. All those recommendations which does not depends upon the context of use (user, tasks, environment and technology), i.e., that have no conditions attached to them, its cells already marked with “Y” (i.e., Yes). For these recommendations, it was assigned $g_{apl} = 100\%$. On the other hand, there are some recommendations which indicate applicable, unless specified condition is applied. For these recommendations, its cells already marked with “C” and g_{apl} is assigned by the evaluator.

3.3 Evaluation Scope

As it is impractical to evaluate all applications of DOSVOX system, the evaluation scope was defined based on informal interviews with computer teachers of two institutes for people with visual disabilities: (i) Instituto dos Cegos de Campina Grande³ and (ii) Instituto dos Cegos da Paraiba Adalgisa Cunha⁴. Thus, the evaluation scope covered four DOSVOX applications: (i) the Keyboard Test, (ii) the file editor (Edivox), (iii) the e-mail (Cartavox) and (iv) the web browser (Webvox).

4 Results

The conformity inspection of the DOSVOX system to Part 171 of ISO standard 9241 [8] aimed to identify accessibility issues, especially those ones that affect visually disabled users. The inspection resulted in $AR_p = 5.21\%$ ($p = 5$, $a = 96$) e $AR_t = 75.00\%$ ($t = 72$, $a = 96$), of a total of a hundred and forty (140) recommendations.

In Table 1 a summary of the accessibility problems categories identified during the conformity inspection is given. For each category, the number of problems identified by evaluation is also showed. The category consists in the description of the clause/subclause given in the checklist of ISO 9241:171.

A problem can be identified from two situations: (i) a recommendation is applicable to a product, but it is not in conformance with the recommendation; or (ii) the recommendation is applicable, but it is only partially in conformity with the established standard.

Table 1. Problems category identified during the conformity inspection

<i>Problem Category</i>	<i>Number of problems</i>
User preference settings	03
General control and operation guidelines	07
Texts/fonts	01
Colour	02
Window appearance and behavior	05
Text equivalents of audio (captions)	01
Media	02
Tactile output	01
Documentation and Help	01
Support services	01

As can be seen, AR_t expressed a successful rating, since it is equal to 75%. However, there are still 25% of recommendations to be fixed in the next version of the product. Besides, PCTM was calculated as well ($PCTM = 83.69\%$). As asserted by Menezes et al. [10], PCTM provides an important contribution to conformity inspection, since it enhances the reliability of inspection results.

³ Institute for the Blind of Campina Grande.

⁴ Institute for the Blind of Paraiba Adalgisa Cunha.

An inspection with $PCTM < 70\%$ can suggest many factors with respect to the evaluation result, for instance, (i) little evaluator's knowledge related to the product, (ii) little evaluator's experience related to conformity inspection or (iii) the need of performing a new conformity inspection with more than one evaluator.

Finally, for evaluating how reliability is the PCTM, a confidence interval (CI) was calculated. Then, $CI = (78.47, 88.90)$ ($\alpha = 0.05$; $s = 22.49$; $n = 72$). As $PCTM \in CI$, then, PCTM is reliable.

5 Final Considerations and Future Work

The main goal of this paper was to present an approach for modeling uncertainty inherent in the accessibility conformity inspections with the Part 171 of ISO standard 9241.

The approach was validated from a case study involving a computational system, developed to for visual disabled people, the DOSVOX system. Besides the classical rates of conformity inspection, AR_p and AR_i , PCTM was formulated and calculated in order to evidence the uncertainty related with the expert evaluation.

Current efforts are being focused on performing conformity inspections of DOSVOX with others specialists, in order to compare the results of evaluations, especially ARs and the MTC. Furthermore, triangulating the results of the accessibility conformity inspection with others evaluation methods (e.g., user performance measurement and user satisfaction measurement).

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OnScreenDualScribe: A Computer Operation Tool for Users with a Neuromuscular Disease

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Abstract. We developed a tool based on a modified number pad aimed at empowering persons with neuromuscular diseases to efficiently operate a computer and enter text. As the keypad lies securely in both hands, the system is ideal for someone who has motor problems using a full-size keyboard but cannot use speech recognition as an alternative method, because of dysarthria. The software offers various assistive techniques; for example, text entry is facilitated with the help of word prediction. An ambiguous mode with word-level disambiguation allows text entry with six keys. Initial empirical results with the system – which is already in regular use – indicate that it indeed represents a viable alternative, since it decreases effort without increasing the time to operate a computer.

Keywords: human-computer interaction, keyboard replacement, mouse emulator, word prediction, ambiguous keyboards, dysarthria, neuromuscular diseases, Friedreich's Ataxia.

1 Introduction

Be it for work or leisure, it is almost impossible today to avoid the computer. Entering text to write a scientific article, to compose an e-mail, or even to control a video game, is often the most important activity in this context. The standard input tools for human-computer interaction – a full-size keyboard and a mouse – allow for fast and efficient computer operation, provided the user is able to operate them.

For persons with disabilities who are often unable to employ a standard keyboard, there is a large variety of alternatives available. The problem is that most alternatives are much less efficient. Many scanning solutions, for example, are prohibitively slow, though only requiring a single input in the form of a switch activation [14,1]. The other extreme is speech recognition. Text entry using speech can even be faster than with the standard keyboard, but entry requires the ability to articulate clearly.

What if someone has a neuromuscular disease and cannot employ speech recognition because of dysarthria? And what if that someone must invest considerable effort to work with a standard keyboard, but is forced to make that investment, since the alternatives are too slow? These questions were the starting point for the research reported in this paper.

With the original objective to help a particular Friedreich's Ataxia (FA) patient (let's call him John), we developed several alternative interaction systems over the last few years. The goal was to help not only one person, but anyone with similar conditions: FA is an inherited, progressive neuromuscular disease that affects the neural pathways between the brain, cerebellum, and muscles [9] and leads to impaired muscle coordination. There is currently no cure for the disease [12], but the individual symptoms can be treated. In a sense, our newest solution – called *OnScreenDualScribe* – is such a treatment since it is intended to reduce the effort required to interact with a computer. The input device the system is tailored to is shown in Fig. 1. The novel idea is to prepare the unconventionally used device – with a form factor that is ideal for someone with a neuromuscular disease, as the keypad lies securely in both hands – to become a comprehensive assistive input tool, capable of conveniently replacing both the keyboard and mouse.

The remainder of the paper is organized as follows. In the next section, we look at various approaches concerning keyboard replacements (albeit mostly restricted to text entry only) reported in the literature. This is followed by an introduction of our solution in two sections dealing with the chosen input device and the software implementation. The system has been evaluated in an initial pilot study, which is described before the paper is concluded with a discussion of the outcome and a reiteration of the main points.

2 Related Work

With the progress in computer technology, methods to help individuals with disabilities enter text by providing a suitable keyboard alternative become more and more sophisticated. Earlier systems [5] use basic techniques such as word prediction [8] to facilitate input. Although operating a plain word prediction utility in the simplest form still relies on keyboard input, such an alternative is, in some sense, a replacement of the standard device with a more enhanced variant. Growing computational power makes it possible to analyze spoken words online. So speech recognition [18,6] can be used as an alternative.

There are many approaches in between that use an input device different from the standard keyboard, but not requiring extensive computational power. Examples include *EdgeWrite*, a text entry system based on two-dimensional traces representing individual characters [17], *Dasher*, which also uses a pointing device for text entry [16], as well as numerous approaches dealing with small, ambiguous keyboards [13,11], or switch-activated scanning systems [15].

Unfortunately, for an FA patient, these approaches either demands too much or too little. In other words, they either require unimpaired motor (or vocal) skills, or they simply do not take full advantage of the true abilities of the target population, thus making computing tasks unnecessarily slow.

Our system is intended as a computer control tool for patients with FA and similar diseases. As will become clear below, an efficient solution involves combining keyboard and mouse replacement in one adequate manual device.

3 Hardware Specifics

We wanted the input device supported in *OnScreenDualScribe* to be inexpensive, readily available, and convenient to handle. It became clear early on that the best choice would be a small, off-the-shelf number pad, turned by 90 degrees counterclockwise, with stickers attached to the keys, remapping them. We finally decided¹ on the device depicted in Fig. 1a, which is a wireless model (for maximum convenience). The stickers and the corresponding key layout are schematically shown in Fig. 1b.

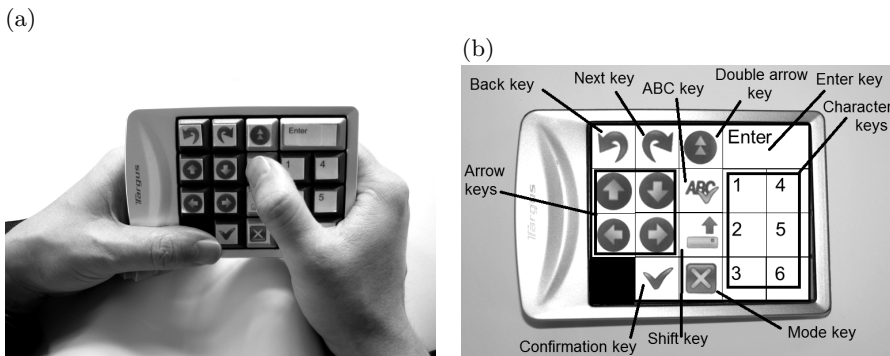


Fig. 1. *DualPad 2.0*: Inexpensive 18-key wireless number pad used for operating a computer; (a) usage: user can reach every key with either thumb without repositioning the hands; left and right edges serve as tactile guide when aiming at the keys; (b) stickers for the 18 keys with explanations.

The left two columns are operated with the left thumb and the remaining keys with the right thumb. The depicted layout is used in most contexts. *Ambiguous mode* is the only exception. Here, the location of some of the keys is slightly different. This is necessary since all character keys are in columns 4 and 5. Therefore, without change, the right thumb would do all the typing while the left thumb would be idle. The actually applied stickers were modified from Fig. 1b to also reflect the second layout.

¹ We tried about seven or eight different number pads until we found one that we considered acceptable.

4 Software Overview

OnScreenDualScribe is written in C++ under the Windows® operating system. It captures physical keystrokes on the number pad but does not pass them through to the active window (this is accomplished by defining all keys as “Hotkeys”). Instead, the software sends virtual input events to the active application. More details are given below.

4.1 General Architecture

The software operates in nine modes, each of which is responsible for different computing tasks. The 18 keys of the *DualPad* are re-mapped, depending on the currently active mode. The program window, which is shown as a narrow vertical stripe on top of all other windows (i.e., it is always visible) at the left or right edge of the screen (see Fig. 4a), displays several mode-specific indicators, for instance, which key is mapped to which function in the current mode.

To help novice users see the key associations, the key indicators resemble the physical layout of Fig. 1b. Two examples are illustrated in Fig. 2, which shows the indicators for *function mode* and *mouse mode* (with almost identical left hand keys).

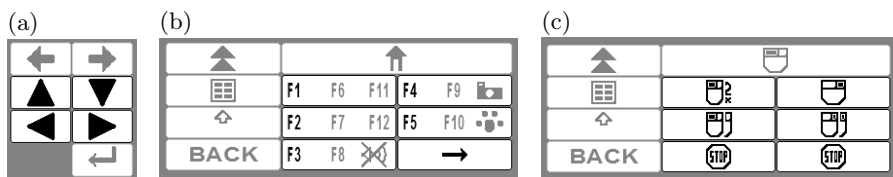


Fig. 2. Indicators for the keys in *function mode* and *mouse mode*: (a) left hand keys for scrolling (*function mode*) or moving the pointer (*mouse mode*) and navigating in a web browser; (b) right hand keys in *function mode* for evoking special virtual keystrokes; (c) right keys in *mouse mode* for generating clicks (left, right, single, double, drag).

Some of the *DualPad* keys directly lead to the generation of virtual keystrokes (or mouse events; see the subsection on pointing device operations). For example, pressing the “Confirmation key” on the *DualPad* in most modes generates an input event that corresponds to striking the RETURN key of a standard keyboard. Other keys either change the program state (e.g., in the course of selecting a word candidate; see below) or alter the currently active mode.

4.2 Text Entry

There are two different methods for entering text in *OnScreenDualScribe*. The basic method, also called *dual mode*, allows users to “write” the characters presented in the two-dimensional 8×6 virtual keyboard of Fig. 3a by selecting a row (with one or two keystrokes on the four arrow keys) and another keystroke on the character key that corresponds to its column.

Despite the labeling, the arrow keys are not used to move the highlight marking the selected row up or down. Rather, striking arrow key a_i once directly highlights row i , striking it twice highlights row $i + 4$ ($i = 1, \dots, 4$). This type of selection scheme is demonstrated in Fig. 3b. Figure 3c shows the selected row on the character keys.

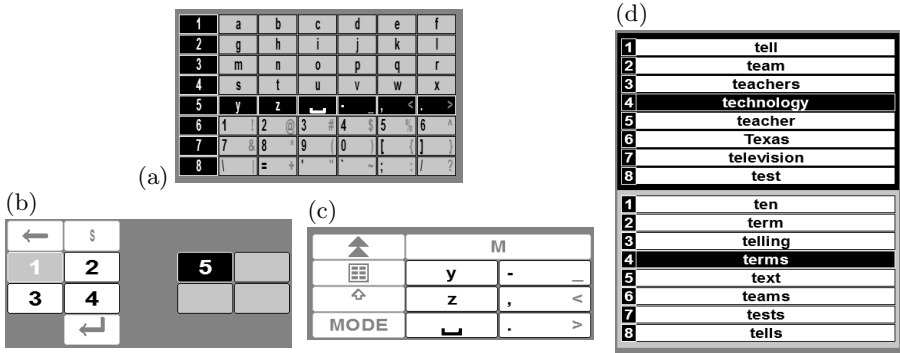


Fig. 3. Text entry in *dual mode*: (a) Virtual keyboard with eight rows and six columns showing the available characters (shifted versions for non-letter characters are shown in gray); (b) left hand keys – arrow keys (here labeled “1” – “4”, cf. Fig. 2a) are used to highlight one of the eight rows of the virtual keyboard; (c) right hand keys – character keys correspond to the highlighted row; (d) word prediction list resulting from entering “te” (i.e., “→2↑5”)

With the exception of “y” and “z”, all letter characters require exactly two keystrokes. Since the highlighted row resets to row five after choosing a character, the *KSPC* (keystrokes per character) for this input method is slightly less than 2.0. However, after each character, *OnScreenDualScribe* looks up the entered string in a dictionary (which is a text file containing 100,000 words, in the English version using the Corpus of Contemporary American English [2]) and presents a frequency-ordered list of extensions. Keystrokes are saved if the intended word is in the list. Selection of a suggested word is done analogous to the selection of a row of the virtual keyboard – the word list is divided into two sublists, and again, one of the eight rows/entries is highlighted in either sublist (see Fig. 3d, Fig. 5c, and Fig. 5d).

To some extent, word prediction brings this “open” text entry technique close to a full-size QWERTY keyboard (where *KSPC* is 1.0). Applying

$$KSPC = \frac{\sum_{i=1}^n (K_{w_i} \cdot F_{w_i})}{\sum_{i=1}^n (L_{w_i} \cdot F_{w_i})}, \quad (1)$$

to the newest edition of the dictionary file – where K_{w_i} is the number of keystrokes (at least) required to enter the word w_i , F_{w_i} is the frequency of w_i in the corpus, and L_{w_i} is the number of characters of w_i [10] – yields a *KSPC* of 1.1169 for *dual mode*.

The second text entry method implemented in *OnScreenDualScribe* consists of an ambiguous keyboard with six character keys and dictionary-based disambiguation. In *ambiguous mode*, character keys are used to compose a sequence of “code characters” represented by the digits 1 to 6. Each code character represents four or five characters of the alphabet (see Fig. 4b), and as the user types code characters, the software matches the code sequence among the words in the same dictionary file as above. The resulting frequency-ordered list of matching candidates contains at most 16 entries (selection as before), including extensions – if there are less than 16 candidates of equal length as the code sequence (see Fig. 4d).

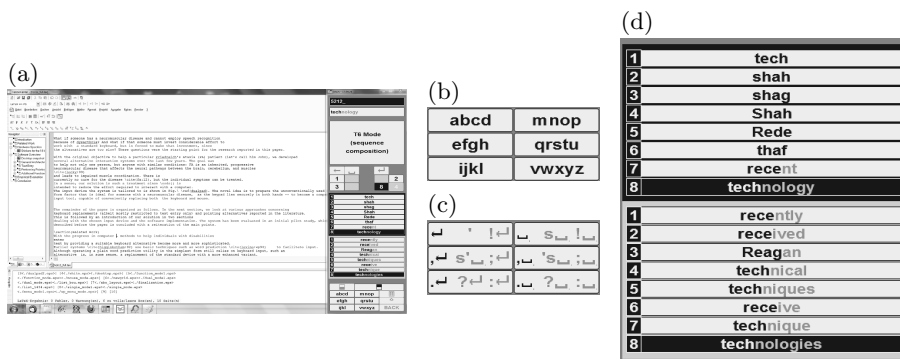


Fig. 4. *Ambiguous mode*: (a) desktop snapshot with program window at the right; (b) default arrangement where 26 letters are distributed over six keys in alphabetic order; (c) options to follow a selected candidate; (d) candidate list belonging to the sequence “5212”

This mode is more efficient than *dual mode* (*KSPC* is only 0.8678), but entering out-of-dictionary words is not possible. After selecting a candidate, the user chooses among several options for finalizing the selection (see Fig. 4c) by adding a space or basic punctuation (which reduces the need to switch to the basic technique between words).

4.3 Performing Pointing Device Operations

In addition to a keyboard, certain computing tasks (such as switching applications or clicking on a URL) require a pointing device or are hard to perform otherwise. Since the *DualPad* is held with both hands, using a manual device for pointing (like a mouse or a trackball) requires constant repositioning of the hands, which is very uneconomical.

Therefore, it was considered necessary to include a *mouse mode* (see Fig. 2c). The challenge was to make it possible to control the mouse pointer precisely, while allowing fast movement across the screen at the same time.

To do this, *OnScreenDualScribe* continually moves the mouse in one direction after the corresponding arrow key is pressed once. The initial speed is very low (ten pixels per second) and is reset when a different arrow key is pressed. However, pressing the same arrow key again accelerates the movement. When the pointer has reached the desired destination, the user generates a click or stops the movement with the right hand keys.

4.4 Additional Functionality

Operating a computer requires keyboard functionality that is beyond plain text entry. *OnScreenDualScribe* provides several ways to use special keys, like SHIFT, CTRL, or ALT. An example is *single keystroke mode*. In this mode, a single keystroke directly triggers a virtual keystroke (as opposed to *dual mode*). It gives access to frequently used keys, like the (regular) arrow keys, ESCAPE, DELETE, or PASTE (Figs. 5a and 5b).

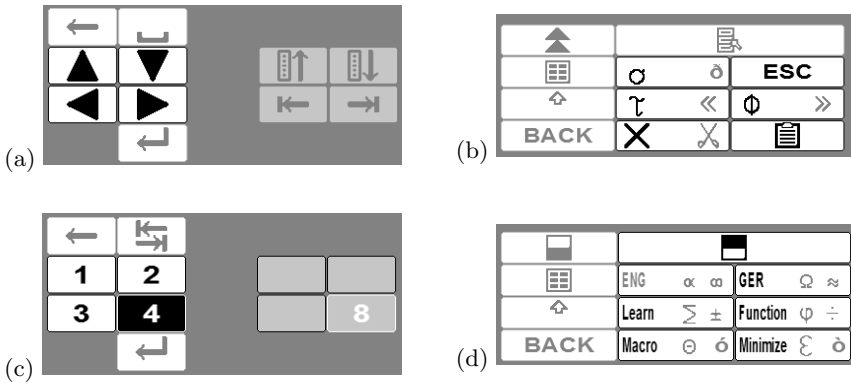


Fig. 5. Key indicators in *single keystroke mode*: (a) arrow keys to relocate text cursor; (b) right hand keys to access common keyboard functions; and *menu mode*: (c) arrow keys to control the highlight in word prediction sublists; (d) right hand keys to select desired sublist or trigger other modes.

Finally, there is a *macro mode* for sending arbitrary keystroke sequences, a *spell check mode* (to check the spelling of an entered word), and a *learning mode* to build and update a personal user-dependent dictionary supplement. The *menu mode* – which also allows users to select word prediction candidates or to toggle between English and German language versions (at runtime!) – is used to activate these miscellaneous modes (Figs. 5c and 5d). The German dictionary is based on [7] – however, statistical data given in our paper (i.e., *KSPC*) refers to the English version only.

5 Empirical Evaluation

The system was originally built for John, a 41-year-old FA patient, who regularly uses *DualScribe* [3], a predecessor system which is limited to a proprietary editor window and is thus unable to control arbitrary applications. John helped evaluate a simpler variant of the tool, which was based on a game controller [4]. A pilot study involved entering portions of a 2,100-character text over the course of five days for at least two hours per day.

He repeated the experiment with the new system, only this time entering the entire text each day (which almost always took less than 120 minutes). On the old system, his entry rate was around 2 wpm; now it is over 3.5 wpm. With the standard keyboard, John is able to achieve entry rates between 2 wpm and 4 wpm, but this demands much more effort than *OnScreenDualScribe* due to frequent typing errors and the need to operate a full-size and cumbersome keyboard.

Furthermore, the first author included a very unconventional form of empirical evaluation: About 90% of this paper was “written” with *OnScreenDualScribe*. The fact that the first author did not switch to the standard keyboard after one or two days certainly speaks to the quality of the interface.

6 Discussion

As *OnScreenDualScribe* allows its users to enter text with fewer keys (often with fewer keystrokes) than usually needed, it reduces the physical load posed on the user. Always knowing which key to press next, when to look at the candidate lists, or deciding if the intended word is present (and where) certainly increases the cognitive load. However, judging this limitation requires considering the target population.

John switched to the tool and its predecessor as soon as they became available – at first, just for composing emails, later, for all computer interaction needs. By now, the tool has become an indispensable assistant that made his life a lot easier. He says: “of course, I have to concentrate, and when I am tired, my writing speed drops, but taking away the effort is much more important for me”. In addition, his entry rate is now, more than half a year after the above mentioned experiment, regularly between 3 wpm and 5 wpm. As a reduced vigilance also resulted in lower entry rates when he was still using the standard keyboard, he is faster with the alternative method at any given point in time.

Besides, John has become so proficient in using the program that he can anticipate the number of letters required before a word appears near the top of the candidate list in *ambiguous mode*. He also developed strategies to easily circumvent problems like out-of-dictionary words (e.g., the word “neuromuscular” is not in the dictionary, but “neuro” and “muscular” are; as John knows that, he can quickly start a new word after having entered “neuro” when trying to enter the compound word in *ambiguous mode* – instead of entering the entire sequence, just to see that the word is *still* not in the list).

This is also the reason why conducting a usability study with a larger number of participants is particularly challenging. Non-expert users should practice with the software for a longer time (ideally several weeks or even months) to be able to make full use of the tool's assistive power. Finding someone who is willing to do that is not an easy task.

7 Conclusion

This paper introduced an assistive computer application, called *OnScreenDualScribe*, which is designed to replace the usual input method for interaction with a computer – involving a full-size keyboard and a mouse – by having the user press keys on an inexpensive, commercially available number pad. The system was developed with the immediate objective to devise a practical and efficient solution for John, a particular FA patient who participated in earlier studies evaluating text entry alternatives, and who also took part in a pilot study testing *OnScreenDualScribe*.

The broader idea is to help not only one person, but anyone with similar conditions. Since it is based on a small, compact manual device, it represents a viable alternative for persons with neuromuscular diseases, who are not able to use speech recognition, but who are (within limits) able to use both hands. Furthermore, able-bodied users looking for a small-size keyboard (e.g., for browsing the Internet on certain TV's) should also be interested in using the system.

After the pilot study, John immediately decided to completely switch to the new tool. The most eye-catching novelty in his workplace is the new 33" monitor he now uses – in his own words: “not a necessity, but a nice addition to my computer equipment, making it easier to scan the word lists”. A standard keyboard and mouse are still on the table, “but only as a fallback option, in case Windows hangs”.

The most important task for the future involves a larger usability study. In addition, debugging and improving the software – as well as designing a proprietary input device – are the next steps.

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Universal Access to Participatory Musical Experiences for People with Disabilities

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Abstract. Participating in music is a promising way to provide therapy for people with neurological and developmental disabilities. Unfortunately people are often unable to participate in music because of cognitive or physical impairment, and the steep learning curve of playing an instrument. We developed the Sensor to MIDI Interface (SMIDI) controller in order to provide a common platform to create MIDI-based musical instruments that are appropriate for people with disabilities. In this paper we discuss the SMIDI controller and three unique applications that use the system. The first is the MusicGlove, a musical instrument that motivates use of the hand through practicing functional gripping movements. The second is a fabric-based sensor technology that can be cut into any size or shape and connects with SMIDI to turn ordinary objects into a musical instrument. The third is a sensor laden stuffed animal that elicits sounds through bending and squeezing various appendages. Through the SMIDI system we hope to make music participation an accessible and enjoyable medium for therapy.

Keywords: music therapy, participation in music, physical disability, musical instruments, stroke, spinal cord injury, autism.

1 Introduction

1.1 Background

Music is a promising avenue for improving mental, physical, and emotional health in individuals with neurological and developmental disabilities [1]. Participating in music through playing a musical instrument, Therapeutic Instrumental Music Performance (TIMP), is one common method for employing music therapy and is most commonly used to exercise and emulate functional movements for motor rehabilitation [2], [3]. Previous studies have shown significant improvement in motor function of a paretic upper extremity in people with stroke through this approach [2], [4], [5]. Unfortunately, people are often unable to participate in music because of cognitive or

physical impairment, and the steep learning curve of playing traditional instruments. TIMP programs commonly use musical instruments intended for able-bodied users and are therefore limited to using instruments that do not require fine motor coordination—such as percussion instruments—or require a trained therapist to physically assist the patient in using an instrument [4]. In this paper, we discuss a platform that enables people with disabilities—such as stroke, spinal cord injury, multiple sclerosis, traumatic brain injury, muscular dystrophies, cerebral palsy and autism—to participate in music regardless of prior musical background or level of disability, and we discuss three music based devices which were developed specifically for disabled populations.

1.2 SMIDI Platform

We developed a Sensor to Musical Instrument Digital Interface (SMIDI) system which interfaces with a plurality of sensors and communicates with a computer through a USB-MIDI protocol (Fig. 1). MIDI is an industry standard protocol that enables electronic instruments to communicate with computers and other MIDI instruments. Using MIDI, commercially available digital audio workstations (DAW), such as Reason or Garage Band (Fig. 2) can communicate with SMIDI. This allows the user to choose a variety of different instrumental sounds that are mapped to specific notes on the SMIDI instrument. Moreover, the SMIDI system has pre-installed musical scales that allow an individual with no musical background to play along with a prerecorded song, with a trained musician, or with another individual that is using the SMIDI system.

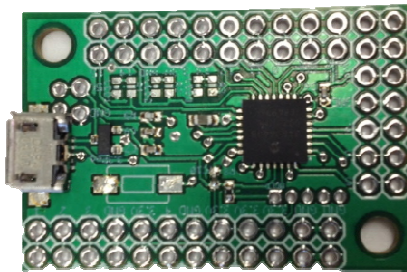


Fig. 1. The SMIDI controller allows for the development of MIDI-based musical instruments that accommodate all levels of physical disability

The SMIDI controller size is 1.5 inches by 1.0 inches, and uses a PIC24FJ64GB002 microcontroller to sample sensor data, convert the data to MIDI commands, and communicates to a computer via a USB-MIDI protocol. A USB 2.0 A-Male to Micro-B Male cable powers the controller and enables data communication and between the SMIDI controller and computer. The controller supports up to 15 I/O channels, 7 ADC channels with 12 bit resolution, and can interface with sensors using SPI, UART, or I2C communication protocols.



Fig. 2. GarageBand is one example of a digital audio workstation (DAW) that can interface with SMIDI instruments. Users select from a large database of instrument sounds (left) that are mapped to specific notes on the SMIDI instrument. Users can also compose music using a SMIDI instrument and a DAW (right).

2 SMIDI Instruments

We discuss three devices that use the SMIDI controller to provide a music-based participatory experience for people with physical disability.

2.1 MusicGlove

The MusicGlove is a device designed to train functional hand movements through music participation (fig. 3). It is a sensorized glove which contains six fabric-based contact sensors situated at the distal section of each digit and one on the proximal interphalangeal joint on the lateral aspect of the finger. To create a musical note, the user must touch the sensor on the thumb to any of the other five sensors. By doing so, the user practices important hand postures such as pincer grasp, key-pinch grip, and thumb opposition.



Fig. 3. MusicGlove is a sensorized glove designed to train functional hand movements

In a usability study with 10 participants with chronic stroke, we found that the MusicGlove could be used by individuals ranging from severe to mild hand impairment (Box and Block assessment > 2) [6] and can accurately measure clinical hand impairment level. We also found that chronic stroke patients who trained with the MusicGlove significantly improved their hand function as measured by an established clinical scale [7].

2.2 Fabric-Based Music Pads

We developed fabric-based touch and pressure sensors in order to provide easy to create custom instruments (Fig. 4). These fabric-based sensors can be cut into any shape or size and connect to the SMIDI system via a standardized 0.100" pitch IDC cable connector. This particular approach allows any surface to become a musical instrument and allows a person to use any appendage to play an instrument—not just the hand. The instrument can therefore be specifically designed to fit the need of the participants with physical disabilities. Figure 4 shows a fabric-based touch piano intended for individuals with mild impairment.

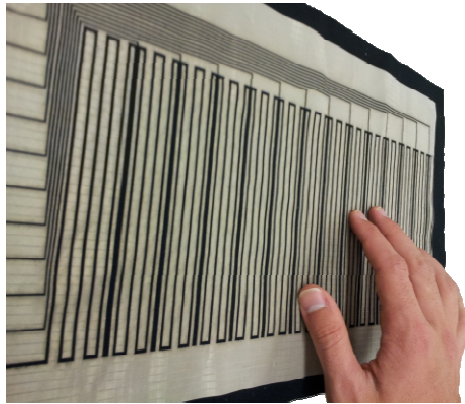


Fig. 4. Fabric-based music pads that can be cut into any size or shape to accommodate a specific level of impairment

2.3 Instrumented Stuffed Animal

The SMIDI platform enables anything to become a musical instrument—even UCI's stuffed animal mascot (Fig. 5). In this example, Peter the Anteater is instrumented with a number of commercially available bend and pressure sensors. Squeezing different sections of the mascot's body elicits a unique note in a pentatonic scale. Pushing upward on the nose elicits a MIDI note that increments in a pentatonic scale, pushing up on the tail increments the octave. This instrument can be integrated into a music therapy program for a child with a developmental disability such as autism [8–10].



Fig. 5. A musical instrument stuffed animal may be used for children with disabilities. Pushing and bending various sections produces unique sounds.

3 Discussion

We developed a platform which facilitates the process of creating custom, music-based technologies that are appropriate for the target disabled population. The three musical instruments presented are each geared towards specific affected populations ranging from stroke to autism. These unique examples are a testament to the flexible and easy-to-use nature of the SMIDI system.

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An Ontology-Based Architecture for Natural Language Access to Relational Databases^{*}

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Abstract. Natural language (NL) access to databases is a problem that has interested researchers for many years. We demonstrate that an ontology-based approach is technically feasible to handle some of the challenges facing NL query processing for database access. This paper presents the architecture, algorithms and results from the prototype thereof which indicate a domain and language independent architecture with high precision and recall rates. Studies are conducted for each of English and Swahili queries, both for same language and cross-lingual retrieval, from which we demonstrate promising precision and recall rates, language and domain independence, and that for language pairs it is sufficient to incorporate a machine translation system at the gazetteer level.

Keywords: Natural Language Interfaces, Databases, Ontologies.

1 Introduction

The problem of using natural language (NL) for database access is still a challenging problem. One specific challenge includes the lack of a suitable language- and domain-independent methodology for understanding unconstrained NL text in the context of a Swahili-English cross-lingual database. The cross-lingual aspect arises from the observation that most systems that support Swahili queries predominantly rely on concatenation of words or abbreviations in English as databases' metadata. Furthermore, the problem of parsing database schema into suitable ontology concepts that can readily map onto parsed NL text remains largely unstudied.

Attempts at machine learning methods have been reported in several reports including [8] and [19]. The main handicap has been the need for training data for each set of database and NL queries and low performance in triple extraction. Other previous studies have tended to concentrate on logic based mapping of syntactically parsed NL to database contents but this has had the challenge of language dependence and brittleness due to reliance on rules and low database portability.

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This paper presents a novel methodology that facilitates natural language understanding of user queries and that helps build structured queries that can be used to access highly structured information sources such as relational databases. We present a language and domain independent approach for understanding unconstrained NL text, show the design of our model and algorithms thereof that facilitate access of data from databases using Swahili and English as case-study languages. We also present results that were obtained from a prototype (developed as part of the wider project) upon which performance evaluations were done.

2 Related Work

Analysis of the related literature reveals the use of three general approaches: semantic parsing, logic mapping and ontology concept mapping.

In applications whose sources are characterized by low levels of structure such as web-based text sources the preferred approach is semantic parsing. Methods applied range from highly annotated machine learning techniques [11] to purely unsupervised techniques [6]. Though these efforts have not directly solved the access to relational database problem and only address question answering in text-based sources, some researchers notably Giordani and Moschitti [8] have taken this approach further by developing a parallel corpus of syntactic trees of NL queries and SQL queries for databases, specifically the Mooney GeoQuery set. The main drawback to this approach is the need for training data for every set of database and NL queries pairs. This approach has therefore not been successful in solving database related problems.

NL access to relational databases has most successfully been tackled through logic mapping [16]. Logic mapping involves morphological and syntactic processing followed by mapping between the query syntactic forms and SQL forms. Usually semantic interpretation is achieved through semantic annotation of the identified phrases. Some successful applications such as Tiscover [5] have been implemented through mapping of phrases. Tagging of phrases in a query with relevant predefined classes is necessary so that each phrase can be labeled and therefore semantically interpreted. Automatic tagging however inevitably introduces errors similar to those in semantic labeling such as poor classification while manual tagging is costly.

Due to these issues among others a different school of thought, encouraged by advances in the semantic web research, has emerged in search of improved models. A recent approach has been reported by the Nokia Research Centre Cambridge [15] where they solved the problem of accessing information stored in RDF repositories targeted to mobile phones users. These works along with other ground breaking works in the semantic web research such as AquaLog [18], Querix [7], NLP Reduce [9], QuestIO [17] and FREyA [4] though not directly solving the problem of relational databases have greatly inspired the approach in this work.

3 The Ontology-Based Database Access Approach

Our approach, which we call Ontology Concept Mapping (OCM), is intuitively derived from the way human beings reason. Bond [2] has outlined a seven stage reasoning process. Levett-Jones [10] also outlines an eight step reasoning cycle resembling Bond's, except that he splits the observation phase into two. The two approaches are harmonized and shown in Fig. 1(a) below.

From this reasoning process one can reconstruct the human reasoning process specific to question answering by developing four layers of abstraction that map onto the seven steps in reasoning. Human beings first attempt to comprehend what the questioner is requesting. At times the information given is scanty or the questioner assumes we can derive more details from general knowledge. It is at this stage that humans attempt to derive reasonable additional knowledge in order to formulate the question fully and subsequently attempt to answer.

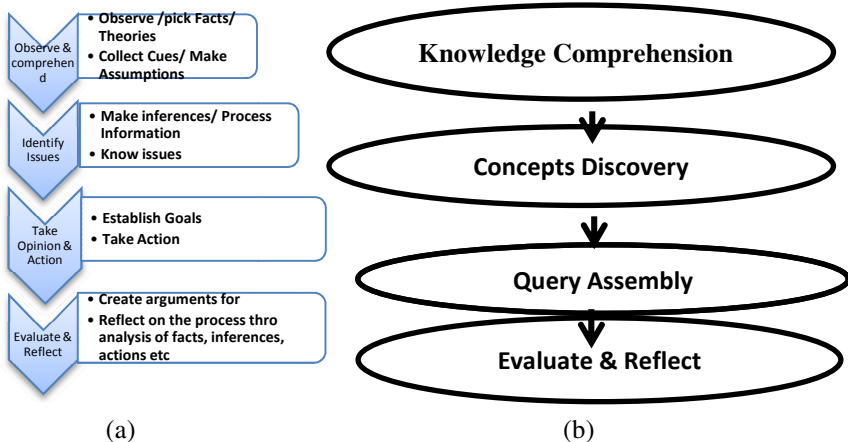


Fig. 1. (a) Reasoning Process (Re-created from Bond (2011) and Levett-Jones (2009) and (b) Layers of Reasoning in OCM Approach

Subsequently we designed a four-layer abstraction model with layers for knowledge comprehension, knowledge discovery, query assembly, and evaluation and reflection as illustrated in the Fig. 1(b).

4 The Architecture

Through the use of feature space and gazetteer models, concepts from the NL query and database ontology are respectively represented and mapped via a matching function. A matching function is then applied to map equivalencies as illustrated in Fig. 2. A simple and effective method of knowledge comprehension and concepts discovery is thus achieved. The triples are then pruned by eliminating triples not based on the composed semantic ontology of the database as these are less likely to yield results and

ultimately assembled as SPARQL queries that can be used to obtain information from Resource Description Framework (RDF) sources such as the semantic ontology for an RDBMS. The last step in Fig. 1(b) which is evaluating and reflecting on the answers provided is meant for self-assessment and automatic adjustment. This step was manually implemented as the algorithm's parameter adjustment and was not automated.

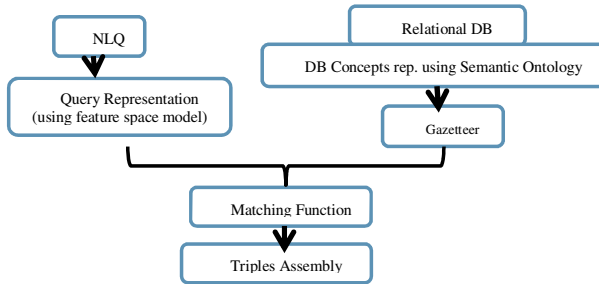


Fig. 2. Concepts Discovery

In the resulting architecture illustrated in Fig. 3 the system accepts user input in the form of full natural language sentences or key phrases or words. Raw text is subjected to linguistic processing that involves tokenizing, stemming, POS tagging and phrase formation based on Swahili collocation formation patterns established in [20]. On the other hand ontology elements relating to class and property names are normalized and stemmed. Instance names are stripped to the root as opposed to class and property which is stripped to the stem. The architecture works with the algorithm provided below.

The Algorithm

1. Assemble tokens list (words and phrases)
2. Comprehend ontology-strange terms that may be synonyms, hypernyms, hyponyms or even known jargon
3. Assemble List of Concepts (Tokens which match ontology elements)
 - Explicit concepts
 - Implicit concepts
 - Concepts include matches to object and datatype properties, classes, instances, rdfs:labels, rdfs:comments and special categories (superlatives and enumeratives).
4. Assemble Triples by
 - Determining Number of participating relations along with Primary and Foreign keys
 - Identify User required properties and constraining instances and their related properties (Filters)
5. Assemble SPARQL Query
 - Depending on discovered number of relations expand each query by heaping more and more triples until exhausted from user input.

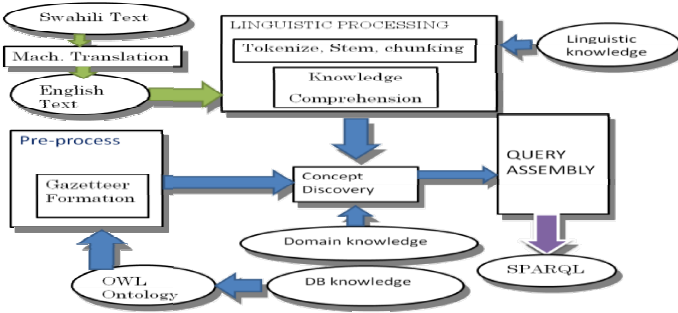


Fig. 3. Architecture for Ontology-based NL Access to DBs (ONLAD)

4.1 Cross-Lingual Issues

One prime motivation behind this research was the quest for using Swahili to access data from databases. Swahili has over 150 million regular speakers in Eastern Africa. Unfortunately, nearly all databases are developed in a nation's official language which is predominantly English or French. This could be attributed to the fact that these official languages also double as the primary training languages and therefore database developers tend to favor their usage in database schema development. On the other hand, casual users tend to prefer using local languages or Swahili, the business languages among the communities. Thus a reasonable solution should have a cross-lingual nature to cater for these differing language usages.

We considered translation at two possible stages: at input (where the model subsequently uses English linguistic processing tools) and at the gazetteer level (where the model subsequently uses Swahili linguistic processing tools). It was noted that elements in a gazetteer are finite for a specific database and can be quickly translated accurately without too much overhead thus ensuring quality. So our system used translation at the gazetteer stage as opposed to NL input stage.

4.2 Parsing of DB Schema and NL Processing

In order to demonstrate how each of these layers work, let us consider the 'Northwind database' which contains information about a company's inventory of its customers, suppliers and products sold. Furthermore, the customers can make orders which can be shipped by shippers whose information is also kept in the database. All information regarding employees is also maintained.

The section below shows how the knowledge comprehension, concepts discovery and query assembly processes occur. It has been shown that casual users prefer the use of short inputs. In some cases grammatical correctness of inputs is not a major priority [12]. Input to the model should therefore essentially be keywords but with capacity for accommodating users who prefer longer questions. At this stage of knowledge comprehension, the system can treat the user words as a bag-of-words and then naively match these words against database ontology similar to [9]. However on a closer look at how database authors represent relation-names and attribute names

(equivalent to ontology class and property names respectively), we need an additional step to provide chunking on the input side and normalization on the ontology side. The preferred chunking is collocation.

4.3 Illustrative Examples

Given an input sentence in Swahili *Nipe majina, tarehe ya kuzaliwa na anwani za wafanyi kazi wote*, (which means ‘Give me the names, dates of birth and addresses of all employees’), we first translate the sentence using an external system (in our case the Swahili-English Google translator tool) to obtain an English equivalent.

A gazetteer, whose full architecture is described in [20] is constructed by identifying all legitimate class, property and instance names and arranges them as triples or class-property pairs. This can be done dynamically at run-time or in a preprocessing stage. Using preprocessing allows more effective translation at the gazetteer level. On the other hand NLQ is assembled in a feature space model whose architecture is described in [20]. The feature space model is a data structure which we implemented as an array and contains basic information of each word in a query such as the stem, hyponym, part of speech tag and other annotations. Conversion of relational databases into ontology was achieved through ‘datamaster’.

The phrase *tarehe ya kuzaliwa* (translated to ‘date of birth’) mentioned above maps onto ontology element {En: dateOfBirth}. The normalized ontology element dateOfBirth yields three separate names; date, of and birth. It is therefore paramount that linguistic processing involves collocation chunking. These can now be matched against the user input. In order to enhance knowledge comprehension and thus usability capacity we used a stemmer. We used the Lancaster stemmer [13] as implemented in the Natural language toolkit [1] for English and a regular expression stemmer for Swahili. In the example above if the user used the word ‘employed’ instead of ‘employees’ which appears as an ontology concept, the system can intelligently conclude that we are referring to employees class — we have illustrated concept discovery. While this example involves the discovery of what we call “explicit” concepts in that they have direct mentions of properties or classes, in other scenarios there is no direct mention. Our approach provides for this implicit concept-discovery by performing simple inference.

Consider the question *Bidhaa gani ambazo huja kwa chupa (Which products come in bottles)?* In this case the following processes occur according to our algorithm. *Bottles* is stripped to *bottle* which in turn maps to instance *bottled* which is found within the ontology as an instance. Since *Bottled* has been tagged in Gazetteer as an instance of categories class through datatype property *Description*, we discover two additional ontology concepts that is,

Categories class and
Description property
and the following triple is created, where FILTER is necessary for instantiating a class’s property value

```
?categories db: categories.description ?description
FILTER(?description = “bottled”)
```

Further the query also has interrogative of type “which” that suggests an identification problem. By default we return instances of classes with properties related to identification of the class; that is name, identification or both if present in that particular class. We ultimately derive the following set of triples:

```
{ ?products db: products.ProductID ?ProductID.
  ?products db: products.ProductName?ProductName.
  ?products db: products.CategoryID ?CategoryID.
  ?categories db: categories.CategoryId ?CategoryID.
  ?categories db: categories.Description ?Description.
  FILTER( ?Description = "bottled") }
```

Note that in database ontologies it is preferable to use both class and property names so as to minimize ambiguity in case multiple classes are using similar property names as in the example customer’s phone and supplier’s phone.

5 Experiments and Results

To evaluate a NL relational database access model we create a framework that takes into consideration precision, recall, support for multiple ontologies, portability and support for multiple languages and/or cross-lingual databases. In addition accuracy, F-score and ‘effect of complexity of the question to precision and recall’ were added to the evaluation criteria. The issue of complexity was handled in line with [5] and [17] where the complexity of a question is assumed to increase with the number of concepts present in a query.

Three sets of experiments were done. We applied the model across three databases namely farmers-db [12], Microsoft northwind-db and University of Nairobi students records database [20]. Each database was subjected to a set of randomly collected questions as described in each sources and the parameters as described above calculated. The farmers’ database was queried with 625 randomly generated questions as described in [12]. For the Microsoft database we used a sample set of 120 questions, of which 100 were generated in [3] to evaluate the Elf system and 20 were generated in [12]. The third experiment for querying University of Nairobi students’ records database had 310 unique questions generated in [20]. The databases which were originally authored in MySQL were converted into equivalent OWL ontologies through data-master plugin on protégé tool. The reasoner within the protégé tool was used to generate the answers from the ontologies. The generated answers were then manually evaluated to determine correctness and determine precision, recall and accuracy.

A full description of all results is beyond the scope of this paper. A summary is shown in Table 1 below. The results indicate a model whose average precision at a Levenshtein distance μ , of 1 (within the matching function) is 0.8393 and increases to 0.9480 on decrease of μ to 0. Precision therefore increases with a decrease of μ while recall decreases. Accuracy on the other hand increases slightly. A suitable parameter for gauging overall suitability would be the F-score, the harmonic mean of precision and recall, which increases from 0.7383 to 0.7525 on tightening μ . This means any NLQ system relying on string matching for extracting explicit and implicit concepts from a database should not permit too much laxity in the matching process.

A high precision is important because it indicates the quality of the parsed queries while recall indicates the extent to which our model generates some SPaRQL queries whether right or wrong. [14] notes that all models decline to answer some questions hence the need for recall. Accuracy on the other hand indicates the extent to which a user expects the correct answer from a given set of questions.

Table 1. Summary of Results

	Levenshtein gap (match function)	Exp. 1	Exp. 2	Exp. 3	Average
Precision (%)	$\mu = 1$	0.839	0.732	0.860	0.810
	$\mu = 0$	0.948	0.936	0.945	0.943
Recall (%)	$\mu = 1$	0.766	0.683	0.600	0.683
	$\mu = 0$	0.646	0.650	0.584	0.627
Accuracy (%)	$\mu = 1$	0.643	0.500	0.516	0.553
	$\mu = 0$	0.613	0.608	0.552	0.591
F-Score	$\mu = 1$	0.801	0.766	0.707	0.738
	$\mu = 0$	0.769	0.707	0.722	0.753

Experimental results also indicate that translation is better done at the gazetteer level as opposed to the NLQ input level.

Minock *et al.* (2008) [21] has provided an elaborate review of performance of the most competitive models in logic-based mapping and semantic parsing approaches based on grammar mapping or statistical mapping, however a brief summary is provided in Table 2 below.

Table 2. Comparison of Results

Model	Precision (%)	Recall (%)	Accuracy (%)	F-score	Main Principle
PRECISE	0.80-0.100	0.550-.775	0.45-0. 775	0.65 - 0.87	Graph Matching [14]
WASP	0.800-0.915	0.600-0.940	0.500-0.866	0.690-0.930	Semantic parsing using Statistical Machine Translation (SCFG-based) [22]
Minock <i>et al.</i> Model	0.600-0.850	0.500-0.800	App. 0.800	0.550-0.820	Synchronous Context-free with lambda calculus expressions (λ -SCFG) [21]
ONLAD ($\mu = 1-0$)	0.810-0.943	0.683-0.627	0.553-0.591	0.738-0.753	OCM Approach [this paper]

The model developed here can support cross-lingual databases. It has high portability and is not affected by distribution drift' because it does not require prior training unlike semantic parsing systems which rely on machine learning. The model is not

affected by long ungrammatical questions nor complex questions with multiple concepts because it rarely relies on syntactic parsing information except for collocation formation. The model however suffers from lower maximum recall and accuracy levels as evident from results because it requires someone to enter information that sometimes is regarded as obvious or superfluous. For example the query ‘give me customers who come from Nairobi’ might require you to add the word ‘name’ within the query so that the system realizes we require ‘customers’ names’. The model can also be easily interchangeable between languages because only the collocation rules need to be imported and the appropriate gazetteer translator installed.

6 Conclusion

This paper has presented a language and domain-independent ‘ontology concepts mapping’ model that converts NLQ into structured queries that can be used to access relational databases. The model is especially suitable for resource-scarce languages with minimal linguistic processing activities. The model capitalizes on the easy conversion of NLQ to concepts which are processed as collocation chunks, and conversion of database schema and data as ontology concepts which are then mapped and assembled as SPARQL queries. We have demonstrated how to overcome cross-lingual issues in database querying. We have successfully applied the model across three databases namely farmers [12], Microsoft northwind and UoN MSc Coordinator [20] where the average precision is 0.87.

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Multimodal Kinect-Supported Interaction for Visually Impaired Users

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Abstract. This paper discusses Kreader, a proof-of-concept for a new interface for blind or visually impaired users to have text read to them. We use the Kinect device to track the users body. All feedback is presented with auditory cues, while a minimal visual interface can be turned on optionally. Interface elements are organized in a list manner and placed ego-centric, in relation to the user's body. Moving around in the room does not change the element's location. Hence visually impaired users can utilize their "body-sense" to find elements. Two test sessions were used to evaluate Kreader. We think the results are encouraging and provide a solid foundation for future research into such an interface, that can be navigated by sighted and visually impaired users.

1 Introduction

Almost all modern professions require the use of the PC. Traditionally it is controlled with the mouse or the keyboard and features a WIMP interface. However, this type of computer interface is sometimes seen as unintuitive. Often considered to be more intuitive is the touchScreen. The next interaction evolution could be the touch-less interface. These interfaces are often accomplished by tracking a user through a special camera. Actions are triggered by placing the hands in specific spots or performing special gestures. We categorize this as a NUI. The interaction techniques are very "similar to those used for the same task in the physical world" [15]. Similar to the physical world we can effectively simulate a virtual shelf where selectable items are positioned in 3D space. Selecting an item in the back would require the user to move his arm towards the screen. Another example for such a SOE is gSpeak. With the Kinect the first generation SOE for the consumer has now reached the market. Up till January 2012 18 million units of the Kinect have been sold and future developments are on the horizon. However, a spread of SOE could lead to interaction problems for people with visual impairments. The missing haptics and navigation in 3D space without any anchor points at could pose significant problems.

The WHO stated in October 2011, that there are 285 million visually impaired people worldwide; 39 million are blind, while the remaining 246 million are categorized as having *low vision*. The report further states that 90% of visually impaired people live in developing countries. In 1990 Boyd et al. [2] cautioned that the WIMP interfaces presented serious interaction challenges for visually impaired user. Visually impaired users are forced to rely on auditory navigation. Any element in the user interface is

represented using auditory cues which the user has to interpret, while simultaneously having to remember where in the interface he currently is. Knowing this current state of interaction is dependent on the short-term memory of the user. Distractions, loud noises or listening to long passages of text, can make users forget where they currently are. It would be beneficial if the user could utilize other senses beside his hearing. For example his proprioceptive sense. Proprioception is the sense of the position, the movement and the balance of the own body. For example, even if a person is blindfolded, he can estimate if his arm is above the head or below and even guess the distance.

In this paper we present Kreader, a prototype that utilizes a SOE specifically designed for blind or visually impaired users. By using this type of SOE, users can use their proprioceptive sense to determine the interaction state. Their body further serves as a frame of reference for interface elements. Our test results are encouraging and indicate the promising future for such an interface.

2 Related Work

The related work can roughly be divided into work that covers the abilities of visually impaired users, work that investigates touch-less interfaces and work that covers the abilities of the Kinect. There is a small intersection where the Kinect is used to help visually impaired users navigate in the real world. Beyond this there does not seem to be any work that investigates a Kinect or touch-less interface for blind or visually impaired users.

The researchers Turunen et al. [20] have developed a MMC **for visually impaired people**. With their software one can watch or record TV, listen to music and view pictures. The software features multimodal means of interaction: speech recognition, speech synthesis, gesture recognition (positioning a mobile phone in key locations), haptic (vibration of said mobile phone) and auditory feedback. One study with visually impaired users lasts between four and ten days, depending on the schedule of the test participant. The test results turn out positive. All test participants find the system easy to learn and would recommend it. The **voice output** is seen as the most important feature. The testers remark that it is confusing to have the same voice for two different functions (subtitles and system output). They would have liked to change the gender, intonation and personalty of the speaking voice.

Pitt et al. [17] investigate which auditory aid helps visually impaired people find objects the fastest. The participants are asked to find a randomly selected object as fast as possible. Results indicate that the 1D is significantly faster than the 2D search, by about a factor of ten.

Ionescu et al. [8] have created a gesture interface for the living room environment that can be used to control any television or set-top that receives infrared signals. The gestures are recognized with the help of a custom 3D depth system, similar to the Kinect, that can detect each finger. Gadea et al. [3] present a collaborative online workspace called uc1c. Users can select icons and windows by pointing at them as well as drag

them to new positions. Application windows and their content can be shared with other users through gestures. Test participants expressed a feeling of empowerment and productivity that they felt while collaboratively using applications and gestures.

Harrison et al. [5] have developed a system that uses the body itself as an input and output medium. A ceiling-mounted depth camera captures the body of a user from above and calculates the joint position. A ceiling-mounted projector is used to project the interface from above onto the body of a user. Harrison et al. [6] present another on-body system called Skinput that can detect where the user tapped his own skin through a worn armband. Accuracy varies depending on the size, how wide-spread the targets are, if the targets are clustered into groups, on the gender of the participant, or where the sensor is placed on the arm. The accuracy is roughly between 85% and 95%.

Kamel Boulos et al. [10] have developed Kinoogle, a kinect-based interface for Google Earth. In addition to being able to track skeleton joints, Kinoogle can also distinguish between an open and a closed hand (a feature the Kinect does not have by default). Gerling et al. [4] explore full-body motion-based game interaction for older adults. Interestingly the designed game was not perceived as too exhausting. Performing gestures is considered to be easy and relatively fun. Participants enjoyed that the gestures allowed them to be active.

Livingston et al. [12] evaluate the noise, accuracy, resolution and latency of the Kinect skeleton tracking software while others focus on the investigate the depth sensing [1] and error source in the Kinect depth data [11,9]. Errors can come from the sensor, the measurement setup (strong light conditions, direct sunlight) or the properties of the object surface (smooth or shiny or geometry that is not fully perceived by the sensor). Even a properly calibrated **sensor** can create errors of random nature for "inaccurate measurement of disparities within the correlation algorithm and round-off errors during normalization". One of the things to consider when working with the Kinect is the *noise*. Noise causes joints to rapidly change their positions in arbitrary ways, even though the user is standing perfectly still. The joints jitter. At a distance of 1.2m to the Kinect the 3D jitter averages 1.3mm. At 3.5m the 3D jitter averages 6.9mm. Such high noise for the wrist could produce problems when trying to accurately select an element with a hand. In the best case the *latency* is 106 ms. In bad cases the latency goes above a mean of 200 ms. The latency depends largely on the amount of pixels that need processing. I.e. how close the user is to the sensor and how many users there are. The results show a quadratic relationship between the amount of pixels in need of processing and the latency.

Kinect research for blind or visually impaired users is either focused on using the Kinect to sense depth in the real world or make Kinect games barrier-free. The Kinect can provide depth information for every pixel that its camera perceives. It has been utilized to facilitate outdoor navigation for blind or visually impaired users [14,7] even in low-light scenarios. The depth data of the Kinect is used to find obstacles which are then communicated either with the six vibration motors in the helmet [14] or with auditory cues [7].

Another work aims to translate visual feedback so that a Kinect hurdle jumping game can be played by visually impaired users [16]. The distance to the next hurdle is communicated to the visually impaired user with periodic haptic feedback instead.

3 Prototype Design

Kreader provides an simple interface for text reading. Wikipedia text is retrieved from the web and synthesized so that visually impaired users can have text read to them. All feedback is provided by auditory means. A minimal, redundant visual interface (figure 1) can be turned on or off. Users can pause/resume reading as well as jump between chapters, sentences and words. Furthermore there are different commands to retrieve text position interpretations.

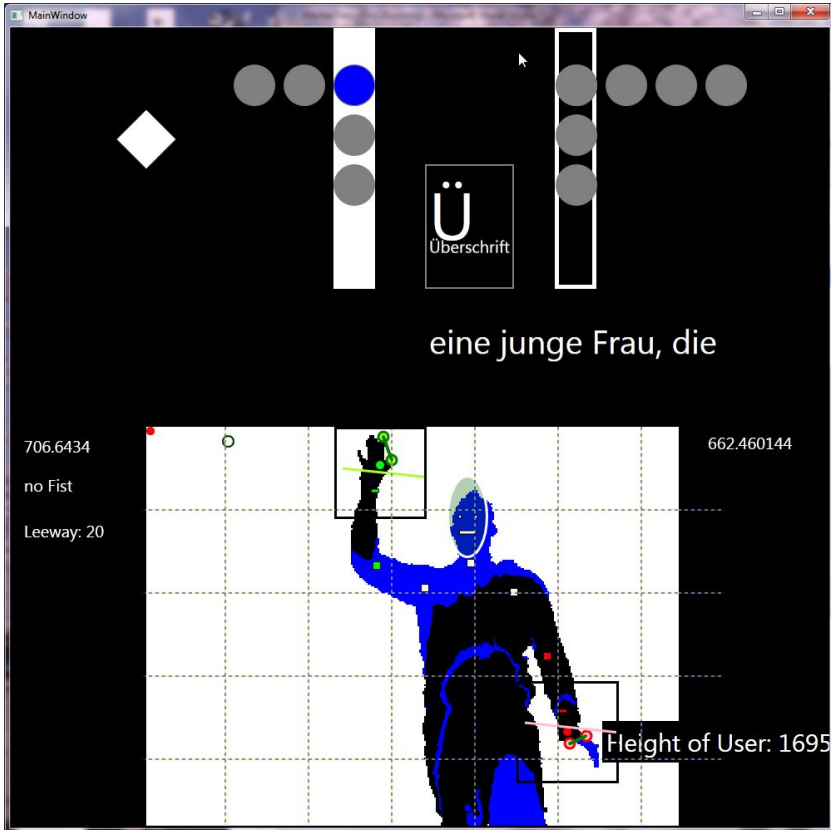


Fig. 1. Kreader Interface

The first and most intuitive gesture is text pausing. Text is only read when the user is facing the Kinect camera. By turning the body, as if to speak to someone off camera, the user can pause the text. All other commands can be reached through a 1.5D menu. The menu is triggered if one or both hands are raised. First users select the category they wish to change by moving their hands vertically in 1D. Afterwards they select the element in that category in 1D. The left hand controls jumping to previous chapters,

sentences or words, while the right hand provides access to the following chapters etc. By pushing the selecting hand towards the Kinect an element is selected. The category and elements are represented by small orbs. All jumps are relative to the current position in the text. For example, let us say that the user is currently listening to the third sentence in the second chapter. To jump to the first sentence in the fourth chapter, the user has to do the following: raise the right hand until the chapter category is reached, move the right hand two orbs to the right and then push towards the Kinect. As soon as the arms are lowered the text reading will continue at the new position. The interface elements, orbs, are positioned in relation to the body of the user. That means their position does not change if the user moves around the room and raising an arm to a position close to the shoulder will always trigger the same orb. We call this ego-centric encoding.

Feedback to which orb is selected is given first through earcon and then through synthesized text. Earcons are brief, distinctive and synthesized sounds that convey information. They also require the least amount of space in short-term memory and distract the least from other cognitive processes [18]. In the case of Kreader we use distinct earcon to notify the user when he reaches a new vertical orb, a new horizontal orb, when he has selected an orb or when he has reached beyond the area of the menu. When the user hovers over an orb for a short while the name of that orb is spoken. That is either the name of that category or the element in that category. For example hovering over the second orb in the sentences category speaks that sentence. Our prototype features two distinct voices, one for the menu and one just for the text reading. Kreader also provides simple voice commands to change the colors of the interface or to retrieve the relative position in the text.

Our prototype is built using the Microsoft Kinect Hardware , Microsoft Kinect for Windows sdk, Microsoft speech sdk, the programming language C# and the ide Microsoft Visual Studio.

4 Test Setup

We conducted two test sessions, the first with ten sighted (referred to as I), the second session with four visually impaired participants (II). Participants of the first test session were divided into two groups, one with the visual interface only turned on for a short familiarization period (Ia) and one with it turned off for the whole test (Ib). The actual test is always performed with the interface turned off. Out of the four visually impaired testers, two participants were blind. The interface for the visually impaired testers was always turned on.

Each session lasted 40 to 60 minutes and was divided into five segments. First the participants were asked to fill out a short background questionnaire, afterwards the first part of a SUXES survey was performed. Then participants were asked to try Kreader for 15 minutes. Thereafter the test partakers were asked to fill out the second part of the SUXES survey and finally the feedback questionnaire. Test results are further complemented by observations during testing.

The Kinect camera is placed on a table, directly below a 17 inch screen that displays the interface. The tester stands two meters away from the screen, facing the Kinect.

The SUXES evaluation method [19] is designed to capture the user experience. Test subjects are asked questions before and ancillary questions after a test period. The questions before the test period ask subjects to give grades between 1 and 7 (highest opinion/expectation) of acceptable and expected experience for different questions. The questions after the test period ask for a grade for their actual experience.

5 Test Results

Figure 2 presents us with a reasonable overview of the Kreader test results by combining the results from both test sessions into one image. The results for the four visually impaired users looks approximately the same. The prototype always performs above the minimum requirements but also reaches heights that are above the requirements. We can see that the best feature are the earcon. A close second is the speech output. The bad score of speech input is due to the low recognition rates and the limited use in the prototype. Test participants often had to repeat the same command up to four times until it was recognized. Even if one command was recognized perfectly, the next one was almost never. This bad score was already anticipated during development and speech control was for that reason mostly limited to commands that provide feedback about the state of Kreader. Only the commands that alter the color can change the state of the prototype. It is worth noting that our participants still would have liked more speech commands.

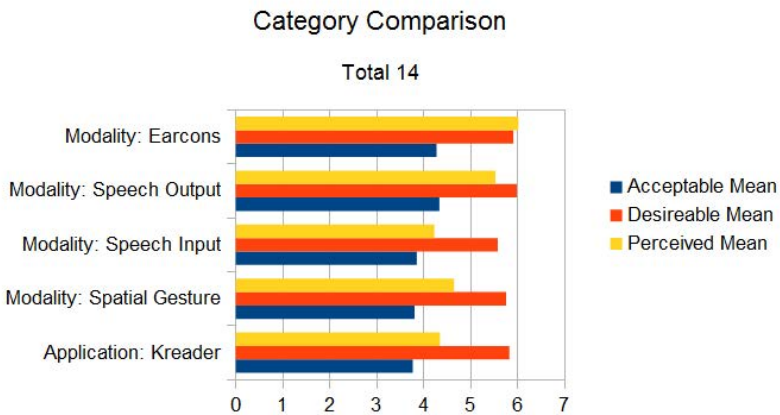


Fig. 2. SUXES(I,II): Results for both tests

Figure 3 gives us better insight how blind or visually impaired users experienced the spatial gestures. Based on these results we can postulate that the gestures are natural, easy to learn, very fast and reasonably pleasant. The first three statements are true as well for the ten sighted participants. These are great results, in line with our expectations and show the promise of such an ego-centric SOE.

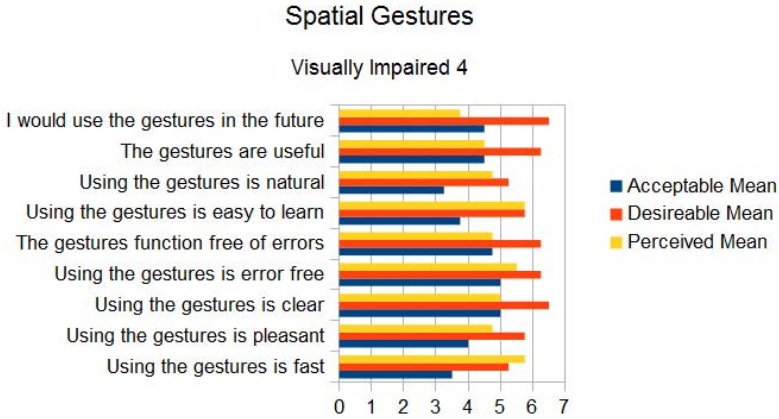


Fig. 3. Feedback(II): Questions B

If we compare the experiences of the two sighted groups (figure 4), we can see that having seen the interface (Ia) significantly improves the experience for usefulness, naturalness, ease-of-learning and clearness. We surmise that having seen the interface for a short period creates a mental model that lasts through the entire test. This model is harder to construct without a visual reference. Group Ia quickly reached a familiarization level with the interface that was first reached by Ib and II at the end of the test period. Hence we think that a longer test period will improve almost every experience short of "function free or errors" and "gestures are free of errors". The first statement measures the perceived robustness. The problem in these two areas stem from joint jitter. The perceived position of a tester's hand is seldom accurate and moves around quite a bit. Even if the hand of a user hovers perfectly still over a menu orb, Kreader can think that the orb next to it is selected. There is a trade off here between errors and speed. Kreader utilizes lazy selection. The current orb grows in size and overlaps with surrounding orbs, which requires the user to move his hands farther to select the next orb. By making the orbs even larger the error-rate can be decreased at the cost of interface speed.

We can also see that our test participants are not that interested in using the gestures in the future. This metric is closely tied to the feature set that Kreader provides. Our sighted participants are not interested in using gestures to have text read to them. Our visually impaired users feel similar. They do not see the benefit in learning a new interface just to have text read to them. This function is already provided by their screenReader. Figure 5 provides further insight. We can see that the attitude towards Kreader is positive. Moderate improvements are required but the test participants would use Kreader again to have text read to them from afar. In fact all participants were very interested in using the Kreader interface to control video or audio playback without requiring a remote to do so. Especially of note is that it was always very clear for the participants how to get back to a know application state, if they got lost. Participants in general (I and II) would have liked more control over the spoken text and found the interface somewhat

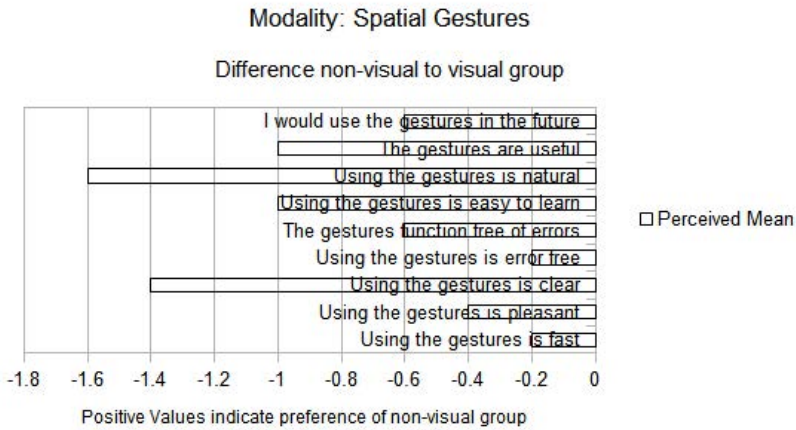


Fig. 4. Feedback(II): Questions B

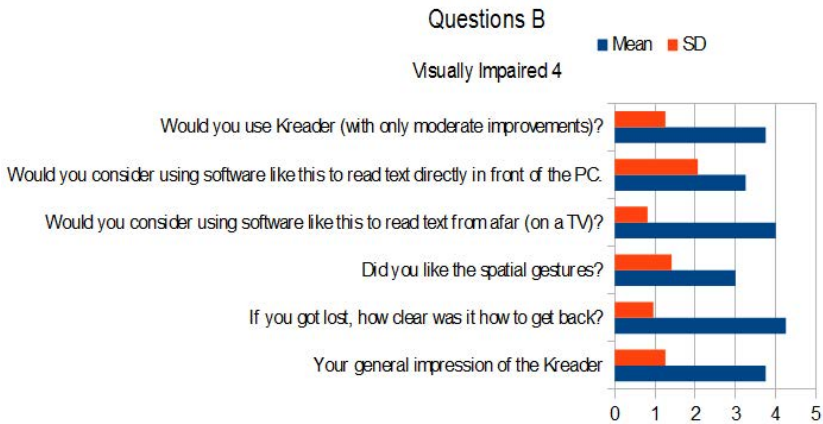


Fig. 5. Feedback(II): Questions B

confusing. Standing during the test was not an issue but the arms grew noticeably tired during the test.

Two blind testers also gave feedback for the visual part of Kreader. They state that they can only perceive the background color of the interface. They can only navigate the interface using auditory cues. Because they can locate the screen, thus know the location of the Kinect camera, it is not a problem for the test participants to use the push-to-select gesture. Any text that the interface displays is too small for them to see. Every letter would need to be much bigger than the 17 inch screen to be visible and readable for them. The other two testers, with a less severe visual impairment, can see the vertical markers, that indicate which orb is active. They can also notice when that marker changes its position.

6 Conclusion

We have created an interface for reading text that both sighted and visually impaired people can use. Moving around the arms gives the interface a kinetic aspect and makes it fun to use. The spatial gestures, while not perfect, are fast, easy to learn and natural. We think the test results prove the benefit of a SOE while also signaling that the proposed interface cannot replace the common interaction methods [13]. Instead Kreader, as it is currently implemented, is an additional and supplementary text reading utility. We imagine that the Kreader interface could be used to control video or music playback on a TV and receive even greater feedback. We think these results are encouraging and provide a solid foundation for future research into such an interface, that can be navigated by sighted and visually impaired users.

7 Outlook

Spatial gestures is an interface concept that our testers are interested in. The text-reading nature of our prototype - Kreader, however, seems to hinder their interest in using our prototype again. Future research should thus look into SOE featuring multimedia content, like videos or music. Studies have shown that visually impaired and blind people are interested in social and multimedia areas, but most often are not provided with an interface they can navigate to a satisfying degree. Also of interest is a long-term study focusing on the physical aspect of spatial gestures. In our study, test participants were limited to 15 minutes of SOE experience. Even after this short time they sometimes reported their arms being noticeably tired. Our gestures are designed so that most interaction happens close to the body, where arm movements are less tiring than, for example, stretching out the arm and pointing on different items on the screen. It would be interesting to see if Kreader can be used for significantly longer continuous durations than 15 minutes and if the body can adapt to this new interaction method. Finally we would like to explore an interface that merges Kreader with an on-body technology like Skinput [6].

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Evaluating Facial Expressions in American Sign Language Animations for Accessible Online Information

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Abstract. Facial expressions and head movements communicate essential information during ASL sentences. We aim to improve the facial expressions in ASL animations and make them more understandable, ultimately leading to better accessibility of online information for deaf people with low English literacy. This paper presents how we engineer stimuli and questions to measure whether the viewer has seen and understood the linguistic facial expressions correctly. In two studies, we investigate how changing several parameters (the variety of facial expressions, the language in which the stimuli were invented, and the degree of involvement of a native ASL signer in the stimuli design) affects the results of a user evaluation study of facial expressions in ASL animation.

Keywords: American Sign Language, accessibility technology for people who are deaf, animation, natural language generation, evaluation, user study, stimuli.

1 Accessible Online Information and Documents in ASL

Many people who are deaf in the United States have lower levels of written language literacy [10]; this makes it difficult for them to read English text on TV captioning, websites, or online documents [7][17]. Animations of American Sign Language (ASL) can make online information and services accessible for these individuals. This paper focuses on our research on ASL; however, many of the techniques and methods could be applied to other sign languages. While it is possible to post videos of real human signers on websites, animated avatars are advantageous if the information is frequently updated; it may be prohibitively expensive to continually re-film a human performing ASL for the new information. Assembling video clips of individual signs together into sentences does not produce high-quality results.

One way to produce animations of ASL would be for a skilled animator (fluent in ASL) to create a virtual human that moves in the correct manner using general-purpose 3D animation software. Since this is too time-consuming and depends too much on the skill of the 3D animator, researchers study automated techniques. The most automated approach is to develop “generation” software, to automatically plan the words of a sign language sentence based on some information input. For instance, in an automatic translation system, the input could be an English text, which must be translated into ASL. While some researchers have investigated ASL generation and translation technologies, the state-of-the-art is still rather limited due to the linguistic challenges inherent in planning sign language sentences [10]. A less automated approach for producing ASL animation is to develop “scripting” software, and allow a human to efficiently “word process” a set of ASL sentences, placing individual signs from a dictionary onto a timeline to be performed by an animated character. Such tools (e.g., [19]) make use of pre-built dictionaries of sign animations, and they incorporate software for automating selection of the transition movements between signs, and other detailed (and time-consuming to specify) aspects of the animation.

The ability to efficiently write and revise ASL is a novel development. Currently, there is no standard written form for ASL that has been accepted by the deaf community. While transcription systems have been proposed, e.g., [14], they typically lack details necessary for capturing grammatically correct ASL animation, and those limitations made them not widely used by signers. As scripting technologies improve, this opens the possibility for future “word processing” and “document creation” in ASL: enabling easier creating and sharing of information in accessible manner.

The linguistic complexity of ASL makes developing animation technologies challenging, e.g., various facial expressions and head movements communicate essential information during sentences. State-of-the-art ASL animation systems do not yet handle facial expressions sufficiently to produce clear output, and our lab is studying how to improve this. An important aspect of our work is user-based evaluation, needed to measure the quality of our models. However, designing an experiment in which native ASL signers evaluate facial expressions is not straightforward; careful design is required. In this paper, we design and evaluate experimental stimuli for use in evaluations of facial expressions in ASL animation. Section 2 explains the importance of facial expressions in ASL, section 3 describes related work, section 4 describes our experiments to investigate how changing the parameters in a stimuli design could affect the results of a user study, and section 5 contains conclusions and future work.

2 Importance of Facial Expressions in ASL Animations

Facial expression conveys grammatical information (questions, negations, etc.) in most sign languages. Eyebrow movements, mouth shape, head tilt/turn, and other facial movements are linguistically required in ASL, and identical hand movements (signs) can have different meanings, depending on the facial expressions performed during the sentence [12]. In a simple case, emotional facial expressions (frustration, sadness, anger) affect the meaning of a sentence. Other facial expressions indicate specific grammatical information about sentences and phrases, e.g.: (1) convert

declarative sentences into Yes-No questions, (2) indicate that a sentence is a WH-word interrogative question (“who, what, where”), (3) invert the logical meaning of a sentence by conveying negation (via head shaking), (4) indicate that some words at the beginning of a sentence are an important “topic” for the upcoming sentence, etc. In this way, a sequence of signs like “BOB LIKE JOHN” could be changed into a Yes-No question (“Does Bob like John?”) or invert its meaning (“Bob doesn’t like John”) by adding a facial expression during an appropriate portion of the sentence. (The timing of the facial expression relative to the signs in the sentence is important).

In a prior study, we experimentally evaluated ASL animations with and without various types of facial expressions, and we found that the inclusion of facial expression led to measurable benefits for the understandability and perceived quality of the animations [11]. However, most prior sign language animation research has not addressed how to synthesize facial expressions [3-5]. To produce an animation with good facial expressions, an animation artist could carefully edit the facial mesh of an animated character to produce beautiful facial expressions, but this is very time-consuming. We want to support automatic synthesis of sign language and scripting of sign language animations. We are studying how to model and generate ASL animations that include facial expressions to convey grammatical syntax information, such as negation; topic; and yes-no, WH-word, and rhetorical questions. Our objective is to determine when signers use these facial expressions, how they perform each, how the timing of these facial expressions occurs in relation to the manual signs, and how the co-occurrence or sequential occurrence of facial expressions affect one another. Thus, we are investigating technologies for automatically planning aspects and timing of face movement. In addition to planning algorithms, we also need a succinct representation of ASL (that can encode a good-quality performance with as few parameters as possible). This makes it practical for a generation system to plan the animation, and it makes it possible for a human using a scripting tool to produce an animation with facial expressions in an efficient manner. We must test both our planning algorithms and our ASL script representation to ensure that they encode sufficient detail for ASL facial expressions that are understandable (and deemed natural) by signers.

3 Related Work on Evaluating ASL and Face Animation

We must evaluate the quality of the facial expressions in an ASL animation to advance research in this field, but it is difficult due to the subtle and complex manner in which facial expressions affect the meaning of sentences. It can be difficult to design experiments that probe whether human participants watching an ASL animation have understood the information that should have been conveyed by facial expressions. The easiest to evaluate is categorical information, e.g., whether (or not) the sentence with a facial expression should be interpreted as a question; it is possible to invent experiments to determine whether a human watching an animation interpreted it as a declarative sentence or as a question, etc. However, some ASL facial expressions convey information in matters of degree, e.g., an emotional facial expression can convey continuous degrees (by intensity of eye-brow movement, etc.). Measuring

whether someone has successfully understood the correct degree is more difficult. In the most challenging case, a facial expression may not affect the superficial meaning of a sentence, but only the implications that can be drawn. For instance, when a signer performs “I didn’t order a soda” with a cluster of behaviors (including frowning and head tilt) during the sign “I,” it can indicate that the signer believes someone else ordered the soda. With facial prominence on the sign “soda,” it could indicate that the signer placed an order, but for something else. In either case, the basic information is the same: the signer did not order a soda, but a different implication can be made.

Researchers studying facial expression of non-signing virtual humans, often evaluate only static faces, e.g., participants must identify the category of the facial expression or assign scores for intensity or sincerity (e.g. [19]). Because sign language facial expressions convey grammatical information and are governed by linguistic rules, additional care is needed to design useful stimuli and questions for evaluations.

Few researchers have explicitly discussed methodological aspects of stimuli design for facial expressions in sign language animation user-studies. Prior research differs as to whether researchers invent their stimuli originally as sign language sentences [6] [16] or as written/spoken language sentences that are translated into sign language stimuli [2][15]. In section 4, we compare both methods, and we study a wider variety of facial expression types; we also investigate the use of comprehension questions, which had not been employed in previous sign language facial expression studies. For inspiration as to how to use comprehension questions, we consider prior research on how humans interpret and understand speech with various prosody [1][13] (speed, loudness, and pitch changes). Researchers designed sets of sentences that, in the absence of prosodic information, contain ambiguity in how they can be interpreted. When prosodic information is added, then one interpretation is clearly correct. Participants in the studies listen to audio performances of these sentences and answer questions about their meaning. These questions are carefully engineered such that someone would answer the question differently – based on which of the alternative possible interpretations of the spoken sentence they had mentally constructed. For example, someone who heard the sentence “I didn’t order a soda” (with prominence on “I”) may be more likely to respond affirmatively to a question asking: “Does the speaker think that someone else ordered a soda?” In designing the studies in section 4, we have used similar experimental design, stimuli, and comprehension questions.

4 Experimental Stimuli Evaluation

The goal of this paper is to identify a methodology for designing stimuli and conducting experiments to measure the quality of facial expressions in an ASL animation. We want to evaluate whether facial expressions in an ASL animation enable participants who view the animations to identify the content of the sentences being performed. In the studies presented in this section, participants look at animations of a virtual human character telling a short story in ASL, and they answer questions about each story. Each story includes one category of facial expression (e.g., Yes-No questions, sadness, etc.). The animations displayed are one of two types: (i) with facial expressions carefully produced by a human animator or (ii) without appropriate facial expressions (i.e., the face doesn’t move). While the experiments in this paper are only pilot studies

used to confirm our methodology, in future work, when we begin to investigate facial expression animation synthesis, our experiments will contain a third type of animation: (iii) with facial expressions planned by our automatic synthesis software.

Deciding on these short stories, creating the animations, and creating the comprehension questions for each story is a process that we refer to as “stimuli design,” and the manner in which this is done can affect the scores collected in a study. The two studies presented in this paper compare two alternative methods for “stimuli design” to determine which is best for conducting ASL facial expression user-studies. There are several variables that we investigate in this paper: (i) whether the stimuli stories originated in English or in ASL, (ii) the amount of involvement of a professional native signer in designing the stimuli, (iii) the categories of facial expressions included in the stimuli, and (iv) the complexity of stimuli (i.e., number of words per story).

In the remainder of this section, we investigate how some of these variables affect users’ opinion by comparing two stimuli sets, which we refer to as our “English-to-ASL” stimuli and our “ASL-originated” stimuli. The primary difference between the sets is the degree of involvement of a native ASL signer in the stimuli-creation process (leading to more fluent ASL sentences in the “ASL-originated” set) and the categories of facial expressions included in each stimuli set. The English-to-ASL stimuli were first evaluated in a study in 2011 [11], and the “ASL-originated” stimuli were evaluated in a new study in 2013.

In both studies, native ASL signers watched animations of a virtual human character, as shown in Fig. 1, telling a short story in ASL. The story was either (i) with facial expressions added by a native ASL signer or (ii) without facial expressions added. Then, participants answered comprehension questions carefully engineered to capture the possible confusion introduced by a misinterpretation of the face. A native signer, who is a professional interpreter, conducted all the instructions and interactions. The animations in both studies were created using identical commercial sign language animation software, Vcom3D Sign Smith Studio [18].

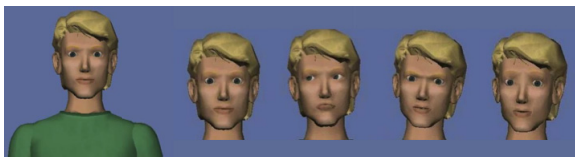


Fig. 1. ASL character and some of the available facial expressions

Our methodology for creating the “English-to-ASL” stimuli was to begin with an English sentence whose meaning would change with/without prosody, and then we attempted to translate the sentence into ASL in a manner that would preserve this reliance on the prosodic information (conveyed by facial expression instead of spoken prosody). Specifically, we asked a native signer (who works as a professional interpreter) to: (i) translate each of the English passages we use into ASL, (ii) use the Vcom3D Sign Smith Studio to produce the ASL animations, and (iii) choose from the available facial expressions repertoire the facial expressions that she thinks linguistically or naturally conveyed the prosodic information for the ASL stimuli. Each animation was produced in two versions: with and without facial expressions added.

<p>1 Original Spoken English Sentence (transcript of audio): I will go to the new restaurant you suggested. It is Chinese?</p> <p>ASL (glosses and facial expressions): I WILL GO NEW RESTAURANT YOU SUGGEST. IT CHINESE.</p>	<p>Comprehension Questions: Q1: Is Charlie asking you a question? Q2: Does Charlie know what kind of restaurant it is? Q3: Did you already tell Charlie that the restaurant is Chinese? Q4: Will Charlie go to the new restaurant?</p>
<p>2 Original Spoken English Sentence (transcript of audio, emphasis on the word "students" to imply that only the students stayed home): It was raining. The students stayed home today.</p> <p>ASL (glosses and facial expressions): TODAY, RAIN. <u> </u>emphasis THEY STUDENT STAY-HOME.</p>	<p>Comprehension Questions: Q1: Did the teachers also stay home? Q2: Is Charlie upset at the students? Q3: Did the students stay home yesterday? Q4: Was it raining today?</p>

Fig. 2. English-to-ASL Stimuli Set examples: (1) yes/no-question and (2) emphasis

There were a total of 28 stimuli with an average of 9 signs in length, and at least one facial expression per story. Fig. 2 shows two examples of stimuli used, as original English and ASL translated transcriptions, and the corresponding comprehension questions. The bars over the script indicate the facial expression to be performed during some of the signs. The stimuli can be divided into 5 categories (Fig. 3), based on the facial expression. The number of stimuli per category is given in parenthesis.

Y/N-Question (4):	The stimuli contained a yes-or-no question. When translated into ASL, a yes/no facial expression was used, without which, it could be interpreted as a declarative statement. See Fig. 2(1).
Wh-Question (4):	The stimuli contained an interrogative (who/what/where) question. The animation included a wh-question facial expression, without which, the sentence may be interpreted as a relative clause: "Last Friday, I saw Metallica. Which is your favorite band?"
Emphasis (8):	The stimuli contained a single word or phrase emphasized, to indicate contrast or incredulity: "It was raining. The <i>students</i> stayed home today." (This suggests the others did not.) "My sister <i>said</i> she ordered coffee, but the waiter brought tea." (This suggests disbelief.) While human signers convey emphasis via pausing, facial movement, and size/speed of hand movements, our animations included facial expression changes only.
Continue (4):	The prosodic cues in these passages convey that the speaker was not yet finished a thought but was only momentarily pausing: "I like to go to the movies and go to plays..." Once again, this information doesn't only correspond to a linguistically meaningful facial expression in ASL, but is communicated through additional signing parameters of speed and eye-gaze direction.
Emotion (8):	The stimuli were performed with a strong emotion (frustration or sadness) that affected their meaning: "Tomorrow is my 30th birthday. I am excited." (A sad face during the second sentence suggests the signer is not really excited.) "Last Friday, my brother drove my car to school." (With an angry facial expression, this suggests that the signer disapproves what her/his brother did.)

Fig. 3. Five categories of facial expression in the English-to-ASL Stimuli Set

Starting with English speech passages when creating stimuli for an ASL animation study seemed like a good approach given: (i) it is true to the goal of ASL animation synthesis, that is converting English text or speech to comprehensible ASL animations; (ii) it makes use of passages that are carefully engineered and successfully applied to collect users interpretation, and (iii) prosodic information in English is often conveyed by facial expressions in ASL. However, it can lead to various problems. First, the English influence might result in ASL stimuli following an English word order, e.g. the ASL sentence in Fig. 2(1) has a rather English-like word order. Second, some of the categories like Emphasis and Continue are communicated by a cluster of behaviors, not a single ASL facial expression, as discussed in section 4.1.

(1) no participant saw the same story twice, (2) the order of presentation was randomized, and (3) each participant saw every story – in either version (a) or (b). Native ASL signers were recruited from ads posted on Deaf community websites in New York. All instructions and interactions were conducted in ASL by a native signer (a professional interpreter). In [8-9], we discussed why it is important to recruit native signers, and we list best-practices to ensure that responses given by participants are as ASL-accurate as possible. Twelve participants evaluated the English-to-ASL stimuli set: 8 participants used ASL since birth, 3 began using ASL prior to age 10 and attended a school using ASL, and 1 participant learned ASL at age 18. This final participant used ASL for over 22 years, attended a university with instruction in ASL, and uses ASL daily to communicate with a spouse. There were 7 men and 5 women of ages 21-46 (median age 32). Sixteen participants evaluated the ASL-originated stimuli set: 10 participants learned ASL prior to age 5, and 6 participants attended residential schools using ASL since early childhood. The remaining 10 participants had used ASL for over 9 years, learned ASL as adolescents, attended a university with classroom instruction in ASL, and used ASL daily to communicate with a significant other or family member. There were 11 men and 5 women of ages 20-41 (median age 31).

Fig. 6 shows the results of the studies that compare English-to-ASL stimuli and ASL-originated stimuli, with the results of the “Emotion” category presented separately from the results from all other categories. Error bars indicate standard error of the mean; significant pairwise differences are marked with stars (ANOVA, $p < 0.10$). Our goal is to identify “good” stimuli for use in studies evaluating ASL facial expression animations. Since a human animator has carefully produced the facial expressions for these studies, “good” stimuli should have a big difference in comprehension scores between the without-facial-expression and with-facial-expression versions. It is important to note that the scores across studies can’t be directly compared, since the sentences and questions may have been more difficult in one study.

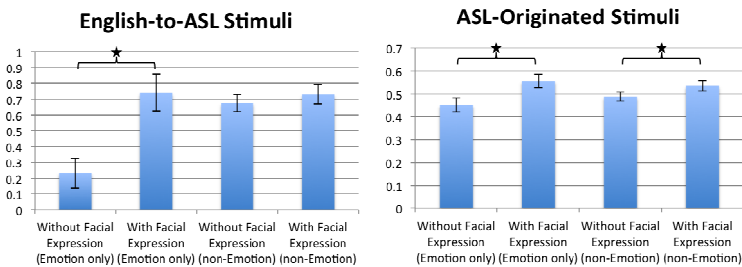


Fig. 6. Comprehension question scores for both types of stimuli, showing results for animations with- and without-facial-expressions, with results for emotion and non-emotion categories

For English-to-ASL stimuli, for the emotion category, adding facial expressions led to significantly higher comprehension scores. However, there was no benefit from adding facial expressions for the non-emotion categories, which didn’t convey the subtle meaning differences that we had intended. Perhaps since the stimuli were first conceived as English stimuli with vocal prosody, something was “lost in translation” when the stimuli were converted into ASL animations with facial expressions.

For the ASL-originated stimuli, adding facial expressions led to significantly higher comprehension scores for both emotion and non-emotion categories. This is a desirable result because it indicates that the stimuli/questions allowed us to distinguish between animations with good or with bad facial expressions (in this case, no facial expressions at all). If we used these stimuli/questions in future studies, we could compare the performance of animations with facial expressions automatically synthesized by our software – to animations with facial expressions produced by a human animator or without any facial expressions. Thus, we could track the performance of our facial-expression synthesis algorithms to guide our research.

5 Discussion and Future Work

This paper has described how we engineered stimuli and questions to measure whether the viewer has understood linguistic facial expressions correctly. Our evaluation methodologies and stimuli will be of interest to other animation researchers studying ASL or other sign languages used internationally. We found that designing stimuli in English and then translating them into ASL was not an effective methodology for designing a sign-language facial expression evaluation study. We have also found that the involvement of native ASL signers in the stimuli design process is important in achieving a high-quality result. In section 4, we preferred the ASL-originated stimuli because we were able to measure a significant benefit from adding facial expressions for both emotion and non-emotion categories. However, the best stimuli for our experiments would show a large difference when facial expressions are added. We note that there was a more dramatic difference in the comprehension scores for the emotion English-to-ASL stimuli. In future work, we may investigate whether we can design ASL-fluent sentences/questions that are analogous to some of the emotion English-to-ASL stimuli, in order to design ASL-originated emotion stimuli with bigger comprehension benefits from good-quality facial expressions. In future work, we also want to investigate how these stimuli would perform during side-by-side comparisons of animations or when evaluated via Likert-scale subjective questions. Guided by the experimental evaluation results we obtain in our studies, we will continue to improve the quality of facial expressions in ASL animations – to increase the naturalness and understandability of those animations – ultimately leading to better accessibility of online information for people who are deaf with low English literacy.

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Multimodal Synthesizer for Russian and Czech Sign Languages and Audio-Visual Speech

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Abstract. This paper presents a model of a computer-animated avatar for the Russian and Czech sign languages. Basic principles of sign language(s) and their implementation in a computer model are briefly sketched. Particular attention is paid to animation principles of the "talking head", which allows for maximum expansion of the functions of the program, making it suitable not only for deaf and hard-of-hearing people, but for blind and non-disabled people too, so the universal audio-visual synthesizer is proposed.

Keywords: Signing Avatar, Speech Synthesis, Talking Head, Assistive Technology, Multimodal User Interface, Universal Access.

1 Introduction

Nowadays world society pays much attention to the problems of disabled persons with partial or full dysfunctions of their organs and sensory systems such as hearing, vision, speech impairments etc.

Animated 3D virtual characters (avatars) are very convenient for sign language (SL) and fingerspelling (FS) synthesis tasks. There is a lot of recent research on 3D signing avatars and SL machine translation systems both in the USA and Europe, for instance: DePaul ASL Synthesizer [1], EU projects Dicta-Sign [2,3], SIGNSPEAK [4,5], SignCom [6], Italian SL [7], ViSiCAST with Visia avatar [8], eSign with vGuido avatar [9], as well as Sign Smith and Sign4Me avatars of Vcom3D [10], SiSi project of IBM [11], iCommunicator system [12], etc. Recent studies were also made on machine learning and motor control in relation to visual speech synthesis. There are experimental works on computer synthesis of lips and tongue movements interpreted by talking head systems [13,14].

The paper is organized as follows: Section 2 describes specificity and general features of the Russian and Czech sign languages; Section 3 presents structure of the multimodal synthesizer, 3D signing avatar as well as information fusion and user interface; conclusions are given in the end of the paper.

2 Specificity of Sign Languages

It is generally known that there is no such linguistic phenomenon as The Universal International Sign Language (SL). Quite the contrary, a lot of SLs (at least 130, according to the Ethnologue¹ report for sign languages of deaf people) have appeared in various deaf communities and changed with time having gotten new lexical items and grammar structures, just like natural languages (NL) spoken by us all over the world. Sign languages have gained legal recognition as means of communication in the USA, Canada, Australia, states of EU and some other countries. Since 1998 the law regulates use of Czech sign language and signed Czech as communication means of deaf in Czech Republic, and since the 30th of December 2012, the Russian SL has been officially recognized in its home country too².

Elaborating of human-computer interfaces, which make it possible for deaf people to interact with the “normal” world, would help SLs to expand their sphere of influence. One of the most challenging problems in this realm is NL-to-SL, SL-to-NL and SL-to-SL translations. Differences in SLs as well as between NLs and SLs cause still troubles at human and machine translation and interpretation due to general lack of knowledge of SL grammars. There are however essential similarities owing to their natural iconicity and visual interpretation.

The sign languages are mainly preferred by the deaf. They are natural forms developed in communities of deaf people. Signed modes of natural languages (manually coded languages) are a bridge between natural and sign languages. Likewise, they use signs, but the grammar and sentence structure is adopted from spoken languages.

2.1 Russian Sign Language and Fingerspelling

One of the most important problems connected with the Russian sign language (RSL), which is used by several hundred deaf people (approximately a half million) in Russia and some Commonwealth of Independent States (CIS) like Ukraine, Belarus, Kazakhstan, etc., consists of a geographical vast of the country and existence of various dialects of RSL, such as Moscow, St. Petersburg, Novosibirsk, Vladivostok, Minsk dialects and others. An expert analysis of electronic and published dictionaries of RSL shows that only 30-40% gestures are similar in the Moscow and Petersburg dialects nowadays.

Fingerspelling is a representation of letters or numerals using only the hands. In contrast to the British and Czech fingerspelling alphabets, all signs in the Russian fingerspelling system are performed by one (right) hand only. Moreover, seven signs of the 33 Russian letters (cheremes) are dynamic ones. Thus the cardinal differences between Russian or American (on the one hand) and British or Czech (on the other hand) fingerspelling signs are: all the Russian and American gestures for letters are one-handed, while most gestures in British and some signs in Czech fingerspelling are two-handed; quite a few Russian letters are dynamic, while all the British or Czech letters are static; besides that, finger shapes in the RSL are more complicated.

¹ www.ethnologue.com

² www.voginfo.ru

2.2 Czech Sign Language and Fingerspelling

It is quite difficult to estimate number of people who are deaf and use Czech sign language. In the Czech Republic the number is about 7500 of deaf signers (0.07% of the population, and about 500000 (4.7%) hard of hearing. Furthermore the Czech sign language can be a primary communication means of the hearing-impaired people. It is composed of the specific visual-spatial resources, i.e. hand shapes (manual signals), movements, facial expressions, head and upper part of the body positions (non-manual signals). It is not derived from or based on any spoken language.

On the other hand the signed Czech was introduced as an artificial language system derived from the spoken Czech language to facilitate communication between deaf and hearing people. Signed Czech uses grammatical and lexical resources of the Czech language. During the production, the Czech sentence is audibly or inaudibly articulated and all individual words of the sentence are simultaneously signed. Czech sign language and signed Czech use fingerspelling less than the sign languages in Russia and CIS countries. The fingerspelling is primarily incorporated in the sentence context of lexical signs to express shortcuts, new words etc.

3 Structure of the Multimodal Synthesizer

In the last years, UWB and SPIRAS have been developing a universal multimodal (audio-visual) text-to-SL & speech synthesizer for Czech and Russian. The synthesizer takes text as an input and translates it into audio-visual speech and SL.

Thus the visual output is available for deaf and hard of hearing people, who can use SL and/or lip-reading; the audio output is oriented for visually impaired people; the audio-visual part of the interface is intended for non-disabled people. The universal multimodal synthesizer consists of several components (Figure 1):

- especially designed text processor that takes text as an input to generate phoneme (a minimal acoustic element of speech) and viseme (a visual equivalent of phoneme) transcriptions, and control selection of HamNoSys codes primarily intended for hand description of fingerspelling [15];
- TTS (text-to-speech) systems that generate auditory speech signal with time labeling corresponding to the entered text [16, 17];
- virtual 3D model of human's head with controlled lips articulation, mimics and facial expressions [18];
- control unit for the audio-visual talking head that synchronizes and integrates lips movements with synthesized auditory speech signal [19];
- virtual 3D model of human's upper body; we employ own skeletal model of the signing avatar, which can be controlled by HamNoSys codes [20];
- audio-visual multimodal user interface that synchronizes output audio and visual speech and gesture modalities, integrates all the components for automatic generation of auditory speech, visual speech (articulation and facial expressions) and avatar's gestures of signed Czech/Russian language and outputs audio and visual signals by PC loudspeakers and a display; the sign language and visual

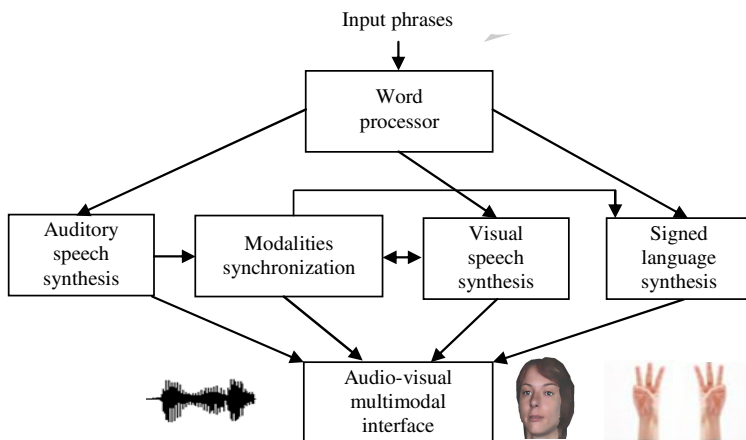


Fig. 1. General structure of the multimodal synthesizer

speech interface is available for deaf and hard-of-hearing people, while audio-speech speech interface is focused on blind and visually impaired people, and the audio-visual talking head provides interaction with ordinary non-disabled users; so the proposed audio-visual synthesizer is a universal HCI interface.

Input phrases of speaking text are given to the input of the system and firstly analyzed by a word-processor. Clauses, words (for audio speech synthesis and video synthesis of lip articulation by the talking head, as well as for signed language output by the full avatar) and letters (intended for fingerspelling synthesis) are found out and automatically processed to the symbols of HamNoSys sign notation. On this basis, the signing avatar outputs manual gestures of sign language/fingerspelling decoding HamNoSys notation symbols.

3.1 Architecture of the Audio-Visual Talking Head

We have implemented a 3D realistic talking head model for both the Czech and Russian languages. The talking head is a text-driven system, and the visual processing part of which is controlled by taking into consideration the results of input text processing and audio TTS with the help of a modality asynchrony model.

The talking head is based on a parametrically controllable 3D model of a head. Movable parts are animated by a set of control points. The synthesis is based on concatenative principles, i.e. the descriptions of the visemes (in the form of the sets of control points) are concatenated to produce continuous stream of visual parameters. In the concatenative approach the co-articulation problem has to be solved to avoid unpleasant or unintelligible (unnatural) visual artifacts. In our case the co-articulation of the lips is modeled by method of selection of articulatory targets [21].

The animation technique uses virtual control points predefined on the face or tongue surface to move vertices of the 3D shape of the model. For smooth movements the vertices surrounding the control points are interpolated; animation is smoothed using the influence zones approach (see Figure 2c). Each influence zone is attached to

one set of control points connected to a 3D spline curve. The shape of the head model was created using 3D scanning system from a real face. The scanning system is based on a digital camera, projection of structured light on the face (moving a vertical thin stripe of white light) and system of four mirrors to obtain stereoscopy while avoiding the stereo correspondence problem [18].

The head model as such is represented by a set of points - vertices of a virtual space which are connected by edges to build up dense triangular surfaces and form a three-dimensional model (Figure 2a). The obtained 3D data are processed, completed by adding manually created other face parts and kept in a file in a virtual reality format (VRML) as a set of vertex coordinates triangular planes and textures of the face of the speaker. The full head model is described by tens of thousands of vertices (Figure 2b), however, only few of them are active, i.e. can be commanded by the program, simulating movements of facial muscles; control of those allows displaying visemes.

The talking head model is also employed for creation of a viseme set in a setup phase of the system, specified by the parameters of the model for given language.

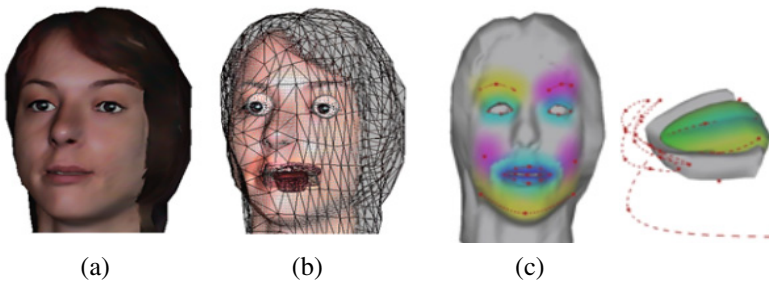


Fig. 2. Talking head: a) view of 3D model; b) view of wired model; c) model influence zones

In the given synthesizer, not only the general model of a head is used, but also additional models of its parametrically controlled facial components: the eyes, tongue, upper and bottom jaws, and internal speech organs. They are created on the knowledge base of anthropological physiology. Each model can be controlled by the program irrespective of the head. One more advantage of creation of separate models of “talking head” elements is possibility to create “an illusion of a live head” (eye-blinking/movements, jaw side-move, breathe movements, etc.).

For Russian language we apply a TTS synthesizer based on allophones and multi-allophones natural waves (ANWs and MANWs) concatenation [16]. The speech prosody synthesis uses an original Accentual Units Portrait (AUP) model for a stylization of tonal, rhythmical and dynamic contours of a phrase. Fusion of these modules allows synthesizing speech with a high degree of intelligibility and naturalness. In the system an incoming orthographic text to be transformed into speech signal undergoes a number of successive operations carried out by specialized processors: textual, phonemic, prosodic and acoustical. The textual processor divides an orthographic text into utterances; transforms numbers and abbreviations into textual form; divides an utterance into phrases; places word stress (weak and strong); divides phrases into accentual units (AU), and finally marks the intonation type of the input phrase.

Synchronization of face/lip movements with synthesized acoustical signal is based on timestamps of allophones in the synthesized speech flow. Duration of every allophone is based on allophone's average length and desired speech tempo. Synchronization of virtual face and lip movements with synthesized acoustical signal is realized on the basis of information known about positions of beginning and end boundaries of each context-dependent phoneme (allophone) in the speech flow. Duration of every allophone is set by the auditory TTS system based on allophone average length and required speech tempo. In order to model natural asynchrony between audio and visual speech cues and to take into account different speech rates, 16 context-dependent timing rules for transitions between displaying visemes are applied [17]; this method allows increasing naturalness and intelligibility of generated audio-visual speech [22].

3.2 Architecture of the Signing Avatar

The goal of an automatic sign language synthesizer is an imitation of human behavior during signing. Sign language synthesis is implemented in several steps. First, the source utterance has to be translated into the corresponding sequence of signs. Then the relevant signs have to be concatenated to a form a continuous utterance.

The architecture of the signing avatar incorporates a baseline sign language translation module experimentally designed for the signed Czech. In general, the sign language translation module uses an automatic phrase-based translation system. Sentences are divided into phrases and these are then translated into corresponding sign speech phrases. The translated words are reordered and rescored using a language model at the end of the translation process. In the architecture, we use own implementation of a simple monotone phrase-based decoder.

The main resource for the statistical machine translation is a parallel corpus which contains parallel texts of a source and a target language. The acquisition of such corpus is complicated by the absence of an official written form of both the sign and signed languages. Therefore we experimentally collected own Czech - signed Czech parallel corpus for baseline setup of the translation system. The decoder and performance of the system is described in more details in [23]. In general, created sign speech phrases determine sign order, dependences and form.

Signing avatar synthesis system creates 3D animation of the upper half of a human figure (Figure 3). The baseline system incorporates 3D articulatory model approximating skin surface of the human body by polygonal meshes. The meshes are divided into body segments describing arms, forearms, palm, knuckle-bones plus the parts of the talking head model. The full animation model is designed to express both manual and non-manual components of sign languages. The manual component is fully expressed by rotations of the body segments. The body segments are connected by joints and hierarchically composed into a tree structure (an approximation of body skeleton). Every joint is attached to at least one body segment. Thus the rotation of one body segment causes rotations of other body segments in lower hierarchy. Joint connection incorporates rotation limits to prevent non-anatomic poses of the animation model.

In addition, synthesis of the non-manual component employs second control through the control points of the talking head model or more general morph targets. Thus the joint connections ensure movements of shoulders, neck, skull, eyeballs (eye gaze) and jaw. The control points and the morph targets allow us to change the local shape of polygonal meshes describing the face, lips, or tongue.

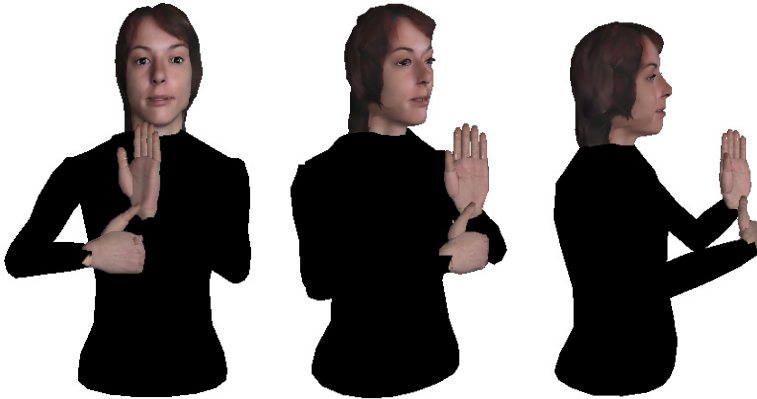


Fig. 3. 3D views of the signing avatar (it shows numeral “16” of the Russian sign language)

The synthesis module incorporates conversion algorithm for Hamburg notation system (HamNoSys, [15]) to create necessary signs and fingerspelling gestures [20]. An algorithm automatically converts the HamNoSys codes to control trajectories and accepts most of the valid combinations of symbols. Final animation frames are the input to animation model. Time sequences of values determine trajectories controlling the joints, the control points or weights of the morph targets.

The algorithm allows modeling almost any configuration and hand movements in the presence of corresponding visual means. It is important too, that the virtual avatar simulates the manner of gesticulation as “humanly” as possible.

3.3 Audio-Visual Multimodal Interface

Synchronization of audio-visual speech with visual gestures is controlled by time stamps of start and end of spoken words generated by the audio speech synthesizer. Since natural speech has a higher tempo than the corresponding signs, then the avatar pronounces and articulates isolated spoken words and waits for the following word until completion of the current gesticulation (if there is no sign for a word in the vocabulary then it is spelled by finger signs with the avatar’s right hand in the case of Russian or both hands in the case of Czech sign language). The proposed SL interface has a lot of advantages:

- it allows a user to see generated visual data from different sides and viewing angles that results in better understanding of spatial information, e.g. distance between the hands and the body or hands each from other;

- it is possible to add new tokens into the sign vocabulary quite easily thanks to the usage of the animated virtual avatar, so there is no requirement to record one human SL speaker (e.g. identity with same dress, haircut and make-up with similar lighting conditions and equipment, in contrast to video recordings);
- it can generate a continuous stream of visual signs without transitions through a neutral position of hands and there are no seen borders between adjacent signs;
- it is possible to change one 3D avatar with another one and to create new models of human beings or characters;
- synthesized signed phrases can be conformed to type of HCI with any required speed, slowing down or speeding up video stream;
- sign language translation module can be conformed to provide next algorithms in the future, which solving translation problems linked with specificity of sign language grammars

The developed multimodal avatar is convenient for deaf and hard-of-hearing people, as well as for blind and non-disabled people, so it is the universal synthesizer designed especially for HCI, interactive dialogue systems, and communication agents [24, 25]. It generates signals of auditory and visual output modalities and fuses dynamic speech gestures with the avatar's hands, auditory speech and lips articulation/facial expressions. Multimedia demonstrations of the proposed synthesizer for signed languages and fingerspelling (one-handed for Russian and two-handed for Czech) are available in Internet [26]. Initial intelligibility test have been performed with sign language synthesizer and signed Czech [27]. For this purpose, 20 videos of short utterances were synthesized. Hearing participants (sign language experts) evaluate each utterance as a whole. Subtitles were added to the videos to show text transcription to the signs and to give the participants original meaning of the utterance. In accordance to the evaluative criteria, the animation of 14 of 20 utterances showed the signs from subtitles. Qualitative user evaluation of the 3D signing avatar for signed Russian and fingerspelling was made with the help of some representatives of the All-Russian society of the deaf in St. Petersburg. They said on novelty and urgency of the system and positively estimated intelligibility and naturalness of lips articulation of the talking head and recognizability of manual gestures of the virtual avatar.

4 Conclusion

The multimodal system is aimed not only for deaf, hard-of-hearing, and hearing impaired people, but is useful for hearing people as well. It is a universal multimodal computer system that is currently tested for synthesis both Russian spoken language (audio-visual modality) and the sign language (visual modality). Generated audio-visual signed Russian speech and language is a fusion of dynamic gestures shown by the avatar's both hands (or only by the right hand in the case of Russian fingerspelling), lip movements articulating spoken words and acoustic speech. Many deaf people are able to lip-read and to understand phrases even without manual gestures. Acoustic spoken language is a natural speech modality for communication with hearing-able people. Avatar's lips articulation synchronized with audio stream

helps to improve both intelligibility and naturalness of generated speech. The proposed universal synthesizer can be applied in various dialogue systems, multimodal embodied communication agents as well as in learning systems.

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Investigation into a Mixed Hybrid Using SSVEP and Eye Gaze for Optimising User Interaction within a Virtual Environment

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Abstract. Brain Computer Interface (BCI) technology has been used successfully in neurophysiological research laboratories, but has had less success when used outside the laboratory and particularly for people with disability. The hybrid BCI approach offers the potential for a more robust solution, with potential better usability to promote greater acceptance. The emphasis on improving human computer interaction may facilitate more widespread deployment, particularly where BCI alone has proved unsuccessful. This paper adapts an existing modular BCI architecture to support a 'mixed hybrid', by combining a BCI with a commercial eye tracker, and suggests graphical user interfaces to facilitate operation and control of a virtual environment.

Keywords: Hybrid, Brain, Computer, Interface, Eye-gaze.

1 Introduction

The Brain-Computer Interface (BCI) has successfully provided both communication and control of environments, by modifying attributes of the electroencephalogram (EEG) [1]. Consequently, this has facilitated the possibility of augmenting human interaction for a range of application domains, including assisted living and leisure activities.

Scalp recorded EEG is a noisy signal that represents a summation of sensory, motor and cognitive activity associated with neuronal and muscle structures in the head and brain. As a consequence, it provides a challenge for the implementation of reliable and robust BCI that can be used over long periods of time, ironically by the people who are in most need of the technology. Conversely, implanted electrodes have been shown to provide better signal quality, with some studies demonstrating successful long-term use [2]. Furthermore, a number of strategies have been employed in order to provide successful non-invasive BCI; the most common being the use of intended movement potentials, such as Event Related De-synchronization (ERD) and Event Related Synchronization (ERS), the evoked response to a 'target' stimulus (known as the P300 potential), and the recording of the Steady State Visual Evoked Potential (SSVEP), activated in response to a visual stimulus typically consisting of predefined

frequencies of flickering light. Regardless of the success of individual strategies, it is important to facilitate a range of BCI paradigms, as one paradigm may be successful for an individual, whereas another may fail. By combining strategies, it is possible to produce a hybrid BCI (hBCI) that can increase the classification accuracy, hence further promote acceptance and adoption of the technology. Indeed, such a hybrid approach has been promoted in the BCI Roadmap [3].

An hBCI may also be devised that combines EEG with some other modality, such as eye-gaze interaction. This can potentially allow the two modalities to work sympathetically, providing respite for the user from focused concentration during either EEG recording or eye tracking based interaction. The modalities of the hybrid system could be used either sequentially or collaboratively, with each responsible for different functionality or combined for the same command classification. However, the latter could potentially lead to disagreement in the outcomes of the classification, and issues may also arise with regard to the technologies working within the same time frame. Furthermore, an alternate reason for incorporating a second modality could be to use one modality as a switch to turn on/off the hBCI system and the other modality for control [4].

This paper extends an architecture developed within the BRAIN project [14] to facilitate an hBCI. Software tools were previously developed for interface development, testing and SSVEP and ERD/ERS recording. The paradigms were used successfully on healthy volunteers outside the laboratory setting. However neither approach was sufficient by itself to facilitate usage with a target brain-injured cohort. Interfaces are proposed to support an hBCI, combining EEG with a commercial eye tracker system.

2 Background

Within the literature, a generally accepted definition of a BCI, is a system that provides a communication channel for users, which does not rely on physical movement [3], [5], [9-10]. From a system's point of view, a non-invasive BCI system provides software applications with real-time access to the cognitive state of the user based on EEG obtained during mental tasks. Regardless of the paradigm employed, a traditional BCI comprises a signal acquisition component that records brain signals, along with a signal-processing pipeline, which performs real-time signal preprocessing, feature extraction and control classification. Additionally, a BCI also contains one or more applications or devices, which provide the focus for both user control and feedback, and an application interface that determines interactions between components of the BCI [3], [7]. The majority of BCI systems focus on intentionally modulated brain signals, in which the outputs originate from brain activity that is directly controlled by the user, known as *Active BCI*. However, BCI systems may also utilize indirectly modulated brain signals and arbitrary brain signals, known as *Reactive BCI* and *Passive BCI* respectively [5], [9]. Furthermore, BCI systems are typically designed to operate in either a synchronous or asynchronous manner, with synchronous systems controlling the periods of user interaction with prompts, and asynchronous BCI permitting users to interact without such explicit cues [6], [11]. The primary applications of BCI systems include communication and control, motor substitution and recovery, and entertainment [9]. While the benefits of BCI systems are often focused

on improving the lives of users suffering from conditions such as amyotrophic lateral sclerosis, BCI may also provide beneficial enhancements and insights for a wide range of users within the context of HCI [5-6].

By taking a user-centered design approach involving target user cohorts during the design process, and incorporating fundamental HCI design principles, more appropriate BCI systems may be realized [3], [18]. Moreover, extending the BCI paradigm by combining such systems with existing devices and assistive technologies, thus leading to the development of hybrid architectures, may help to overcome some of the challenges of using BCI as a single communication channel [1], [3-4], [6].

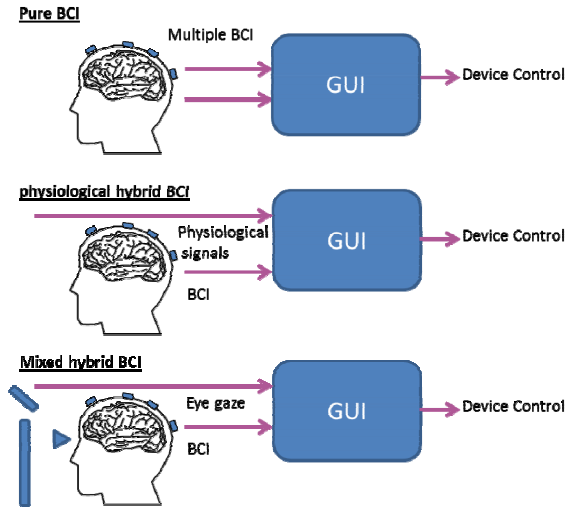


Fig. 1. Hybrid BCIs: pure, physiological and mixed

Such hybrid BCI (hBCI) systems are emerging that promote an innovative approach to the design of BCI, which permits users to utilize a broader range of communication strategies [6]. Indeed, hBCI is commonly defined as a system comprising at least one BCI communication channel that is utilized in conjunction with another assistive technology or input device [1], [3], [6], [10]. For example, an hBCI may derive input signals from a BCI and secondary BCI, known as a *pure hybrid*, or a BCI and signals from a secondary device based on either physiological sensors or communications, known as a *physiological hybrid* and *mixed hybrid* respectively [6], see Figure 1. Consequently, the two input devices are collaboratively employed, with signal processing being performed either sequentially or simultaneously [3], [6], [8], [10]. Subsequently, hBCI opens up the possibility of generating multimodal user interfaces, which facilitate augmented interaction that is more intuitive and natural for users [3]. However, due to the challenges associated with the complementary integration of multiple input mechanisms, the development of hBCI systems is considered to be more difficult task than the development of traditional BCI systems [6]. Furthermore, a key challenge for such systems is to increase the period of reliable operation, while reducing adverse impacts on the user [7].

3 EEG and Eye Tracker Hybrid BCI

This paper focuses on hBCI systems that combine BCI with an eye tracking system. Due to the robust, high bitrates associated with the input channel from an eye tracking system, binary command constraints associated with the low bitrate associated with BCI can be circumvented, resulting in a complementary hybrid system [5], [9], [12]. Currently, a number of examples of such hBCI systems exist that are primarily focused on touchless HCI [5-6], [8-9], [11-13]. These include the use of gaze based input with asynchronous ERD-based BCI for *search and select* tasks featuring both easy and difficult selection conditions within a two-dimensional environment [5-6], [9]. SSVEP and ERD/ERS-based BCI have been utilized in combination with eye tracking for search and selection tasks, and interaction with simple puzzle games [12]. Likewise, hBCI featuring asynchronous BCI and eye tracking have also been employed for text-entry applications [11] and three-dimensional search and select tasks [8]. Such research has shown that the use of eye tracking systems are appropriate for search [5], [9], [12], however without an additional communication channel, such as BCI, selection is difficult due to identifying suitable fixation times, known as *dwell time*. Indeed, by combining eye tracking with BCI, the issues associated with dwell times may be successfully addressed [9], [11].

Additionally, it was found that using information from the eye tracker to adaptively update the BCI component of the hybrid system resulted in a substantial reduction in the number of false positives observed [11]. Within the majority of these systems, a multimodal approach has been used, whereby pupil gaze is used to initially perform spatial navigation and either a fixation threshold, or imaginary selection command, forces a switch in input modality, subsequently permitting selection to be achieved using a predetermined mental state [8-9], [11], [13]. Although some degree of success has been observed with these hBCI systems, a number of issues have also been identified, including the need to define appropriate selection commands [5], [9], and the necessity to conduct both calibration and the time-consuming process of user training for the BCI system in order to ensure good overall performance of the hBCI system [8], [12]. Moreover, it was found that hBCI systems based on eye tracking and BCI were potentially suited to applications where rapid changes in the complexity of stimuli occur [8], and, in general, the use of BCI as a 'selection' mechanism in such hybrid systems reduced the overall level of user frustration [9].

In order to support research into hybrid systems, a number of generalized frameworks for hBCI systems have been developed, including the Tools for Brain-Computer Interaction (TOBI) architecture [6] and OpenBCI software framework [10]. A number of BCI-related software solutions exist. For example, TOBI proposed modular architectures, which utilized standardized data acquisition components and interfaces in order to permit researchers to develop hBCI systems. Similarly, the OpenBCI framework comprises a complete, modular software solution that supports a range of EEG-based BCI paradigms and the development of parallel hBCI systems. Subsequently, by making the underlying platforms increasingly accessible, the availability of such generalized platforms can further promote research and development into hBCI systems [1].



Fig. 2. Eye tracker (Tobii) interacting with Graphical User Interface

Eye tracking is an assistive technology often used for patients with peripheral muscular dysfunction. The commercially available Tobii system [16] uses both reflected light and infra-red signals to detect the subject's pupil, determine his/her gaze trajectory and map this to an on-screen target, see Figure 2 for general set-up. In this figure the stimulus-acquisition unit is located below the monitor. It allows spatial coordinates to be extracted, thereby providing gaze interaction information to other applications. Eye gaze systems have the potential to change the way users interact with computers. It is an intuitive technology that can increase speed of interaction with a computer screen. Alternative systems based on web cam technology may be constructed for less than a hundred Euro. For example a low cost system may use a laptop web cam or alternatively a miniature camera can be attached to traditional spectacle frames; both using image processing techniques to isolate the pupil and hence infer gaze. In all systems a calibration is required for each recording session, to relate eye gaze to screen resolution. Head movement must also be compensated, and tends to be better controlled in the more sophisticated systems.

4 Architecture

Within the architecture developed for BRAIN [13],[19] a set of UDP packets provided input to control the interface. The values allocated to User Datagram Protocol (UDP) packets related to the appropriate BCI classification (from a signal analysis component such as BCI2000). For example, with SSVEP there were 4 flashing Light Emitting Diodes (LEDs) surrounding the computer screen, each relating to a particular navigation arrow and hence facilitating 4 way directional control. These four classifications have been given the (arbitrary) codes 401, 402, 403, and 404. When employing the user interface for ERD/ERS, the navigational structure needed to accommodate 3-way or even just 2-way directional control, as reliable class discrimination proved more difficult. Again the input to the user interface was UDP packets with codes 501, 502, 503, 504 for all possible directional outcomes. This architecture allowed for a version of the same interface to be used for ERD/ERS. The result was a design that could

be tailored easily to ERD/ERS or SSVEP, but was not a concurrent hybrid system. There was no inbuilt mechanism to automate the switch between modes. However, the modular architecture does lend itself to further development for a hybrid BCI that can work simultaneously or sequentially. Signals evoked from the user (SSVEP, ERD/ERS, and eye tracker) are attributed meaning and actuate the interface. Thus the eye tracker packets can be allocated 601, 602, 603 and 604.

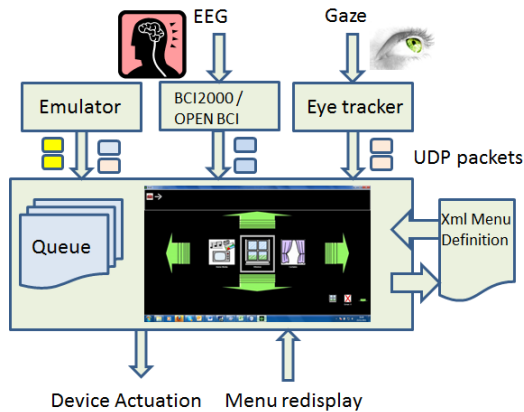


Fig. 3. Architecture of the Graphical User Interface

Command classification data was produced by a BCI2000 processing package [15] and transmitted to the GUI application using the UDP communications protocol, thereby maintaining a clear separation between the functionality of the GUI and the signal processing. The GUI has subsequently been interfaced with the OpenBCI platform [10], which was developed in Python and is freely available under the GNU General Public License. The GUI was developed in Java, thus permitting operating system independent deployment. A menu structure employs a virtual representation of a domestic environment, using images of rooms and appliances. By providing a flexible GUI and modular platform, multiple paradigm support has been facilitated.

Testing the usability of such a multi-modal interface can initially be conducted by using emulator tools which can generate packets to prescribed profiles. Thus it is possible to produce sequences of SSVEP, ERD/ERS and eye tracker packets, without subjects, in an initial experimental phase. Hence an hBCI comprising SSVEP and eye tracker can be emulated. The simulation can extend to both sequential hybrids and collaborative hybrids. Emulation and testing strategies were devised as part of BRAIN [19]. A Catcher utility stimulates the user to follow a set of directional instructions, classifying responses; providing a paced, objective means of assessing accuracy of BCI command classification performance. An accessibility tool generates a user specific estimate of tolerance to inaccuracy when interacting with the interface. This can be contrasted to the results obtained by the Catcher giving a usability indicator.

5 User Interface Design

The difficulty in design is determining the most natural mechanism for control for each application. This is complicated by the fact that some BCI mechanisms work better for some users than others do. A classification of the types of control typically used in an interface and the associated BCI that can handle this might go some way in determining the best-suited combinations. Eye gaze facilitates free cursor control, by providing a high bandwidth, highly responsive channel with good accuracy, assuming appropriate calibration. Discrete cursor control (4-way, 3-way, 2-way) can be achieved using SSVEP (and ERD/ERS). It is suitable for navigating through a hierarchical structure or a grid of icons. Selection of an onscreen icon, toggling a state of a device may be achieved with either modality or a combination. Issues to be considered are: how many packets are required to trigger a command and the latency associated with packet generation and classification. BCI can achieve higher classification accuracy for fewer classes, which makes it suited to hBCI.

Figure 4 provides a simulation of a hBCI GUI configuration that brings together SSVEP with eye gaze technology, using the eye gaze to (quickly) direct the horizontal navigation of the user interface, and SSVEP to trigger a command (reinforcement of eye gaze, downward arrow). This also can act as a safeguard against early ‘exit’ from the interface (reinforcement of eye gaze, upward arrow). Vertical navigation can potentially use ERD/ERS to reinforce selection.



Fig. 4. Simulation of eye tracker with SSVEP for selection

The aim of the eye gaze is to rotate the images in the centre of the interface. At the top level of the hierarchy this is a series of images or icons relating to the user’s home environment. Once the desired location is the centre image then some mechanism is required to select the location and move down to the next level of hierarchy, now displaying the devices within that location. SSVEP rotation of the images was slow and required substantial focus on the appropriate LED. This was mounted on the edge of the screen and made it difficult for the user to see when they had reached their icon of interest. Replacing this control using the eye gaze creates a more natural process. Activating selection can then be achieved using the SSVEP with an LED placed at the bottom edge of the screen. This would signal a more robust intent than eye gaze dwell time alone with the aim of reducing errors. In such a structure errors confound usability by requiring the user to retrace their steps. Movement back up the hierarchy can

again be activated using the SSVEP (a second LED). This hybrid architecture requires two distinct stimulus frequencies, which creates a much simpler and robust classification task. Further work could also be investigated into including the eye gaze parameters into the classification process to further ensure that the correct decision is made. For example eye gaze dwell time can be used to assist the EEG classification process. Figure 5 illustrates the concepts menu search, scrolling and command selection and enactment, in the eye tracker. Off-line processing superimposes red dots on the image to indicate the location of gaze and their diameter indicates dwell time.

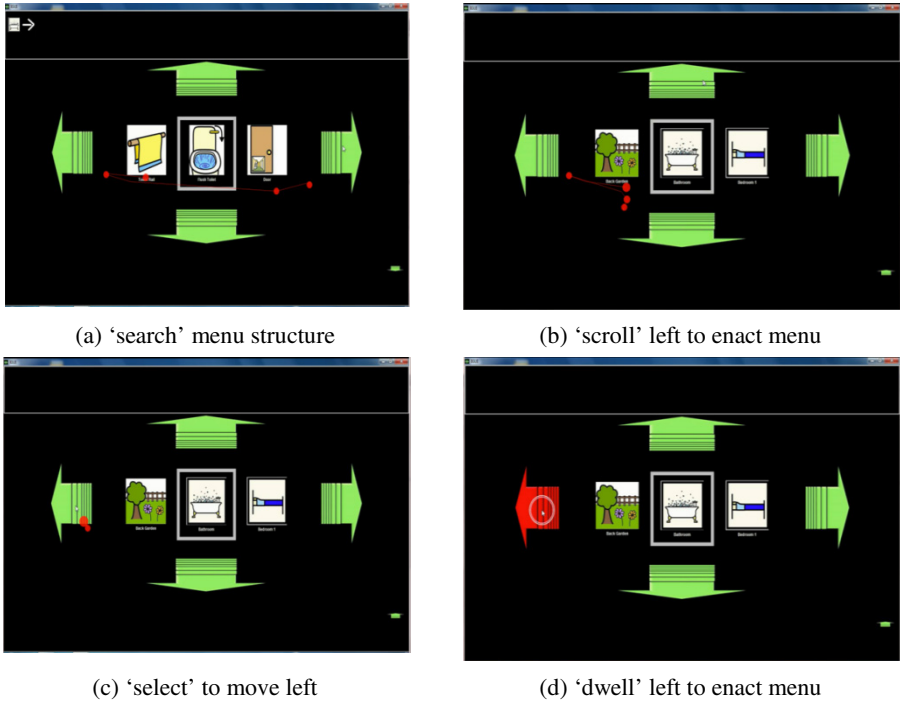


Fig. 5. Eye tracker interaction with Graphical User Interface

6 Discussion

SSVEP operation used 4 LEDs mounted around the outside of a computer screen. In order to navigate a particular direction the user has to make a cognitive link to the LED associated with that direction. The location may mean that the user may no longer have full view of the screen and the changes that they are affecting. Aside from the physical constrains some users found this a cognitive challenge. Within BRAIN two out of 5 target users (i.e. those with some brain dysfunction) were not confident concerning the outcome or consequences of the action of activating an arrow using the flashing LEDs. Only one user was fully confident to navigate to a selected menu item without assistance. Due to the confusion between directional command arrows

and the manipulation of menu icons the other users found it difficult when trying to navigate to a specified item. Technically competent users had little difficulty operating the interface. This concurred with other studies in which the use of a computer based system is an immediate hurdle to encounter before even considering the complexity of the BCI itself [17].

While integration between the BCI system and eye tracker is on-going, there are two main drawbacks to the proposed hybrid system. Firstly, the Tobii system is expensive, hence is only applicable to laboratory based testing. Secondly, the API is not open source, therefore has limited value as a research tool. The ideal solution would be to produce a fully open system that utilizes commercial, off-the-shelf webcam technology for eye tracking. Although such a bespoke eye tracker may not meet the performance of the Tobii system, it could offer the potential to enhance the efficacy of the BCI in a hybrid system to the extent that usability is significantly enhanced but the extra cost in terms system complexity is negligible; thereby closing the gap between, the minimum accepted accuracy for system operation, and the achievable accuracy [19]. By making GUI and HCI tools available, it may be possible to facilitate hBCI development, which can be easily deployed outside the research environment. We believe that improved more robust BCIs, such as the hybrid proposed, will be required to engage users with difficulties, i.e. those that can best avail of this technology.

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Odours and Spatialities: Designing Sensory Experiences

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Abstract. Smell is a chemical phenomenon, historically signified and culturally shared; it creates deep interactions, enforcing social structures or transgressing them. From natural environments to urban spaces, the large variety of odours can stimulate olfactory senses and evoke experiences, in which pleasant and unpleasant, and even non-smelling scents, are combined as parameters of spatial limits. The main aim of this paper is to contextualize some chemical and cultural aspects of smells, and their potential to create and reconfigure spatial orientations. Based on Constance Classen, David Howes, and Anthony Synnott's researches, odours are understood as cultural classification systems, and therefore they are possible modes of ordering the world. At the end, some projects and scent maps are brought since odours are considered an aesthetic medium to design evocative experiences and perceptive access modes.

Keywords: Odours and spatialities, perception and accessibility, spatial experiences, design and technology, art and technology.

1 Introduction: Odours and Spatialities

Events in everyday life are perceived and registered by sense organs of more than one modality. Consequently, the coordination and integration of information derived from different sensory systems are essential for providing the perception of the environment to control actions within it.

Considering the multiple sensory dimensions of the world and the visual perception predominance in contemporary culture, this text highlights people's olfactory qualities to sense and to make places. Olfaction represents a subset of the sense of smell and is related to chemical dialogues, anatomy and behavioral responses; it is a dynamic and interdependent relationship between anatomy and behavior, genetic capabilities and cultural characteristics (Morton 2000: 256) [1].

Semantics aside, an odour perception is usually caused by a physical substance – molecules light enough to evaporate and be carried on air currents to the nose. The sensory cells in the nose convert a chemical signal – the molecule – into an electrical signal (a nerve impulse) that travels up the olfactory nerves to the brain for interpretation. Its material dependence tensions other characteristics such as fluidity and adaptation, creating an emerging context to elaborate other patterns and models of territorial occupancies.

Natural odours are composed of a large number of molecules – roses, for instance, release 172 different odour molecules. Nonetheless, the most dominant of these determine which sites on the membrane will react the most strongly, while the other substances make secondary contributions to the scent. Sobel states,

We uncovered a clear correlation between the pattern of nerve reaction to various smells and the pleasantness of those smells. As in sight and hearing, the receptors for our sense of smell are spatially organized in a way that reflects the nature of the sensory experience. (apud Weizmann Institute 2011) [2]

In addition, the findings confirm the idea that people's experience of smells as pleasant or unpleasant is hardwired into physiology, and not purely the result of individual preference. The researcher does not discount the idea that individuals may experience smells differently. He theorizes that cultural context and personal experience may cause a certain amount of reorganization in the smell membrane over a person's lifetime. This means that a smell can trigger an odour perception – the expectations alter the perception of actual odours; 'odours we think are benign – pleasant, fade from awareness, while those we believe to be hazardous – unpleasant, hold our attention and stay strong. [...] Thus, smells do not happen to a passive nose alone' (Gilbert 2008: 89-90) [3]. The brain actively determines the physical and cognitive aspects of odour perception, controlling how much scent enters the nose and the intensity of smelling; some interpretation of that smell, based on context cues and personal history, materializes behavioral responses. It means that the nose and the brain constantly reshape the awareness of the smellscape while people signify it differently according to cultural and social situations.

Smell and language have a complex relationship. According to Gilbert,

Strictly speaking, smells exist only in our heads. Molecules exist in the air, but we can only register some of them as 'smells'. Odours are perceptions, not things in the world. The fact that a molecule of phenylethyl alcohol smells like rose is a function of our brain, not a property of the molecule. (2008: 25) [3]

For many animals, a smell is a call action, a trigger for a biologically hardwired survival response; in contrast, human cognitive abilities codify smells into symbols and make them signify. Gilbert states that 'Physical equipment – size of brain areas, number of nerve cells or receptor types – may be less important than what the brain does with the information once it arrives' (2008: 66) [3].

It is useful to distinguish the types of odour. According to Howes et al. (1994) [4], 'an odour can be either natural (for example, body odour), manufactured (for example, perfume), or symbolic (for example, the belief that each race has a distinct odour – a scientifically untenable proposition)'. The attempt to classify the use of smell is determinant to think about perceiving and reading the world – human interactions. That is, it refers to the use of odours in ritual and everyday contexts, often with the perspective of transforming and reshaping the world.

Smells are both carried on the breath and taken in by the breath as it provides life-giving air to the body. Body fluids, also commonly associated with the life force, all have distinctive odours as well. These bodily odours, emanating as they do from the interior of a person, give the impression of conveying the person's essence, or essential being. (Classen et al. 1994: 16) [5]

According to Howes et al. it is possible to define

a cultural olfactory classification based on the uses of odours: classifying people, animals, and plants by their natural odour and/or by the symbolic odours attributed to them (example: different races each have a different smell); classifying groups within a society (examples: men and women, children and adults); classifying spaces, domains, universes by reference to the environmental odour of different territories; establishing a valued system based on olfactory symbolism (example: characterizing certain odours as good or bad and assigning them to different beings or states in order to signify). (1994) [4]

The first example is the Andaman Islanders' date calendar based on biological plants cycle; they have named the different periods of their year according to the fragrant flowers that are in bloom at different times. 'Their year is thus a cycle of odours and their calendar, a calendar of scents' (Classen et al. 1994: 105) [5]. The Desana tribe, of the Amazonian rainforest region of Colombia, believes that each tribal group has its own characteristic odour, determining a characteristic territorial scent; men and women also have different characteristic odours. Thus, 'the smellscape of their environment consists of a variety of distinct olfactory zones criss-crossed by the different scent trails of the people, animals and plants which live in them' (Classen et al. 1994: 99) [5]. While most people find the odours of burning and decay unpleasant, the Dasanetch, a farming and cattle-herding people of Ethiopia, recognize that both bad and good smells are necessary to the rhythm of time and life, and that one olfactory season prepares the way for the next (Classen et al. 1994: 105) [5]. Among the Brazilian Bororo tribe, living in the Mato Grosso region of Brazil, the two basic smells, putrid and sweet, signify the two basic cosmic forces: life and spirit. This simple olfactory division determines the structure of Bororo beliefs and practices concerning the body, the social and natural orders, and the spirits (Classen et al. 1994: 102) [5]. From those distinct social structures it is possible to comprehend that olfactory codes continue to be allowed to recreate hierarchies at a semi-subconscious or subconscious level. The cultural difference is the smell, as the dominant sense to orient social bonds, to determine space-time relationships, and to exhibit behaviours which we call territoriality. In so doing, people use odours to distinguish between one space or distance and another.

2 Scent Marks and Maps

Focusing on odours and space relationships, several projects are now presented. The physical dimension is not a static area within which things happen structured by senses, but a dynamic environmental flow evoked by smells and odours. The proposal of projects is to situate the local through the scents and to potentialise other modes of behaving and being in the city.

The Scents of Space artwork is a collaborative project with Usman Haque, Josephine Pletts and Dr Luca Turin. The group presented smells used spatially to create fragrance collages; their intention was to form scent zones and borders that are

configurable on the fly. Considering the boundary as a static space in time, the border is a dynamic zone that accepts exchanges while configuring its blur limits.

The installation is a simple translucent enclosure, nine metres in length, which glows inwardly during the day and outwardly at night. Smooth and continuous laminar airflow within the exhibition space is generated by an array of fans and controlled by a series of diffusion screens (Figure 1). Computer-controlled fragrance dispensers and careful air control enable parts of the space to be selectively scented without dispersal throughout the entire space. Smells are emitted in response to people's movements, and travel slowly through the space until the visitors choose to mingle the fragrances with their body movements.

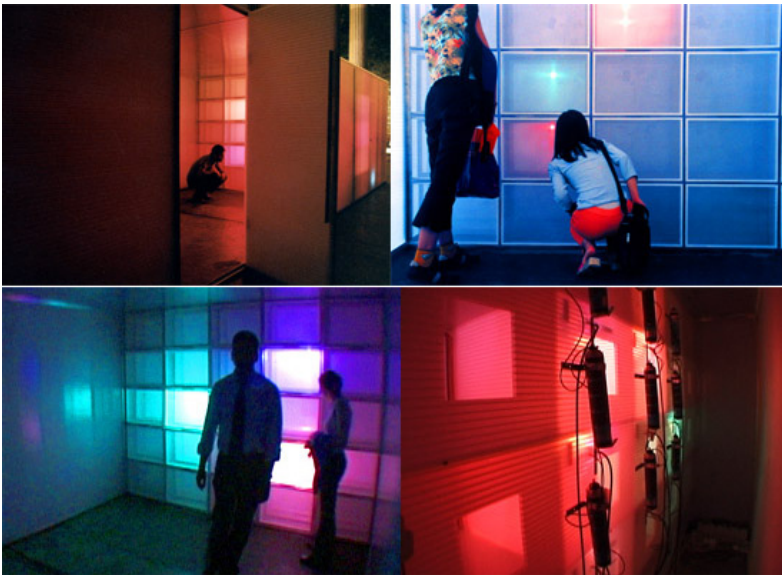


Fig. 1. Scents of Space

(<http://www.haque.co.uk/scentsofspace.php>)

The same intention of exploring the evocative nature of the olfactory senses can be seen in Rion Willard's project, named *Scents of Space*, which sought to investigate how spatial perception is coloured and layered by people's memory. Using a series of delicate wind-operated devices, spaces from the past were reintroduced into the Shoreditch Triangle through smells and aromas that would have once existed in these locations.

Jenny Marketou with her work *Smell It: A Do-It-Yourself Smell Map* (2008) created an interactive visitor project in which participants are given a street map and then invited to walk around the neighbourhood to record their olfactory experiences. Back in the gallery, viewers can add their odorous encounters to a wall-sized, collectively drawn map to show the diversity of subjective responses to smell and the shifting of the neighbourhood smellscape from one day to the next (Figure 2).



Fig. 2. Smell It: A Do-It-Yourself Smell Map, 2008
 (http://www.jennymarketou.com/works_2008_6.html)

Another urban experience for developing a scent narrative is the New York Times online map (Figure 3). The author, Jason Logan, walked along the streets by nose, exploring combinations of day and night smells in different neighbourhoods, liberated by the heat of summer. The shifts and transitions not only help to locate him in the city but add zest to his everyday life. For him

some prosaic scents recurred (cigarette butts; suntan lotion; fried foods); some were singular and sublime (a delicate trail of flowers mingling with Indian curry around 34th Street); while others proved revoltingly unique (the garbage outside a nail salon). Some smells reminded me of other places, and some will forever remind me of New York. (2009) [6]

The Japanese website, named Nioibu [i] – the smell club, and its proposal of pinpointing distinct odours throughout the world inspired other projects to catalogue smells according to specific urban areas, such as the Great British Smell Map [ii], New York Subway Smell Map and smell maps for the cities of Minneapolis and St Paul in Minnesota.

Odours lend character to objects and places, making them distinctive, and easier to identify and remember. They are immediate, local and can bond people with their environments. Therefore, considering scent marks as a medium may also reveal hidden elements of space and place and facilitate the questioning of visual assumptions or messages; people, using ambient qualities of scents, can immerse, persuade, mislead, or create topological experiences.

Theorizing embodied geographies, Kate McLean has developed sensory maps of several cities (Figure 4) ‘to seek alternative platforms for meaningful communication, including multi-sensory, non-visual and the stimulation of personal memory through the creation of ambiance’ (McLean 2012) [7]. Scents create physical borders and constitute topological maps since their inner chemical characteristics of fluidity and adaptation evoke exchanges and influences from the neighborhood.

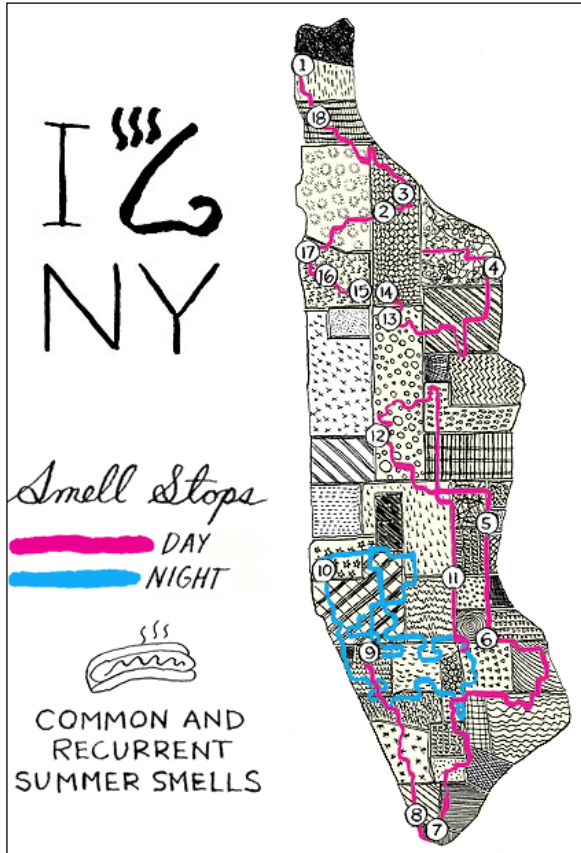


Fig. 3. Scents of the City of New York

(<http://www.nytimes.com/interactive/2009/08/29/opinion/20090829-smell-map-feature.html?th&emc=th>)

Relating humans and spaces as cross-cultural interactions, Hall (1990) [8] identified eight dimensions of proxemic behaviours. In essence, Hall's proxemics studies features of physical space maintained between interactants without being aware of it, and the sense of smell has a high potential capacity of promoting these. For him, the olfaction code – a mode of presence and degrees of body and space odours, includes aspects of nonverbal behaviours determined by the physical distance too. Olfaction seems to provide a more direct and less premeditated encounter with the environment; and one which cannot be turned on and off. It provokes an unmediated sense of the surrounding townscapes.

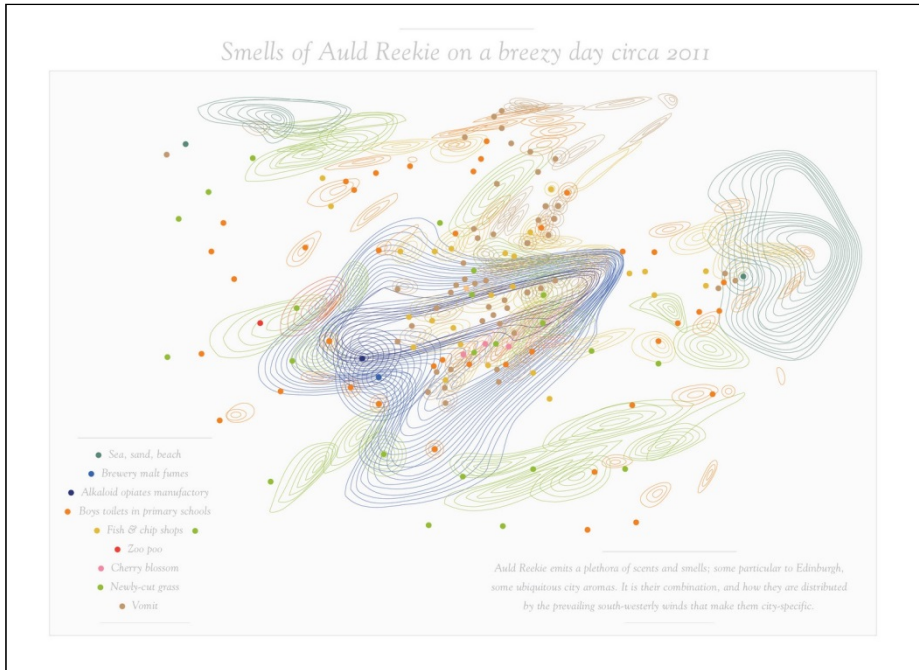


Fig. 4. Scents of the city of Glasgow, August 2012

(http://www.sensorymaps.com/maps_cities/glasgow_smell.html)

3 Final Considerations

Smells are invested with cultural values and comprehended as a means of and model for defining and interacting with the world. According to Haque (2004) [9], people when related to smell experiences can have the ability to organize spatial experiences, and so, to signify modes of behaving in the world. Reaffirming, Rodaway (1994: 62) assumes ‘the role of smell in geographical experience, such as organization of space, spatial relationships, locatedness, orientation in space, and characterization or senses of place’ [10].

Positioned in both personal and shared collective experiences, projects presented evoke a kind of multisensory rapture, in order to commune in memory, association and understanding. Some visual and others not, topological maps are results of those experiences and ask another attitude from participants to embody the physical space. So, space perception is not only a matter of what can be perceived but what can be screened out, and the olfaction is another perspective to access the world.

Olfactory classification systems produce meanings, specific logics, and these codes are local rather than universal. Each system can only be studied in its actual context, and it is necessary to consider the integration among other senses – visual, audible, and tactile. Rodaway (1994: 36-37) [10] further suggests that there are five distinct ways in which different senses are interconnected with each other to produce a sensed environment: co-operation between the senses; a hierarchy between different senses, as with the visual sense during much of the recent history of the West; a sequencing

of one sense which has to follow on from another sense; a threshold of effect of a particular sense which has to be met before another sense is operative; and reciprocal relations of a certain sense with the object which appears to afford it an appropriate response. So, the idea of osmology [11] and its distinct related schemes of sensory symbolism reassure that odour-meanings are linked to colour-meanings, and visual-meanings to sound-meanings, and so on.

Another important consideration is the impossibility of containing the odours, determined by their chemical characteristics; the specific condition creates an aesthetic potential of escaping and crossing physical boundaries, as molecules blend different elements into olfactory wholes. Smells and odours evoke reactions from people, questioning privacy, discrete visions and superficial interactions.

4 Notes

[i] <http://www.nioibu.com/>

[ii] <http://theridiculant.metro.co.uk/2009/01/help-us-create-the-great-british-smell-map.html>

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Subunit Modeling for Japanese Sign Language Recognition Based on Phonetically Depend Multi-stream Hidden Markov Models

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Abstract. We work on automatic Japanese sign Language (JSL) recognition using Hidden Markov Model (HMM). An important issue for modeling sign is that how to determine the constituent element of sign (i.e., subunit) like “phoneme” in spoken language. We focused on special feature of sign language that JSL is composed of three types of phonological elements which is hand local information, position, and movement. In this paper, we propose an efficiently method of generating subunit using multi-stream HMM which is correspond to phonological elements. An isolated word recognition experiment has confirmed the effectiveness of our proposed method.

Keywords: Hidden Markov models, Sign language recognition, Subunit, Phonetic systems of sign language.

1 Introduction

Sign language is the visual language of deaf people. It is also natural language, different in form from spoken language. To resolve a communication problem between hearing people and deaf, projects for automatic sign language recognition (ASLR) system is now under way[1,6]. Sign is represented by various combinations of posture or movement of the hands, eyes, mouth, and so on. These representations of sign are happen both sequentially and simultaneously. There remains a need for an efficient method that can modeling such simultaneous events.

In this paper, an important issue to modeling sign is that how to determine the constituent element of sign (i.e., subunit) as similar as phoneme in spoken language. We addressed the method to generate optimal subunit automatically. In order to achieve it, we adopt the technique for statistical modeling based on hidden Markov models (HMMs). In addition, sign language has own system and it is therefore desirable to take account its language structure as well as possible. We also focused on some linguistic feature of sign to classify subunit more effectively by using phonetically depend HMMs. An isolated sign recognition experiment using RWC video database has confirmed the effectiveness of our proposed method.

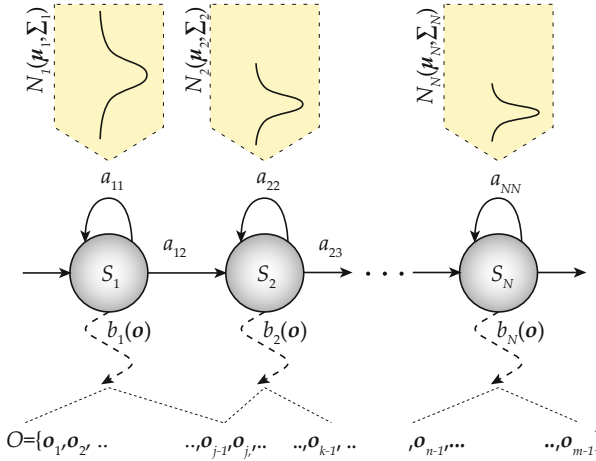


Fig. 1. An example of left-to-right hidden Markov model

2 Methodology

2.1 Hidden Markov Models

Goodness has been proven with the ability of HMM modeling time-varying signals such as speech. Due to similarity between speech and sign language as time-series pattern, HMM is often employed in automatic sign language recognition [9,10,12]. HMM is a model composed of N states $S = (S_1, S_2, \dots, S_N)$ connected with each other based on the state-transition probability $a_{ij} = P(q_t = i | q_{t-1} = j)$ from state S_j to S_i . Each state outputs observation vector \mathbf{o} based on probability distribution $b_i(\mathbf{o})$. The parameter of HMM λ is defined as $\lambda = (A, B, \pi)$ using $A = \{a_{ij}\}_{i,j=1}^N$, $B = \{b_i(\cdot)\}_{i=1}^N$, and initial state-transitional probabilities $\pi = \{\pi_i\}_{i=1}^N$. As the output probability distribution, a single Gaussian distribution was employed. Thus the mean vector $\boldsymbol{\mu}_i$ and covariance matrix \mathbf{U}_i of Gaussian distribution are state parameters of HMM.

Model parameters λ , which is trained by the given training sequence $\mathbf{O} = (\mathbf{o}_1, \mathbf{o}_2, \dots, \mathbf{o}_T)$ based on the equation $\lambda_{\max} = \underset{\lambda}{\operatorname{argmax}} P(\mathbf{O} | \lambda)$ is normally calculated by Baum-Welch algorithm. The maximum likelihood state sequence concerning the \mathbf{O} is represented as $\mathbf{Q} = (q_1, q_2, \dots, q_T)$. It is given by maximizing $P(\mathbf{O}, \mathbf{Q} | \lambda)$, and is effectively calculated by Viterbi algorithm. Vector sequence \mathbf{O} is segmented to be assigned to each state, and $P(\mathbf{O}, \mathbf{Q} | \lambda)$ is the evaluation value about \mathbf{O} calculated from λ .

2.2 Generation of Subunits Composing Sign HMMs

Each sign follows a variety of motion, but similar short motions are partly included. In this paper, these common elements referred to above are called subunits, and are regarded as fundamental component for all signs like the phoneme dealt with in a spoken language.

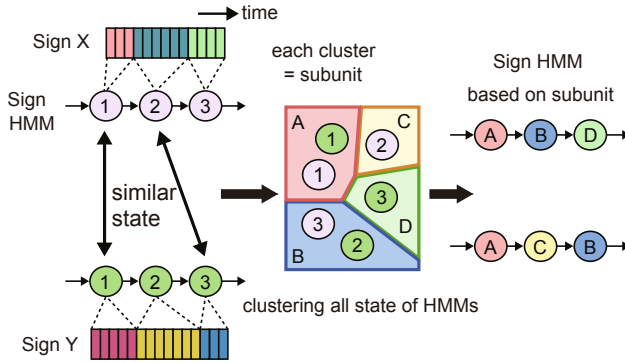


Fig. 2. How to obtain the subunits

Figure 2 shows the process of generating the subunit by using HMMs. Roughly, our method consists of two step in order to obtain subunits. In the first step, several isolated sign HMMs are trained separately as initial model. A sign HMM makes approximation to the sequence of sign motion as a chain of small number of states. Because a particular segment in the sign corresponds to each state, the similar states over different signs can be regarded as a common element of the sign. In the second step, subunits are obtained by applying clustering technique on all states of isolated sign HMMs. At this stage, inter-cluster distance is defined as the maximum within the distance between the two states belonging to two different clusters. And inter-state distance is defined as Eq. 1. i and j are state number, V is the number of dimensions, μ and σ are mean and variance of state parameter.

$$d(i, j) = \sqrt{\frac{1}{V} \sum_{k=1}^V \frac{(\mu_{ik} - \mu_{jk})^2}{\sigma_{ik}\sigma_{jk}}} \tag{1}$$

We adopted tree based clustering algorithm in order to tie the states. Finally, the output distributions across different sign HMMs are shared with each other when they has visual pattern similarity.

2.3 Phonetic Depend Subunit

In order to handle simultaneous events, we adopt some linguistic feature of Japanese Sign Language (JSL). Dr. Kanda said that manual behavior in JSL can be represented by three types of phonological elements, which are hand position, movement and shape [7,8]. These three elements are happened simultaneously. For this reason, it was difficult to separate subunit correctly if sign feature parameter was represented as a single stream. In order to solve this problem, a multi-stream HMM are applied to build subunit. The feature vector of each frame is splitted into three phonetic stream, and a multi-stream isolated sign HMM are trained for each word. Phonetic depend subunits are obtained by clustering each state of multi-stream HMMs as same manner as

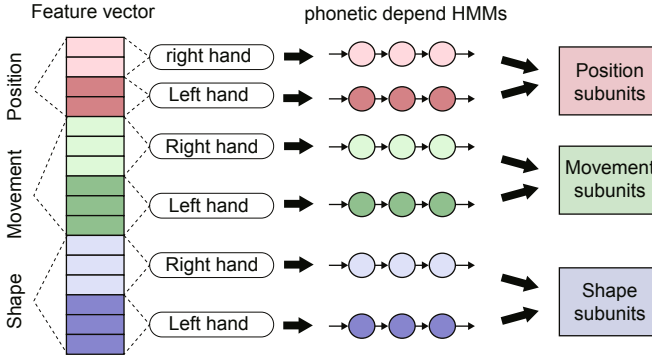


Fig. 3. Phonetic depend subunit modeling

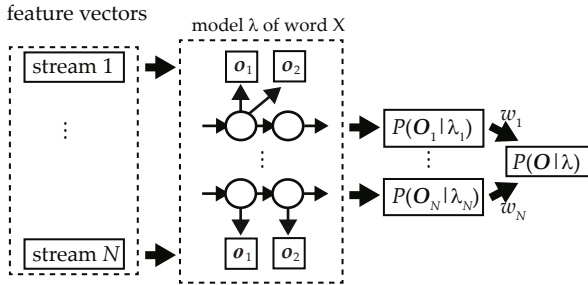


Fig. 4. Recognition method by integrating likelihoods calculated from each stream

described in section 2.2. Because clustering are applied for each phonetic element, partially similar state will be merged and generate subunit effectively.

Recognition process using multi-stream HMM is performed as shown in Figure 4. The integrated likelihood is calculated as in Equation 2. It is noted that $P(O_s|\lambda_s)$ means the likelihood in the stream s against feature vector O_s . And w_s represents the weight parameters between the streams.

$$P(O | \lambda) = \prod_{s=1}^S P(O_s | \lambda_s)^{w_s}, \sum_s w_s = 1 \tag{2}$$

3 Experiment

As an evaluation experiment, isolated sign recognition is conducted. We used three kind of modeling method:

- **Conventional Method:** Typically left-to-right HMM for each sign which are trained by several utterances. We also used single-stream HMM and multi-stream HMM.

Table 1. Details of RWC multi-modal database (1998 version)

Number of signer	4 (2 males and 2 females)
Number of sign	308
Number of data	8 times per sign (4 × 2 takes)
image size	320 × 240 pixel
frame rate	29.7 frame / sec (NTSC)
Number of frame per sign	56 ~ 144 frame

Table 2. Details of experiment conditions

	Conventional	Proposed 1	Proposed 2
Number of sign	1003 set		
Train Test	train: 600 sample 3 person × 2 takes × 100 sign) test: 200 sample 1 person × 2 takes × 100 sign) leave-one-out cross validation (4 set)		
Feature parameters	location: hand position (4 dim.) movement: Δ, Δ^2 (4 + 4 dim.) hand shape: PCA coefficient of hand region (first 16 components) $+\Delta + \Delta^2$ (16 × 3 dim.)		
Stream weight	$position : movement : shape = 0.25 : 0.60 : 0.15$ $lefthand : righthand = 1 : 1$		
Number of state	5 ~ 35	25	25 per stream
Number of subunit	–	100 ~ 1,200	100 ~ 1,200 per stream

- **Proposed Method 1:** Each sign is represented as subunits concatenation
- **Proposed Method 2:** Each sign is represented as phonetic depend subunits concatenation

3.1 Database and Experimental Settings

The database used in the experiment is the RWC video database of the isolated signs of JSL[13]. Table 1 shows the details of the database. The database contains the data of 4 signers, each signer performs the same set of 308 signs, and recording is individually done twice with respect to each signer. In this experiment, data for 3 signers (6 utterances for every sign) are used for training HMMs, whereas data for a remaining single signer are used for recognition by taking up all the combinations available within this constraint. The number of the subunits generated by the clustering is changed from 100 to 1,200 with 100 increments in between. Other experiment details are shown in Table 2.

In order to obtain hand position and movement, the hand tracking algorithm finds the centroid of a moving hand region. Hand shape feature is also obtained by the well-known Eigenface method as applied to detected hand region images[16]. We used 60 dimensional feature vector sequence as sign representation. Δ is calculated by Eq. 3.

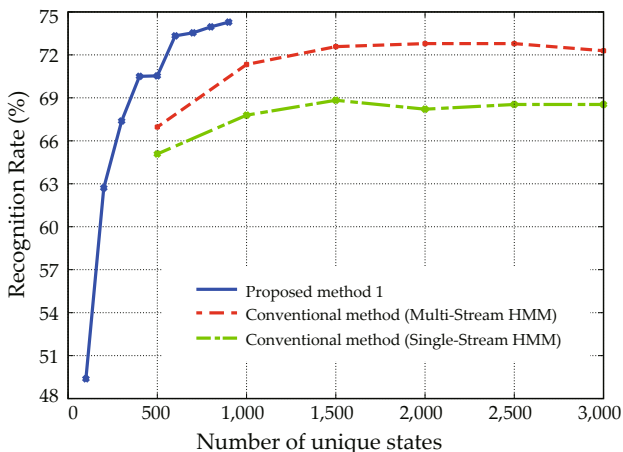


Fig. 5. An experiment result of conventional method and proposed method 1

Where $c(t)$ is a coordinate of hands at time t , θ is fixed to be 1 in this experiment. The same formula is applied to Δ obtain Δ^2 . These parameters called dynamic feature are generally used in speech recognition.

$$\Delta c(t) = \frac{\sum_{\theta=1}^{D_w} \theta(c(t + \theta) - c(t - \theta))}{2 \sum_{\theta=1}^{D_w} \theta^2} \tag{3}$$

3.2 Result

Figure 5 shows the result of the word accuracy for conventional and proposed method 1. The horizontal axis represents the model complexity. It means the granularity of classification for state of HMMs. If this value is small, small number of subunit and more generalized subunit are obtained. The experimental result shows that subunit model can get a better recognition performance than conventional method as phonetic independent model. In addition, higher recognition performance is also achieved by small number of subunits.

Figure 6 also shows the result of the word accuracy for proposed method 1 and 2. It is noted that the result of method 1 in both figure 5 and 6 is identical. As the result, our proposed method 2 is superior to the method 1.

We also conducted a survey with varying number of subunits for each stream. The number of the subunits generated by the clustering is changed from 100 to 900 for each stream (the number of possible combination is 729). Figure 7 shows the result of recognition accuracy in case of hand shape subunit number at 200, 400, 600, and 800. This result shows the importance of hand shape information. Therefore, It is necessary to optimize the number of sub-units in each stream.

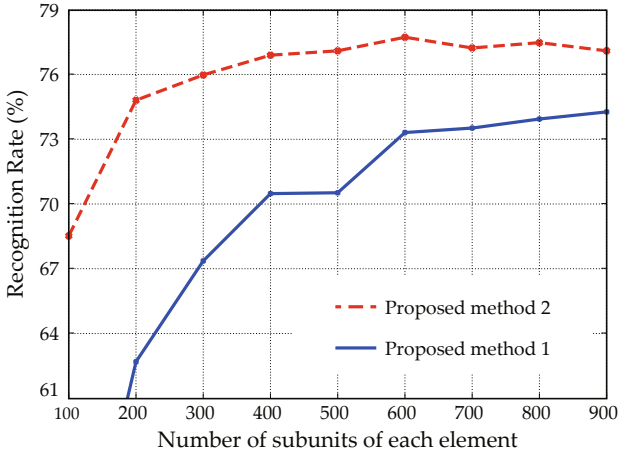


Fig. 6. Sign recognition accuracy of proposed method 1 and 2

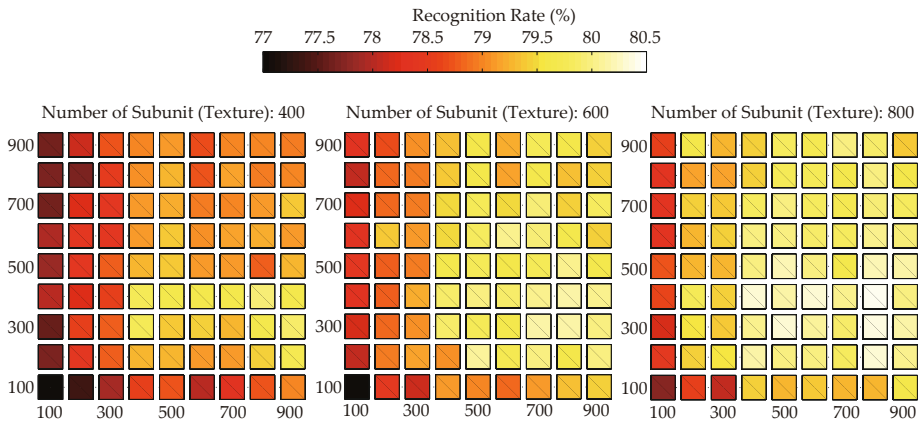


Fig. 7. Research of the number of subunits for each phonological category

4 Conclusion

In this paper, we presented a subunit modeling in order to take into account simultaneous events of JSL. The key point of our method is automatic subunit generation technique using phonetic depend multi-stream HMM. Experimental results on RWC JSL video database showed effectiveness of our proposed method and improvements in isolated sign recognition accuracy. In addition, higher recognition performance is also achieved by small number of model parameters.

Our feature work is stream weight optimization in order to adjust a balance of each sign. And, not only hand movement but hand shape, facial expression etc. are important for sign language essentially, thus more appropriate feature of sign should be used.

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A Biological and Real-Time Framework for Hand Gestures and Head Poses

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Abstract. Human-robot interaction is an interdisciplinary research area that aims at the development of social robots. Since social robots are expected to interact with humans and understand their behavior through gestures and body movements, cognitive psychology and robot technology must be integrated. In this paper we present a biological and real-time framework for detecting and tracking hands and heads. This framework is based on keypoints extracted by means of cortical V1 end-stopped cells. Detected keypoints and the cells' responses are used to classify the junction type. Through the combination of annotated keypoints in a hierarchical, multi-scale tree structure, moving and deformable hands can be segregated and tracked over time. By using hand templates with lines and edges at only a few scales, a hand's gestures can be recognized. Head tracking and pose detection are also implemented, which can be integrated with detection of facial expressions in the future. Through the combinations of head poses and hand gestures a large number of commands can be given to a robot.

Keywords: Hand gestures, Head pose, biological framework.

1 Introduction

With the advent of newer and more complex technologies has come an increasing effort to make them easy to use. Some years ago computers were only used by specialized technicians, but nowadays even young children and elderly can use complex technology with great ease. The way how we use computers, cell phones and other devices has drastically changed because we began to research and implement natural ways of interacting with them. Part of that research effort consists of the analysis of humans and their actions such that machines and software may be designed to match our natural behaviors. One of the areas of interest for such interpretation is the recognition of human gestures, as they are used as a natural, intuitive and convenient way of communication in our daily life. The recognition of hand gestures can be widely applied in human-computer interfaces and interaction, games, human-robot interaction, augmented reality, etc.

Gesture analysis and recognition has been a popular research field for some years and numerous approaches have been developed. Interest in this area has

spiked since the advent of low-cost and very reliable depth-based sensors like the Kinect [12,15]. Although many gesture-based interfaces have been developed, to the best of our knowledge none of them is biologically inspired. Most of them are based on traditional methods from computer vision.

A method for hand tracking and motion detection using a sequence of stereo color frames was proposed by Kim et al. [6]. Another approach, which consists of the recognition of gestures by tracking the trajectories of different body parts, was developed by Bandera et al. [1]. In this method, trajectories are described by a set of keypoints and gestures are characterized through global properties of those trajectories. Suk et al. [13] devised a method for recognizing hand gestures in continuous video streams by using a dynamic Bayesian network. Suau et al. [12] presented a method to perform hand and head tracking using the Kinect. One- and two-handed gestures are also recognized by analysing the trajectories of both hands. Also using the Kinect, Li [15] presented a method that is able to recognize nine different gestures and identify fingers with high accuracy.

Although some methods do work fairly well for a specific purpose, they may not be suitable for a more profound analysis of human behavior and gestures because these are very complex. In this paper we complement a biological and real-time framework for detecting and tracking hands [4] with head movements. This framework is based on multi-scale keypoints detected by means of models of cortical end-stopped cells [7,9]. Cell responses around keypoints are used to classify the vertex type, for creating annotated keypoints [3]. The model has been extended by multi-scale line and edge information, also extracted by models of cortical cells. We also developed a model for optical flow based on annotated keypoints [4]. By integrating optical flow and annotated keypoints in a hierarchical, multi-scale tree structure, deformable and moving objects can be segregated and tracked over time.

Hand and gesture recognition is obtained by using a simple line and edge template matching algorithm which relates previously stored templates with the acquired images across two scales. By using only five hand templates with lines and edges obtained at two different scales, a hand's gestures can be recognized. By tracking hands over time, false positives due to complex background patterns can be avoided. We also focus on head movements because they too can be an important part of human-robot interaction. When combined with the recognition of facial expressions (ongoing work) it will provide invaluable information for natural human-computer and human-robot interaction. Our framework addresses the most common movements: leaning left/right and nodding (up/down) (shaking left/right is ongoing work). These can be used to give feedback to a robot, expressing doubts or affirming or criticizing actions, respectively. By combining a few head movements with hand gestures, a large number of instructions can be given.

The developed system does not require any prior calibration. Since the cell models have been optimized for running on a GPU, a speed of about 10 frames per second can be obtained, which is fast enough for real-time applications.

2 Multi-scale Lines, Edges and Keypoints

In cortical area V1 we find simple, complex and end-stopped cells [9], which are thought to play an important role in coding the visual input: to extract multi-scale lines and edges and keypoint information (keypoints are line/edge vertices or junctions, but also blobs).

Responses of even and odd simple cells, corresponding to the real and imaginary parts of a Gabor filter [9], are denoted by $R_{s,i}^E(x, y)$ and $R_{s,i}^O(x, y)$, i being the orientation (we use $N_\theta = 8$). The scale s is given by λ , the wavelength of the Gabor filters, in pixels. We use $4 \leq \lambda \leq 20$ with $\Delta\lambda = 4$. Responses of complex cells are modeled by the modulus $C_{s,i}(x, y) = [\{R_{s,i}^E(x, y)\}^2 + \{R_{s,i}^O(x, y)\}^2]^{1/2}$.

The basic scheme for line and edge detection is based on responses of simple cells: a positive or negative line is detected where R^E shows a local maximum or minimum, respectively, and R^O shows a zero crossing. In the case of edges the even and odd responses are swapped. This gives four possibilities for positive and negative events. An improved scheme [9] consists of combining responses of simple and complex cells, i.e., simple cells serve to detect positions and event types, whereas complex cells are used to increase the confidence. Lateral and cross-orientation inhibition are used to suppress spurious cell responses beyond line and edge terminations, and assemblies of grouping cells serve to improve event continuity in the case of curved events. We denote the line and edge map by $LE_s(x, y)$.

Keypoints are based on cortical end-stopped cells [7]. They provide important information because they code local image complexity. Furthermore, since keypoints are caused by line and edge junctions, detected keypoints can be classified by the underlying vertex structure, such as K, L, T, + etc. This is very useful for most matching problems: object recognition, optical flow and stereo disparity. In this section we briefly describe the multi-scale keypoint detection and annotation processes. The original model has been improved such that multi-scale keypoints can be detected in real time [14].

There are two types of end-stopped cells, single and double. These are applied to $C_{s,i}$ and are combined with tangential and radial inhibition schemes in order to obtain precise keypoint maps $K_s(x, y)$. For a detailed explanation with illustrations see [7] and [14].

In order to classify any detected keypoint, the responses of simple cells $R_{s,i}^E$ and $R_{s,i}^O$ are analyzed, but now using $N_\phi = 2N_\theta$ orientations, with $\phi_k = k\pi/N_\theta$ and $k = [0, N_\phi - 1]$. This means that for each of the 8 simple-cell orientations on $[0, \pi]$ there are two opposite analysis orientations on $[0, 2\pi]$, e.g., $\theta_1 = \pi/N_\theta$ results in $\phi_1 = \pi/N_\theta$ and $\phi_9 = 9\pi/N_\theta$. This division into response-analysis orientations is acceptable according to [5], because a typical cell has a maximum response at some orientation and its response decreases on both sides, from 10 to 20 degrees, after which it declines steeply to zero; see also [2].

Classifying keypoints is not a trivial task, mainly because responses of simple and complex cells, which code the underlying lines and edges at vertices, are unreliable due to response interference effects [2]. This implies that responses must be analyzed in a neighborhood around each keypoint, and the size of the neighborhood must be proportional to the scale of the cells. The validation of the line and

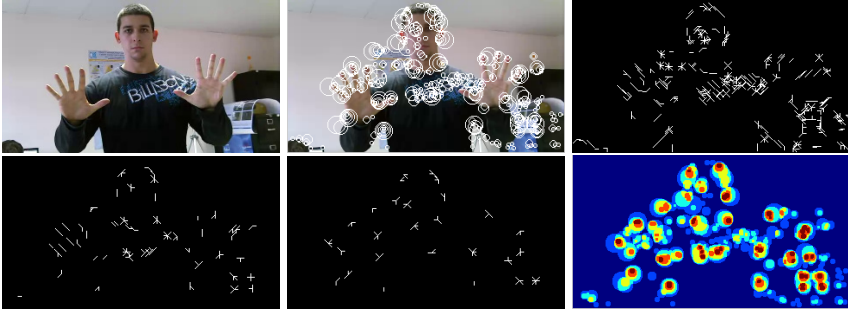


Fig. 1. Left to right and top to bottom: input frame, keypoints detected at all 5 scales, annotated keypoints at scales $\lambda = 4, 8$ and 12 , and the frame’s saliency map where red indicates higher and blue lower saliency

edge orientations which contribute to the vertex structure is based on an analysis of the responses of complex cells $C_{s,i}(x, y)$. At a distance of λ , and for each direction ϕ_k , responses in that direction and in neighboring orientations ϕ_{k+l} , with $l = \{-2, -1, 0, 1, 2\}$, are summed with different weights equal to $1/2^{|l|}$. After this smoothing and detection of local maxima, each keypoint is then annotated by a descriptor of 16 bits which codes the detected orientations. In the case of keypoints caused by blobs with no underlying line and edge structures, all 16 bits are zero.

This method is an improvement of the previous method [3]. It provides a more detailed descriptor of the underlying line and edge structures, with a significant increase in performance and with a negligible loss of precision. The first five images in Fig. 1 illustrate keypoint detection and annotation at the given scales. For more illustrations see [7].

3 Optical Flow

Keypoint detection may occur in cortical areas V1 and V2, whereas keypoint annotation requires bigger receptive fields and could occur in V4. Optical flow is then processed in areas V5/MT and MST, which are related to object and ego motion for controlling eye and head movements.

Optical flow is determined by matching annotated keypoints in successive camera frames, but only by matching keypoints which may belong to a same object. To this purpose we use regions defined by saliency maps. Such maps are created by summing detected keypoints over all scales s , such that keypoints which are stable over scale intervals yield high peaks. In order to connect the individual peaks and yield larger regions, relaxation areas proportional to the filter scales are applied [7]. Here we simplify the computation of saliency maps by simply summing the responses of end-stopped cells at all scales, which is much faster and yields similar results. Figure 1 (bottom-right) illustrates a saliency map.

We apply a multi-scale tree structure in which at a very coarse scale a root keypoint defines a single object, and at progressively finer scales more keypoints

are found which convey the object's details. For optical flow we use five scales: $\lambda = [4, 20]$ with $\Delta\lambda = 4$. All keypoints at $\lambda = 20$ are supposed to represent individual objects, although we know that it is possible that several of those keypoints may belong to a same object. Each keypoint at a coarse scale is related to one or more keypoints at one finer scale, which can be slightly displaced. This relation is modeled by down-projection using grouping cells with a circular axonic field, the size of which (λ) defines the region of influence, and this process continues until the finest scale is reached; see [3].

As mentioned above, at a very coarse scale each keypoint – or central keypoint CKP – should correspond to an individual object [7]. However, at the coarsest scale applied here, $\lambda = 20$, this may not be the case and an object may cause several keypoints. In order to determine which keypoints could belong to the same object we combine saliency maps with the multi-scale tree structure.

At this point we have, for each frame, the tree structure which links the keypoints over scales, from coarse to fine, with associated regions of influence at the finest scale. We also have the saliency map obtained by summing responses of end-stopped cells over all scales. The latter, after thresholding, yields segregated regions which are intersected with the regions of influence of the tree. Therefore, the intersected regions link keypoints at the finest scale to the segregated regions which are supposed to represent individual objects.

Now, each annotated keypoint of frame i can be compared with all annotated keypoints in frame $i-1$. This is done at all scales, but the comparison is restricted to an area with radius 2λ instead of λ at each scale in order to allow for larger translations and rotations. In addition, (1) at fine scales many keypoints outside the area can be skipped since they are not likely to match over large distances, and (2) at coarse scales there are less keypoints, λ is bigger, and therefore larger distances (motions) are represented there. The matching process, as for building the tree, is now done top-down. Previously it was done bottom-up [3]. Due to the use of a more detailed descriptor for keypoint classification than in [3], matching keypoints at the coarsest scale provides sufficient accuracy to correctly match entire tree structures. An additional gain in performance is due to the reduced number of comparisons at finer scales, because of existing dependencies between keypoints in the branches of the tree structure. Keypoints are matched by combining three similarity criteria with different weight factors:

(a) The distance D serves to emphasize keypoints which are closer to the center of the matching area. For having $D = 1$ at the center and $D = 0$ at radius 2λ , we use $D = (2\lambda - d)/2\lambda$ with d the Euclidean distance (this can be replaced by dynamic feature routing [3,8]).

(b) The orientation error O measures the correlation of the attributed orientations, but with an angular relaxation interval of $\pm 2\pi/N_\theta$ applied to all orientations such that also a rotation of the vertex structure is allowed. Similar to D , the summed differences are combined such that $O = 1$ indicates good correspondence and $O = 0$ a lack of correspondence. Obviously, keypoints marked “blob” do not have orientations and are treated separately.

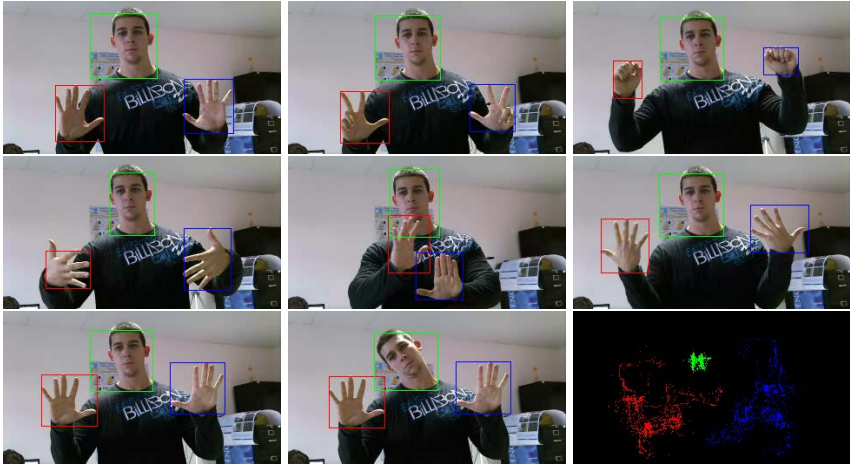


Fig. 2. The optical flow model applied to a person while performing several hand and head gestures. Hands and head are marked by their bounding boxes. The bottom-right image shows the combined centers of the boxes.

(c) The tree correspondence C measures the number of matched keypoints at finer scales, i.e., at any scale coarser than the finest one. The keypoint candidates to be matched in frame i and in the area with radius 2λ are linked in the tree to localized sets of keypoints at all finer scales. The number of linked keypoints which have been matched is divided by the total number of linked keypoints. This is achieved by sets of grouping cells at all but the finest scale which sum the number of linked keypoints in the tree, both matched and all; for more details see [3].

The three parameters are combined by grouping cells which can establish a link between keypoints in frame $i - 1$ and i . Mathematically we use the similarity measure $S = \alpha O + \beta C + \gamma D$, with $\alpha = 0.4$ and $\beta = \gamma = 0.3$. These values were determined empirically. The candidate keypoint with the highest value of S in the area (radius 2λ) is selected and the vector between the keypoint in frame $i - 1$ and the matched one in frame i is computed. Remaining candidates in the area can be matched to other keypoints in frame i , provided they are in their local areas. Keypoints which cannot be matched are discarded. Figure 2 shows a sequence with tracked hands by using optical flow.

4 Hand/Head Tracking and Gesture/Pose Recognition

To initialize the tracking and recognition process, it is only required that at the beginning the user stands still, looking straight ahead and showing the palms of both hands to the camera. As the first step in the processes that will be described in this section, we use skin color segmentation to detect both hands and the head as previously applied in [10]. If I is an input frame, we can use the following expression to get a binary skin image, I_s , where skin is marked in black

and all the rest is white: $I_s(x, y) = 0$ if $\varphi[I(x, y)] = 1$, otherwise $I_s(x, y) = 255$, where $\varphi = [(R > 95) \wedge (G > 40) \wedge (B > 20) \wedge ((\max\{R, G, B\} - \min\{R, G, B\}) > 15) \wedge (|R - G| > 15) \wedge (R > G) \wedge (R > B)]$, with $(R, G, B) \in [0, 255]$.

After obtaining the skin regions we can obtain three regions: left hand, right hand and head. Then we apply two filters: the first one is an erosion which removes small regions, and the second one is a dilation which makes the remaining regions more homogeneous. After this we apply a fast blob detection algorithm [10] to obtain the coordinates and sizes of the three biggest skin regions. The region with the highest y coordinate will be considered as being the head. The system will use the head blob's dimensions to calculate the reference ratio $R_r = h/w$, with h the height and w the width, as a reference for the neutral pose. The detection of head poses is done like previously in [10]. We use five head poses: face straight forward, head up, head down, head leaning to the left and head leaning to the right. To detect the up and down poses we use a very simple method which consists of comparing the blob's actual ratio R_a , to an upper (U_{thr}) and a lower threshold (L_{thr}). The latter are determined from the reference ratio R_r , computed during the initialization: $U_{\text{thr}} = 1.1 \times R_r$ and $L_{\text{thr}} = 0.9 \times R_r$.

To detect the left- and right-leaning poses, two vertical lines, at distances $w/6$ and $5w/6$ inside the blob's box are considered. The average position of black pixels on each of these lines is calculated and the two resulting positions are used to detect the two poses: when the user leans the head to one side, the average positions will go up and down relative to the middle of the box ($h/2$). A minimum vertical distance MVD of $0.2 \times h$ between both positions was determined experimentally, such that small lateral movements can be ignored. The two poses are detected when (a) the vertical distance between the two positions is larger than the MVD, and (b) one of the positions is higher than $h/2$. The latter position determines the side of the movement: left or right.

While the head will normally be at a static location, hands may be constantly moving and therefore they must be tracked. To do that we employ the optical flow as explained in the previous section. The recognition of hand gestures is more complex than the detection of the head's poses. To recognize hand gestures, we need to use a single template, at a few different scales, of each gesture. The templates are previously prepared so that they are available for online matching when the system is working. To prepare the templates, we apply the previously described line- and edge-extraction algorithm at two different scales, and then dilate the resulting maps to make the templates more robust against small differences between them and the real frames containing moving hands. Each template is a binary image which contains white lines against a black background. Example templates are shown in Fig. 3.

To perform the template matching in a fast way, we only compare the templates with the regions tracked by optical flow. This way no processing time is wasted in other image regions. The matching process is done in two steps: (a) direct template matching and (b) template density matching. In step (a) we take a tracked region and apply the same process that was used to prepare

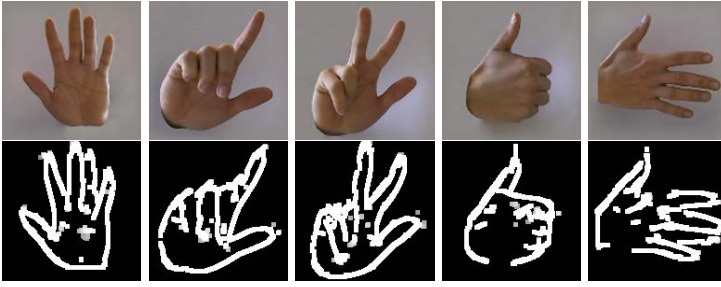


Fig. 3. Top: five hand gestures. Bottom: their dilated templates at scale $\lambda = 8$.

the templates. Then we shift each template over the tracked region and at each shift position we compare them, pixel by pixel, and count the number of white pixels, P_w . Basically this is a 2D correlation process. We divide P_w by the total number of white pixels in the template, P_{wt} , and store the resulting value in a probability map at the center position of the (shifted) template. The result is a 2D histogram or correlation matrix in which higher values indicate a better correspondence between the tracked region and the template.

In step (b), template density matching, we verify whether the test region has the same ratio of white and black pixels as the template. This must be done because if only direct matching was used, some complex textures, for example on a (moving) T-shirt or (static) background can result in false detections of some templates. Again we use the shifting window with the same size of the template and, for each shift position, we calculate the ratio between the number of white pixels and the total number of pixels in the window, $R = W_p/T_p$, where W_p is the number of white pixels and T_p the total number of pixels. Like before, this ratio is stored in a similar probability map.

After these two steps we combine both maps for each template, giving a 70% weight to the first map and 30% to the second one. This yields a single probability map for each template. This process is applied at the two scales used ($\lambda = \{8, 12\}$), and the two probability maps are mixed prior to multi-scale recognition, thereby giving equal weights to the two scales. At this point we have a single but multi-scale probability map for each template. Every time that a value greater than a threshold value occurs ($T = 60$ was experimentally determined), the system considers that the gesture which corresponds to that map has been recognized, and at the peak location. When more than one gesture is recognized, only the one with the greatest probability value will prevail. Figure 4 illustrates the matching process (top) together with the detection of head poses (bottom).

5 Discussion

In this paper we presented a biologically inspired method for hand detection, tracking, and gesture recognition. By using optimized algorithms for the detection of keypoints plus lines and edges, and by selecting only a few scales, the

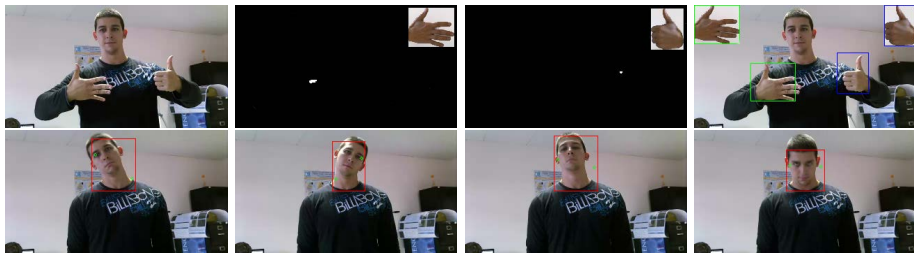


Fig. 4. The top row illustrates hand gesture recognition: input image, thresholded probability maps of the two detected gestures with their peaks in white, and the final result. The bottom row shows examples of the recognition of four head poses: right, left, up and down. Along the vertical edges of the bounding box, the two green points show the average location of skin-colored pixels.

method can run in real time. Even when using a cheap HD webcam, very good results can be obtained. This we expected due to our previous experience with cortical models: multi-scale keypoints, lines and edges provide very useful information to generate saliency maps for Focus of Attention or to detect faces by grouping facial landmarks defined by keypoints at eyes, nose and mouth [7]. In [11] we were able to use lines and edges to recognize facial expressions with success, and in [9] we have shown that lines and edges are very useful for face and object recognition. The method included here for the detection of head poses is not biological, but in principle we can integrate our methods for face detection and recognition of facial expressions.

Biologically inspired methods involve many filter kernels, here in eight orientations and at several scales. In order to achieve real-time processing, we only use five scales for optical flow and region segregation. For gesture recognition we use lines and edges at only two scales. The system's main limitation is the costly filtering. The optimized GPU implementation allows us to process at least 10 frames/s with a maximum resolution of 600×400 pixels and using at least 6 scales if coarser scales are used. The main bottleneck for using large images and fine scales is the 1 GByte of memory of the GPU, because of the Gaussian pyramid employed in the filtering.

Future work will focus on motion prediction, a process that occurs in cortical area MST. We also intend to increase the precision such that individual fingers can be detected in combination with a larger number of gestures. The ultimate goal is to apply 3D processing in the entire process, with emphasis on body language. This can be done by using cheap off-the-shelf solutions like a Kinect or two webcams with a biological disparity model.

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Challenges for Inclusive Affective Detection in Educational Scenarios

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Abstract. There exist diverse challenges for inclusive emotions detection in educational scenarios. In order to gain some insight about the difficulties and limitations of them, we have analyzed requirements, accommodations and tasks that need to be adapted for an experiment where people with different functional profiles have taken part. Adaptations took into consideration logistics, tasks involved and user interaction techniques. The main aim was to verify to what extent the same approach, measurements and technological infrastructure already used in previous experiments were adequate for inducing emotions elicited from the execution of the experiment tasks. In the paper, we discuss the experiment arrangements needed to cope with people with different functional profiles, which include adaptations on the analysis and results. Such analysis was validated in a pilot experiment with 3 visually impaired participants.

1 Introduction

Our current research framed in the MAMIPEC project (TIN2011-29221-C03-01) focuses on exploring the application of affective computing to develop accessible and personalized learning systems that consider a user context where appliances and devices are used to provide a richer and more sensitive user interaction [1]. To detect emotions from users' interactions in an e-learning environment, we designed an inclusive individual large-scale experiment aimed to record multiple measures (qualitative, self-reported, physiological and behavioral). The participation of users with disabilities in such experiment posed several challenges. For example, the logistics of the whole experiment was considered, including the accessibility of the informed consent or other relevant questionnaires that had to be filled out by the users. Also, the accessibility and usability aspects of the interaction with the hardware and software were taken into account (e.g. replacement of visual stimuli by some other ways of access—such as audio recordings—in visually impaired users), both with traditional and emerging user-computer interaction techniques [2]. Furthermore, applicability of computer-based affect detection techniques to users with different abilities deserved specific analysis (e.g. detection of keyboard related events instead of mouse pressure for those who cannot use the mouse). In this context, we analyzed the requirements to

gather emotional data from people with different abilities, including people with disabilities. Such analysis has been validated in a pilot with 3 visually impaired participants. Background for the work and experiments carried out are presented next.

2 Related Works

According to existing literature, learners' affective state features a strong relationship with the cognitive process [3]. Affective modeling is a sub-area of affective computing [4] that involves i) detection of users' emotion and ii) adaptation of the system response to the users' emotional state. User experience (UX) is a related HCI area, which is also relevant to our research activities. UX involves two important qualities: traditional HCI usability and accessibility balanced with hedonic and affective design. The latter improve user personal (as well as others') situation in relation with the e-learning resource, as they will not only guide the future behaviour of the individual, but also because these subjective aspects will be communicated to others [5], and therefore will have a crucial effect on how the learning system is to be adopted by professionals and students in real situations.

Affect detection follows different approaches: i) qualitative methods (i.e. interviews, think-aloud [6]), ii) self-reported information, which can be gathered through questionnaires, iii) behavioral information can be obtained from either interactions with access devices, such as mouse and keyboards [7], or by using behavioral observational scales, where the participant behavior is coded on pre-assigned categories or by means of hardware sensor data that collect facial expressions, posture analysis, pressure on the mouse, etc. [8], and iv) physiological or neurological information (i.e. Electrocardiogram -ECG-, Galvanic Skin Response -GSR-, functional magnetic resonance imaging -fMRI-, etc.). Most of the technology and tools involved in detecting affective states in the educational domain are common to other affective computing areas [9]. Combinations of multiple sources of data and contextual information have improved the performance of affect recognition [10].

According to [11] user experience measurement should essentially be self-reported, trajectory-based and adaptive. They state that traditional techniques such as questionnaire, interview, and think-aloud remain important for capturing self-reported data, but that there are experimental variables to be "measured, modelled and formalized". It is also the viewpoint expressed in [12], where authors believe that psychophysiological measurements provide important possibilities in product development and can help to deepen and expand the insights gathered by traditional methods. In [13] a method is presented for continuously modelling emotion using physiological data.

In relation with the participation of people with disabilities in affective computing experiences, in [14] a classification based on different stages of affect processing, such as sensing, recognizing, interpreting, selecting, and expressing affects is proposed. Based on that classification, [15] compiles a list of impairments or disorders involving deficiencies in affective processing, as well as the affective computing technologies which are useful in addressing such deficiencies in several application contexts. Visual, hearing and mobility impairments, learning, developmental and anxiety disorders are included. Specifically, for people with visual impairments (including low vision and blindness) using chats or videoconferences, problems in

sensing visual affective information (face and body gestures) are reported. Furthermore, facial affect recognizer and emotional text readers are proposed as useful affective computing technologies for the aforementioned computer mediated services. According to [16], unaided visually impaired lose 55% of the affective information that people without those sensorial impairments are able to process. Similarly, in [17] it is referred that “important information in a conversational exchange comes from body language, voice prosody, facial expressions revealing emotional content, and facial displays connected with various aspects of discourse”. Furthermore, it is widely agreed that spontaneous facial expressions produced by blind people are the same as those of sighted under the same elicitory emotional situations. However, in blind individuals occur frequently head and eye blindisms, which do not involve the facial muscles associated with emotions, but rather have more to do with an attempt to improve orientation for maximizing the information coming from audio stimuli [18, 19]. That has to be taken into account while recoding facial expression in order to assess affective characteristics of the computer interaction of blind people. This seems especially important among congenitally blind people. Anyhow, whatever gathering methods are used, and according to [20], a multi-method multi-operation measurement approach should be adopted, including triangulation of mixed measures through appropriated protocols.

Furthermore, a number of issues related to conducting UX evaluations with disabled and older users need to be raised [21], such as whether they will use assistive technologies in using the system under evaluation. It is also important that the needs of participants in the evaluation are taken carefully into consideration. Personnel running the evaluations need to be sensitive to their needs. Issues to consider include transport, accessibility of the evaluation facility, accessibility of explanatory materials and consent forms available in the appropriate alternative formats, suitability of the pace of the evaluation for the participants (e.g. older participants may appreciate a slower pace of evaluation).

3 Experiment at the Madrid Science Week

To detect emotions from users’ interactions in e-learning environments, we designed a series of large-scale experiments for the 2012 Madrid Science Week (MSW) (based on several previous pilot studies) that recorded multiple measures (qualitative, self-reported, physiological and behavioral) during the execution of cognitive tasks. We proposed four activities in the accessible dotLRN learning platform, 1 collaborative and 3 individual. In this paper we are only referring to the individual activity so called “Ambient intelligence: an affective mathematical tutor for daily life mathematics”, where 18 people took part. Sessions were scheduled every two hours, with a capacity for up to 4 participants (i.e. the number of experimental stands we had). In each experimental stand there was one researcher (tutor) in charge of recording the measures and supporting the participant along the session. An additional researcher was taking notes of relevant physical movements of all participants. There was also a master guiding the activity in a synchronous way. Several sensors and devices were used to collect data from users’ affective states: i) a sensor belt with the following sensors (ECG, GSR and respiratory rate); ii) Kinect for Windows for face features extraction;

iii) webcam (with integrated microphone); and iv) keyboard and mouse (via a key-logger and a mouse tracker). Along with the physiological and behavioral recordings, participants filled in some personality trait questionnaires as these characteristics relate to how students respond to attempts to provide them affective scaffolding [22]. The data gathered by the sensors was complemented with emotional feedback collected directly from learners in terms of the SAM scale [23] to measure emotions in a dimensional space [24]. The activity was divided into several phases and tasks:

Phase 1 (Preparation) consisted in: 1) *Welcome*. Participants were thanked for their participation, assigned a stand for the activity and introduced to their tutor; 2) *Information Consent*. Participants were informed on the activity and asked their permission to gather their participation data anonymously. All participants agreed to have their data recorded; and 3) *Sensors attachment*. Each tutor was in charge of attaching the physiological sensors to the participants. In order to acquire the electrocardiogram signal, disposable Ag/AgCl electrodes were placed in the chest and also bilaterally on the internal side of each ankle. The respiratory rate was recorded by means of Pneumograph belt strapped around the chest. Regarding the GSR another two 8 mm snap style Ag/AgCl pellet embedded into a hook and loop fastener band were attach to the middle phalanx on the index and middle finger of the non-dominant hand (not to interfere with the typing and mouse control). The temperature sensor was attached directly to the internal side of the non-dominant hand wrist by means of a tennis wristband. Participants adopted a normal setting position all through the session and they were instructed not to cross legs.

Phase 2 (Getting Information) consisted in: 1) *Demographic information*. Data, such as gender, age, studies, occupation, illness related to heart and brain, physical activity, emotional control and technological experience was collected by the tutor; 2) *Personality questionnaires*. Participants were asked to fill in the Big Five Inventory (BFI) [25] to reveal the main five structural dimensions of personality (Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism) and the General Self-Efficacy Scale (GSE) [26] to assess the self-beliefs of participants to cope with a variety of difficult demands in life. In the pilot experiments, the questionnaires were available on-line at the platform. However, it was found that filling in printed questionnaires was more convenient as it consumed considerably less time. 3) *Data gathering launching*. Once participants filled out the questionnaires, sensors were launched (e.g. physiological sensors, webcam and Kinect) as well as the tracking software (i.e., mouse, keyboard and computer tracking).

Phase 3 (Calibration and pre-baseline) consisted in: 1) *Physiological sensors baseline*. Participants were asked to relax themselves for 2 minutes in order to measure their physiological signals in the absence of any external stimulation; 2) *Expectative report*. Participants were asked to type short paragraph about their expectations for the activity, both to find out the level of involvement on the upcoming activity and to have some data to compare the typing behavior with the data obtained during the experiment; 3) *Polygraph task*. With the goal of calibrating elicited emotional response, 7 questions, which fluctuated from neutral (e.g. "Is Paris the capital of France?") to very lock-in ones (e.g. "Have you ever take advantage of a colleagues' work?"), were formulated; 4) *Emotional images*. 8 images selected from the International Affective Picture System (IAPS) [27] database -rated by a normative sample-covering the emotional dimensional spectrum were shown to the participants in an

emotional incremental way. Participants were asked to rate valence and arousal with the SAM scale.

Phase 4 (Mathematical activity) consisted in: 1) *Problems*. Three groups of problems were given to the participants. The first group contained simple mathematical problems to see how each participant reacted when doing mathematical tasks, such as “Arthur has as many euros as the lowest 3-digit number. Adela has as many euros as the biggest 2-digit number. One of them lost one euro and then, both of them had the same amount of euros. Who did lose the euro?”. The second one had an equivalent difficulty level that previous. Nevertheless, participants were told that they were even easier than the previous ones, and therefore the time need to accomplish them was limited to 3 minutes. The goal here was to try to elicit certain level of frustration and stress. In the third one simple graphical logical series were presented. The goal here was to try to elicit a relief from previous task and finish the session with a sensation of joy and happiness. The structure was the same for each group of problems. First, a question and four possible answers, with only one correct, were provided. Once participants selected one alternative and submit the response, explained feedback was provided. Then, they had to fill in the SAM scale, similarly as done with the images task; 2) *Emotional reports*. After each group of problems, participants had to write corresponding paragraphs regarding how they had felt when doing the problems, what they were thinking, what problems did they cope and how did they dealt with them.

Phase 5 (Closing) consisted in 1) *Physiological sensors baseline*. Participants were asked, again, to relax themselves for 2 minutes in order to check the recovery. Sensors were withdrawn; 2) *Feedback from participant*. Participants were asked to fill in the Positive and Negative Affect Schedule (PANAS) [28] that consists of 20 adjectives that describe different emotional states; 3) *Feedback to participant*. Participants were told about the purpose of the tasks they had carried out, debriefed and dismissed.

4 Inclusive Experiment

The participation of users with disabilities in the MSW experiment implies several challenges. On the one hand, the accessibility and usability aspects of the interaction with the hardware and software used in the experiment needed to be addressed. On the other hand, applicability of computer-based affect detection techniques to users with different abilities needed to be appropriately analyzed. Thus, to make the experiment accessible to students with visual impairments, several adaptations were made. Before going into the details, there are 3 general comments: 1) All the software and the electronic materials prepared for the MWS experiment tasks were chosen/produced with accessibility in mind; 2) Material’s accessibility was tested with the same accommodations and assistive technologies (e.g., Jaws screen reader) the participants declared to use; 3) In case any participant declared to use a different version from the one available at the laboratory, relevant differences were briefed before the experiment started. Modifications per phases and tasks are the following:

Phase 1 (Preparation). In the *Welcome* task, a team member was waiting for the participant at the building entrance upon their arrival by taxi, in order to welcome and guide them to the laboratory. In the *Information Consent* task, days before the session

took place an accessible electronic version (MSWord) of the document was emailed to the participants. They could either reply to the invitation email with a statement saying they were willing to participate or print and sign a hard copy of the consent, maybe with the help of a personal assistant. In the *Sensors attachment* task, special emphasis was made in describing what particular sensor was to be positioned, and how it was to be done.

Phase 2 (Getting Information). In the *Demographic information* task, additional information was asked: i) level and cause/time of the impairment; ii) accommodations needed to use the computer; and iii) their skills with their assistive technologies (e.g., novice, advanced, etc.). In the *Personality questionnaires* task, the first participant (a blind person using Jaws screen reader) was told to use the e-learning platform to access the questionnaires on-line. But as previously noticed in the pilots of the MSW, the time required to fill them in was too long. Therefore, for the other two participants, adapted hardcopy versions were done: a Braille version issued by the Spanish National Organization for the Blind (ONCE) and an Arial 14 pt bold version produced by our team.

Phase 3 (Calibration and Pre-baseline). Modifications were done to the *Polygraph* task. Visual contents from MSW were substituted by an alternative item without visual content. Equivalent emotional elicitation level was used. In the *Emotional images* task, 8 standardized emotional sounds, ordered from the least to the most unpleasant and from the least to the most arousing, from the International Affective Digital Sounds (IADS) [29] were used to calibrate the emotional response instead of IAPS. Sounds were presented binaurally through headphones. Participants were asked to judge them in valence and arousal dimensions by using a 9-point scale, instead of the SAM, similarly to what was done with the original images.

Phase 4 (Mathematical Activity). Modifications were done to the *Problems* task. In particular, for the limited time problems, to compensate potential lower browsing speed for either screen reader or enlarged screen users, 1 extra minute was allowed in comparison with the original sessions. Anyhow, and similarly to the original session, allowed time was not enough to fulfill the task completely. It allowed participants to complete the first couple of problems, so that the time could seem realistic to them. The graphical logical series were replaced with alphanumerical or numerical logical series, with similar level of difficulty.

Phase 5 (Closing), the same adaptation as for the personality questionnaires were done in the *Feedback from participant* task.

5 Discussion of Results from the Experiments with Participants with Disabilities

In this section we present some qualitative results from the experiments with the 3 participants with disabilities (two blind and one with low vision). It is noteworthy that with that reduced amount of participants, the analyses that can be performed are partial, taking into account that all of them performed the experiment under different

access conditions. The purpose of the experience was not to get conclusive results but to bear out the main challenges and difficulties that were involved. The first limitation for a homogeneous gathering of data is the fact that the sources of information were not evenly collected for all the participants. For example, the mouse interaction was only used for one of them (i.e. not totally blind) which performed the task in a very similar manner that the ones on MSW sessions. The visual impairment required the adjustment of font size on screen or paper and the luminosity level, as well as reducing the sight distance from screen –very close distance, approximately 20 cm. This adaptation interfered with the collection of facial expression information, given that the distance from the Kinect and the framing area were out of range most of the time.

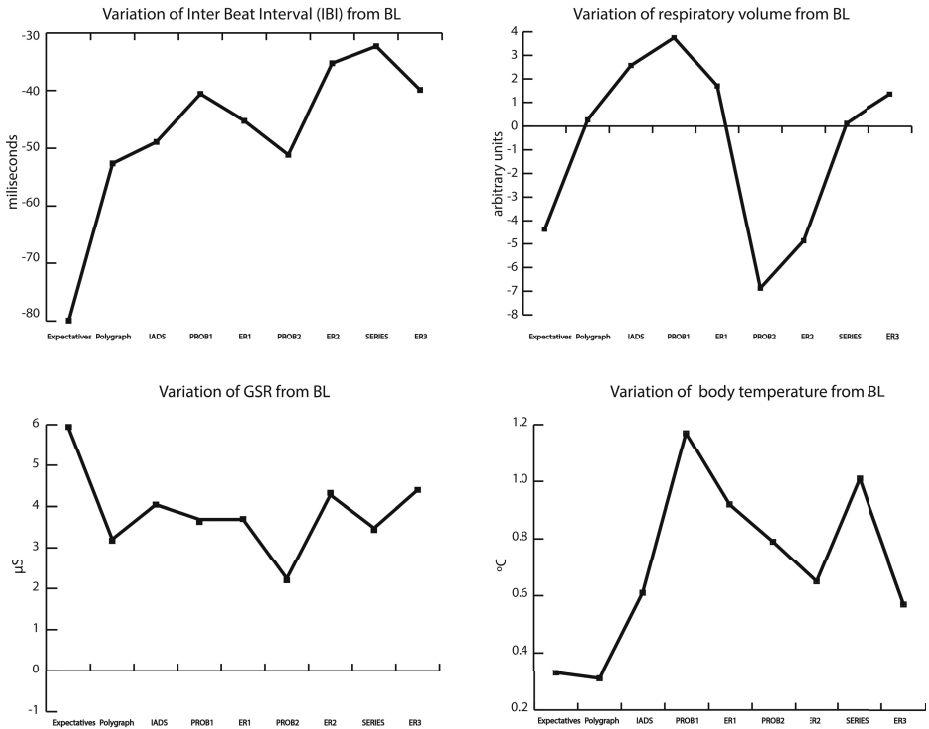


Fig. 1. Evolution of physiological signals through task phases for one of the participants with disabilities respect to baseline (BL)

Another issue to be considered regarding Kinect and totally blind participants (especially when acquired from birth) is the need to use a filter to withdraw the “blindism movements”, not associated with emotional reactions that eventually could be present on the recording. Moreover, when participants are blind a discrimination of the keyboard used for browsing by means of Jaws or the typing behavior itself is needed. Keyboard is one of the affective information sources and in this context interferes with the navigation usage. On top of that problem is the increase of finger movements among Jaws users while browsing (increasing the noise on GSR data).

Regarding the physiological data, using a general descriptive approach, variations related to tasks were observed. Graphics taken from one of the participants are depicted in Fig 1. Reactions towards the tasks were observed, appearing variations among different phases of the experiment. Especially those reactions were observed during the three problem resolutions phases: easy ones, time-limited and alphanumeric series. Data shows a smaller reaction in initial phases as compared with problem phases, and especially with the time-limited one. In the latter, the biggest reaction was observed in all variables, coinciding with users self-reporting stress sensation. Also, emotional sounds generated relevant changes across all the physiological variables. It is also observed a great change in all the emotional reports (ER1, ER2, ER3) filled after the problems (PROB1, PROB2, SERIES3). These changes can be consistent with the fact that participant increase motor demands as this task implied typing.

6 Conclusions and Ongoing Work

Inclusive detection of users' affective state while using e-learning resources implies several challenges. The experience described in this paper aimed to detect emotions in an e-learning system by recording multiple measures (qualitative, self-reported, physiological and behavioral) from users, including people with visual impairments.

In order to ensure the inclusiveness of the experiment, a two-stage pilot has been planned and implemented. During the pilot, several issues have been addressed. The accessibility for the target groups regarding all the experience procedures and materials has been ensured, including the tasks, logistics, the informed consent and the recognition certificate. Regarding the materials used for the tasks where emotional responses were measured, which posed accessibility problems for visually impaired people, adapted media (e.g. sound instead of image, alphanumeric or numerical logical series instead of graphical logical series) have been provided. Despite generic accessibility guidelines have been observed, specific adaptations may be needed for users with other impairments (e.g. mobility, hearing impairments, etc.).

Reactions have been identified after the analysis of recorded physiological variables (especially during the execution of limited-time problems, as it is depicted on Fig. 1). However, the remaining recorded variables deserve a careful analysis, to check to what extent they could be considered as a reliable source of emotional information (e.g. disentangle keyboard usage from browsing or typing). They are particularly interesting because they require no devices attached to the participant, increasing the ecological validity of the experiments that aim to study the interaction with e-learning platforms and to elucidate the role of emotions in such an interactions. Additionally, the noise extraction of that signals is a key aspect that should be addressed. Moreover, it would be desirable to carry out a more extensive data collection to be able to perform further analyses and comparisons among all the recorded variables for different access profiles (e.g. Jaws, ZoomText, Braille Refreshable Display, etc.). It would be of great value to know whether the type of access generates an emotional reaction itself (as a consequence of an increase of cognitive load) added to the one elicited by the ongoing task (e.g. additional source of stress).

As a conclusion it can be stated that elicited emotions by means of the type of tasks manipulation were reflected in the recorded variables for participants with disabilities in an analogous way that happened among the participants of the MSW without disabilities, as expected. Nevertheless, although the adaptations of the recording procedures that were followed seem to have been of worth, some problems arose. In this sense the recording of facial expressions and the analysis of the typing behavior deserve more attention in future works. Finally, additional physiological or neurological measurement (e.g. EEG) could result of help in order to better characterize affective reactions during learning for people with disabilities.

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Enriching Graphic Maps to Enable Multimodal Interaction by Blind People

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Abstract. Geographical maps are by their nature inherently inaccessible to blind users since the information is conveyed mainly in a visual way. The attempt to convert all the information to an alternative modality allowing satisfactory exploration by blind people is a very active field of research. Several studies offer interesting solutions currently only available as prototypes. The work described herein investigates multimodality, focusing on the tactile interaction skills of a blind subject. Given the difficulty of rendering all the information available in a generic map in a tactile and/or text (Braille) format, the challenge is to provide additional substantial information content through different means: speech synthesizer, text or sound alerts and vibration events that the user may call as needed. A further challenge of our work is to make a map opportunely modified to "speak" for itself, without using dedicated devices, through web technologies and the possibility of easily developing programs for Android-based mobile devices.

Keywords: Blind, visual impairment, tactile maps, graphics maps, multimodal interaction, Android, accessibility.

1 Introduction

In this study we investigated designing an architecture that addresses the accessibility problems experienced by blind users when exploring geographic maps, by providing more efficient information. We believe that the use of multi-modal interaction (i.e., conveying information through multiple channels) is the key to more satisfactory use of the map. In Web exploration, ensuring accessibility to the blind means allowing the screen reader to correctly interpret page content, making navigation via keyboard less sequential and more usable. The issue of a sequential reading is more evident if the content to be accessed is mainly visual, as in a map. Some attempts to make maps accessible use virtual cursors managed by a keyboard. The use of cursors is an improvement, since the map is navigable and accessible, but does not resolve the problem: navigation is still sequential, even with a keyboard controller

(right-left/high-low). Furthermore, all vision-oriented information such as shape, arrangement, type of item, and so on, can be lost by a blind person who relies on only textual and non-graphical content. In addition, information is conveyed mainly through audio, so the user must listen to a large amount of data, often leading to greater disorientation. In contrast, we attempt to enable the user to rely on touch for basic exploration, and on hearing (sounds or audio texts) for more detailed exploration. Involving more than one sense can help create a mental model of the map that is more immediate and closer to the real content.

In this paper we illustrate our proposed approach through a case study, analyzing opportunities and modalities to combine tactile and gestural interaction and audio feedback to make maps easy to explore on a mobile device for the blind. To this end, we designed a prototype for an enriched multimodal map, focusing on the user interface rather than on the implementation. In the following, after a related work section, we will introduce our approach by describing aspects and issues encountered when designing a map to use in our approach. Section 4 describes the methodology used to apply multimodal contents to a case study. The paper ends with Conclusions.

2 Related Work

Literature on accessibility and usability of geographic maps for visually impaired people can be grouped into two main categories: 1) Maps that allow one's localization and orientation in real time, including applications that use a GPS signal to detect the user's current position and provide information within a limited spatial range; 2) Maps providing information on a region of interest, for planning travel, destinations, stays, etc. In this case the interface for exploration can be fundamental and thus its design accuracy is crucial. The output of existing applications is generally vibration or voice. Focusing on the latter group, some studies have investigated how to generate the ideal accessible map starting from common online maps, retrieved in a variety of sizes/formats, neglecting the final user interface (UI). Several algorithms have been developed to extract the type of information they contain to present it in a more accessible format [1], [2]. Another branch of research focuses on user needs and behavior in map exploration, studying which information is relevant and the typical way a blind person interacts to obtain more effective feedback [3]. Poppinga et al. [4] conducted a preliminary study on how the information provided by relationships between relevant objects on the map can be conveyed in an interactive way with the smartphone's vibration motor combined with speech synthesis, in order to increase the map's accessibility on touchscreen devices. The study showed that it is possible to get a basic overview of the map layout even if a person does not have access to the visual representation. Zeng et al. proposed ATMap [5], an interactive tactile map system that enables users to act and search on the map, shown on a graphic-enabled Braille display, and to create and share annotations on geographical reference to points of interest, such as text attached to the geographical position of the objects on a 2D tactile map. Graf [6] proposed the concept of Verbally Annotated Tactile (VAT) maps to support the task of navigating complex environments indoors and outdoors. VAT

maps combine a verbal annotation system as a propositional component and a tactile map as a spatial component. Zeng et al. [7] analyzed what other types of information, not only geographic, could be acquired from the location-based *You-are-here* maps, and presented a tactile *You-are-here* map system on a portable pin-matrix device (PMD) proposing a collaborative approach to gathering information, accessibility of geographic annotation by users. Schmitz et al. [8] experimented with a system that allows blind users to explore indoor and outdoor maps on a Tactile Graphics Display having additional information via text-to-speech output. The maps are stored in XML files and displayed as normal graphical output, thus the system is not limited to a specific graphics display.

However, most of the proposed applications are still in prototype form, and a practical platform that could support a blind person in their orientation is not yet available. Despite the complexity of the investigation, the problem of the quality of the feedback provided to the final user remains a challenge. In addition, the typical architecture proposed includes a desktop PC connected via USB with a touch/Braille display that does not guarantee the portability of the system [9], [1], [5].

3 The Proposed Solution

3.1 Method

Our study aims to design and apply sounds, spoken messages, vibrations and gestures offered by the mobile touch-screen devices to allow a blind user to perceive element distribution, shapes and types, and more easily obtain additional information. Furthermore, a mobile device is useful for taking the “enriched map” anywhere, and no dedicated device is required to explore the map. In our approach, we first need a physical map (hard copy) of the desired area, such as a tactile map obtained using special heat-sensitized paper containing microcapsules, ink, and a heat fuser. Next, we enrich content and interaction with sounds, vocal messages and gestures so that the map can be easier to perceive and explore for blind users. When the tactile map is superimposed on an electronic version on a touch-screen device (tablet), the user can interact with it by gestures and taps in a more interactive way.

3.2 Designing the MAP

The design of a tactile map should be a recursive process involving the end user in the early stages, not only in the subsequent evaluation. The goodness (quality) of a tactile map is the result of various considerations, including the technology used to realize it. Currently, two types of technologies dominate the large-scale production of maps: (shaping) vacuum modeling and the use of microcapsule paper with heating machines. Some studies compare the two technologies [10], [11], [12]. The results show preference for one or the other technology from time to time, since everything depends on the context in which the map is used and on user experience [11]. Regarding best practices in the use of symbols and the design, no standardized conventions are

available [13]. Gardiner in his doctoral thesis in 2001 [14] proposed a set of guidelines which emphasizes the context of use of the map, the importance of having a clear idea of user needs and demands regarding the map, and the fact that the choice of symbols reflects a preliminary choice of the technology/material to be used. Other authors [15] proposed a set of symbols, each with their maximum/minimum perceptible size. Paladugu et al. [16] also evaluated their different patterns, proposing a specific set of symbols.

Based on current literature and previous considerations, we began designing the map. It should be portable and usable indoors and outdoors. The purpose of our map will be to represent a region and provide an overall picture of the place before visiting it. For providing well-built and fully satisfactory maps for the user, we follow criteria suggested in [14]: 1. Simplify the images as much as possible; 2. Represent only items with a certain specificity; 3. Objects cannot be represented in a superimposed way, they must be aligned and separated; 4. Eliminate perspective; 5. Observe the scaling ratio and respect the proportions between different elements; 6. Observe the minimum threshold of perceptual ability (about 2 mm); 7. Contextualize the drawing with a caption. To provide the user with an overview of the place to visit, we used maps from OSMs (Open Street Maps). A typical scenario might be that the user wants to know in advance what is around a certain area, e.g., the hotel s/he has booked or the venue for a conference. Some studies showed that exploring the region in advance in a virtual environment is significantly helpful for orientation in the real context [17], [7].

We chose for our study a map of Lucca (Tuscany, Italy) covering a range of 0.65 km² in the downtown area. The OSMs web platform provides the map in osm (xml-like) format as well as in SVG format. We downloaded the map descriptions in both formats in order to be able to modify it according to our needs. We modified it by means of an xml compiler and the APIs provided by OSM using Inkscape. The resulting map was then embossed using swell paper and a Minolta heating machine. The original map was modified in order to eliminate unnecessary elements and add the symbols needed to improve tactile exploration. All the modifications on the map needed to be made taking into account how the embosser (heating machine) works. The main constraint was to concentrate the ink on the point of interest (POI), allowing its discrimination among the other elements. All POI need to be well-pronounced. Essentially we chose these modifications: 1. Eliminate the buildings (because they make it difficult to reveal an event/gesture on the screen); 2. Maintain the text along the street even when not readable (too small) because it helps to associate its presence with a street; 3. Add a symbol (a spiral line) at the center of a large space to indicate that is a square; 4. Add small rectangular pieces on a circumscribed space to indicate that the space (route or square) is pedestrian; 5. Accentuate the profile of routes to make them more perceivable in a tactile format; 6. Maintain the shape of historical buildings such as churches; 7. Add a label in a specific position on the map to allow exploration in the correct position in terms of cardinal points.

Passing the map through the “oven” produces an embossed map with about 1-mm relief well-perceptible by touch (Fig. 2). It has the disadvantage of not allowing any adjustment of the height, which is the same for all the elements (symbols).



Fig. 1. Example of map: on the left the original SVG map, on the right the modified map

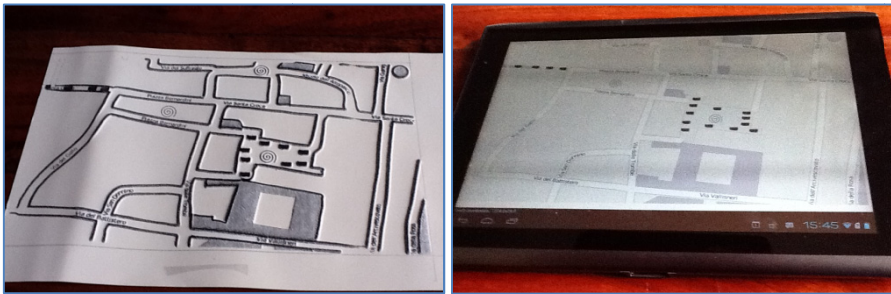


Fig. 2. Embossed map on the left and digital map over the tablet on the right

4 Adding Multimodal Content

In this section we present several different modalities considered for obtaining a multimodal enriched map accessible to a blind person. In particular, we focused on the third one for our purposes.

4.1 SVG Map with a Touch Screen Monitor

We intend to design a system for creating multimodal maps that are portable and usable everywhere. The constraint of portability limits the choice of available devices, power and features that could reduce the efficacy of the interaction. To evaluate this potential reduction, we first tested our prototype using non-portable hardware equipment. In this first example the previously designed SVG map is uploaded on a server and read by an internet browser (such as Chrome or Mozilla Firefox). A monitor touch screen (3M multitouch, 22 inch) is connected to the PC. The tactile map is placed above the screen, superimposed on an electronic version of the same map, and the blind user can interact with it using both hands simultaneously. The electronic map is enriched with events, implemented in Javascript and embedded on the SVG tags, that are able to respond to the user interaction. An SVG file includes several tag paths; retrieving the id of each path and adding specific classes to each one, we are able to read it through DOM associating each one with an mp3 file containing information to be read or sounds alerts. The information is thus accessible each time a

Javascript listener detects a user interaction. To avoid an overflow of information, we decided to activate each feedback with a single/double tap and not for events such as mouse over. Thus, the user can explore the map without disturbance and activate a call back only when s/he need information not provided by touch. The advantage of this solution is that the map has a good size that allows screen exploration with two hands in a more natural interaction. The browsers for the PC read correctly almost all SVG tags and attributes, and feedback is provided quickly. A disadvantage is related to the non-portable large touch screen.

4.2 SVG Map with Tablet

We tested the same solution described above by using a 10-inch touch-screen tablet, thus adapting the size of the swell paper to the 10-inch size of the tablet. Considering that the interaction is based on the browser's ability to read SVG tags and all the elements added via Javascript, performance greatly depends on the browser. Unfortunately, cross-browser compatibility is not yet assured for PC desktop browsers nor for mobile browses, so with this solution we faced problems such as reduced compatibility with SVG tags, reduced compatibility with javascript, and poor readability of different formats for sounds or vocal feedback. In addition, the small screen size degrades the layout rendering of the map, and the audio file process is often slow, requiring more than 20 seconds to be played.

4.3 Android App with PNG Map

To tackle the problem described above, another solution was investigated making use of a PNG image read by an Android app. In this case the multimodality will be added using a 10-inch Tablet Android Honeycomb v.3.0. The small size probably limits the information inserted in the map but enhances the portability of the system. The Android App has been implemented using an Image View widget that is associated with our map converted to a PNG file. All the information retrievable in the SVG format is preloaded in specific arrays that are then read by the App. For this reason we do not need an SVG image during the interaction, but just its associated PNG file. The java class implemented on Android makes use of an e-gesture library to intercept the user interaction. Feedback is provided to the user in three possible formats: using a TTS Engine, using vibration or using an mp3 player.

To provide an example of application of this methodology, we used the map on Fig.1(b). We have added the following multimodal content:

1. TTS engine is used to pronounce the name of each route; the gesture listener is activated along the entire path representing a route, thus the user can tap anywhere along the path.
2. When the user touches a filled-in shape, it means it is a historical building and its name is vocalized by the TTS. In particular, if it is a church, a bell sound can be also heard for 2 seconds.
3. A vibration is sent to the user for pedestrian regions (squares, routes, etc.) along with tactile feedback through small pieces embossed on the map.

4. In correspondence with a large space with well-defined contours, if it is a square the user receives its name and can have confirmation by means of a symbol placed in the center of the space (spiral line).

5 Evaluation/Results

All the prototypes have been evaluated by a blind user who is part of our research team. As expected, interaction is more comfortable with a medium-sized screen that allows a larger scale for each element of the map and more effective discrimination among elements. However, since in this case the interaction depends on the browser's ability to correctly interpret SVG tags, feedback (called with TTS Engine or mp3 player) is often not promptly provided and is difficult to customize. The multimodal map on the Android tablet and the tactile paper sheet are perceived as more interactive and rapid in responses: feedback provided could be as detailed as possible and its reproduction is quick and efficient. However, the screen's small size requires a smaller, simplified map, and exploration is conducted using one hand at a time.

6 Conclusions and Future Work

The work presented here is an attempt to make geographical maps more accessible to blind people. The main challenges faced in our approach regard information extraction from the selected map and its conversion to a machine-readable form as well as to implementation of a client-side application that enables the device to respond to the user's interaction by providing all the (previously extracted) desired information. The multimodal prototype described for our case study provides the user with information by exploiting a prepared tactile map that is superimposed on an electronic version of the same map running in a SVG player or embedded in an Android App. Our case study aimed to investigate a possible multimodal enriched interface that can be suitably perceived by a blind person through different modalities – i.e., tactile, vocal and audio messages. Thus, we did not consider how the procedure could be automatized in practice. For our present purpose we concentrated on how tactile and audio aspects could be combined to obtain a more enriched multimodal user interface. The design phase is a crucial step in the entire work and it is the most difficult to automate. Future studies will address improvements in terms of process automation.

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I-Ball: A Programmable Sporting Aid for Children with a Visual Impairment to Play Soccer

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Abstract. The Interactive Ball (“I-Ball”) is a programmable tonal soccer ball that varies its output based on measurements from an inertial sensor. As a sporting aid for children with blindness and low-vision it makes participation in team sports more accessible without a conspicuous constant tone and in a manner the provides information when stationary. The paper presents the design rationale of the system. Exploitative evaluation with visually impaired users indicates that the encoded information provides utility, but also that noise and wind are complicating external factors that can limit perceptual range.

Keywords: Accessibility, adaptive user feedback, HRI, sporting aids.

1 Introduction

“Smart” sporting aids have long been an area of research interest in the sports sciences and biomechanical domains, especially for the analysis and support of elite sports. Commercially, while a plethora of sporting goods and toys is available, they tend to be a rather motley collection of designs and, in general, focused on being entertaining. Instead, the focus of this research is to introduce a programmable sporting aid to make the field sports, chiefly soccer, more accessible to children with visual impairment by assisting with ball localization and motion estimation tasks.

Current solutions have children with visual impairment participate by using special balls with conspicuous noise makers (i.e., bells or simple buzzers) that engender alienation, and provide sparse feedback to the player. Specialized sports, such as goalball [1] and beeper base-ball [2], while active and fun, do not easily allow for a normative experience in which they are able to play alongside their fully-sighted peers [3, 4]. Instead, it is preferable to make common team sports, such as soccer, more accessible. These activities are not only fun, but conducive to the development of interpersonal skills (e.g., sporting terms are part of the vernacular) [5]. From a social perspective, it is important that the players with blindness or low vision have a normative experience and be able to play alongside their fully-sighted peers as team members [3].

Towards this, the paper presents a programmable sporting ball with an integrated inertial sensor module that provides motion information to players via a piezo beeper. It varies tones in response to motion and then focuses on how changes in the tone (pitch,

frequency, volume) and action (the extent that various motions couple to output sounds) affect the interaction of both the players and their team members. This paper presents initial tests on the operation and performance of the ball in both an indoor gymnasium environment and an outdoor field. It shows that the adaptive tones do improve mean localization time, but that noise and wind are complicating external factors that can color results.

The ball is programmable. While not explored in depth in this work, one of the advantages of this is that the relationship between the tone and the motion could be varied (e.g., to user or environmental conditions). This additionally allows for more dynamic mappings between the motion and the tone beyond a linear relationship, particularly if the output device (speaker) allows for a wide range of tones.

This paper introduces the basic concept of a programmable sporting aid for field sports such as soccer. A brief background of this domain is given in Section 2. Section 3 presents the design of the “Interactive-Ball” or “I-Ball” as based on a small circuit assembly embedded in a foam soccer ball. Initial trials from this unit are presented in Section 4. The paper concludes with some considerations on the current design and areas for future work from both accessibility and robotics interaction perspective.

2 Background

Sport is an inherently dynamic and spatial exercise. While it may be contended that vision is the spatial system par excellence, people with visual impairments are capable of acquiring a fully global conception of space [6] and may build up a set of spatial relations that are functionally equivalent to those of sighted people [7]; however, due to the limited sensory channels, they do so more slowly and by different means [8].

While a host of electronic aids has been developed [9], these have mostly concentrated on mobility, and primarily towards sensing obstacles in or near the traveler’s path and include “robotic” devices such as sensorized canes [10] and range-measuring glasses [11]. Even within the realm of sports, current aids are limited. Beeper balls [12] produce a fixed tone regardless of the balls motion and thus can lead to confusion or frustration [1]. Balls with an embedded bell [13] or those covered in a plastic bag [14] can not be heard when stationary and effect the motion and game-play of the ball as they are often rigidly attached to the ball’s exterior. Despite this, there is evidence that these are less frustrating to sighted team-mates and thus allow for a richer form of interaction.

Previous work on “smart” assistive devices for people with visual impairment focused on detecting objects that may obstruct the person and providing navigation guidance [15–17]. Such capabilities alone are not sufficient to play soccer; players need to identify and track the ball while it is moving quickly through the air, on the ground, bouncing, etc.

There is a more global problem of absolute orientation and navigation that is separate from mobility. The wide-availability, compact size, and self-contained operation of commercial inertial sensing elements has led to diverse applications in robotics [18] and embedded systems in general. Yet, reliable in-field motion tracking of agents over extended durations (while close) is not available due to drift and model variation over time. Video based solutions, such as motion capture, are not practical as they are expensive and require a structured environment. Thus, for this particular case, relative motion

rates are used as these are less sensitive to absolute localization errors. This is consistent with a non-speech sonification approach as this is better at providing information about an object's relative motion [19].

Robotics provides tools and frameworks to allow for a programmable interface to facilitate adaptive modulation of the (sound) output so as to the encode sensory information needed to conceptualize ball position and spatial motion in a manner that is robust to noise from bystanders and the environment.

3 Design of a Programmable Sporting Ball

An interactive ball (or “I-Ball”) has been developed to assist people with visual impairment play sports. It comprises a hollow foam soccer ball and uses a microcontroller to vary the tones emitted by a miniature buzzer based on a motion sensor (see Fig. 3). Since it is programmable, it provides a richer and more diverse form of interaction by allowing the tones to be changed easily.

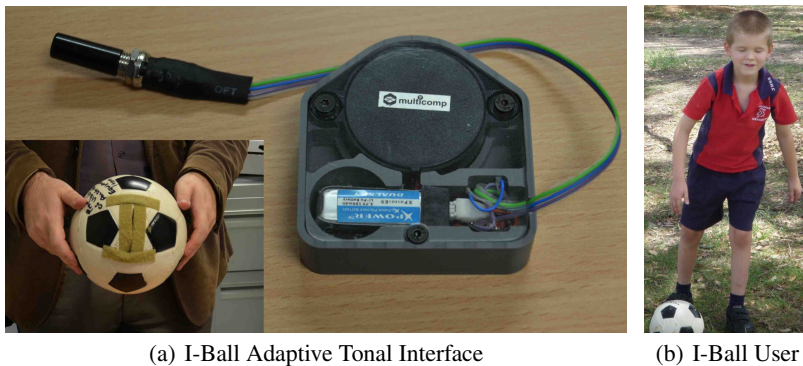


Fig. 1. (a) The I-ball features a smart embedded circuit, a rechargeable battery, and a gyro to provide an adaptive tonal assistance (in inset: ball with circuit installed). (b) A child with total vision impairment playing soccer using the I-ball.

Based on this, the I-Ball produces a quiet background tone that is increased in pitch and volume depending on the roll rate of the ball as measured using the MEMS gyro, in this case an Invensense MPU-9150. The design of the ball is based on the needed to present location information about the ball when stationary (hence the base tone) and to information about the motion of the ball (hence a second variation pitch varying tone tied to roll rate). The microcontroller, in this case a PIC 18F14K22, mixes the tones in a smooth manner so as to minimize conflicting harmonics and minimize dissonance.

3.1 Modes of User Interaction

As noted, sport is not only important for physical exercise, but also social development and peer interaction. The programmable interface affords many degrees of freedom to the designer from playing music files to varying operation by time of day. For simplicity,

the study uses simple tones and focuses on the relative interaction via user studies of various tonal couplings to roll rate against a baseline control of a fixed tone (i.e., the standard beeper ball). The buzzer period (T_{buzzer}) in microseconds (μs) is determined from the magnitude of the gyroscopic motion (\mathbf{g}_x , \mathbf{g}_y , \mathbf{g}_z) in (degrees/second) and is given by the following relationship:

$$g_{\text{mag}} = \sqrt{\mathbf{g}_x^2 + \mathbf{g}_y^2 + \mathbf{g}_z^2} \quad (1)$$

$$g_{\text{val}} = \min(0, \max(g_{\text{mag}}, 2000)) \quad (2)$$

$$T_{\text{buzzer}} = \frac{125000 \cdot 16}{((3/196) \cdot g_{\text{val}}) + (19/10)} \quad (3)$$

Operation of this approach is assessed by monitoring the motion rates of the ball and via user feedback surveys and camera footage that is subsequently analyzed to determine game durations and the level of teammate interaction.

4 Evaluation

The I-Ball has been prototyped within a foam ball and is undergoing field testing. Initial feedback on the ball suggests that the extra interaction flexibility afforded by the programmable interface allows for a richer interaction and longer periods of play by both the visually-impaired and fully-sighted. Exploitative evaluation of the I-Ball was conducted in collaboration with several experts from Vision Australia and Sporting Wheelies in both indoor conditions with younger children and in more dynamic field tests conditions (in this case with adults).

4.1 Gymnasium Testing

An initial, indoor evaluation of the I-Ball was performed in a gymnasium as part of a regular set of sporting exercises conducted by Sporting Wheelies in which there were 12 participants (not including staff). The ball was evaluated in two sporting activities. The first one was a team ball passing game in which the ball is kicked back and forth between a coach in the center and participants on an outer ring (see also Fig. 2(a)). In this activity the user is blind-folded (as some of the visually impaired retain partial eyesight and as the game includes participation of their siblings) and has to rely on the sound of the ball as well as cues given by the (sighted) coach when passing the ball. The tones helps the user assess the location and rate of the ball. The second activity is individual dribbling (shown in Fig. 2(b)) of the ball towards a soccer goal whose location is known in advance. Here the tones help the user track the ball and its reaction (chiefly angular speed) to being kicked.

The response of the ball as measured using videographic analysis shows that play-times and play frequencies as compared to a conventional beeper ball are increased. The I-Ball's internal IMU shows a relatively rapid gameplay with the ball being kicked about once every 10 seconds. With regards to (sighted) teammates, it is found that after

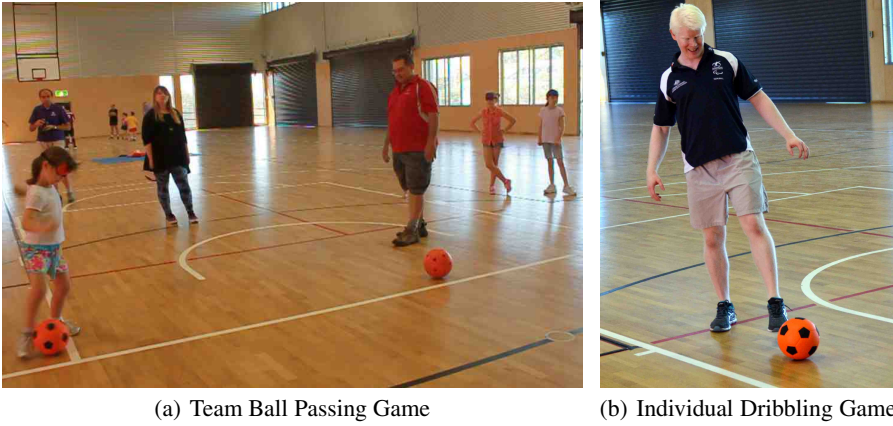


Fig. 2. (a) After locating the ball, a participant is about kick the ball back to the coach in the center who will then kick it to the next player in the circle. (b) An expert evaluates I-Ball dribbling.

the players get familiar with the ball and over its novelty that they find it less distracting than a standard beeper ball. The motion as recorded by the I-Ball is low-pass filtered (3rd-order Savitzky-Golay) to remove noise and bias. Figs. 3(a) and 3(b) illustrate the motion as seen in both exercises.

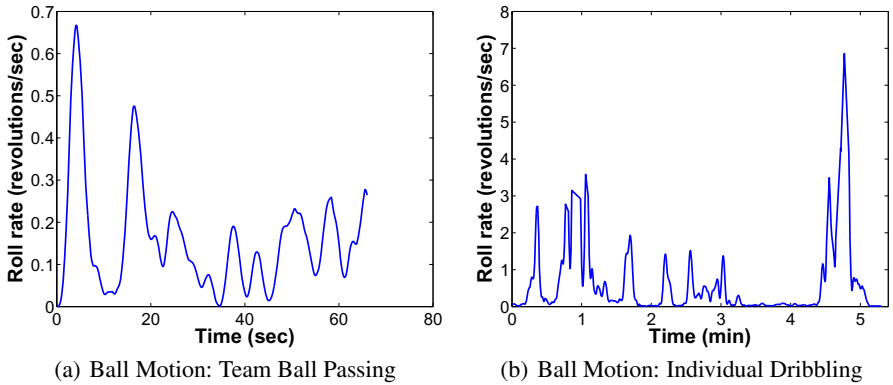


Fig. 3. (a) Ball passing using the I-Ball shows a relatively smooth gameplay with little down-time and relatively quick passing cycles (~10 seconds). (b) In the case of dribbling the distance is longer and the ball needs to be dribbled multiple times. The I-Ball supported the relatively swift/strong style engaged due to the distance which results in higher roll rates.

Subjective evaluation of the ball was positive, but noted that the sound of the beeper could not be heard clearly from a distance. Simply making the ball louder can be distracting at close range and is not efficient. Thus suggesting the use of an adaptive volumes and/or tone depending on an estimate of how far the ball is from the user.

4.2 Field Testing

More dynamic field testing of the I-Ball was performed outside in a grass field. In these initial tests several experts from Vision Australia examined the more dynamic performance of the I-Ball. This involved both rolling and throwing motions between three players arranged in a 20-meter triangle.



Fig. 4. Initial outdoor evaluations of the I-Ball have been done for dynamic ball motions associated with (a) throwing and (b) catching. These tests confirm that sonic localization can be challenging when the ball is moving quickly and that noise and wind are complicating external factors that can limit perceptual range.

These tests helped refine assumptions on the sonification of the ball and on the perceived loudness of sound. For example, the use of a buzzer, while more energy efficient than a speaker, has limited tone pattern variations and its sound can be masked by other similar sounds (such as the warning buzzer of a reversing vehicle). Mechanical issues are also non-trivial as the forces and velocities encountered can be large, which particularly stresses the packaging and closures (in this case, Velcro). Unlike indoor spaces, there is no structure for the sound to reverberate, thus resulting in an apparent attenuation and more challenging localization, particularly for catching tasks. As with indoor sports, the tests show the importance of communications between the players as part of relaying information about the ball's motion.

4.3 User Surveys

Participants additionally were able to provide qualitative design feedback via user surveys. Some highlights of the feedback received (as categorized by function) include:

- Sound emission effectiveness and directional feedback:
 - The sound emission allows participants to hear where the ball is coming from almost all of the time

- Intermittent beeping transitioning into beeps which are closer together when the rate of the ball increases does help
- Judgment of Ball Speed:
 - When the ball is moving back and forward within a small space 3-4 metres, the ability for the alternation in sound is hard to pick up and hence cannot be used that well within this range to judge speed/rotations.
 - Once participants are further apart (5m or more) the ability for participants to pick up changes in rate of motion are more readily made
- Ball location when it is possessed by another player:
 - The ability to judge the location of the ball of course becomes more difficult the further the participant is away from it
 - Open spaces compared with closed indoor spaces naturally decrease hearing levels due to a number of factors such as lack of sound reverberation and the inclusion of more background noise.

5 Conclusions

The I-Ball is introduced as a programmable, adaptive sporting aid to beneficially assist those with a visual impairment participate gently in social sporting activities such as passing motions in soccer. Exploitative evaluation of the I-Ball has shown that while an adaptive tone does provide motion guidance, it can be masked by environmental and mechanical factors. Motion analysis of the ball shows engagement and that a diverse set of users can quickly intuit the motion and positional information conveyed by the buzzer. Qualitative user feedback indicates that the I-Ball is interactive and fun, but there is scope for a better methods of sound transmission to the user.

6 Future Work

Future work will consider hardware usability improvements based on the current analysis. For example, the use of a speaker array would produce sound more uniformly, could provide greater levels of sensory substitution by more richly modulating motion information in the sound, and would allow for customization of the tones so as to better address environmental conditions and user needs.

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Design of Intuitive Interfaces for Electric Wheelchairs to Prevent Accidents

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Abstract. Japan has more than 200 accidents related to electric wheelchairs every year. Current electric wheelchairs do not have any device for accident prevention; it can be said they are dangerous vehicles. In order to mitigate the situation, we have proposed and implemented an interface that makes user recognize the surrounding circumference so that it prevents electric wheelchair accidents. In this paper, we present the design, implementation and feasibility study of intuitive human interfaces for electric wheelchairs.

Keywords: Prevention of accidents, Electric wheelchair, HMD, Multi touch panel, Assistive technology.

1 Introduction

We have more than 200 traffic accidents related to electric wheelchairs each year in Japan, according to the National Police Agency Traffic Bureau (see Table 1) [1]. Since this statistics does not include either accident that turns out to be electric wheelchair versus electric wheelchair or any isolated accidents that occur on electric wheelchair alone, we can assume that we have more accidents related to electric wheelchairs.

Table 1. Transition of traffic accident casualties of electric wheelchair

	2005	2006	2007	2008	2009	Total
The dead (people)	11	10	5	11	12	49
The wounded (people)	264	245	216	222	218	1.165
Total (people)	275	255	221	233	230	1.214

These accidents are classified into four categories (see Table 2). The majorities of accidents occur between 8 in the morning till six in the evening (see Figure 1). Therefore we can assume that we have enough daylight to solve the problems.

When a person is walking, he or she is observing the surroundings without thinking. If anything potentially dangerous things seem to happen, he or she can instantaneously recognize the situation. This is because, while walking, one continuously moves one's eyes and neck to check circumstances. However, once one starts riding on a wheelchair, one finds there are so many blind spots due to narrow range of the sight, because the electric wheelchair lowers the viewpoint of its user. Thus it limits the sights. Objects that are not obstacles for usual walkers become serious obstacles for one who is riding on an electric wheelchair. In addition, roads are not always flatly even therefore an electric wheelchair is not going straight. That confuses rider's driving sense, and causes mistakes, and then accidents.

Table 2. Electric wheelchair classification toll (2005-2009)

	Collision in front	Collision from back	Crossing road	Others
The dead (people)	1	5	37	6
The wounded (people)	81	112	611	361

In order to mitigate the situation, we have proposed and implemented an interface that makes user recognize the surrounding circumference so that it prevents electric wheelchair accidents. Our purpose is producing a plausible interface that prevents accidents related to electric wheelchairs. In order to achieve this purpose, we have implemented the following features for an electric wheelchair:

1. A viewer that provides the rider of an electric wheelchair the same height and the range as that of walking people so that he or she can easily recognize the surrounding situation.
2. A display that estimates and forecasts the track of the electric wheelchair when it goes on a road with inclination.
3. An interface for above features that provides intuitive operation and lessen fatigue.

The structure of the balance of this paper is as follows. The second section describes the related works. The third section describes the system configuration. The viewer, the forecast and display system, and multi-pointing interface are described in this section. Fourth section reports the feasibility study to evaluate the interfaces on an electric wheelchair. Finally we conclude our discussion in the fifth section.

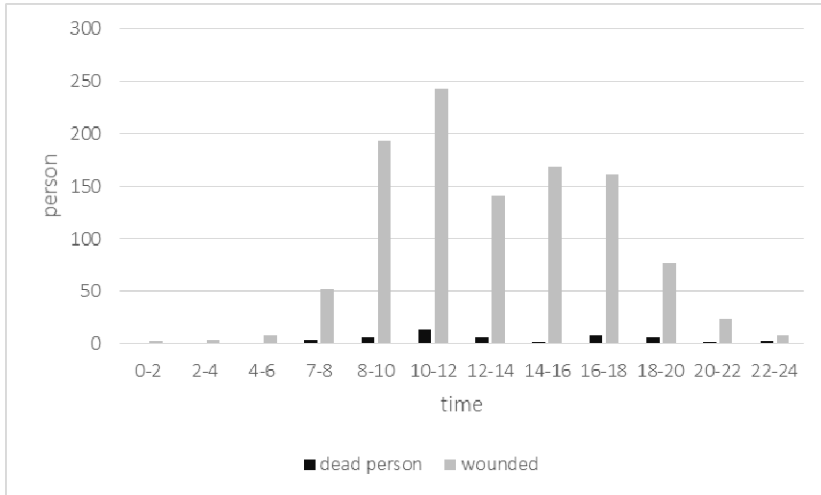


Fig. 1. Electric wheelchair time zone different toll (2005-2009)

2 Related Works

There are several techniques that observing surrounding circumstances with cameras [2-5].

Sato proposed an electric wheelchair that equipped 36 cameras to detect obstacles in the all directions by using spherical image and range information [2]. It also detects and recognizes the gesture and the riding position of the user so that it may decelerate and stop automatically. However, it can only recognizes 4m in radius for surrounding situation.

Toyota has produced an intelligent parking assistance system [3]. It assists a driver when he or she puts the car in a garage or performs a parallel parking. It recognizes the parking frame with a sensor installed in the front of the car and a camera installed in the back of the car. The system automatically operates the steering wheel to park. The problem of this system is that it cannot grasp all the surrounding situations, because its purpose is solely parking a car.

Nissan Motor has similar product namely the around view that synthesize image for parking a car [4]. It uses four super-wide angle cameras and synthesizes the images from the cameras and produces a look-down image of the car. Since this system also aims to assist parking, it provides relative position of the car but fails to provide the sense of distance in the surrounding environment.

The multi-view camera system of Honda employs fisheye camera in the front, back, left and right of the car, and synthesizes four images to produce several different images [5]. It also fails to recognize the entire directions of the circumstance.

Ueno et al have proposed a system that detects the road surface condition [5]. The system detects the road side from an image that is captured by the stereoscopic cameras and a standard image, and analyzes them based on the group of parallax distribution. However, it doesn't forecast the track the car will take. All the viewer systems just described are equipments for automobile, and not suitable for electric wheelchairs.

In general, the joystick is the control interface device for people with movement disorder to operate electric wheelchairs [7, 8]. Nakajima et al have proposed a touch pad system that reduces fatigue and can be operated only by the tip of a finger [9]. They have developed an electric wheelchair controller of this type for the muscular dystrophy patients who are not able to operate the joystick. They report that their touch pad system provides the same usability as the joystick, and provides less fatigue. However, they also report that telling the moving direction is not easy, the number of operations is limited, and the multi-touch is impossible, because the system allows the user to use only one finger.

There are several interesting interfaces are developed [10-12]. They are intuitive interfaces using transparent reflectors. When the user put fingers on the surface of the reflector, the light reflect at the pointed positions and the camera can catches the positions where fingers are put. The advantage of this type of interfaces is that it allows the user points multiple positions simultaneously. PERCEPTIVE PIXEL uses infrared rays LED [10]. The system emits the infrared rays into the medium plate so that the ray doesn't leak. In Microsoft Surface [11], infrared rays leaks because it irradiates infrared rays from the outside of the board. However, it uses less number of infrared rays LED's than PERCEPTIVE PIXEL.

Maesako et al proposed a system that irradiates visible light to a semicircle and transparent board [12]. Even though three dimensional is possible, it is only used in the darkness. These are screen interfaces and none of them are used for interface for driving wheelchairs.

3 System Configuration

In order to implement a viewer, we have installed three cameras in a side part of the wheelchair and cut out arbitrary images from any directions and displayed them in a head mounted display (HMD). The three cameras observe the road condition, forecast the track, and display them in HMD.

We propose two methods to display images in HMD. One is installing an acceleration sensor in HMD and operating with leaning of the head, and the other is installing multi-pointing interface that makes the user easy to grasp and operate on the elbow rest.

We have implemented a multi pointing interface with a camera. The user gestures to direct cameras and other operations to get and to display images in HMD as well as to operate the electric wheelchair. In contrast to the joystick, the switch, the button, and other conventional interfaces, the gesture interface can be arbitrary size and shapes. It allows flexible customization.

In order to provide the user the same view as the standing person, we set a camera at the top of a pole attached with the wheelchair as shown in Figure 2. In order to get wide view for surveillance, we employ the all-around lens for the cameras.

Moreover, three cameras provide several views. As shown in Figure 3, taken on the right side of wheelchair, back and left as well as right side have cameras for to capture images from three directions. Thus these cameras provide enough visual information for surrounding environments. Thus the blind spots around the wheels tend to be minimal for the electric wheelchair user.



Fig. 2. Installation position of camera



Fig. 3. Difference of glance

Since multiple cameras provide several views, the user can switch one image to another acquired from the cameras by the gestures. The system provides suggestions how to perform the gestures and how to acquire the images displayed in HMD so that the user can intuitively get enough information about the surrounding environments.

The user of the electric wheelchair can interact with the system through gesture. In order to achieve intuitive interface, we employ infrared rays and a transparent reflector. When the user performs a gesture on the transparent reflector, the spots where user's fingers touch shine so that the camera can recognize the contact zone. Figure 4 shows how the user performs a gesture, and Figure 5 shows the extracted contact zone. The transparent reflector has three dimensional shapes so that the user can grasp easily (Figure 6).

The user may need to get several views from HMD while busily operating the wheelchair. The user cannot perform gestures to control display images. In such a case, the user can operate the display images in HMD by leaning the his or her head. In order to implement such a medium, we have installed a triaxiality acceleration sensor (MMA7361L made in Freescale with ArduinoDuemianove328 microcomputer) on the HMD. Because we need to measure how much the head of the user inclines (figure 7).

We made the center point of HMD 90 degrees, and zero degree denotes the right hand side and 180 degree denotes the left hand side. In Figure 8, we show that how accurate the sensor obtains the degree that the user inclines his head. We have measured the angle of the degree of leaning of the head 100 times.



Fig. 4. Diffused reflection image

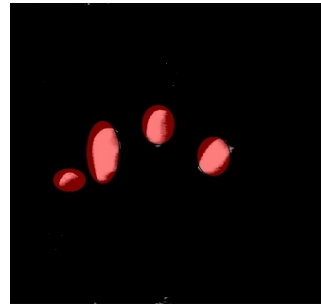


Fig. 5. Extraction image



Fig. 6. Operation of interface



Fig. 7. HMD and acceleration sensor

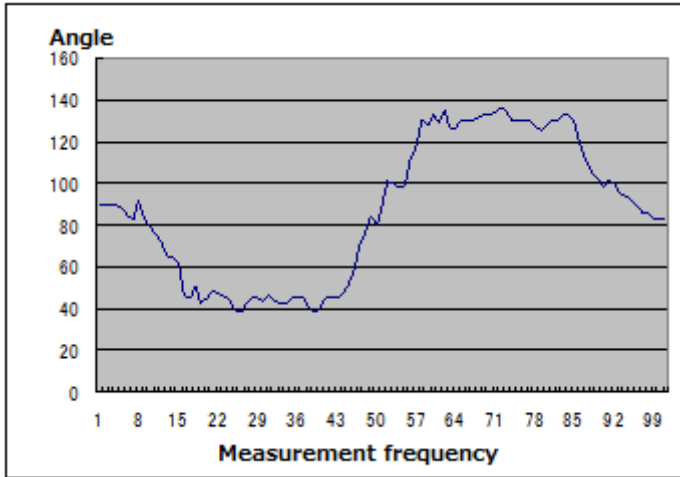


Fig. 8. Measurement results

4 Feasibility Study

We are conducting two types of feasibility studies on our interfaces. One is the surround mode experiment and the other is the bird-view mode experiment.

The purpose of the surround mode experiment is how effective for the user to grasp the situations around him or her at the height of standing person. We have measured how long it took for the users of the wheelchair to grasp the 360 degrees circumstances. In order to measure the time, we put A4 papers around the user with HMD, and the user inclines his head to switch displays to get the images that cover 360 degrees. Ten users participated in the experiments. Table 3 shows the results of the experiments. We can observe that the fastest tracker can find all the papers in 26.84 seconds. The slowest person took 74.1 seconds. The average was 38.6 seconds.

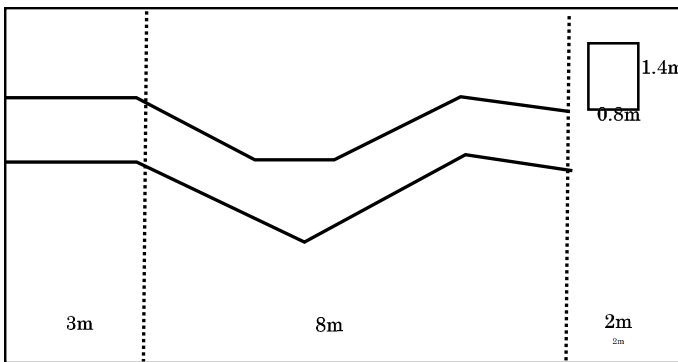


Fig. 9. Test course for bird-view mode experiment

The purpose of the bird-view mode experiment is how effective for the user to grasp the situation around the wheels so that the user can control the wheelchair to drive through narrow aisles without touching the walls and other obstacles. The user is expected to drive the wheelchair straight in 3m, and to drive S-shaped curve aisle in 8m, and finally to park the wheelchair at the designated parking area as shown in Fig. 9. Ten users participated in the experiments. Table 4 shows the results of the experiments. We can observe that the fastest tracker can find all the papers in 26.84 seconds. The slowest person took 74.1 seconds. The average was 38.6 seconds.

Table 3. Measurement Results

	in second
A subject A	33.28
A subject B	32.62
A subject C	29.23
A subject D	38.77
A subject E	46.40
A subject F	33.33
A subject G	74.10
A subject H	32.25
A subject I	39.42
A subject J	26.84
Average	38.6

Table 4. The time to get through the aisle and to park

	without bird-view	with bird-view
A subject A	161	244
A subject B	208	172
A subject C	213	191
A subject D	190	232
A subject E	100	173
A subject F	182	279
A subject G	214	175
A subject H	182	202
A subject I	172	201
A subject J	231	272
Average	185.3	214.1

Table 5. The number of accidents

	without birdview	with birdview
A subject A	8	2
A subject B	4	3
A subject C	6	5
A subject D	5	2
A subject E	9	4
A subject F	7	8
A subject G	8	8
A subject H	1	3
A subject I	4	2
A subject J	6	1
Average		

The results of the surround mode experiment suggest that one can obtain circumference through HMD and cameras. Our conjecture was confirmed, but taking 38 seconds in average to do so is outrageous. We need to perform further improvements. The experiments with multi-pointing interface are in progress.

The results of the bird-view mode experiment suggest that one can get through the winding aisle with the bird-view assistance more easily than without the assistance. The bird-view mode certainly assists the users to get through the aisle safer, but not faster. It is natural for a user drive the wheelchair cautiously while checking more information. The reduction of potential accidents hugely counterbalances the time period to check the bird-view. Our conjectures about the usability and safety were confirmed, and we are satisfied with results, even though there is a room for improvements. The experiments with multi-pointing interface are still in progress.

5 Conclusion and Discussion

We have proposed and implemented an interface that makes user recognize the surrounding circumference. We have implemented the following features for an electric wheelchair:

1. A viewer that provides the rider of an electric wheelchair the same height and the range as that of walking people so that he or she can easily recognize the surrounding situation.
2. A display that estimates and forecasts the track of the electric wheelchair when it goes on a road with inclination.
3. An interface for above features that provides intuitive operation and lessen fatigue.

Feasibility study is now in progress using an electric wheelchair. Even though preliminary experiments suggest favorable results, there is some room for improvement. We are re-designing our interfaces while continuing to conduct the feasibility study to provide more flexibility to the users.

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Using Sonification and Haptics to Represent Overlapping Spatial Objects: Effects on Accuracy

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Abstract. For blind and visually impaired people, the access to spatial information is crucial. Therefore, the development of non-visual interfaces to spatial representations, e.g. maps and floor plans, are important tasks. In earlier empirical work [19], we investigated virtual haptic floor plans, accessible through a Phantom force feedback device, which allows haptic exploration of virtual objects (walls), in combination with sonification for representing overlapping objects (windows). In the following we present an empirical study on multiple-overlap constellations (in the room-plan scenario: walls, windows and radiators). We reduced the complexity of the environments from complete apartments to only one wall and overlapping subsections, to focus on the spatial accuracy of acquired knowledge. This one-wall experiment has two goals: to compare the accuracy of size and position estimation with the experiment with complete apartments and to investigate the usability of sonification to represent overlapping entities at walls. Qualitative measures on the correctness of overlap-relationship identification and quantitative investigation on the accuracy of size and position estimations are discussed. The results can be extended to the use of sonification to represent overlapping entities in general.

Keywords: Spatial Knowledge Acquisition, Virtual Haptics, Sonification, Representational Multimodality.

1 Haptic-Audio Representations of Indoor Environments

The use of spatial knowledge is ubiquitous in our daily life. But, for blind and visually impaired people, the access to spatial information is limited to non-visual perception. Therefore, in recent years, modern human computer interfaces that rely on other perceptual channels to interact with users have been implemented. These are intended to help blind and visually impaired people to overcome problems in acquiring spatial knowledge caused by the absence of vision. For example, virtual haptic floor plans can provide spatial knowledge of indoor environment [9, 17, 19]. In a prior study with blindfolded participants, which explored palm-structured apartment using a Phantom Omni force feedback device (<http://www.sensable.com>), we have shown that humans—even when the sense of vision is absent—acquire spatial knowledge with very good performance [19]. After exploring the virtual haptic floor plan—using mostly a wall following strategy—their knowledge about the explored apartment was tested with respect to layout topology and size estimations. A second

group of participants explored the same apartment layouts containing supplementary information about the size and the position of windows provided by sonification. The participants of this study showed good knowledge with respect to the position of windows. Besides, we discovered that when the sonification can be invoked during wall following, higher quality of shape knowledge is achieved in some cases, since beyond space perception common sense knowledge about apartments can be exploited.

However, the results also showed that the accuracy on the size estimation of the windows was not satisfying [19]. Analyzing the exploration behavior of the participants as well as knowledge they acquired, there seems to be primary candidates for bringing about these inaccuracies, (1) they are caused by perceptual limits of using sonification to re-present windows in virtual haptic floor plans, and, (2) they are effects of intentional and attentional patterns of behavior, namely that users intending to acquire a floor plan may focus their attention mainly on the layout of rooms and the apartment, and only with minor priority on the windows.

To solve this problem, we foreground in the present paper the interplay of perceptual and conceptual processing of overlap constellations. In particular, to inspect how precise the size estimation of linear spatial entities can be achieved by using a sonified haptic interface, we conducted an experiment considering explorations of individual walls with varieties of overlap constellations (Fig. 1). By this experimental design, the cause candidate (2) is applicable. The investigated wall-window configurations were the same as that in the virtual haptic apartments. The accuracy of both size and position estimation of the windows were compared.

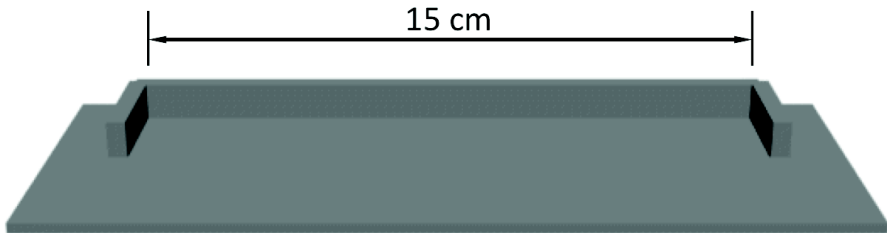


Fig. 1. The one-wall virtual haptic model employed in the empirical experiment

On the other hand, wall following with concurrent ‘window following’ is not the only case of spatial overlapping in room plan exploration. In modern residence apartments, not only windows, but also radiators are commonly regarded as integral elements of the wall constitution on the internal surface. It is also worth noticing that a radiator is often located below a window in the vertical dimension. These facts can easily arouse the overlapping between ‘window following’ and ‘radiator following’ to emerge during wall following in the exploration of 2.5-D virtual haptic floor plans. An appropriate re-presentation solution of overlapping spatial entities explorable without the sense of vision is still lacking. So the second study described in this paper investigates the usability of re-presenting spatial overlapping among three different types of linear entities in sonified haptic environments. More specifically, we focus (i) on a qualitative investigation on the recognition of overlaps and (ii) on a quantitative investigation on size and position estimations of the linear entities. In the following sections of this paper, we discuss our designing of the human computer interface, the conducting of the empirical experiments as well as the results.

2 Haptic-Audio Representation of Spatial Overlaps

2.1 Designing a Multimodal Interface

Multimodal designs are playing more and more important roles in modern human computer interfaces. In some HCI applications where the sense of vision is absent, other perceptual channels are used as substitution. The haptic channel might be one of the most popular perceptual substitutions for graphical representations for people without the sense of vision [8, 17]. But as pointed out by Loomis, Klatzky and Lederman there is a drawback brought by the localized characteristics of the haptic sense [12]. Verbal assistance may further improve the knowledge acquisition of haptic graphics [11]. But as the complexity of graphics increases, more mental effort will be needed to process larger amount of verbal assistance, especially for (geo-)metric or size information, e.g. length, breadth or width of spatial entities, which, in addition, is challenging to describe in textual forms. Non-speech and sonification has been widely employed in HCI interfaces. But so far sonification has been mainly used to address the information overload of verbal assistance [4, 13, 14]. Recent work has shown that sonification offers an effective help in representing ‘spatial-overlaps’ involving two different types of entities in graphical representation by representing the two types of entities separately via haptic and audio channel in an analog fashion [19]; in visual graphics color-coding is an easy and highly adequate solution. However it is common for graphical representations to bear spatial overlaps involving more than two types of entities. A typical example could be that in the floor plan view (2D), the location of the wall, the window and the radiator usually overlap one another. Fortunately human beings are able to form concurrent audio input into separate sound streams depending on several particular properties (e.g. frequency, rhythm, timbre, and the location of sound origins) [2, 16, 18]. This implies the potential of mapping of concurrent haptic following to concurrent audio stimuli. Yet the plausibility of using representational multimodality of sonification to support the acquisition of analog knowledge involving ‘spatial-overlap’ in haptic graphics has not been explored. In this paper, we realize the representational multimodality of sonification by assigning different frequency and rhythm to audio stimuli.

2.2 Realization of the Interface

We used a Phantom Omni haptic device for virtual haptic exploration, and the software was implemented based on the open source SDK released by CHAI 3D.

In order to keep the virtual haptic exploration free from complexities induced by complex virtual apartment-environment, and to focus only on perception and recognition of size and position, as well as of linear spatial overlaps, we used a virtual haptic model that only re-presents an individual wall section (Fig. 1). The one-wall model was 15 cm in length, with a boundary of 2 cm at both end of the wall section, and was placed on a solid horizontal plane. The wall and the two boundaries are 1 cm in height. So wall following exploration strategy can be perfectly supported.

For the windows and radiators in this virtual haptic environment, users are supposed to suffer from the “lost in haptic space” phenomenon when these entities are rendered as raised blocks [7]. If these entities are represented by means of different haptic features (such as different friction, magnetic properties and etc.), users could suffer from instability of virtual haptic texture [6]. And different haptic features may also leads to instability in exploration speed, so as to introduce ‘experimental artifacts’ in length and proportion estimation during wall following. In order to maintain steady and smooth haptic wall following, we decided to re-present the windows and radiators with audio stimuli.

For a window, we used a stable harmonic tone of 261.63 Hz (C4 as musical note). For a radiator, we used a harmonic tone of 277.18 Hz (C[#]4 as musical note) but with salient and regular rhythm, so as to be distinguishable from the windows. But as we are not experts in synthesizing audio stimuli with scientific approaches, we use salience within the rhythm to support the taxonomy for the stimuli employed in our research.

The moment the haptic interact point (see the grey point as a depiction in Fig. 2) enters the defined sonification field, the corresponding sonification will fire out. The spatial field that re-presents either a windows or a radiator is defined as haptically non-perceivable cuboid, whose intersection is a square with sides of 1 cm. All the sonification fields were placed sticking to the walls seamlessly. So the invoking of the sonification can be done during the wall following, with tolerance of reasonable noise of the hand movements.

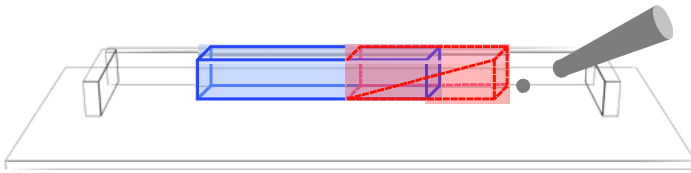


Fig. 2. The depiction of the one-wall virtual haptic model with other two different types of objects, where the blue block (left) represents a window and the red one (right) represents a radiator

3 Experiment

3.1 Materials

We conducted a repeated-measures experiment with 30 different virtual wall models. The virtual walls numbered from 1 to 13 were named as “Set A”. Virtual walls of number 17 to 25 were “Set B”. Number 26 to 30 were “Set C”. In Set A, the same window configurations that occurred in the complete apartment experiment were repeated. A quantitative between group comparison of the performance with respect to the size and position reproduction of the windows was investigated. In Set B, all theoretically possible spatial relationships between a window and a radiator were simulated. The window-radiator configurations in Set B were a genuine sonified

haptic adaption of *Allen's interval algebra* for temporal [1, 15]. Set C was covered for comparison and balancing reasons. With these experimental materials, we investigated the usability of re-presenting window and radiator by representational multimodality within auditory stimuli (harmonic tones with and without rhythm), and we contribute to discover the influence on the accuracy of perception brought by the overlapping of the stimuli.

Table 1. Depiction of virtual wall models employed in the experiment (the black color was used to represent the wall, the dark grey for the radiators, and the light grey for the windows)

Nr.	Set A	Nr.	Set B	Nr.	Set C
1		14	before/after	26	
2		15	before/after	27	
3		16	meet	28	
4		17	meet	29	
5		18	overlap	30	
6		19	overlap		
7		20	equal		
8		21	equal		
9		22	during		
10		23	during		
11		24	starts/ends		
12		25	starts/ends		
13					

3.2 Procedure

25 participants (15 female, 10 male, mean age: 24.9 years, *SD*: 3.5 years) contributed to this empirical study. They were all sighted and right-handed university students having no or little experience with haptic force feedback devices. The participants were blindfolded when they were doing the haptic exploration. We selected sighted university students as participants mainly for two reasons. First, blind and visually impaired people may not be familiar with the force feedback device we use. Thus, the time and efforts for training section could be difficult to estimate. Second, based on a big number of relevant research results collected by Cattaneo and Vecchi [5], sighted people and blind people are not significantly different in elementary audio and haptic sensitivity. With this experiment, our purpose is to investigate the usability of representational multimodality of audio stimuli. And the complexity of the virtual haptic model and the sonification stimuli we used in the experiment was also seriously limited. With these facts taken into consideration, the reported experiment was a pilot Human-Computer Interaction study based on a haptic-audio perception task. Thus the blind, the visually impaired, as well as the sighted were all appropriate experiment participants.

All the participants were first trained how to operate the force feedback device and how to deal with the experimental tasks for about half an hour. Then they were asked to explore 30 different virtual wall models in randomized order. There was no time limit for the exploration. After every exploration trial, the participants were given an answer sheet, on which a depiction of the wall of 10 cm in length was printed. The experimental task was to sketch all the windows with the blue color and the radiators with the red color as accurate as they could (Fig. 3). The participants were well informed that the width of the sonification filed was not of interest through out this experiment. The entire experiment of one participant lasted from 60 to 150 minutes. There was a short break of 10 to 15 minutes when the experiment was half done. At the end of the entire experiment, the participants were asked to fill in a questionnaire about their attitude towards the usability of this sonified haptic interface.

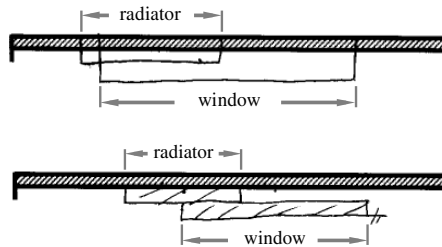


Fig. 3. Two examples of sketches produced by different participants after exploring wall configuration number 19, where the shorter object was sketched in red re-presenting a radiator, and the longer one was in blue re-presenting a window

3.3 Evaluation

As sketch is considered as a reliable data source of spatial cognition [3, 10], the evaluation was based on the analysis on the sketches.

The qualitative evaluation on the recognition of spatial relationship between the window and the radiator was done by analysis of the sketches of Set B. Referred to the original models (Table 1), if the corrected color was used to sketch the corresponding entity, and the correct spatial relationship could be recognized by the researchers, the spatial relationship of the wall configuration was regarded as correctly recognized by the participant.

Quantitative evaluation was done on the accuracy of size and position estimation of the entities. As exemplified by Fig. 4, for the size estimation analysis of an entity AB, we measured the length of the sketched entity, which is the length of segment A_1B_1 . The value taken in statistic analysis for size estimation was in percentage. It was yield by dividing the absolute value of the difference between the measured length A_1B_1 and the correct length A_0B_0 , by the length of the printed wall (10 cm). So the size estimation error of an entity could be computed by equation (1):

$$\Delta\text{Size} = |A_1B_1 - A_0B_0| / (10 \text{ cm}) * 100\% \quad (1)$$

Similarly, the position estimation error could be computed by equation (2):

$$\Delta\text{Position} = |M_0M_1| / (10 \text{ cm}) * 100\% \quad (2)$$

where M_0 is the midpoint of the entity in the original model, and M_1 is the midpoint of the sketched entity.

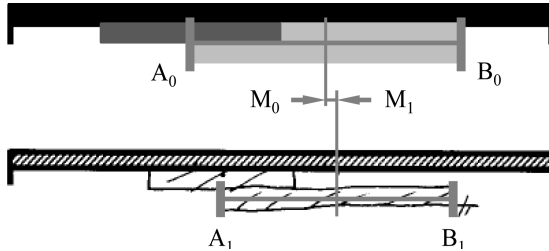


Fig. 4. Example of sketch analysis

4 Results

By going through the qualitative investigation, we tried to discover whether it is possible to re-present spatial knowledge with overlapping between different types of linear entities with representational multimodalities of auditory stimuli in sonified virtual haptic exploration.

On the other hand, with the quantitative investigation, we were able to address two issues. First, we were able to know whether the accuracy of size and position estimation is different when the entities are explored in an apartment and only long an individual wall. Second, we focused on the influence of complexity on the accuracy of size and position estimation. In particular, we focused on the influence on the accuracy of estimations brought by the overlapping of the entities and by having different number of entities at the wall.

4.1 Qualitative Investigation

The usability investigation was constrained upon the qualitative correctness of the spatial relationship between one window and one radiator. According to the result of the analysis, all participants were able to reproduce all the re-presented spatial relationship correctly. This result strongly indicates that, in the qualitative level, spatial overlapping of linear entities can be re-presented by using representational multimodality. Again, we would like to argue that depending on having various rhythms is only one appropriate modality in auditory stimuli that could support spatial overlapping in virtual haptic exploration, and we do not exclude the existence of other (even better) representational modality for overlapping re-presentation purpose.

In the questionnaire, the participants reported that it was easy for them to understand and interact with the virtual force feedback device and the sonification. They were able to acquire the desired information by individual wish. In general, the experiment task was not challenging for them. However the wall configurations where an

overlap between a window and a radiator takes place were considered as the most challenging situation by almost the participants.

4.2 Quantitative Investigation

Apartment Exploration vs. One-wall Exploration. We compared the data of Set A with the data collected in the (apartment) experiment [19]. As illustrated by Fig. 5, in the one-wall scenario experiment, the error made by the participants was significantly decreased with respect to both size estimation ($t(19.54) = 9.50, p < .001$) and positioning of the windows in comparison to the apartment experiment reported in [19] ($t(21.08) = 8.38, p < .001$ ¹). This result implies that the low performance in the complex apartment scenario results from the complexity of the environment in the apartment experiment. The weak performance of the estimation in apartment scenario was very likely due to the cognition focus during the exploration was on other perspective, such as the layout of the apartment or the sizes of every room.

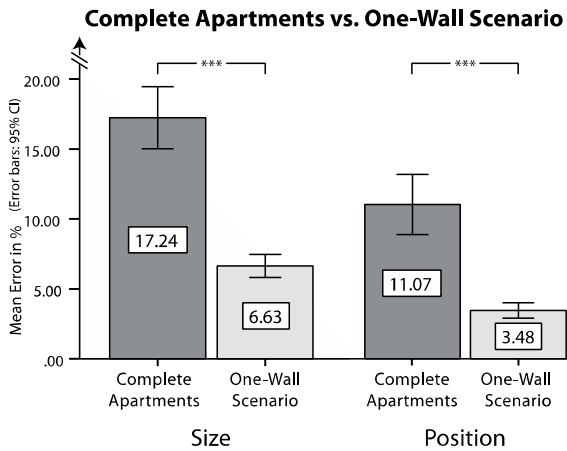


Fig. 5. Comparison of size estimation and positioning between exploration of complete apartment and one-wall scenario

Other Factors on Estimation Accuracy. In this part, we made quantitative analysis on the data of Set B to control for influences on accuracy of both size and position estimation.

First, in configurations with overlap between the window and the radiator, the error in size estimation was significantly larger than in configurations without overlap ($t(24) = -3.49, p < .01$; see Fig. 6 (a)). The accuracy of positioning the objects was not significantly different ($t(24) = -.77, p > .05$).

Second, when there were two objects on the wall, the accuracy of size estimations was not significantly different ($t(24) = -.22, p > .05$), but positioning accuracy was lower ($t(24) = -2.43, p < .05$; see Fig. 6 (b)).

¹ To correct for deviations from normality, the position estimation data was square-rooted. The reported p-values for the comparison are corrected for significant deviation from homogeneity of variances.

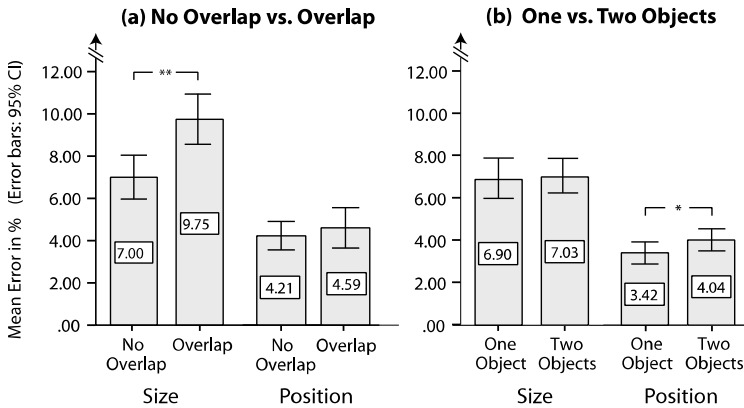


Fig. 6. Within-group comparison over size estimation and positioning accuracy

5 Discussion and Conclusion

With a combination of virtual haptics and sonification, overlapping entities can be represented as (geo-)metric spatial knowledge entities. Size and position of the represented objects can be perceived fairly good with a small amount of error (under 10% for size estimation, and about 4% for positioning). But it is more challenging to perceive precisely when overlap between two types of sonification takes place or when there are more than one object at the wall. The results of this study seem to be extendable to other types of overlaps, in particular 2D-overlap.

With respect to the design of human-computer interfaces, the results point towards the necessity to respect the interrelationship of representational complexity and accuracy of information presented by sonification early in the design process.

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Part V
Brain-Computer Interfaces

Effortless Passive BCIs for Healthy Users

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Abstract. While a BCI usually aims to provide an alternative communication channel for disabled users who have difficulties to move or to speak, we focused on BCIs as a way to retrieve and use information about an individual's cognitive or affective state without requiring any effort or intention of the user to convey this information. Providing only an extra channel of information rather than a replacement of certain functions, such BCIs could be useful for healthy users as well. We describe the results of our studies on neurophysiological correlates of attention, workload and emotion, as well as our efforts to include physiological variables. We found different features in EEG to be indicative of attention and workload, while emotional state may be better measured by physiological variables like heart rate and skin conductance. Potential applications are described. We argue that major challenges lie in hardware and generalization issues.

Keywords: Passive BCI, user state monitoring, attention, workload, emotion, EEG, MEG, NIRS, physiological measures.

1 Passive BCIs for Healthy Users

We here present the results of research that was done the last couple of years by TNO Soesterberg, the Donders Institute and University of Twente in the context of Brain-Gain, a large collaborative Dutch programme on Brain-Computer Interfaces. Within our project we focused on healthy users.

Brain-Computer Interfaces (BCIs) are traditionally conceived as interfaces that allow paralyzed people to consciously control external devices, e.g. for communication purposes. These BCIs aim to replace conventional channels of communication and control that are not available to these users, such as speech and button presses, by intentionally produced brain signals. This idea of BCI has been called active BCI (Zander et al., 2008; Zander & Kothe 2011). Active BCI still needs to go a long way in order to be useful for healthy people since it is difficult to compete with channels of communication and interaction devices that healthy users have at their disposal in terms of ease of use and information transfer rates. In order to assist healthy people in the near term, we think that BCIs should not aim to replace input modalities like manual input and speech, but should aim to retrieve information about the user state from brain signals that is otherwise difficult or impossible to obtain (Coffey et al., 2010; Van Erp, Lotte & Tangermann, 2012). The BCI loop is closed by making use of this information online. These kinds of BCIs are also referred to as passive BCIs (Zander et al., 2008; Zander & Kothe 2011), where the term passive refers to the user: in order to use these BCIs, the user does not need to actively control the system through his or her brain signals—rather, the system uses brain signals that occur spontaneously. Examples of (prospective) passive BCIs are BCIs using error related potentials to correct the outcome of manually controlled action (Zander et al., 2008) and BCIs that monitor workload in order to switch off secondary tasks when workload gets too high (Kohlmorgen et al., 2007). Clearly, passive BCIs could be valuable for disabled users as well, possibly in combination with active BCIs.

Challenges that go with developing passive BCIs are to determine 1. which user states can be observed robustly by a BCI and 2. how information about the user state should be applied to support the user. In our studies, we focused on the first of these challenges. In examining correlates of user states, we not only included neurophysiological but also physiological measures. We indicate directions regarding the second challenge. These directions also include applications that make use of (neuro)physiological signals offline and therefore cannot be regarded as BCIs, but since they are based on the same knowledge and methods we did not want to exclude them here.

2 Robust User State Detection

2.1 Attention Detection

Several of our studies were involved with neural correlates of attention allocation. Overall, the results of our studies are consistent with the idea that alpha activity (8-12 Hz) suppresses certain brain areas and therewith enhances processing in other brain areas (Klimesch et al., 2007) rather than alpha indicating general idling of the brain (Pfurtscheller et al., 1996). Händel et al. (2011) asked their participants to covertly attend to either a left or a right random-dot kinematogram. As expected, occipital ('visual') alpha was higher contralateral to the unattended side than to the attended side. Furthermore, a stronger lateralization correlated to a higher chance that the direction of motion at the unattended side was not perceived correctly (i.e. was more strongly suppressed). Bahramisharif et al. (2010) showed that alpha does not only distinguish between left and right visual attention, but can be used to estimate the direction of attention relative to eye fixation with up to 51 degrees accuracy. Another

study that is consistent with the Klimesch hypothesis is Brouwer et al. (2009) who found that alpha power over the occipital cortex (as well as certain eye movement parameters) indicated whether an observer attended either to visual or auditory stimuli. In this case, high occipital alpha power did not indicate that the observer was not paying attention, but that she or he was attending to auditory stimuli. A study on memorizing the order of words (Meeuwissen et al., 2011) perhaps most strongly suggested that alpha does not simply indicate general idling. Participants were presented with sequences of three words, followed by rehearsal periods. For words whose order was successfully retrieved, parieto-occipital alpha during the corresponding rehearsal periods had been higher compared to rehearsal periods following words whose order was not retrieved successfully.

Application. Brain and peripheral signals indicating the kind and amount of attention could enable a system to estimate whether a user properly processed information that was intended for him or her to be processed or remembered, e.g. in an air traffic control situation. Learning or performance could be enhanced by repeating information that is expected to be poorly processed or remembered (Jensen et al., 2011), or warnings could be issued. In addition to behavioral (eye movement) measures, (neuro) physiological signals might be useful to evaluate whether displays or advertisements draw attention as intended.

2.2 Workload Detection

Another user state that seems to be reflected well by brain signals, and which is a useful state to know about, is mental or cognitive workload. There is an abundance of studies investigating (neuro)physiological correlates of workload. While it is not clear yet which indicators are most reliable, studies that examined EEG spectral variables next to other physiological variables such as different eye and heart related measures, concluded EEG to be the most sensitive or promising indicator of workload (Berka et al., 2007; Brookings et al., 1996; Taylor et al. 2010). We used the n-back task to investigate workload (or more specifically memory load which is considered to be a reasonable approximation of workload: Berka et al., 2007; Grimes et al., 2008). In the n-back task participants view successively presented letters. For each letter they have to decide whether or not it is the same as the one presented n letters before. By increasing 'n' memory load can be increased without affecting visual input and motor output - confounding variables that impede interpretation of results of many previous studies on correlates of workload. In one study (Brouwer et al., 2012) we found that both ERPs and power in EEG frequency bands could be used to differentiate between high and low workload for almost all participants after a short time interval. Combining both types of EEG indicators resulted in a further (albeit modest) improvement of classification performance. We are currently studying whether peripheral physiological signals can improve performance or replace brain signals. Coffey et al. (2012) used NIRS (near-infrared spectroscopy) in combination with EEG to estimate workload. While EEG measures brain activity through electrical signals emitted by the brain, NIRS measures the blood oxygenation in recorded regions of the brain, thereby providing a measure of brain activity with a very different physiological basis.

However, for combining NIRS and EEG signals we could not show significant workload classification improvement over EEG alone.

Application. Workload measures could be used online to properly dosage tasks e.g. during driving (Kohlmorgen et al., 2007) or issue warnings that help is needed. Offline, continuous measures of workload could be used to evaluate different systems (e.g. interface designs) or perhaps to evaluate an individual's mastering of a task on a deeper level than only performance measures (c.f. Koenig et al., 2011).

2.3 Emotion Detection

We identified (neuro) physiological correlates of emotion (valence and arousal) as induced by presenting blocks of emotional pictures and/or sounds. Heart rate (variability), skin conductance level and EEG turned out to be differentially sensitive to valence, arousal and the modality in which the emotion was presented (Mühl et al. 2011ab, Brouwer et al., submitted). As expected, skin conductance was higher for high arousing stimuli than for low arousing stimuli. As also found before, heart rate was higher for pleasant compared to unpleasant stimuli. The effect of arousal on heart rate in studies using perceptual emotional stimuli has been unclear; in our studies we found a decrease in heart rate (and increase in heart rate variability) with arousal. This would be consistent with increased attentional processing of arousing perceptual stimuli (Codispoti et al., 2001; Graham, 1992; Lacey & Lacey, 1970). The effects on EEG were consistent with the notion that emotion increases attentional processing of the emotional stimuli and differentiated the two modalities: posterior alpha decreased during visual stimulation and increased during auditory stimulation (especially during emotional stimuli), while it tended to be the other way around for anterior areas. Our results suggest that while brain signals are suitable to inform about user states that are related to cognitive or sensory processing, for emotion related user states peripheral signals are probably more informative. We performed two studies aimed at detecting mental stress or arousal using heart rate, skin conductance and facial temperature. One study was performed in an eye laser clinic where participants who were or were not about to undergo surgery quietly sat for two minutes while physiological measures were recorded. Individuals about to undergo surgery had a significantly higher heart rate. A classification model was correct in about 70% of the cases estimating whether a person was going to undergo eye laser surgery or not. This was mainly caused by a difference in heart rate; adding other features to the classification model did not improve results much. In the other study, we tested a new, fast and easy algorithm that turned out to effectively induce mental stress while avoiding confounding variables such as movement or speech. Participants were presented with arbitrary sentences (about vacuum cleaners), each time followed by a counter counting from 60 to 0 seconds. The final sentence assigned the task to sing a song starting at the moment that the counter reached zero. A simple sliding-window algorithm detected an increase in skin conductance after the onset of this sentence for 21 out of 25 participants. An increase in heart rate could be detected for the same number of participants. The number of participants for which the onset of the 'sing-a-song' sentence was successfully detected increased slightly to 23 when these measures were combined.

Application. Knowledge of the user's emotion could be applied online to improve different kinds of Human-Computer Interaction. Games may be adjusted to elicit the right level of valence and arousal (Gürkök et al., 2012). In exposure therapy used to treat phobias, knowledge of the patients stress or arousal level may allow the therapist to apply the right level of exposure of the fearful stimulus (Popovic et al., 2006). A sudden strong physiological-emotional response of a monitored individual may indicate that he or she is in danger. A strong physiological-emotional response to approaching security officers in a waiting cue for safety screening at the airport could be an indication of illegal intentions. Finally, measures reflecting emotions could be used (offline) to evaluate interventions taken to reduce mental stress, e.g. in a hospital's waiting room.

3 Challenges

Several challenges in different areas prevent passive BCIs from being abundantly used as yet. We discuss two major ones.

Firstly, robust, user friendly but high quality measurement equipment needs to be developed, especially to reliably and easily record EEG. Impressive progress is being made (Patel et al., 2012; Zander et al., 2011) and first user friendly EEG measurement equipment is on the market. However, it is not always clear to what extent these systems record EEG or whether they mostly capture eye and muscle movements. An interesting development in physiological measurements is measuring heart rate through analysis of images made by a conventional camera (Philips Vital Signs) which makes it possible to measure heart rate without attaching sensors. For some of the proposed applications, user friendly equipment is less of an issue, e.g. when (neuro)physiological measurements are used in an offline fashion for the purpose of system evaluation, or for patients in exposure therapy who are engaged in therapy for relatively short times.

A second major challenge is generalization. Passive BCIs (just like other BCIs) employ classifiers that need to be trained on labeled training data. Subsequently, the trained classifiers are used to classify new data. Training data should closely resemble the new data. However, it can be difficult in practice to create training sets that are similar to the data that needs to be classified, especially when one wants to have a quick and easy training phase. One of the essential differences between the training and the application phase can be in the targeted cognitive or affective state: workload as manipulated in the training phase, e.g. by using an n-back task, may (neurophysiologically) differ from workload that varies in the application phase, e.g. during air traffic control. The stimulus and task environment is likely to differ strongly as well: other, additional stimuli could be present in the application phase than in the training phase and users may be engaged in other, additional mental processes. It is difficult to simply equate the training phase to the application phase since the stimulus and task environment during the application phase is variable and unpredictable. Furthermore, it is difficult to know what the targeted mental state during application is, which is one of the reasons why tasks or stimuli are used during training that do enable labeling of data (and thus differ from those in the application phase). In-depth, theoretical

knowledge of the relevant parameters and processes is indispensable to face the generalization challenge. Reuderink (2011) discusses generalization issues with respect to variability within and between users, and potential ways to make classification algorithms more robust which may help to reduce the generalization problems as described above as well.

4 Hybrid BCIs

Much of our research included other signals besides EEG which is the most commonly used input for BCI: NIRS, heart rate variables, eye movement variables, skin conductance and facial temperature were used and in some cases combined in classification models to check whether user state estimation could be improved over using a single neurophysiological measure. An improvement would be expected since different measures are differently sensitive to noise. In addition, different measures could capture different components of the same user state, both in a physiological sense (such as capturing electrical and metabolic correlates of cognitive workload) and in a psychological sense (such as capturing frustration and cognitive activity during high workload). Individuals may also differ in the extent to which certain variables reflect certain user states. Finally, more variables are simply expected to result in more robust estimates. While there were positive trends, we did not demonstrate a drastic improvement yet for the combination of NIRS and EEG to estimate workload, ERPs and EEG frequency measures to estimate workload, and peripheral physiological variables to estimate mental stress. Strong improvement is not expected when variables reflect the same processes and one of the variables is an obviously better estimator than the others.

5 Conclusions and Recommendations

Active BCIs are very important since they may dramatically improve the quality of life of a small group of individuals with severe medical conditions. Passive BCIs for healthy users hold the promise to improve the quality of life a little for a large group of people and could also be of great value to disabled users as well. Still, research in this area is relatively scarce. We would like to encourage research on passive BCIs, and we would like to stress to researchers in the field that besides brain signals other (currently still more accessible) physiological signals should not be ignored. Our (and others') research provided suggestions on user states that can be detected and first steps were taken into applying knowledge of these user states online.

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Brain-Computer Interfacing for Users with Cerebral Palsy, Challenges and Opportunities

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Abstract. It has been proposed that hybrid Brain-computer interfaces (hBCIs) could benefit individuals with Cerebral palsy (CP). To this end we review the results of two BCI studies undertaken with a total of 20 individuals with CP to determine if individuals in this user group can achieve BCI control.

Large performance differences are found between individuals. These are investigated to determine their possible causes. Differences in subject characteristics are observed to significantly relate to BCI performance accuracy. Additionally, significant relationships are also found between some subject characteristics and EEG components that are important for BCI control. Therefore, it is suggested that knowledge of individual users may guide development towards overcoming the challenges involved in providing BCIs that work well for individuals with CP.

1 Introduction

Cerebral palsy (CP) is an umbrella term used to describe a group of disorders of the nervous system, which result in functional disorders to movement and posture [1]. CP is commonly caused by injury or damage to the fetal or infant brain, such as, for example, hypoxic ischemic brain injury. Although CP is non-progressive specific symptoms may change over time as the individual grows [2]. Additionally, motor disturbances in individuals with CP are often accompanied by disturbances to perception, cognition, communication, and behaviour.

Motor control impairments exhibited in individuals with CP can include problems with executing intended movements, posture, and muscle tone regulation. In some instances individuals may be unable to control a wide range of muscles and may, hence, exhibit near complete paralysis. Additionally, lack of muscle tone regulation may lead to spasticity [3].

As a result, individuals with CP may experience a range of challenges in their lives. As muscle control over the face and vocal cords may be impaired communication may be restricted. Such problems may place a number of restrictions on the daily lives of individuals with CP and result in them relying on care-givers for many of their day-to-day needs [2].

Brain-computer interfaces (BCIs) have been proposed as a potential tool to help meet some of the needs of individuals with CP [4]. BCIs have been proposed as an assistive device to aid with communication (for example by providing speller to speech applications) and help with movement control (for example by providing wheelchair control). BCIs have also been proposed to assist with rehabilitation efforts (for example by providing positive reinforcement to the desired neurological activation patterns associated with desirable movement). Specific applications envisioned for individuals with CP include applications for emotional management, facilitation of learning, improvement of rehabilitation therapies, improvement of health management, enablement of play, and improvement of users' abilities to express decisions.

A BCI device is an example of an assistive human-computer interface (HCI) technology which attempts to allow control of a computer by modulating neuro-physiological processes [5]. BCIs, therefore, may allow severely disabled individuals the possibility to control a computer, and hence communicate and interact, without having to rely on efferent nervous system activation. As such, individuals with no other communication pathways, or those with severe challenges to their ability to produce precise or reliable motor control (such as individuals with CP), may potentially be able to benefit from use of a BCI.

BCIs have been proposed as an assistive device to help with, for example, communication [6] and wheelchair control [7]. They have also been shown to allow control of computers and devices by a number of different patient populations - such as patients with spinal cord injuries [8] and patients after incidence of stroke [9] - as well as healthy individuals.

One of the most popular methods for acquiring signals from the brain for use in BCI control is the electroencephalogram (EEG). This is a non-invasive and relatively cheap method for acquiring potential differences in electrical activity recorded from different places on the surface of the scalp. Such potential differences result from summed post-synaptic potentials arising from electrical activity concentrated mainly in cortical neurons.

However, the broad range of symptoms apparent in individuals with CP, coupled with the cause of the condition, damage to the fetal or infant brain, makes it unclear whether BCI devices are usable by such a population.

To attempt to address this issue it has been further proposed that hybrid BCIs (hBCIs) may be of some benefit to such individuals [10]. hBCIs combine two or more types of BCI or a BCI and control based upon some other physiological signal(s) with the aim of thereby improving performance over that achievable with a single BCI [11]. However, prior to attempting to provide hBCIs to users with CP it is important to first assess to what extent users with CP can gain control of a BCI and which types of BCI can be controlled by users in this group.

To this end we review two studies from our group to demonstrate whether, in some cases, BCI control is possible by individuals with CP. Differences in subject characteristics are also compared to BCI performance and EEG component strengths over both studies to determine if subject performance is determined by any of their characteristics (e.g. age, gender etc.). If some subject characteristics

are determined to significantly relate to performance this has the potential to allow identification of whether other individuals with CP who share those characteristics could potentially control those BCIs.

There are a very wide range of differences between individuals with CP. Symptoms may range from very mild to very severe, may involve one, or both, sides of the body, and may involve different body parts more or less severely [12]. Symptoms may include torsion spasm, dystonia, athetosis etc. These may occur in isolation or in combination at varying levels of severity [13]. Additionally, spasticity may also be exhibited by individuals with CP [14]. Dependent upon the symptoms exhibited there may be specific challenges presented in attempting to obtain clean EEG signals from specific individuals with CP.

BCIs rely on the detection of patterns of neurological activity, which can be modulated by the users to attempt to achieve control. However, it is unclear how brain damage in individuals with CP affects these neurological responses.

Two brain responses frequently used for BCI control are the steady state evoked potential (SSEP) and the sensorimotor rhythm (SMR).

SSEPs are changes in relative band-power over baseline in response to the user attending to a regular stimulus such as a flashing light or a vibrating tactile stimulus [15]. The EEG band-power at the same frequency as the stimulus exhibits an increase over baseline in response to attendance to the stimulus. A popular choice of SSEP for BCI control is the steady state visual evoked potential (SSVEP) in which a visual stimulus, such as a light, is used [15].

SMRs are observed as changes in relative band-power over the sensorimotor cortex, and relate to planning and execution of movement and a number of other cognitive tasks such as mental rotation, spatial navigation, word-letter association etc [16]. Particular cognitive tasks exhibit different patterns of SMR changes over different cortical regions and at different frequency bands.

All these brain responses have been shown to differ between subjects and within subjects over different recording sessions. It is unclear whether we are able to measure equivalent responses in individuals with CP, when compared to other patient groups or healthy subjects, due to the various neurological factors associated with CP.

2 Methods

Two studies have been conducted by our group to determine, firstly, whether we can detect steady state visual-evoked potentials (SSVEPs) or sensorimotor rhythms (SMRs) from individuals with CP and, secondly, whether those changes may be used to produce effective online BCI control.

2.1 Measurements without Feedback

Offline measurements were conducted to determine if we are able to detect the necessary brain patterns for BCI control from individuals with CP. Two BCI types were investigated SSVEP BCIs and SMR BCIs.

Subjects. Six individuals with CP participated in this measurement session. Details of the subjects for these measurements and the measurements with feedback are both listed in table 1. Institutional review board (IRB) ethical approval was obtained for all measurements.

Table 1. Subject details for both measurements conducted with and without feedback. GMFCS denotes the Gross motor function classification system score [17], Orthopaedic disorders are denoted by codes which indicate lower limb disorders (MMII) or upper limb disorders (MMSS). The subjects' dominant hand is either, left (L), right (R), bilateral (B), or unknown (-). Subject codes indicate subjects who participated in offline studies without feedback (N-) or in online studies with feedback (F-).

User	Sex	Age	GMFCS	Orthopaedic disorders	CP type	Sensory disturbances	Hand
N-01	M	36	IV	MMII	Spastic Hemiplegic	-	R
N-02	M	30	V	MMII, MMSS	Dystonic-spastic	-	L
N-03	M	34	V	MMII	Athetosis	-	R
N-04	F	38	IV	MMII	Dystonic	Myopia	R
N-05	F	62	IV	MSI	Spastic Hemiplegic	-	R
N-06	M	38	V	MMII, MMSS	Dystonic-spastic	-	L
F-01	M	53	V	MMII, MMSS	Dystonic	-	L
F-02	M	36	V	MMII, MMSS	Dystonic-spastic	-	L
F-03	F	52	IV	MMII	Spastic diplegia	Myopia	R
F-04	M	22	IV	MMSS, MMII	Acquired cerebral damage	-	R
F-05	M	32	V	MMII	Acquired cerebral damage	Blind, left. Deaf, left.	B
F-06	F	20	-	MMII, MMSS	Dystonic	-	-
F-07	M	34	IV	MMSS, MMII	Athetosis	-	L
F-08	F	58	IV	MMII	Spastic diplegia	Myopia	R
F-09	F	32	IV	MMII	Spastic	-	L
F-10	F	36	V	MMII, MMSS	Spastic	-	L
F-11	M	38	V	MMII, MMSS	Dystonic-spastic	-	L
F-12	F	36	V	MMII, MMSS	Dystonic	Myopia	L
F-13	M	37	IV	MMII, MMSS	Spastic	-	-
F-14	F	31	IV	MMII, MMSS	Spastic	-	-

Recording. EEG was recorded at 512 Hz using a g.USBamp system (g.tec, Austria) from electrodes FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4, Pz, O1, and O2. Electrodes were grounded at the right mastoid and referenced to the left.

SSVEP Paradigms. Two stimuli were presented on screen (one to the left and one to the right). The user was cued to attend to one or the other for 10 seconds via an arrow appearing in the centre of the screen and remaining in place for 2 s followed by an 8 s period of attention to the appropriate stimuli. This is repeated 10 times (either left or right) per session. After each session the user was asked if they would like to continue or stop.

SMR Paradigm. The user was asked to attempt to kinaesthetically imagine either hand or foot movement. Each movement was visually cued by presenting pictures of either the hand or the foot. Pictures were presented in the centre of the screen for 2 seconds and the user was instructed to perform the cued action for 6 seconds. Each action was cued 10 times per run, with different numbers of runs per user dependent upon when the user elected to stop.

2.2 Measurements with Feedback

Subjects. Fourteen individuals with CP voluntarily participated in this study (seven male, age range 20 to 58 with a median age of 36, SD = 10.97). IRB ethical approval was obtained for all measurements. Details of these participants are also listed in table 1.

Recording. EEG was recorded from 16 electrode channels via the g.tec GAM-MAsys system with g.LADYbird active electrodes. The following channels were used; AFz, FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4, PO3, POz, PO4, O1, Oz, and O2. The reference electrode was placed on either the right or left ear and the ground electrode was placed at either TP7, TP9, or at FPz. EEG data was sampled at a frequency of 512 Hz and saved to file.

SSVEP. The SSVEP paradigm consisted of four square targets in the form of four red boxes arranged in a quadrangle. Stimuli were rapidly changed between red and black at frequencies of (clockwise from top left) 6.66 Hz, 8.57 Hz, 12 Hz, and 15 Hz. Users were cued to attend to one of the targets via an arrow which remained in place for 6 s. Additionally, a fifth null condition was cued by a cross. Feedback was provided by highlighting a selection frame around the target. Inter-trial intervals were uniformly distributed between 3 – 5 s. Each SSVEP run consisted of 20 trials with equal numbers of trials for each class.

Classification was performed via canonical correlation analysis (CCA) described in [18]. Thresholds were initially set to 0.2 for each stimulation frequency.

CCA was applied in a sliding window to segments of the EEG of length 2 s and a step size of 0.0625 s. Feedback was presented to the user if the output of the CCA method exceeded the threshold for 0.5 s consecutively.

Sensorimotor Rhythms. The SMR paradigm consisted of an initial calibration phase followed by an online feedback phase.

During the calibration phase the user was asked to perform four different mental tasks in response to a cue. The tasks were to kinaesthetically imagine movement of either hand, kinaesthetically imagine movement of the feet, perform mental arithmetic, or perform mental word-letter association.

The timing of individual trials was as follows. Second 0: a fixation cross appears in the centre of the screen and remains for the duration of the trial. Second 1.5: a cue appears on screen indicating which task to perform. This cue remains until second 3.5. Remaining time: this was the imagery period and the user was instructed to perform the cued task, halting when the cross disappeared.

During the imaginary period a bar was used to display the LDA classifier distance from the users ERD/S. Increased classifier distance caused the bar to fill from left to right. An individual run in both the training and feedback phases contained 32 trials. For further details the reader is referred to [19].

2.3 Performance Differences

Relationships between the subject characteristics, average performance at each BCI and strength of EEG components were investigated to attempt to determine the reasons for performance differences between subjects. Stepwise multi-linear regressions were performed with subject details as predictors and either BCI accuracies or component strengths as criterions. The following characteristics were used as predictors; age, gender, GMFCS score, Orthopaedic disorder, CP type, Sensory disturbance, handedness, heart rate, head movement, EEG signal quality index (SQI) [20], and finally the type of measurement performed (with or without feedback). Separate regression analyses were performed for SSVEP band-powers, ERD/S strengths, and accuracies at SSVEP- and SMR-BCIs.

Adjusting for multiple comparisons (2 BCI types and 2 criterion; component strength and performance) is done via Bonferroni correction. Thus, the significance level is adjusted from $p = 0.05$ to $p = 0.0125$.

2.4 Signal Quality

The quality of the EEG recorded is assessed in two ways. First, a detailed visual inspection is conducted of the signals to identify the distribution of artifact contaminated epochs and the types of artifacts. Second, the signal quality index (SQI) is adopted from [20] to provide an analytical measure of the signal quality.

Visual inspection labels portions of the EEG as clean of artifacts, containing blinks, containing Electromyographic (EMG) artifacts, containing movement artifacts, or containing slow EOG artifacts.

3 Results

SSVEPs. SSVEPs are first passively evoked during offline measurements. Doing so produces clear peaks in the spectrogram relating to SSVEP stimulation frequencies below 15 Hz in 3 of the 6 investigated subjects. Classification of SSVEP

was attempted in 2 of the 6 users with a statistically significant classification accuracy of 0.75 ($p < 0.05$) achieved with one (subject N-01).

SSVEPs are also used during measurements with feedback with a further 14 subjects. Doing so produces, as reported elsewhere [19], significant online classification accuracies ($p < 0.05$) in 5 of the 14 users.

Sensorimotor Rhythms. During offline measurements SMR responses are visible in 4 of the 6 investigated subjects and classification is significant ($p < 0.05$) in 4 of the 6 subjects. The EEG in the 2 of the 6 subjects without discernible SMRs are heavily contaminated with artifacts.

During attempted online BCI control clear sensorimotor rhythms are visible in 12 of the 14 users with artifacts contaminating the spectra in the remainder. The online classifier identifies enough trials to be trained with 10 of the 14 users and online classification is statistically significant ($p < 0.05$) in 6 of those users. Of those users one user exhibits significant correlations between the classifier output and the artifacts present in the signal. Thus, of the 14 users who attempted online BCI control via SMR modulation, 5 were successful.

3.1 Performance Differences

User performance accuracies at the SMR BCI are found to significantly relate to age ($r^2 = 0.455$, $p = 0.010$, significant) and mean SQI values ($r^2 = 0.812$, $p = 0.029$, insignificant after Bonferroni correction).

User performance accuracies at the SSVEP BCI are not found to significantly relate to any of the users' characteristics.

3.2 Component Difference

ERD/S strength is found to significantly relate to the subjects CP type ($r^2 = 0.376$, $p = 0.007$, significant) and mean SQI values ($r^2 = 0.654$, $p = 0.015$, insignificant after Bonferroni correction). Note, subjects with Dystonic and Spastic diplegia exhibit larger ERD/S effects than other CP types. However, it's very important to note that the number of types of CP in the study population means each of the six CP types is only represented by a few subjects (see table 1). Thus, only very low confidence can be given to the generalizability of this result. The SSVEP component strength is found to significantly relate to the mean SQI values ($r^2 = 0.723$, $p = 0.037$, insignificant after Bonferroni correction).

Mean SQI values are found to relate to subject gender ($r^2 = 0.323$, $p = 0.006$, significant) and orthopaedic impairment type ($r^2 = 0.564$, $p = 0.038$, insignificant after Bonferroni correction).

3.3 Signal Quality

Table 2 lists the percentage of the measurement contaminated by each type of artifact and clean EEG in the recording from each subject. Note that the EMG contamination is the most prevalent of the artifact types.

Table 2. Percentage occurrence of each type of artifact over subjects with feedback. Note, artifact labels are not available for subject F-06 due to occasional periods of ground electrode detachment.

Subject	Percentage of recording					
	Blink	EMG	Movement	Failing electrode	Slow EOG	Clean EEG
F-01	10.11	21.61	6.71	0.18	6.91	54.93
F-02	4.75	50.63	1.55	0	0.27	42.79
F-03	6.76	11.19	3.58	0	0.13	78.35
F-04	3.67	33.45	0.59	0	0	62.35
F-05	2.10	17.53	0	0	0	80.37
F-07	0.73	39.12	12.63	0	0	47.89
F-08	4.03	14.67	0	0	0	81.29
F-09	9.20	20.83	1.09	0	0	68.87
F-10	6.58	40.77	2.84	0	0	50.07
F-11	1.48	2.89	5.27	0	0.17	90.20
F-12	0.16	42.18	0	0	0	57.66
F-13	1.95	7.83	1.94	0	4.64	83.65
F-14	3.34	48.22	1.53	0	0	46.98
Mean (\pm STD)	4.22 (3.15)	26.99 (16.14)	2.90 (3.58)	0.01 (0.04)	0.93 (2.20)	65.03 (16.26)

4 Discussion

This work demonstrates that BCIs could be suitable assistive devices for individuals with CP. It is seen that the electrophysiological processes SSVEPs and SMRs may be observed in EEG recorded from individuals with CP. Significant BCI classification accuracies are also achieved with both paradigms.

The results suggest that the key characteristics relating to BCI performance are users' age, CP type, and EEG quality. Subject age exhibits a positive correlation with SMR BCI performance. Thus, older subjects perform better at BCI control. SQI is seen to significantly relate to the subjects' gender and orthopaedic type. Male subjects are observed to produce worse SQI measures. Note, that the numbers of male (11) and female (9) subjects are insignificantly different.

Taken together the key characteristics which determine performance in this group of subjects are gender, age, and measures of their CP diagnosis (CP type and orthopaedic type). This finding may help guide the customization of specific BCIs to specific individuals with CP. For example younger users with CP may require more repetitions or longer trials before an ERD response can be significantly identified. Alternatively, these findings may indicate cases when BCI control is not feasible for some users, or would require a customized design.

It is observed that there is no significant relationship between SSVEP band-power changes and any measures of impairment. However, there is a significant relationship ($p < 0.05$) observed between the strength of the ERD/S in the frequency range 8 - 13Hz and the subjects' age. The ERD/S strength increases with age. As CP is a lifelong condition this suggests that ERD/S strength is increasing with time the subjects have lived with the condition. We suggest that the older the individuals with CP the more practised they are at movement and hence the better able they are to produce strong ERD/S effects.

Some of the relationships identified between BCI performance and user characteristics are non-significant after correction for multiple comparisons. However, Bonferroni correction may be overly conservative and erroneously identify results as insignificant. Therefore, future work will aim to expand the number of subjects to see how well these results generalize.

Large amounts of artifact, in particular EMG, are observed in EEG from this user group. EMG artifacts are particularly prevalent on occipital electrodes impacting SSVEP accuracy. As the amount of artifact contamination is very high - over 50% in some subjects - it is crucial to remove artifacts in such a way that the EEG may still be used for BCI. We, therefore, suggest artifact removal methods should focus on EMG. A proposed method for this is described in [21].

5 Conclusion

Control of either an SMR or an SSVEP BCI is possible by some users with CP. Some user characteristics are seen to significantly correlate with performance and/or EEG component strength. However, many challenges remain in providing BCIs that work effectively for a large number of users with CP.

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Multi-modal Computer Interaction for Communication and Control Using EEG, EMG, EOG and Motion Sensors

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Abstract. This work introduces a new system to allow persons with motor disabilities to control remote devices and communicate with their environment. This system consists of a real-time data processing computer that analyzes biosignals like the electroencephalogram (EEG), electromyogram (EMG), electrooculogram (EOG) and a second computer that controls a smart home system, a robot, a TV, a webcam and social networks like Twitter and Facebook. The user can choose the input method that best suits his/her individual condition. A comparative study over 11 healthy subjects and different input methods showed best performance of EMG and mouse inputs, followed by EOG and EEG based inputs. However, the usability might change for disabled persons.

Keywords: EEG, EMG, EOG, motion tracking, BCI.

1 Introduction

Brain-computer interface (BCI) technology has been recently adapted to work not only for communication but also for control purpose [1]. However, it also has been proven that available BCI methods might not be optimally suited for individual subjects due to several reasons and has been termed e.g. BCI illiteracy [2]. In order to overcome this drawback, other methods like the introduction of hybrid BCIs have been proposed. This manuscript introduces a novel system for persons with motor disabilities to control remote devices and communicate with their environment. The main goal of this study was to compare the performance of the system for different input modalities.

The proposed system includes BCI methods based on evoked potentials (steady state visually evoked potentials (SSVEP) and P300) and consists of (i) the "UserPC" which is used for biosignal data acquisition, data conditioning and processing for analyzing EEG (electroencephalogram) signals but also for analyzing muscle activities measured from the forearm (EMG, electromyogram), eye movements (blinking) activities (EOG, electrooculogram) as well as capturing motion from one arm by a modified Wii controller (Nintendo Inc., USA) and (ii) an "AdminPC" which allows to control various devices like a smart home system, a robot, a TV, a webcam or to communicate via the social networks Twitter and Facebook.

In contrast to previous implementations the user can choose now from different input methods and selects the one that best suits his/her individual needs. The user interface is identical for all input devices and consists of a selection matrix displayed on a computer screen representing high level control commands. Users can switch between the different input devices easily without any impact on the frameworks' functionality. This allows a comparison of the performance of the input methods.

2 Methods

2.1 System Overview

The proposed prototype is a fully integrated technical system and the goal is to allow handicapped users with functional or other disabilities to interact with smart devices (television, cameras, etc.) and other services (Twitter, Facebook,) inside and outside their home to increase independence and social inclusion. The system improves both direct and indirect interaction between the user and information and communications services. A more easy interaction should be enabled by creating tools that allow controlling inner and outer user environments using different BCI techniques (SSVEP, P300) or adding other input functionalities based on EOG, EMG or motion signals.

In this paper six different input signals have been utilized to implement in total 11 input controls with 1D and 2D cursor control options (Fig. 2). This approach allows users to select the control/input mode that optimally suits his/her needs for the specific control task. The prototype provides the following input and control methods:

- (i) Mouse control
- (ii) Electromyography EMG-1D control
- (iii) Electromyography EMG-2D control
- (iv) Steady state visually evoked potential EEG-SSVEP control
- (v) Electrooculography EOG control
- (vi) Motion control Wii-1D using IR emitter
- (vii) Motion control Wii-2D using IR emitter
- (viii) Motion control EMG-2D with EMG selection control
- (ix) P300 evoked potential control
- (x) P300-EMG control
- (xi) P300-SSVEP control

In order to investigate the performance of the proposed system, users were asked to perform specific navigation tasks. Therefore a presentation matrix was shown on a computer screen and users had to perform selections based on 3 different types of navigation (see Fig. 2). Selections could be made (i) by using a mouse cursor and clicking on the specified item from the matrix, (ii) by increasing muscle activity over one forearm captured from a single EMG channel allowed navigation type (a), (iii) by increasing muscle activity over both forearms captured from two EMG channels

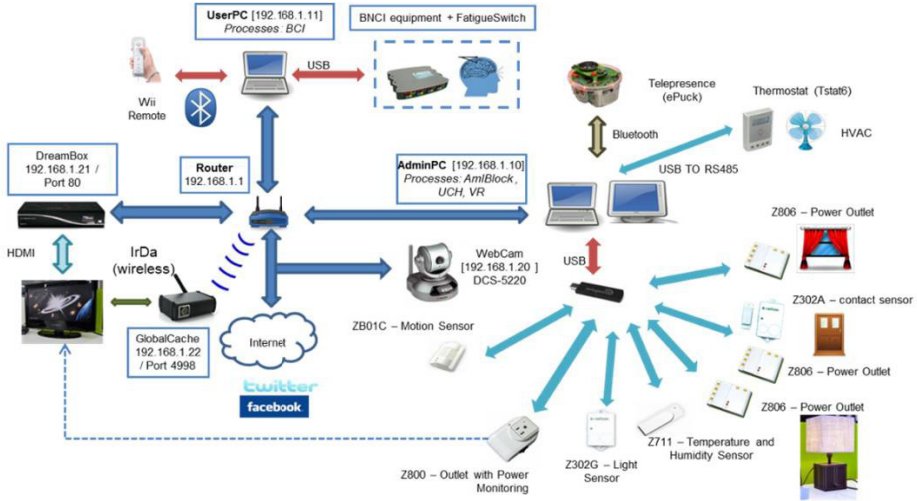


Fig. 1. System overview containing the “UserPC” that runs the BCI system. The connected “AdminPC” is controlling all the connected devices via network and ZigBee connection. The whole human-computer interaction system consists in principle of the user interface layer, the signal processing layer and a decision making layer. Finally a selected command is sent via a network (UDP) connection to the ambient intelligence system that coordinates the execution and steers all the connected devices.

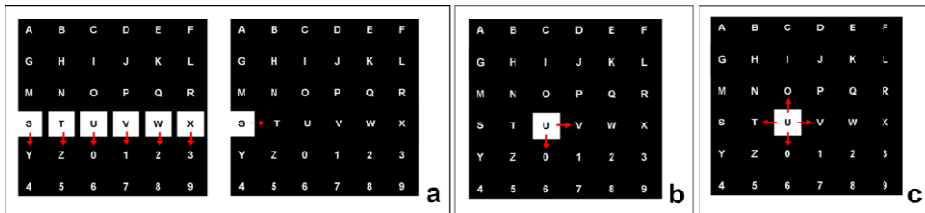


Fig. 2. Matrix interface for user interaction. Three different types are available: (a) row/column selection, (b) restricted 2D selection and (c) full 2D selection.

allowed selection type (b), (iv)/(xi) by using a SSVEP based BCI that provides 4 options to move the cursor within the matrix allowed selection type (c), (v) by using an EOG selection method that measures the occurrence of a specific eye blinking pattern allowed navigation type (a), (vi) by using a Wii controller for right hand motion control and cursor movement within the matrix allowed selection type (a) and (vii)/(viii) using a Wii controller with 2D motion control to steer the cursor with full 2D mode allowed selection type (c). The P300 BCI control allows to chose any selection without moving a cursor (ix)/(x).

2.2 Experimental Setup

A total of 11 healthy subjects participated in the study. For the measurement of the biosignals a 24bit biosignal amplifier (g.USBamp, g.tec medical engineering GmbH, Austria) controlled via a MATLAB/Simulink interface was used. The sampling frequency has been set to 256 Hz for all signals. For biosignal measurements the active electrode system g.GAMMABox equipped with sintered g.LADYbird electrodes (g.tec medical engineering GmbH) or disposable electrodes were used.

For each input method (mouse, Wii-1D, Wii-2D, EMG-1D, EMG-2D, EOG, EEG-SSVEP and P300) all subjects performed predefined tasks that included 17 selections (such as turning on the TV, controlling the volume of the TV, operating a web cam, logging into Twitter and posting a word, ...). The experimental paradigm started with a 1min resting period followed by 6 selections, 1min resting period followed by 11 selections and ended with a 1min resting period.

The performance was assessed based on the time to complete the task, the number of incorrect selections and the false positive rate in the resting states.

An additional experiment was performed to compare P300 fixed number of flashes to a statistical method approach. A total of 9 healthy subjects participated in this study and where instructed to follow the same experimental paradigm used before (1min rest, 6 selections, 1min rest, 11 selections and 1 min rest). The number of flashes needed and time to complete the experiment paradigm tasks where compared for both P300 processing methods. Results for the combined approaches P300-EMG and P300-SSVEP will be reported elsewhere.

2.3 Principles of Control

Mouse Control. The computer mouse is a pointing device that functions by detecting two-dimensional motion relative to its supporting surface.

EMG-1D and EMG-2D Control. Muscle activity was collected from one (for 1D movement) or two (for 2D movement) bipolar derivations from the extensor digitorum muscle of one or both forearms. An input can only be achieved if the muscle activity exceeds a certain threshold. Therefore, a simple calibration procedure to define the input thresholds for either one or two muscles is used. The user had to perform a sequence of 5 muscle contractions on either the left or the right arm. The maximum amplitude of the muscle activities are selected and multiplied by the factor of 0.6 to obtain corresponding thresholds. These limits can be exceeded by the user with rather little effort (details of threshold selection for EMG can be found in [5]).

Wii-1D and Wii-2D Motion Control. The motion activity of an arm was detected via an in house modified Wii controller. The Wii controller tracks relative movements with respect to a fixated infrared LED. In this experiment the Wii controller is positioned at a fixed location in front of the user. Depending on the physical abilities and needs of the user, the LED can be mounted to the arm. If moving the arm and therefore the LED, the Wii controller captures the relative movements. If a user is not

able to move the arm but can still move the head, the LED can be mounted on the user's forehead or chin. A calibration procedure was performed to assure that all parts of the presentation matrix could be accessed.

EEG-SSVEP Control. For SSVEP BCI 8 active EEG electrodes were mounted over the parietal/occipital areas (details of the recordings can be found in [3]). A total of 4 light sources, each flickering at specific different frequencies, were mounted next to the computer screen. By simply looking to one of the four flickering light sources a certain command could be selected. By looking to another light source another command was selected. Relevant EEG features were computed based on a minimum energy (ME) method [4] and classified into one of four desired movement classes using a linear discriminant analysis (LDA). To reduce the number of false positive selections, a classification to a zero class provided an idle state that occurred when no target was selected by the user. This entails rejecting any classification result for which the residual error probability of the classification result was larger than a predefined limit.

EOG Control. The EOG selection mode is useful for those patients that have still control of eye blinking even if they do not have perfect gaze control. The EOG approach detects the eye blinking by measuring the electrical activity of the corresponding muscles controlling the eye lid. If a special blinking sequence is detected then a moving cursor is stopped and the icon at this position is selected. Eye blinking activity was collected from one bipolar derivation and electrodes were mounted vertically above and below the right eye.

P300 Evoked Potential. For P300 BCI control 8 active EEG electrodes were placed over central and parietal areas (details of electrode montage and recordings can be found in [6]). A P300 evoked potential can be measured if a user concentrates on one target icon of the selection matrix. All icons of the selection matrix are flashed on and off in a random way and the subject is instructed to simply count the numbers of flashes that occur for his target icon. Paying attention to the rare flashing target event elicits then a P300 evoked potential which is detected by the BCI system. The number of flashes that occur per icon can be prefixed or a statistical approach can be selected which stops the flashing of the icons depending on the significance level of the user's evoked potential, thus typically reducing the time needed for perform a selection.

3 Results

Tables 1 contains the results of the time needed per subject to complete the test protocol for the different input methods. Table 2 contains the selection errors during the active phase of the experiment and table 3 contains the number of false positive selections during the resting phase. All subjects performed a test run with all input devices. One subject was not able to use the SSVEP based BCI and another subject had to terminate the experiment due to personal reasons. Table 4 shows the online accuracy of the individual input methods.

Table 1. Time to complete the test protocol using 7 different input methods. The last two rows yield the average (avg) time and standard deviation (std) of the results across all subjects.

Subject	Mouse	Wii-1D	Wii-2D	EMG-1D	EMG-2D	EOG	EEG-SSVEP	P300
	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)
1	242	300	281	328	340	435	450	960
2	269	414	313	342	346	520	905	880
3	257	327	289	390	340	424	598	1015
4	259	452	278	350	364	360	895	955
5	261	386	283	374	597	-	525	875
6	270	383	314	350	420	392	-	-
7	266	342	302	348	315	354	-	-
8	266	434	296	330	350	395	500	1185
9	255	430	296	343	327	317	580	910
10	257	395	320	367	360	384	710	880
11	242	345	343	363	376	363	616	1016
avg	258.5	383	301	353	376	394	642	964
std	9	47	19	18	75	53	164	94

Table 2. Selection errors during the active phase of the test protocol

Subject	Mouse	Wii-1D	Wii-2D	EMG-1D	EMG-2D	EOG	EEG-SSVEP	P300
	(#)	(#)	(#)	(#)	(#)	(#)	(#)	(#)
1	0	0	0	0	0	0	1	2
2	0	5	3	1	0	6	13	0
3	0	3	1	0	0	0	5	1
4	0	4	0	0	2	1	8	0
5	0	1	0	0	2	-	5	0
6	0	0	1	1	1	0	-	-
7	0	0	2	0	0	0	-	-
8	0	4	0	0	0	1	10	4
9	0	3	0	0	0	0	4	1
10	0	0	1	2	0	2	3	0
11	0	0	3	1	0	0	7	1
avg	0	1.8	1.0	0.5	0.5	1.0	6.22	1
std	0	1.9	1.1	0.6	0.8	1.8	3.79	1.2

The minimal average time to complete the test protocol was 301 +/- 19 sec for the Wii-2D control (disregarding the standard mouse control) and the maximal average time 964 +/- 94 sec for the P300 control.

The minimal average selection error during the active phase was 1.0 for Wii-2D and EOG control and the maximal average selection error was 6.22 for EEG-SSVEP control. The minimal average false positive selection was 0.0 for Wii-1D and EMG-1D control and the maximal average false positive selection was 3.4 for EEG-SSVEP control. The mean accuracy for the individual input methods was > 91% for EMG-1D, EMG-2D, EOG, P300, Wii-2D, Wii-1d methods. The mean accuracy for EEG-SSVEP was 74%.

Table 3. False positive selections during the breaks of the test protocol

Subject	Mouse	Wii-1D	Wii-2D	EMG-1D	EMG-2D	EOG	EEG-SSVEP	P300
	(#)	(#)	(#)	(#)	(#)	(#)	(#)	(#)
1	0	0	0	0	0	0	2	1
2	0	0	0	0	1	3	6	0
3	0	0	0	0	0	0	1	1
4	0	0	0	0	0	0	10	0
5	0	0	0	0	0	-	5	0
6	1	0	0	0	0	0	-	-
7	0	0	0	0	1	0	-	-
8	0	0	0	0	0	0	2	3
9	0	0	0	0	1	0	1	0
10	0	0	1	0	0	0	0	0
11	0	0	0	0	1	0	4	0
avg	0.1	0.0	0.1	0.0	0.4	0.3	3.4	0.6
std	0.3	0.0	0.3	0.0	0.5	0.9	3.26	1

Table 4. Mean accuracy of the individual input methods

	Mouse	Wii-1D	Wii-2D	EMG-1D	EMG-2D	EOG	EEG-SSVEP	P300
Acc (%)	100	91	94	98	98	95	74	95

Fig. 3 shows the comparison between the prefixed number of flashes needed to perform the P300 selection task and the optimized number of flashes and time needed based on the statistical method. The prefixed number of flashes was set to 270 and the minimal number of flashes was 70 for subject 7 and the maximal number of flashes needed was 210 for subject 5. The prefixed time to complete the task was 390 sec. The minimal time needed for the task was 120 sec for subject 7 and the maximal time needed was 300 sec for subject 5.

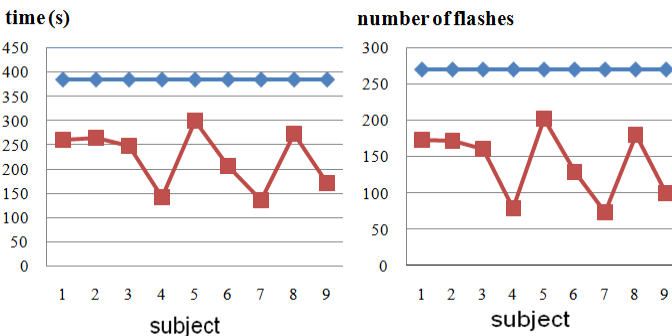


Fig. 3. P300 comparison of fixed number of flashes (blue line with diamonds) and statistical method (red line with squares). Left panel: Time needed for each subject. Right panel : Number of flashes needed for each subject

4 Conclusion

Results show that the conventional input device (mouse) outperforms any other used method in healthy subjects. However, the Wii-2D input method was faster than the EMG-2D and BCI based methods, and the EMG-1D or EMG-2D input control was the most accurate method.

The implemented input methods displayed acceptable performance with accuracies > 90% (except for the EEG-SSVEP method which showed an accuracy of 74%). Hence these methods may be beneficial also for users with special needs.

The specific selection task results with respect to accuracy and time depend on the user's anticipation of the input methods. However, trial durations for the input selection task were not prefixed except for the P300 method based on fixed number of flashes, as the time to finish the tasks and the related accuracies yield better insight in the performance and usability of such a system.

The P300 input method was on the one hand the slowest tested method, but had on the other hand a very high accuracy and low error ratio. We notice that the selection tasks based on a BCI methods last also longer, since the participants never experienced a BCI before. With some user training the number of flashes can be reduced significantly as tested on a long term study (work under revision to be published). Introducing the statistical method for in the P300 processing allows typically also faster selection times and therefore higher speed. In the best case the time needed to perform a selection has been reduced by 73% on average (subject7). In the worse case (subject 5) speed has been reduced 25% on average.

The current study serves as a base for further experiments with physically disabled users to find the optimal input method with respect to comfort, speed and robustness for each individual person.

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Experimental Art with Brain Controlled Interface

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Abstract. This essay presents experimental computer artworks using Brain Controlled Interface (BCI). It points to a preliminary contextualization and general development emphasizing affective, sensory, poetic and aesthetic experiences intermediated by mindware devices. BCI offers a new research art field using a low-cost neuro system to explore human mind's untapped potential. A BCI for a Java3D framework allowed to arrive at the concept of exoendogenous interactivity. The main contribution of this essay is the novel use of affective quantified data to provide emotional feedback to computers and participants while experimenting an art piece, intertwining human affective states with computational autonomous processes. May one say that computer agents, by capturing world percepts, perceive the human mind activity? Possible answers to this question may open poetic and aesthetic research fields for artists, leading to a better understanding of how computers collect and respond to emotional states within human minds.

Keywords: Brazilian Computer Art, Brain Controlled Interface (BCI), exoendogenous interactivity, Caracolomobile, affective computing, awareness widgets, Emotiv neural EEG headset, machine percepts.

1 Introduction

Brain Controlled Interfaces (BCI) offers a new research field for artists. It allows them to glimpse at human mental capabilities using a low-cost off-the-shelf affective neuro system to interface with computers in order to explore and experiment with human mind's untapped potential. The experiments related here point to the poetic and aesthetic computing possibilities of BCI for the creation of artworks. Since sensations, perceptions and emotions play the most important role in any artwork and few research efforts are exploring the potential of BCI within the art domain, a proof-of-concept was conceived. It is an artistic experiment pointing to some inquiries that have been gathered, which aim to investigate possible uses of affective interfaces for experimental artworks. Artists create metaphors clustering hypotheses, conjectures and intuitive perceptions, without the intention of demonstrating them as scientists do.

Since there are not many artists experimenting with such interfaces just a few are quoted here. Some important research institutions focusing on similar issues in other domains were added. The rest of the paper is organized as follows: Section 2 describes a few artworks and concepts related with Human Computer Interface (HCI) and Brain Controlled Interface (BCI); It describes a first artwork created by Fraga in 2010, the robot 'Caracolomobile' [7]. This robot uses a BCI interface to control its expressive movements and sounds; Section 3 presents a novel possibility for artworks developing the concept of exoendogenous interactivity with the use of BCIs to capture emotions directly from the brain. These emotions are outputted to interfere in endogenous autonomous processes happening within the computer environment; Section 4 discusses the affective interface being investigated; finally, Section 5 presents the conclusions and possible developments for future artworks.

2 Related Work

2.1 Human Computer Interface (HCI) and Exoendogenous Interactivity

The interactivity in digital devices reveals advances over all collective imagination. The physical universe contains objects from the real world which are translated by mathematics, art and computer codes. What one is able to perceive are reflections of the world filtered through perceptive and cognitive systems, as stated by Claude Shannon and Charles Sanders Peirce. Therefore, one concludes that any worldview can be attributed to a set of relations, visual perceptions, and languages integrated as systems of values and beliefs that underlie culture. Larry Manevitz points to the fact one is working with mathematical neuroscience with applications being developed and applied during the recent advances in brain science.

The advances in mathematics and art through computer technology present a scenario of transformations ever experienced in the history of mankind. In a short time the technology changed ergonomic perceptual, sensory and cognitive behaviors, among others. To explore a Brain Controlled Interface (BCI) we have to establish a direct functional interaction between a human or animal brain and an external device [1]. There are numerous recent advances in BCI development and implementation driven by scientific and technological achievements. BCIs can be applied to assisting, augmenting, or repairing human cognitive or sensory-motor functions. Recent technological advances allow real-time on-line processing of multi-channel EEG data. The BCI also is called a mind-machine interface (MMI), or direct neural interface, or a brain-machine interface (BMI).

The French art professor Edmund Couchot defines interactivity in two ways: exogenous and endogenous interactivity [3]. Exogenous interactivity happens when the interactor's¹ act over the artworks domain whose environments are programmed to answer for their actions, transforming them. Within endogenous interactivity environments there are virtual or physical autonomous agents who interact with one

¹ The word interactor was created by the Brazilian theorist and art critic Arlindo Machado to refer to the participant's actions within an interactive computer art experience.

another and with the setting following a diverse set of rules and algorithms independently from the interactor's actions. In what Fraga has defined as exoendogenous interactivity the interactors affect either the state or the behavior of these autonomous agents. These aspects will be better developed at sections 3 and 4.

2.2 Brain Computer Interface (BCI) in Experimental Artworks

When one refers to systems, specifically in brain-computer relationship, one understands the processes that are embedded in their architecture. This understanding leads to late nineteenth century discoveries by Willem Einthoven (1860-1927), Dutch physician, who contributed to the advancement of Science in electrophysiology, culminating in the development of the electrocardiograph. The successors of Einthoven advanced the coronary and angina syndromes theory, among other medical theories of great importance in the history of medicine. On the other hand, there is also the excitement when discussing the theory of models of later artificial intelligence applications, unprecedented in the history of applied sciences.

The history of BCIs started with Hans Berger's discovery, in 1924, of the electrical activity of the human brain and the development of electroencephalography (EEG). Following Berge's discoveries, the first BCI was described by Dr. Walter Grey, in 1964. After the 70's, computing, electronics and sensors technology allowed the development of external devices and algorithms capable of simulating the motor cortex firing patterns of neurons with their specific muscular responses. Actual researches in nanotechnology, biomaterials, and humans central nervous systems (CNS) are allowing the commercialization of BCI affordable devices. As stated before, BCI is a new research field for artists, which allows one to explore and experiment the human mind's potential glimpsing at its mental capabilities.

There are not many artists experimenting with such interfaces. Among them one may quote the Canadian Sandra K² that proposes to draw with brain waves and the musician Eduardo R. Miranda of the University of Plymouth, UK, that researches a BCI "that can detect and recognize musical ideas in the minds of composers with up to 99 percent accuracy" [10]. These researches may be applied in games. BCI gaming is a recent field and most games are still in the proof-of-concept stage [16]. It is important to say that in 2006, Paul Fishwick at MIT, pointed to the aesthetic computing possibilities of BCIs [6] and many important institutions are developing BCI research in other domains. Although they do not focus on art they are relevant to the field. Bellow we quote just a few of them such as: The MaxPlanck Institute of Intelligent Systems³ [19]; the MIT [9] and Microsoft [18].

² See: <http://neurofuture.blogspot.com.br/2006/10/brain-computer-interface-drawing.html>

³ The MaxPlanck Institute of Intelligent Systems points to Brain-Computer Interfaces (BCIs) as mindware enabling "subjects to communicate by intentionally modulating their brain's electromagnetic field. This field can be recorded outside the brain by methodologies such as EEG, MEG, or ECoG, analyzed with the aid of machine-learning algorithms, and then translated into commands that may be used to control computers or neuroprostheses".

In Brazil the computer artist and researcher Tania Fraga, one of the authors of this paper, is working with BCI interfaces to develop artworks. In 2010, she created the robot 'Caracolomobile'⁴ [7] (Figure 1) and is now developing the virtual reality environment, 'NumericVariations' (work in progress, Figures 3, 4, and 5), in collaboration with Pichiliani and Louro.

This whole quest was begun in 2007 when Fraga had the opportunity to try the NeuroSky headset [11] prototype at Yuri's night at NASA Ames Research Centre. After this mind blowing experiment many questions have arisen. By brainstorming the aesthetic and poetic possibilities that have been opened up by such an approach the authors have come up with a set of questions:

- Would it be possible to generate physical objects movements with any kind of mental process without any invasive procedure?
- Has a focused thought the ability to affect expressively a virtual environment or a physical mechanical system or object?
- May a consciously controlled affective state provoke expressive changes in the dynamic of an autonomous computer process?
- Would an unconscious affective state affect the dynamic of the virtual environment in any expressive way?

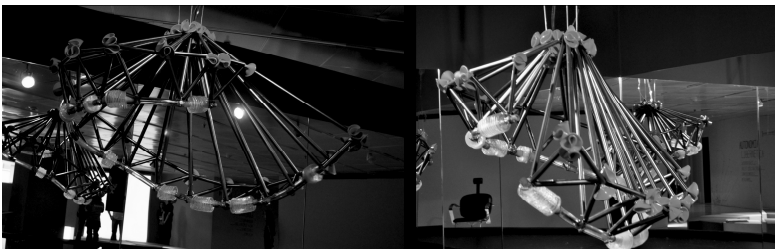


Fig. 1. The robot 'Caracolomobile'

In 2010 Fraga received an award from the Brazilian Itau Cultural Institute to build an experimental artwork, a pneumatic robot, 'Caracolomobile', for the Art and Technology biennale, 'Art.ficial Emotion 5.0' [4]. Therefore it was time to look for answers for some of the questions formulated above and the robot 'Caracolomobile'

⁴ The robot is a responsive object made of anodized blue titanium with flexible red silicon and polyurethane details. It is controlled by a pneumatic system related with an affective system that allows it to present expressions through sounds and movements. The robot 'perceives' the interactor's affective states expressing itself in answer to these stimuli. A Java interface (Emotiv-J) allows the robot to identify the interactor's emotional states captured through the Emotiv neural headset, a not intrusive device, which reads the mind fluctuations. This headset has 16 neural sensors able to articulate expressive, affective and cognitive states. The neural headset communicates the interactor's affective and expressive states to the robot's recognition system. The system identifies these states and translates them into images, sounds and movements. See [2].



Fig. 2. Different interactors wearing the Emotiv headset device

was built. It answers expressively with movements and sounds to affective and expressive human states. The robot acts in symbiosis⁵ with the interactor using a graphic interface to monitor these affective and expressive states captured by the Emotiv neural headset [5] (Figure 2).

The Emotiv neural headset was developed by a multidisciplinary international scientific team among whom we may quote the awarded Director of the Center for the Mind from Sydney University, Allan Snyder, and Neil Weste, renowned inventor, one of the authors of the CMOS system, who also developed projects at Bell Labs, Cisco Systems and many universities [20].

According to Theodore W. Berger, BCIs may be classified into two categories, “depending on the placement of the electrodes used to detect and measure neurons firing in the brain. In invasive systems, electrodes are inserted directly into brain tissue. In non-invasive systems, electrodes are placed on the scalp and use electroencephalography (EEG) or electrocorticography (ECoG) to detect neuron activity. (...) Other sensing methods employed in BCI systems in an auxiliary capacity include magneto encephalography (MEG), thermography, functional magnetic resonance imagery (fMRI) interpretation, and analysis of near infrared spectrum (NIRS) activity” [1].

In 'Caracolomobile' the headset's sixteen neuro biometric sensors capture the interactor's mind fluctuations and transmit them to the robot that answers them with sounds and movements. Built with titanium tubes, shaped as a snail shell, 'Caracolomobile' was hanged over an artificial water mirror surrounded by mirrors showing itself at many angles. The robot opens itself producing low pitch sounds when the interactor is relaxed. It closes emitting high pitch, almost hysterical, sounds when she/he is stressed. It was designed and built in modules: a pneumatic module, an electronic module and the BCI module [2].

Due to the short time available to develop the hardware and software (three months only) strict priorities had to be set up. Therefore, as stated above, it was chosen that the robot would answer to meditative and expressive affective states with pulsating

⁵ The definition of symbiosis that better fits the present context was proposed by Licklider quoted by Donald Norman. The proposed concept of symbiosis results from the “fusion of two components, human and machine, and the mixture is soft and fruitful, the resulting collaboration exceeding what anyone is capable of doing alone” [12].

movements and sounds, opening and closing itself. The sounds were pre computed since there was no time to program a composing musical interface. The movements resulted from the interplay of three pneumatic actuators controlled by three valves and three electronic boards. ASC values were used to set up a control table with values related to the amount of air to be blown. Therefore it was possible to create a repertoire of possible movements to be chosen to express the mind fluctuations digitalized by the headset. During the three months of its development some basic movement patterns were created, but the expressiveness of such movements needs improvements. After the exhibition finished the research has continued and different sizes of pneumatic cylinders have been tried. After such experimentations it was possible to arrive at the conclusion that the main difficulties to achieve the desired fluidity of movements were due to the interplay of varied tensions and compressions in the dynamic spiral trelliswork structure. These problems are mechanical and are not due to the BCI, but by understanding them it has been possible to adapt the parameters aiming to achieve the desired aesthetic and poetic goals.

3 Novel Possibilities for Artworks: Exoendogenous Interactivity

In 2003, with a previous grant from Itau Cultural Institute, Fraga began to develop a Java 3D framework for virtual reality artworks. Since 2006 she has adapted a set of very simple algorithms⁶ allowing the development of endogenous artworks where autonomous processes happen within the computer environment. With Pichiliani and Louro's collaboration a much bolder approach was conceived arriving at the concept of exoendogenous interactivity, which will be better explained in the next section. This approach goes forward into the artistic search for poetic and aesthetic qualities entwined with the scientific search for logic and exactitude and the technical search for functionality.

4 The Affective Interface

Aiming to investigate the possibilities of an affective interface for the experimental artwork, 'NumericVariations' (work in progress), a proof-of-concept was conceived. It also explores the Emotiv low-cost off-the-shelf affective neuro system using it "to provide emotional awareness information" [15] for artwork systems.

The artwork's virtual reality environment is composed by six cyberworlds. Each two of them approach one different algorithm achieving opposite aesthetic and poetic results. These algorithms allow autonomous processes to develop within the computer environment. The BCI captures the interactor's affective states of calm/excitement and input them into the autonomous agents' behavior parameters. Therefore the virtual agents change their behaviors accordingly to these human emotions. The calm/excitement states are transcoded as positive values.

⁶ These algorithms are: collision detection, flock and growth algorithms, and game of life algorithm. Only the three former ones are being used in 'NumericVariations'.

The ranges of calm/excitement detected by the interface provide the output scores reflecting the interactor's affective changes over time periods. In cyberworlds 'Branqueza' and 'Negreza' (Figure 3) these scores are passed as velocities and size of spheres that autonomously collide with the 'ground'. For cyberworlds 'DancingBots_01' and 'DancingBots_02' (Figure 4) a flock of dancing bots⁷ were programmed to behave by seeking and escaping from one another. The scores are passed as values that allow the bots that seek, the seekers, to run more or less eagerly after the bots that escape, the escapees. Therefore they define the dynamic of the autonomous process happening. For the cyberworlds 'FractalGrowth_01' and 'FractalGrowth_02' (Figure 5) the scores are passed as the ageing time of the growing processes.

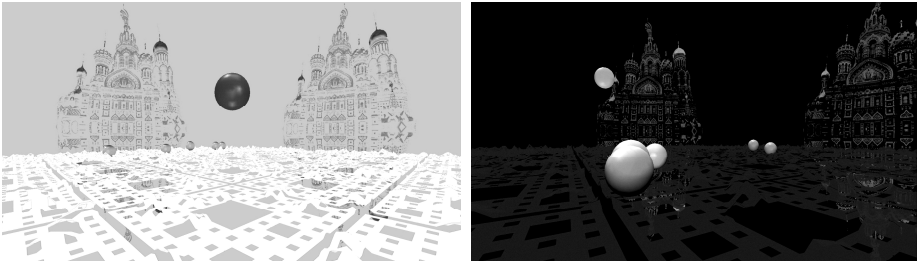


Fig. 3. 'Branqueza' (left) and 'Negreza' (right): virtual worlds with autonomous collision processes affected by human emotional states

“Emotions play an important role in human interaction, communication, coordination, and cooperation. (...). While there is a growing interest in providing computational support for recognition and representation of emotions, few research and artistic efforts explore the potential of BCI to collect, represent and explore emotional awareness (...). The study of emotions involves many disciplines such as neurology, psychology, and physiology. From the computer science point of view, the Affective Computing area explores how computing relates to, arises from, or deliberately influences emotions [14] arguing that by conferring the computers with abilities to recognize, model, and synthesize emotions, human-human and human-computer interaction will be improved” [15].

By reflecting upon these experiments the necessity to have a better understanding of some of the perceptive processes involved arose. Due to the peculiar characteristics of these artworks Peirce's theory of perception⁸ [13] was chosen as the most adequate to reflect upon and to understand such processes. Therefore it is necessary to briefly point to Peirce's definition of percept. Percepts are reflections of the physical world. They go through the sensory system unveiling dimensions of the material things for all beings, including animal, plants and machines. Artists assemble experiments with

⁷ Bots are virtual autonomous agents.

⁸ To Peirce's theory of perception see Lucia Santaella [17].

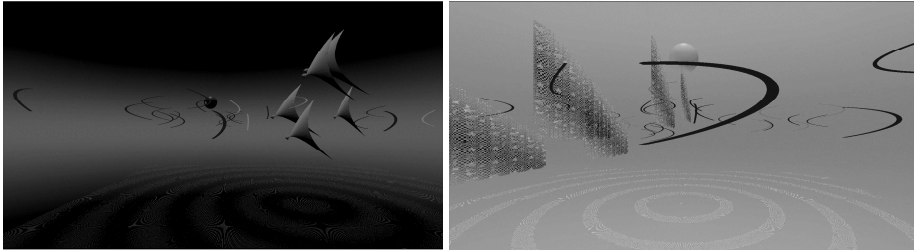


Fig. 4. 'DancingBots_01' (left) and 'DancingBots_02' (right): virtual worlds with autonomous flock behaviors affected by human emotional states

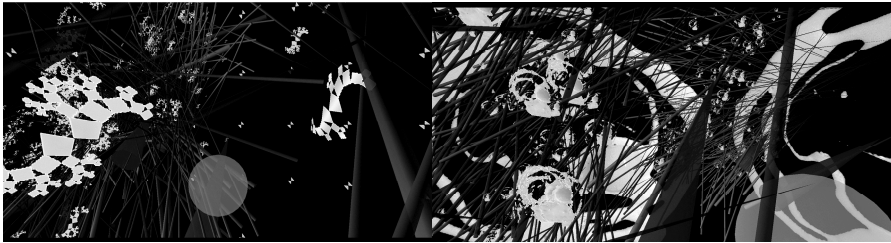


Fig. 5. 'FractalGrowth_01' (left) and 'FractalGrowth_02' (right): virtual worlds with autonomous growing processes affected by human emotional states

signs aiming to create actions or situations rich in percepts. Such percepts are characterized as signs, interdependent and plurals, among subject-sign-language and the object-thing. They spread over us “through all sensory pathways”. They fly within ones perceptive processes being “absorbed by the nets of interpretative models” one is doted [17]. Within the machine's processes the percepts are analyzed and evaluated in function of the action one intends to achieve from the machine, adapting them for aesthetic and poetic purposes.

5 Conclusions and Future Work

In this essay, the exploration of Brain Controlled Interfaces (BCI), aiming to experiment with poetic and aesthetic possibilities, used a mindware to capture emotional data exploring them in artworks. The main contribution of this paper is the novel use of affective data obtained directly from the brain to provide emotional feedback to the public interacting with the art work.

The main question is to inquire about the related possibilities to intertwine human affective states with computer autonomous processes. May one say that the computer agents, by capturing world percepts, are perceiving the human mind activity? How they convey, interpret, and react to it? Possible answers to this question may open poetic and aesthetic research fields for artists, leading to a better understanding of how computers collect emotional states within human minds, applying brain sensing

technologies for the art domain. Also, the exploration of this relation between the artwork and the interactor may reshape how one feels, behaves, understands and, ultimately, treats computer autonomous process after being aware of one's own emotions. The authors believe this approach represents an initial step in exploring a relevant area by applying it to Computer Art investigation.

To complement this approach for future works, one has to consider potential scientific applications of BCIs that are beyond visible controllers such as: motion control, medical devices, controlling home appliances, phone address books, haptic devices, web search engines, among others. Some mathematical and artworks may improve natural ideas through BCIs explorations for visual images generation. The IMA-SP [8] recent group works are demonstrating human ability to voluntarily regulate the activity of neurons responsible for visual images generation. The experiments were based on mathematical models and exploratory programming together with aesthetics through computer arts concepts. 'Ilustrativo' (Figure 6) is an example of this approach. In it EEG is recorded by electrodes placed on the scalp and digitized by an analogical to digital converter device (ADC). Computer process extracts features most suitable for identifying the subject's intentions. When intention is classified, a certain command is sent to an external device (e.g. a display). Feedback provides the subject with results of his/her actions thus allowing him/her to adapt to the system behavior.

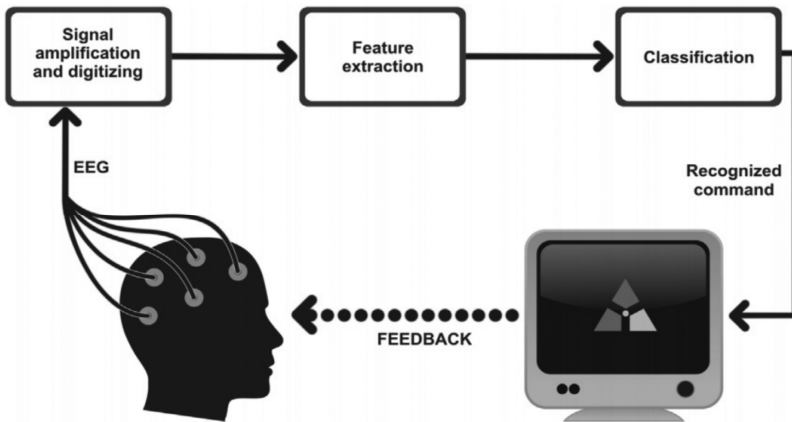


Fig. 6. General scheme of an EEG-based BCI [20]

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Multi-Brain Games: Cooperation and Competition

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Abstract. We survey research on multi-user brain-computer interfacing applications and look in particular at ‘multi-brain games’. That is, games where in one or other form the (EEG-) measured brain activity of more than one user is needed to play the game. Various ways of integrating and merging brain activity in a game context are investigated. Existing research games are mentioned, but the emphasis is on surveying BCI research that will provide ideas for future multi-brain BCI games.

Keywords: brain-computer interfaces, multi-brain games, social games.

1 Introduction

In previous years we have seen a growing interest in brain-computer interfacing (BCI) in the human-computer interaction (HCI) community. Before that, BCI was researched with the aim to help disabled persons and provide them, among other things, with a hands-free ‘communication channel’ to type messages, to control prostheses, or to navigate a wheelchair. Our research, instead, has focused on BCI for ‘healthy’ users, in particular on its use for games [1,2]. There are good reasons to do so. In games and entertainment applications we are not limited by thoughts and concerns that relate to patients and disabled persons. We can use our fantasy and can allow situations and events in non-real-life situations, happening in virtual worlds. We can allow cooperation and competition with multiple and distributed users and we can allow interaction modalities and effects that are unusual but can be believable, depending on the design of the game. Gamers don’t behave as disabled people in need. They have different motivations and expectations. That introduces problems and new challenges. Game designers have to design for challenges or otherwise to make use of the existing challenges in a meaningful manner, rather than to avoid them.

In 2012 a roadmap for BCI research appeared [3]. The roadmap was initiated by the FP7 research program of the European Union. Unfortunately, the roadmap stayed close to traditional BCI research. It hardly took into account new research opportunities coming from embedding BCI research in HCI research, in particular multimodal interaction [4,5] and artificial intelligence research. The problems (or

challenges) that were identified in the roadmap (reliability, proficiency, bandwidth, convenience, support, training, utility, image, standards and infrastructure) do also rise when we look at BCI for games, entertainment and artistic applications. However, they can be dealt with in a different way. A game is about challenges and an interactive art installation may be provocative and surprising rather than that it acts according to our expectations; teasing, frustrating [6] and deceiving. Hence, rather than being effective in a traditional sense, such applications are about manipulating experiences [7], and in particular hedonic experiences [8].

A bottleneck that prevents wide-spread use of BCI is the set-up encumbrance. A standard configuration requires an EEG cap with several electrodes, it has to be positioned on the head of the user, gel is required between scalp and electrodes to get good signals, and only after ten or more minutes of preparation time the user is physically connected to the BCI device. Presently so-called “dry” electrodes that don't require conductive gel and wireless connections have been introduced, reducing set-up time. Attractive headsets are now becoming available from BCI game companies. The other bottleneck is reliability. People can be trained to use a BCI, but not everybody can perform in a satisfactory way. BCI signals are subject-dependent and even for one subject there is variability depending on mood, emotions and fatigue. For certain applications repeated trials are needed in order to be able to make a decision about a mental state or to be able to map detected brain activity to appropriate control or communication commands. However, also for this bottleneck there are positive developments such as progress in signal analysis, artifact removal methods, and machine learning. Moreover, for some applications, as we will discuss in this paper, rather than recognizing brain activity of one user and deciding how to use it, we can have recognition of brain activity of many collaborating users involved in the same task. Maybe this multi-brain computer interfacing can lead to more reliable decisions and certainly it can lead to new and interesting applications of BCI.

Both for traditional BCI and multi-brain BCI it is useful to distinguish between active and passive BCI. Active BCI requires real-time or near real-time BCI. There is voluntary control of brain activity, meant to control an application. In a passive BCI situation the brain activity of a user is monitored. The user is not necessarily aware of it and does not attempt to steer it. This information can be used to adapt the environment, but not necessarily in real-time.

In this paper we discuss and survey applications and ideas on multi-brain-computer interfaces, with the aim of using these ideas in future multi-brain BCI games. In section 2 section we look at some research and applications in which information from multiple brain activity measurements is used to make decisions or to analyze multi-party interaction performance. Section 3 is about two important characteristics of games: competition and collaboration. Section 4 attempts to make clear that current BCI research makes it possible to talk about future BCI games that require input from brain activity of multiple users. Finally, in section 5, we present some conclusions.

2 Using BCI from Multiple Brains

Before looking more closely to what we call multi-brain games it is useful to have some remarks about BCI applications. We look at some examples where BCI is used in the context of information extracted from multiple brains. Clearly, gamers use their brains to compete and to collaborate, hence, whenever more than one player is involved in a game we can talk about multi-brain games, but, of course, it is better to speak of multi-user or multi-party games. Brain activity from multiple persons is measured and analyzed for neuromarketing purposes. An interesting example is neurocinematics [9] where similarities in spatiotemporal responses across movie viewers are studied. Future applications may require real-time processing of such brain activity in order to have collective or individual decisions about the continuation of a movie while watching.

There is certainly more research in which multibrain activity is investigated, where the immediate goal is not yet real-time applications, but where real-time applications, also in the context of games, can be foreseen. Mostly, at this moment in this research no active BCI control by users is present. There is, for example, measuring and analyzing of brain activity of persons engaged in the same task. There is the general aim of researching how this engagement shows in their brain activity. But there can be an added aim to learn from this and maybe support and improve this joint activity. This can then be done off-line, taking care of better conditions for future joint activity. And one step further, doing this analysis and interpreting the information real-time, that is, when the joint activity takes place, and then using this information to guide the users in their activity.

Whenever there is joint activity, the assumption is that there is some activity synchrony visible in the brain activity of the participants. Clearly, a conversation is a joint activity and coordination and nonverbal synchrony, including mimicking, is a well-known phenomenon. As reported in [10], there is also a spatiotemporal coupling of the speaker's and the listener's brain activity. In this research fMRI is used to record brain activity, hence, rather far away from the applications we have in mind. Nevertheless, the results support our idea that brain activity from different persons can be measured, analyzed and integrated in order to be used as a source of information to guide behavior and to control or adapt an environment in which the persons perform their activity. As is the case in other research on speaker-listener synchrony, the tighter the coupling between activities, the more successful is the joint task. As a possible application, can we off-line improve the conditions that lead to more synchrony? How do we model a social robot or an embodied agent such that its awareness of this synchrony can be used to have real-time adaptation of behavior?.

From this two-person activity we can move to multi-party or team activity. What kind of brain activity can we detect and integrate when we have a team of 'players' (not necessarily players in a game, but, more generally, persons involved in a joint activity). Can we get information about progress (successful collaboration) and use this information to improve conditions for such team activity? And, as a next step, based on real-time analysis and integration, being able to support and improve the joint activity? For example, during a meeting, can we decide and make group members aware that there is a convergence or divergence of opinions? In a multi-user game with participating teams, and when obtained real-time, such information can

certainly help to win the game. Clearly, game, entertainment and artistic environments can be designed in such a way that each kind of combination of one and more persons, individual and joint voluntary control of brain activity and other, not consciously produced brain activity, can get a role in the environment.

Chris Berka and her colleagues [11] have a research program that aims at studying team cognition using BCI. They use wireless EEG headsets to measure attention, engagement and mental workload of the members of a team that has to play a serious game: a submarine piloting and navigation simulation. The aim is to achieve measures of the quality of the team performance and use these measures to adapt and rearrange tasks and responsibilities for more optimal team performance. At this moment this adaptation and rearrangement is not done in real-time. In a multi-user entertainment game such information can also be used to remove team members or to rearrange tasks among team members for a next game session. But obviously, real-time adaptation would be much more useful.

In this example [11], team members do not manipulate their brain activity. Brain activity is monitored; hence we have a passive multi-brain BCI application. Rather than monitoring one individual engaged in a task, a group of collaborating persons (the team) is monitored with the aim to achieve and maintain 'neurophysiologic synchrony' (a positive team rhythm). While in this case the team effort concerns a serious game (a simulation of a critical real-world situation), the application could as well be a multiplayer entertainment game with competing teams and where optimal team performance is a goal as well.

Knowing about a collective mental state of a group of users can find interesting applications in game, entertainment and artistic applications. Being able to improve, in real time, decision processes by measuring and aggregating activity of all the brains of people involved in the decision making, as can be the case in multi-user games that allow the forming of teams makes it also possible to issue commands to a game as the result of volatile team brain activity. We will return to this in section 4 of this paper.

3 Competition and Collaboration with BCI

Competition and collaboration are important characteristics of games. For that reason we now look at research in which BCI is studied from a competition and collaboration point of view. Other characteristics of games and how they relate to BCI can be found in [8]. A viewpoint in the examples that we discuss in this section is that at least two players are involved. And that at least one of them has his or her brain activity measured and it plays a role in the game. This can be to control the game (active BCI) or to adapt the game (scenario, levels, and environment) to the user. The user does not consider these game changes as unnatural and is not necessarily aware (and hence does not try to influence it) that game changes are caused by his or her brain activity.

As a side note, notice that we consider these issues in the context of human-computer interaction. Hence, one of the partners involved in a game may as well be an artificial agent (physically or virtually embodied agent, e.g., a social robot or a virtual receptionist) or the environment or a device that acts and is supposed to interact in a humanlike way. As an example we can mention the study of [12] where a humanlike robot teacher has access to the brain activity (attention/level of

engagement) of a student and adapts his behavior to this activity by raising his voice or have more expressive gestures. In a competitive game environment knowledge about brain activity of a human opponent may give an unfair advantage to such an artificial agent. But that is also the case in a competitive game where a human player has access to the (interpretation of) brain signals of a competitor without having his own brain activity being exposed.

Obviously, when more than one person is involved in a BCI game, the social setting will have impact. Are players co-located or distributed? Is there an audience? What does the audience see and is there interaction between audience and players? In [13] the aim of the research was to investigate the use of BCI in a social setting (a small group of friends or relatives) and in particular the presence and the role of bodily actions of one of the group members playing a simple commercial BCI game while others are watching. In this game the BCI control is obtained from brain activity related to relaxation and concentration. Players used bodily actions (gestures, gaze, and facial expressions) to achieve a desired mental state. But they also used bodily actions to indicate their thoughts to the spectators in the group.

Interactions between co-located BCI gamers have been studied in [14]. We designed a game for research purposes: Mind the Sheep! (MTS!). It can be implemented as a single-player game, a cooperative multi-player game and, although we didn't experiment with that, a competitive multiplayer game. Moreover, it allows both BCI and non-BCI play for players. In our study we introduced a two-player cooperative version of this game to study social interaction between players. Both co-located players wear an EEG cap. The game visualization consists of a 2D map that contains simple representations of a meadow, a sheep pen, dogs and sheep. Players select and move dogs around to herd and eventually fence the sheep in. A dog can be selected with BCI (SSVEP evocation). The players can cooperate through gestures and speech to develop and execute a joint strategy. But of course, they see also at the screens what actions the other player takes. There is no integration of brain signals. If one player stops, the other can continue but may take more time to finish the task.

It is more usual to have two-player games where the players compete, each player volitionally using his or her brain activity to compete. This competition point of view where only BCI as input modality to a game is used, can be illustrated with two more examples from earlier research. Consider a BCI version of the well-known Pong game, a virtual tennis game that can be played by two gamers that control their bats (up and down) to hit a tennis ball back to their opponent. Motor imagery (imagine hand movements) has been used to implement a BCI version of this game [15]. That is, individual motor imagery controls the bats, and there is no processing that looks at - or compares - the brain activities of the individual players.

This is different in what was probably the first competitive BCI game, Brainball [16]. In this game we have two players competing. They are expected to compete by relaxing and their performance is measured by EEG. The player who is the best in relaxing wins. The game is made interesting by visualization of the players' performances that control a ball moving on a table between the two players that are seated on the ends of this table. This visualisation has impact on their performance and makes the game also attractive for an audience that can decide to support or disturb relaxation of a player. Clearly we need real-time BCI measurement and

control of this rolling ball. Brain activity of the players is compared and the difference determines the direction of the ball (moving into the direction of the player who is less relaxed). Hence, this is a different kind of competition, from the point of view of processing brain activity, than in the BrainPong example.

There are of course more examples where players manipulate their brain activity in order to play a particular BCI game. Our interest is in games where players have to compete or collaborate to play a certain game using brain activity. Relaxing to issue a command in a competitive environment has also been done in the ‘Mexican Stand-off’ [17]. This is a two-player game where the gamers relax in order to perform: that is, to fire a gun and kill an opponent. But certainly, being able to look at and experience the performance of their opponent, a gamer can try to increase his or her performance by comparing it with the performance of the opponent. Depending on the visualization or other information communicated to the gamers, such a stand-off game can be compared with a relaxation-based BrainPong game.

Less obvious is a cooperative two-player game where one player's brain activity is used to support the second gamer in his or her task. This second gamer does not necessarily use BCI. In [18] the authors look at games where players have different roles. One player is physically active while a second player uses his or her mastery of brain activity to provide favorable conditions for the performance of the first player. As mentioned in this paper, new games can be designed where a player's (traditional) game controller input can be modulated by collaborating BCI input, or where game activity is modulated by joint authority over game control input. Clearly, this includes a situation where brain activity of both players is measured and used in the collaborative control of a game. But it also allows games where there is competitive control over a game object. The authors introduce a Multi-User Video Environment (MUVE) that has been designed with both cooperation and competition in mind. Brain activity of one or more players can be used to disturb the physical control input of an opponent or opponents (or the other way around) and competition can be based on BCI input only.

4 Toward Multi-brain Games

We now have seen various possibilities for BCI input to games where players compete or collaborate. Usually this concerns two players, but suggestions that involve generalizations to more players are sometimes given. Moreover, the social setting of a game and associated social interactions emerged as an interesting research issue.

Interestingly, in what appears to be the oldest BCI game (BrainBall), there is a volitional contest by both players to control the same object in the game. In the other examples players use their brain activity to perform their own task in a collaborative or competitive game (MTS!, BrainPong), or they try to influence (in a collaborative or in a competitive way) the performance of the other player (MUVE). More subtleties in these distinctions can be introduced, e.g. by looking at dimensions such as social interaction and audience involvement and the role of passive BCI in these games. And, of course, we need to look at the consequences of having more than two players involved in multi-party and multi-brain games.

When looking at a possible definition of multibrain computer interfacing it now should be clear that it is unwise to be restrictive. Clearly, two or more persons need to be involved. Brain activities of two or more persons have to be integrated in the application. But, not necessarily at the same time and not necessarily in a synchronous way. In traditional multimodal interaction research we have one person interacting with an application using different modalities. The modalities can complement each other and fusion of the different modalities helps to solve ambiguities and can lead to more robustness. Usually three levels of fusion are distinguished, the data level, the feature level and the decision level. Fusion is meant to make the interaction effort stronger, to make clearer what is intended by an individual user.

We can also speak of fusion at different levels in the case of a cooperative game. For example brain activity of two or more players can be combined to have them make a particular decision in a game or to have them lift a spaceship in a virtual game environment, a task that would have been much more difficult if only brain activity of one player could be used. This is not some peculiar property of the brain activity modality. Lifting hand and arm gestures, facial expressions, or gaze behavior of two or more gamers could be implemented to have the same result. Or, any combination of different modalities that are used by different persons.

In the case of brain activity, comparable brain activity seems to be the most obvious first choice for data level fusion. But that may change in the future when we learn more about dependencies between different BCI paradigms. In a cooperative game situation fusion at the level of decision making can mean making a joint decision or doing a joint activity, but it can also mean a division of labor where players take responsibility for subtasks that help in reaching their joint goal.

Also in a competitive game where two or more persons are involved we can talk about fusion of information coming from different modalities and coming from different participants. Again, for the sake of discussion, let us focus on the brain activity modality. When we have competing players, rather than ‘adding’ information, on whatever level, we let the system (interface, game) compare (‘subtract’) information and make decisions that benefit the ‘winner’ or ‘winners’ who have outperformed with their joint brain activity the losers. Deciding when and how a team of BCI gamers has outperformed another team for deciding about or doing a particular activity can again be done at the data, feature and decision level. However, it should be mentioned that at each level different information is available to guide decisions. As an example, at the decision level we can use common sense and domain knowledge and we know about methods from artificial intelligence research that help us to represent and to reason about such knowledge. At every level of fusion, methods are available that take into account level context.

All these observations make it more difficult to get closer to a definition of multibrain games. Or, less difficult, to a decision that we should accept that there cannot be one definition and that multibrain games are just games in which measured brain activity of two (or more) gamers can be used to control commands or will be used to adapt a game to its users. Fusion of modalities of one user is an issue, but also fusion of modality information coming from different users (competing or collaborating) is an issue. There is another issue, when we talk about fusion, who is

taking care of it? In traditional human-computer interaction a multi-sensor system provides input to computing power and intelligence that makes decisions. In games, but not only in games, human decision making can be used about to decide about how to integrate and fuse information, including brain activity information, coming from different modality sources and from different users.

An interesting example is the Multimodal Brain Orchestra (MBO) presented in [19]. This orchestra has four performers and a conductor. Two of the four performers can use P300 to trigger emotionally classified discrete sound events. Two other performers use SSVEP to modulate articulation and accentuation of an earlier recorded MIDI sequence. The conductor uses a WII-mote as a baton and can decide when the sound events have to be triggered and he can decide about tempo modulations. Hence, evoked brain activity from different performers is directed by the conductor. There is feedback from the music and visualization. In this example there is, if we understand it well, no ‘adding up’ or otherwise processing of joint activity at the level of brain signals or features extracted from brain signals. There is a human decision about the fusion of the classification results (SSVEP and P300).

Having now discussed the different ways brain activity from two or more sources can be integrated (and not claiming completeness), we now look at research that has been done in the past and that supports our ideas about having multibrain BCI games in the near future by demonstrating that brain activity of multiple persons can be used in applications. Some examples, not really aimed at collective decision making or performing an action through collective brain activity were already mentioned in section 2. Knowing about a collective mental state of a group of users can find interesting applications in game, entertainment and artistic applications. But even more interesting is being able to improve, in real time, decision processes by measuring and aggregating activity of all the brains of people involved in the decision making process, as might be the case in multi-user games that allow the forming of teams. Teams allow some kind of ‘collective wisdom’ to make decisions. Real-time decision making by a team of users rather than an individual user has been investigated in [20]. In this research twenty users had to make perceptual decisions, that is, deciding when confronted with a series of pictures whether a particular picture was a face or a car. Prediction of a decision based on aggregated brain activity turned out to be possible and, compared with an individual user, both the decision accuracy and decision speed could be improved. Clearly, applying such research results in a multi-player game context can make those games more interesting to play. Collaborative brain-computer interfaces have also been studied by Wang and colleagues [21]. It is investigated how EEG data from twenty users can be used to predict and decide about movements. Clearly, this is the kind of information that can be used in a multi-player game that allows the forming of teams and can have team performance included in the game, rather than just have input from individual players only.

We conclude with the currently nicest example of a multi-brain game, “BrainArena” [22], that in a simple setting illustrates some of the ideas mentioned above. It is a simple football game with a ball and goalposts displayed on a screen in front of the two players. There exist two versions of the game, a collaborative and a

competitive one. The players wear EEG caps and use motor imagery (imaging left or right hand movement) to get the ball rolling in the direction of the goalposts. In the competitive version their actions are opposed and the player with the best performance wins, in the collaborative version the brain activities are merged and players steer the ball in the desired direction. Hence, in the competitive version it can be seen as a motor imagery version of the earlier mentioned BrainBall game. It can also be compared with a motor imagery version of BrainPong, but in that case each player has its own object (a bat) to control, while in BrainArena they compete to control an object (the ball).

5 Conclusions

We discussed the use of BCI as an input modality in a multiparty context. We discussed the various ways brain activity can be integrated in game contexts. We also focused on integrating brain activity from multiple persons. It is clear that many problems related to BCI in general have to be attacked. It can also be concluded, as we did in [1], that it is possible to design multiparty games in which multi-brain activity is included, and it can be done in such a way that it introduces interesting challenges to the gamers, rather than shortcomings of technology. Team decisions or team leader's decisions in a MMORPG (Massively Multiplayer Online Role-Playing Game) can be based on collective thoughts of a team or a sub team. Obviously, synchrony of thoughts is a problem here. However, natural game events can trigger joint and synchronized event related brain activity among team members. The potential role of 3rd party team communication software such as TeamSpeak should be considered. And again, perfectness would be unnatural. A 'synchronized kill' in the "Ghost Recon, Future Soldier" game does not have to be perfect. Joint brain and synchronized brain activity can be triggered because of various artificial stimuli that are designed in the game. There can be natural moments to take an explicit vote on how to continue or make an otherwise important decision. But fast decision making based on merging of brain activities of a large team, accepting that not yet everyone in the team is ready for it, is also natural.

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A Passive Brain-Computer Interface for Supporting Gaze-Based Human-Machine Interaction

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Abstract. Tracking eye movements to control technical systems is becoming increasingly popular; the use of eye movements to direct a cursor in human-computer interaction (HCI) is particularly convenient and caters for both healthy and disabled users alike. However, it is often difficult to find an appropriate substitute for the click operation, especially within the context of hands-free interaction. The most common approach is the use of dwell-times, but this can lead to the so-called “Midas-Touch” problem. This problem is defined by the fact that the system incorrectly interprets fixations due to long processing times or spontaneous dwellings as a user command. The current study explores the event-related potentials (ERPs) that might indicate a user's intention to select. Therefore, Electroencephalography (EEG) data was recorded from 10 participants during an interaction with a dwell-time system within a selection process. The aim was to identify EEG potentials related to the intention to interact (i.e. the selection of targets on a screen) and to classify these against EEG potentials unrelated to interaction during random fixations on the screen. As a result, we found a clear negativity over parietal electrodes for the intention of item selection. This negativity did not occur when participant fixated an object without intention to select (no specific intention). We robustly could classify the underlying brain activity in most of our participants with an average accuracy of 81%. The presented study provides evidence that the intention to interact evokes EEG activity that can clearly be detected by passive BCI technology. This leads to a new type of implicit interaction that holds the potential to improve human-machine interaction by increasing efficiency and making it more intuitive.

Keywords: EEG, passive BCI, implicit interaction, gaze-based interaction.

1 Introduction

Imagine a surgeon operating on a patient: both her hands are occupied, but, at the same time, she may want to be able to control a computer in order to retrieve

information about the patient's physiological state. In such a situation, a hands-free mechanism for computer control, i.e., cursor movement and object selection (similar to a mouse click), is desirable. In the early 1990s, Jacob ([1], [2]) has proposed to use the human gaze as input channel for human-machine interaction (HMI) in order to provide a natural and hands-free way of interaction (see also [3]). With recent technical developments that make eye tracking systems more exact and affordable, this form of interaction has become popular and first systems have arrived on the consumer market.

An advantage of gaze-based human-machine systems (HMSs) is the fact that it is very natural to use the eye for cursor movements. Usually, humans direct their attention towards an object by looking at it before pointing at it. Therefore, it is convenient to have the cursor position at the user's gaze location. However, it becomes tricky to determine an appropriate substitute for the selection operation as the eye does not provide a natural mechanism for this. Blinking and dwell time, i.e., a gaze fixation on an object for a particular duration, provide just limited solutions. The former has the disadvantage of involuntary blinks leading to a large amount of unintended selections. When using the latter, one faces the problems that fixations unrelated to the intention to select are interpreted as commands. Unintended selections can therefore occur due to spontaneous dwellings at random objects [4]. Moreover, it is hard to find an optimal dwell time for all stimulus complexities. The stimulus processing time might exceed the dwell time leading to an involuntary selection. This problem of unintended selections has been termed Midas-Touch-Problem because the user tends to feel comparable to the ancient King Midas who had the gift that everything he touched, even his food, turned into gold and because of this he almost starved to death ([1], [2]). Prolonging the dwell time may be one solution; however, in that case experienced users might become annoyed because the speed of the system is too slow leading to a speed-accuracy-trade-off.

Therefore, it may be worthwhile to make use of other hands-free input channels to find a more natural way of substituting the selection process. In the last years, brain-computer interfaces (BCIs) have been proven to be useful as a new communication channel independent from standard human output channels ([5], [6]). These systems transfer activity of the human brain linked to certain cognitive states as measured with electroencephalography (EEG) into commands for the computer. In the context of HMI, especially active and passive BCIs seem to bear good prospects to improve natural interaction ([7], [8]). For active BCIs, the user has to generate a certain brain state or EEG potential (e.g., by imagining an action like moving hands), whereas passive BCIs utilize information about the ongoing user state (e.g., situational awareness, user intentions, affective state) for an automated adaptation of the system [8]. Passive BCIs establish a secondary interaction cycle, next to that of the primary interaction the user is involved in. This additional interaction is implicit [23], meaning that users do not consciously send commands through the BCI. They might not even be aware that they are providing input through the passive BCI. Implicit interaction through a Passive BCI opens up BCI-based applications for users without disabilities [24] by decoupling them from the transferred information bit rate [24]. Additionally, nowadays dry and portable EEG electrode systems became available [9–11], so that HMI based on brain activity is more than mere utopia.

Recently, a system combining gaze input for cursor movement and an active BCI for the selection process was presented ([12], [13]). There, the users had to look at an object on the screen and simultaneously imagine a hand movement in order to select it. Over different stimulus complexities participants were as successful in using the BCI-based selection as in solely gaze-based interaction triggered by dwell times optimally chosen for the given stimulus complexity. As the selection based on active BCI is independent from stimulus complexities, it outperforms the common dwell time selection. Additionally, participants favored this system as they could work in their own pace, not disturbed by false selections when resting their eyes. To our knowledge this was the first study enhancing gaze-based HMI with the help of BCI input that was demonstrated in an online system. As a downside, the imagination process loaded some extra workload on the users, so that it may be promising to utilize a passive BCI to elicit the selection.

Based on a pre-study presented in [14]¹ we investigate the passive BCI in based gaze interaction. Participants were asked to find a target in a set of distractors. In trials where the target was present they were asked to select it by dwell time (class 1), in trials where no target was among the stimuli they were asked to return their gaze to the fixation cross and wait for the experiment to continue (class 2). Participants were not informed that the experiment would only continue if they rest their eyes on the cross for the same dwell time as during target selection. Hence, participants must show a very similar behavior during both classes, but clearly have a different state of mind. Our hypothesis is (based on the results from [14]), that we can discriminate the difference between these two states of mind (intention to interact / waiting) by a passive BCI. Such a passive BCI could then be used as a selection command in a very intuitive gaze based interaction. Items you intend to select are selected automatically, without the need of sending any additional command, while items you are just studying or looking at, will not be selected.

Here we will validate this hypothesis by an offline analysis of EEG data collected in the above-mentioned experimental paradigm.

2 Methods

2.1 Experimental Set-Up

Data sets from 14 participants (6 male; average age of 27 years) were included in the analysis. All of them were right-handed and reported being free of neurological

¹ The experimental setup of [14] was refined in this study as it included an unintended confounder between the two classes. The post-selection behavior was different between both classes. As subjects were asked to move their eyes to the center of the screen in Class 1, they might prepare for a saccade might have induced a readiness potential. As they would not have such an eye movement in Class 2 it is unclear what the basis of the signal investigated in [14] was. The experimental setup used in this study is corrected for this flaw.

disorders. EEG and electrooculogram (EOG) were recorded using 135 impedance-optimized electrodes (actiChamp, BrainProducts, Gilching, Germany). Eye movements were tracked with an IG-30 remote eye-tracker (IntelliGaze™ System, alea technologies, Teltow, Germany) module, which was also used for gaze-based interaction.

All participants were given verbal and written instructions and had to calibrate the eye tracker and to train how to interact gaze based. Each trial started with the presentation of a fixation cross for one second. Then a set of two or four different geometric objects containing either no or one target (a triangle or a hexagon) was added to the scene, at different locations on the screen (figure 1). In case a target was presented (class 1, intent to interact), participants had to selected the target out of either one or three distractors by means of dwelling at it for 1s. After successful selection of the target, it was replaced by a cross hair starting the next trial and with a new set of geometric objects. The cross hair did always appear at the location where the fixation of the last trial ended. In trials where no target was present on the screen participants were asked to look at the fixation cross until the new trial starts (class 2, no specific intention). Participants did not know that a new trial only would start after a successful fixation of the cross hair for 1 s. The experimental design ensured participants showing the same gaze-based behavior in both classes even though they had a different intent.

2.2 Data Analysis

Event Related Potentials (ERPs). For the analysis of event-related potentials (ERPs), we compared the averaged EEG signal at central electrodes relative to the dwell time selection in both classes. Scalp topographies were inspected for spatial location of the ERP. All scalp-electrodes were considered for the topographies.

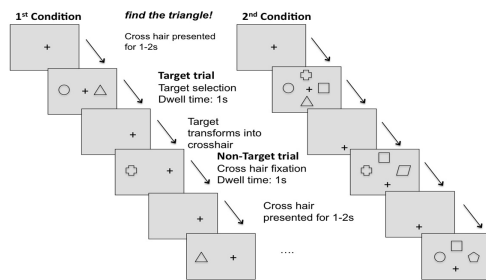


Fig. 1. Trial procedure: target and task combinations

The experiment consisted of twelve blocks, each containing 20 trials (10 for each class). While in six of the blocks 2 items were displayed per trial (condition 1), the other blocks contained 4 items each trial (condition 2). All participants completed

three blocks of each target and task combination in randomized target and block order. Thus, a total of sixty target and sixty non-target trials for each condition was recorded.

Classification. For defining our BCI approach, we used the open-source toolbox BCILAB [15]. Features were extracted by the Windowed Means approach [16] and classification was done with a Linear Discriminant Analysis (LDA, [17]) regularized by Shrinkage [16]. The defined approach is a subsampling of the data catching the trend of the signal and resulting in normally distributed features. Hence, a LDA is a very well chosen classifier for this decision problem, as it provides an optimized decision plane and suffices a very low Vapnik–Chervonenkis (VC) dimension [18].

The Windowed Means approach was parameterized with a series of non-overlapping windows of 50 ms length starting at 1050ms and ending 400 ms before the item (geometrical or cross) was selected resulting in a 13 (windows) x 128 (EEG channels) = 1664 dimensional feature space. Due to volume conduction, features in each temporal time slice (each 50 ms window) are spatially correlated [19]. Hence, the number of independent features is unknown but should be lower. Nevertheless, the ratio between independent dimensionality and the number of trials (240) is very bad.

We defined a classification model along this approach for each subject individually, calibrated on the data of both of the sessions (with 1 and with 3 distractors). An estimate of the online reliability of the defined model was derived by a [5,5]-times nested cross-validation [17] with margins of 5 (default by BCILAB, [15]). The inner runs of the nested cross-validation were 5-folded and served for the selection of the regularization parameter of the Shrinkage. The outcomes of the 5-folded outer runs, regularized by the one Shrinkage parameter derived in the appropriate inner runs) gave the estimates for the reliability of each runs model. The overall reliability was then given by the average of each single runs' reliability. The validity of this estimate is supported by the low probability of over-fitting of classifiers with low VC dimension [18], by the fact that the bad ratio between feature dimensionality and number of trials can be counterbalanced by a well-chosen Shrinkage regularization [16] and that we properly applied a nested cross-validation.

3 Results

Here, we present results from a selection of 10 of the 14 investigated subjects. Data from four subjects was skipped as we encountered technical problems with our eye tracker (mainly with the calibration) during their sessions. Estimates of classification accuracies and the average can be found in Table 1. Average accuracy of the skipped subjects was about 51.5%.

Table 1. Classification accuracies resulting from offline cross validation in 10 selected subjects

Subject ID	Accuracy	Subject ID	Accuracy
1	0.65	6	0.81
2	0.81	7	0.75
3	0.82	8	0.75
4	0.91	9	0.85
5	0.91	10	0.82
Average:		0.81	

Figure 2 shows event-related potentials (ERPs), averages of multiple instances of preprocessed EEG signals related to a specific event, in fronto-, central- and parieto-central electrodes. They show a negativity, starting 1100 ms before the final selection. This Negativity is strongest on parietal sites and attenuating while moving to frontal sites, as it can be seen in the related topographic plots. Figure 3 shows ERPs for channels reflecting eye movements. Here we see clear differences between classes from 1200 to 1050ms before selection.

4 Discussion

The aim of this study was to identify EEG potentials that occur during gaze-based HMI and can be utilized as possible input in a passive BCI system to select target objects on the screen. Especially it should show that it is possible to classify eye gaze fixations that are related to the intention to interact with objects on the screen against spontaneous, selection-unrelated fixations in a relatively natural HMI environment.

Classification results strongly support our hypothesis. The fact that features evoked from eye movements are clearly separable in time from those taken for classification, and the fact that the investigated negativity can be found clearly localized at parietal sites contribute as well. Taken together with the fact of a different topography in Class 1, showing only a 5th of the activity present in Class 1, supports a validation that the presented passive BCI indeed is based on cortical processes and not on artifact activity like eye-movements or muscular activity. This is important as the presented passive BCI is intended to work in gaze-based systems in very different environmental contexts. We assume that behavior changes easily with such contexts, which would lead to changes in eye and muscular activity. This would reduce the reliability and robustness of the classification of the passive BCI. As it is very likely that this is not be the case for cortical activity related to cognitive processes, we are confident that the approach presented here will be stable in different application scenarios.

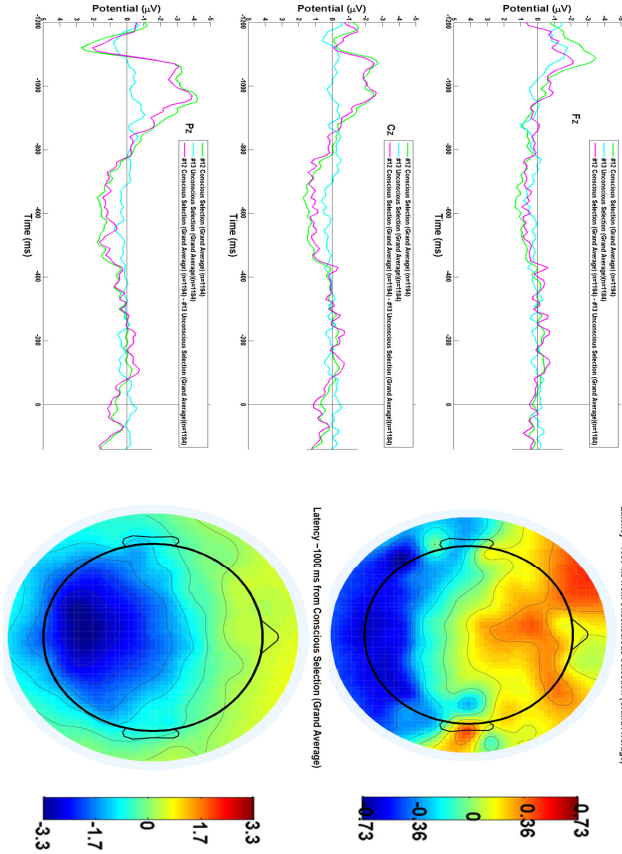


Fig. 2. Top: 3 ERP plots from frontal, central and parietal electrodes. Green curves for Class 1, blue curves for Class 2, purple curves: Difference Plot. Y-Axis in microvolt, X-Axis in milliseconds, 0 is item selection. Bottom: Topographic Plots, left: class 1, intent to interact, right: class 2, no specific intention. We see a clear negativity between -1100 and -850 ms in Class 1, which is not present in Class 2. Class 2 shows no relevant deviations from the baseline.

Looking at the conventional EEG analysis reveals a negativity over parietal electrodes. It clearly is related to the intended selection of an object of the screen (intention to interact) and does not occur in case participants were fixating the cross hair without intention to select (no specific intention). It nicely shows that brain activity in the beginning of a fixation for a selection is different from EEG activity during fixations unrelated to selection and thus may reflect the psychological difference. Future studies need to examine the revealed potential in more depth in order to determine its neuropsychological background. Therefore, source localization of EEG components should be accomplished using independent component analysis (ICA) [20]. By this, cortical generators of the potential can be identified leading to its better neuropsychological understanding. In addition, it is worthwhile to verify the occurrence of this potential in other experiments and real world applications to ensure its robustness, which is necessary for building reliable BCI systems.

Moreover, we performed an offline BCI analysis of the potential in order to provide an estimate for the classification accuracy in a potential online passive BCI system. We were able to robustly classify the revealed brain activation in most of our participants with an accuracy up to 91% using standardized BCI algorithms (e.g., see [21]). This value is well above chance level according to the work of Müller-Putz et al. [22]. Such high classification accuracy suggests that using this potential in a passive BCI system is well possible. Moreover, it seems likely that more complex analysis involving classification on components derived by ICA analysis could even improve performance. Additionally, it would assure even more that classification is based on neuropsychological reasonable EEG activity and not on eye movement or muscle artefacts.

We had technical problems with the eye-tracker in four participants resulting in very low classification accuracies for these participants. This can be explained by the fact that poor eye tracking calibration might lead to a delay in the actual selection of the target object in certain trials. Variability in the length of the fixation could kind of “wash out” the event-related potential as its start may be shifted by up to several hundred milliseconds. This in turn affects the features extracted and may thus deteriorate BCI classification accuracy. All in all, although improving classification accuracy is necessary, it seems that offline BCI classification worked fairly well for the revealed potentials.

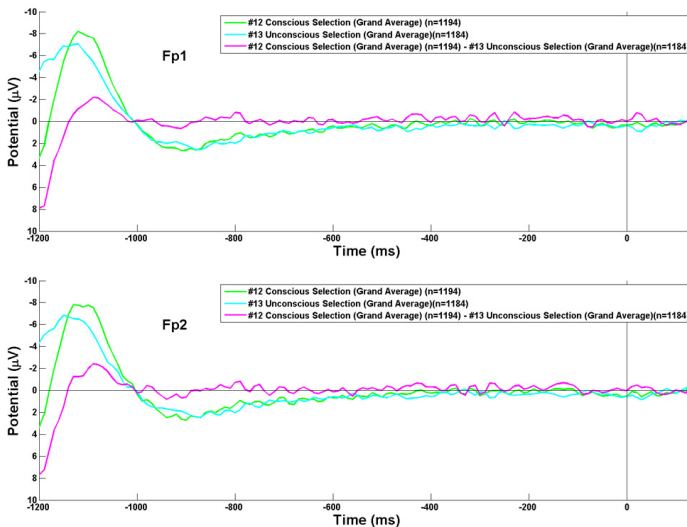


Fig. 3. ERPs reflecting eye movements. Green curves for Class 1, blue curves for Class 2, purple curves: Difference Plot, 0 is item selection. Here, we see a difference in timing between classes while the peak amplitude is stable.

The presented passive BCI could be applied in gaze-based interaction. In a first scenario it could replace dwell times as selection command. The benefit of this approach would be that users could interact very intuitively. Only those items would be selected which they plan to interact with. A drawback would be the lack of a selection command that can be triggered voluntarily. Users might experience this as a kind of loss-of-control [25], which could reduce the usability of systems. A second scenario would be using this passive BCI in addition to a dwell-time triggered selection command. The BCI could be used as a “second guess” improving the reliability by eliminating false positive selections.

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A Collaborative Brain-Computer Interface for Accelerating Human Decision Making

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Abstract. Recently, collective intelligence has been introduced to brain-computer interface (BCI) research, leading to the emergence of collaborative BCI. This study presents an online collaborative BCI for improving individuals' decision making in a visual Go/NoGo task. Six groups of six people participated in the experiment comprising both offline and online sessions. The offline results suggested that the collaborative BCI has the potential to improve individuals' decisions in various decision-making situations. The online tests showed that using Electroencephalogram (EEG) within the first 360 ms after the stimulus onset, which was 50 ms earlier than the mean behavioral response time (RT) (409 ± 85 ms), the collaborative BCI reached a mean classification accuracy of $78.0 \pm 2.6\%$ across all groups. It was 12.9% higher than the average individual accuracy ($65.1 \pm 8.1\%$, $p < 10^{-4}$). This study suggested that a collaborative BCI could accelerate human decision making with reliable prediction accuracy in real time.

Keywords: brain-computer interface (BCI), group decision making, Electroencephalogram (EEG), collaborative BCI.

1 Introduction

In human-performance studies, a team of individuals usually outperforms individuals especially when performance requires diverse skills, judgments, and experiences under time constraints [1]. Two heads are better than one, known as collective intelligence, the mechanism and neural basis of which has recently attracted growing attention of researchers in psychology and neuroscience [2, 3].

Recently, the collective intelligence has been introduced to the brain-computer interface (BCI) research field. For Instance, the concept of collaborative BCI has been proposed in [4] and [5]. Through offline demonstrations of collaborative BCIs, these studies suggest that a collaborative BCI, which integrated neural information from multiple individuals, can outperform a single-brain BCI. More recently, we implemented the first online collaborative BCI in a visual target detection task [6].

The huge potential of using a collaborative BCI to improve human performance has attracted many researchers and engineers' interests. For instance, Riccardo et al. [7] reported the application of a BCI system in a simulated spacecraft control task and the potential benefits of its extension to a collaborative multi-user BCI system. Riccardo et al. [8] subsequently explored the advantages of using an off-line collaborative BCI in a simple visual matching and a decision-making task. The g.tec company also demonstrated a collaborative P300 speller [9]. These studies suggested that combining brain activity of multiple users performing the same task might improve the overall BCI performance, compared to individual BCIs, and lead to extended applications of BCIs.

Here, this study presents the design and implementation of a truly online collaborative BCI for improving individuals' decision-making performance in a visual Go/NoGo task. To the best of our knowledge, this is the first demonstration of a single-trial EEG-based group decision making using an online collaborative BCI. To further explore the advantages of using the collective BCI system, this study also evaluates its performance under the tasks with different difficulty levels with an offline analysis.

2 Material and Methods

2.1 Subjects

Thirty-six (aged 19 to 28 years, mean age 23, 8 females) healthy university students from Tsinghua University participated in this study. They were divided into six groups (six participants in each group).

2.2 Experimental Setup and Paradigm

As illustrated in Fig. 1, the collaborative BCI system comprises six 16-channel EEG amplifiers synchronized by trigger signals from a server computer, which was also used for stimulus presentation and data analysis. A Media-Key multimedia teaching

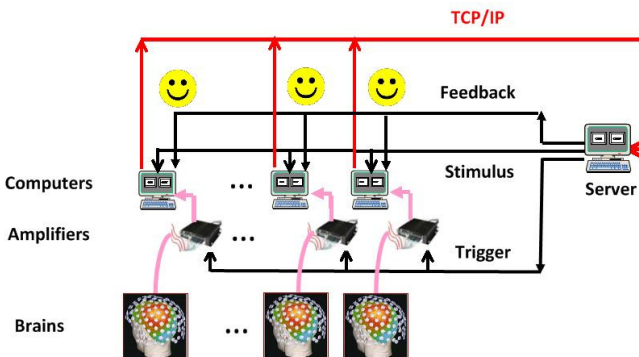


Fig. 1. Experimental setup of the collaborative BCI system

system delivered the stimulus to six LCD monitors (one in front of each subject) simultaneously. EEG data from each subject were sent to a computer via TCP/IP for real-time analysis.

The subjects were seated comfortably in armchairs at a distance of 80 cm from the monitor. During the experiment, a series of images including face images (Go tasks) and car images (NoGo tasks) were presented to the subjects. The subjects were instructed to press a button as quickly as possible when they recognized a face image, otherwise withhold the response. Once the button was pressed, an electrical event signal would be sent to the trigger channel of the amplifier and would be recorded in the software running on the computer. Sixteen-channel EEG data were collected by a standard EEG system. Electrodes were placed according to a standard international 10-20 montage at Fz, F3, F4, Cz, C3, C4, Pz, T5, T6, Oz, Fpz, F7, F8, P3, P4, POz, with a left-mastoid reference. The sampling rate was 1000 Hz.

The experiment comprised an offline training stage and an online test stage. The offline sessions were used to collect pilot data to train the classifiers, while the online sessions were used to evaluate the performance of the proposed collaborative BCI system. In the offline sessions, different difficulty levels were implemented to evaluate the performance of the collaborative BCI in decision-making under different situations. The difficulty level of the task was controlled by varying the phase coherence of the Go and NoGo images (45%, 35%, and 30%, difficulty level from low to high). The images of six conditions were equally and randomly distributed during the experiment. In the online experiments, for simplicity, only the images with the phase coherence value of 45% were used.

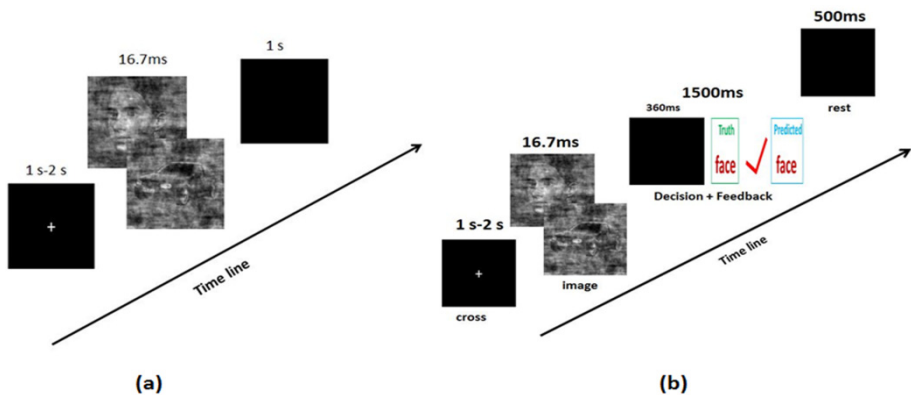


Fig. 2. Experiment diagram of (a) offline experiment and (b) online experiment

As illustrated in Fig. 2 (a), in the offline experiments, at the beginning of each trial, a fixation cross was presented at the center of the screen for a random duration from 1 to 2 seconds, followed by an image (about 16.5×16.5 cm) presented for 16.7 milliseconds (the period of one rendered frame). Following the image presentation, there was a one-second period for the subjects to make decisions and motor responses

before the next trial started. Fig. 2 (b) illustrated the diagram of the online experiments. Compared to the offline experiments, the multi-channel (Fz, F3, F4, Cz, C3, C4, Pz, T5, T6) EEG data within the first 360 ms following stimulus presentation were used to predict the upcoming decision. After classification, visual feedbacks (presented and predicted image types) were presented on the screens. This decision and feedback stage lasted 1500 ms followed by a rest period of 500 ms.

The training stage consisted of five blocks of 120 trials each, resulting in a total of 600 trials. Of them, 200 trials at the phase coherence value of 45 were used to train the classifiers. The trained classifiers were applied to the online testing session consisting of a block of 120 trials (60 images of cars and 60 images of faces).

2.3 Data Analysis

Behavior Data

In order to evaluate the general behavior performance of the subjects, this study calculated the averaged motor response time and accuracies across all the subjects during the tasks with different difficulty levels.

EEG Data

In the offline analysis, EEG data were first downsampled to 200 Hz and then band-pass (1-40 Hz) filtered using the `eegfilt` function in EEGLAB [10]. To validate the collected EEG data, the data were first re-referenced to the common average reference (CAR), time-locked to stimulus onsets and averaged across trials and subjects to obtain grand averaged event-related potentials (ERPs). This study then used a machine-learning classifier to predict the Go/NoGo decision based on single-trial ERPs following stimulus presentation. To estimate the performance of the system, 5-fold cross validations were used to evaluate the prediction accuracies during the task with phase coherence value of 45%. Specifically, this study calculated the accuracies of the individual and collaborative single-trial EEG classification (Go vs. NoGo) of the six groups of people with different time window lengths (from 150 ms to 250 ms with an interval of 20 ms, and from 250 ms to 400 ms with an interval of 50 ms). As illustrated in Fig. 3, after band-pass filtering, the signal-to-noise ratio maximizer (SIM) algorithm [11] was used to extract each subject's ERP components from multi-channel EEGs through spatial filtering. The first three ERP components of each condition were selected as features for classification. A two-layer support vector machine (SVM) classifier was then applied to predict the Go/NoGo decision. The feature vector constituted by the outputs (the probability of the trial to be a Go task) of the first-layer classifiers for all subjects was forwarded into the second-layer classifier to make the group decision. The program was implemented using the LIBSVM toolbox [12].

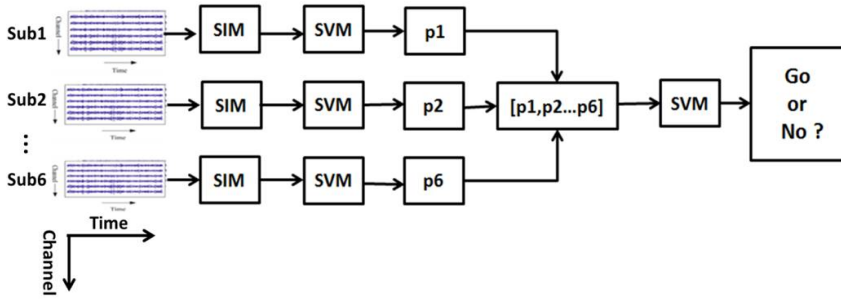


Fig. 3. Diagram of feature extraction and classification in the collaborative BCI system

It is also of great interest to see the potential of the collaborative BCI for making a group decision under the situations with high difficulties. To this end, in the offline analysis, 5-fold cross validations were used to estimate the accuracies under the tasks with phase coherence value of 35% and 30%. However, as the available samples of Go and NoGo conditions for each subject were limited and unbalanced according to behavioral performance (cf. Fig. 4(b)), we found that the individuals' single-trial EEG classification accuracy was close to the chance level in these situations. To improve the SNR of single-trial ERPs, we alternatively first averaged the signals across all the subjects participated in the experiment (hence, the group size was 36). The resultant cross-subject averaged ERPs were forwarded to the SIM algorithm to derive spatial filters and then classified by the SVM.

In the online experiments, the signals of each trial were resampled at 200 Hz, and digitally filtered at 1-30 Hz with a twentieth-order causal filter. The feature extraction and classification methods illustrated in Fig. 3 were subsequently applied for prediction. The length of time window used for real-time data analysis was set to 360 ms.

3 Results

3.1 Behavior Results

Fig. 4 (a) shows that subjects' response time increased as the task difficulty level increased. The response times were 409 ± 85 ms, 461 ± 113 ms, and 470 ± 113 ms at the phase coherence of 45%, 35%, and 30%, respectively.

Fig. 4 (b) shows that subjects' detection accuracies decreased when the phase coherence value decreased ($92 \pm 1.5\%$, $74 \pm 3.8\%$, $64 \pm 3.5\%$ corresponding to phase coherence values of 45%, 35%, and 30%). This phenomenon was more pronounced in the Go trials (decreasing from $96 \pm 2.0\%$ to $63 \pm 6.7\%$, and $41 \pm 6.0\%$). It may suggest that the subjects tend to response very cautiously during the experiments, preferring holding the button rather than making a response.

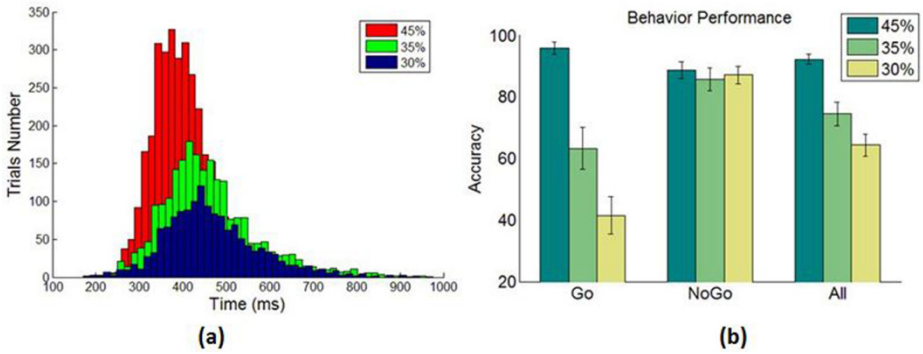


Fig. 4. (a) The distributions of response time of correctly responded Go trials with different difficulty levels. (b) Behavior accuracies of different tasks. Go, NoGo and All denote the Go (face) trials, NoGo (car) trials and overall (Go and NoGo) trials respectively.

3.2 Offline Results

Grand Averaged ERP

Fig. 5 (b) shows the robust ERP components evoked by Go (face N170 at T6) and NoGo (larger N2 and P3 at Fz) trials. The difference waves were very pronounced at several scalp channels (see Fig. 5 (a)). Thus, it could be inferred that the components contributing most to the classification were the face-specific N170 component in the Go condition, and the larger N2 and P3 components in the NoGo condition.

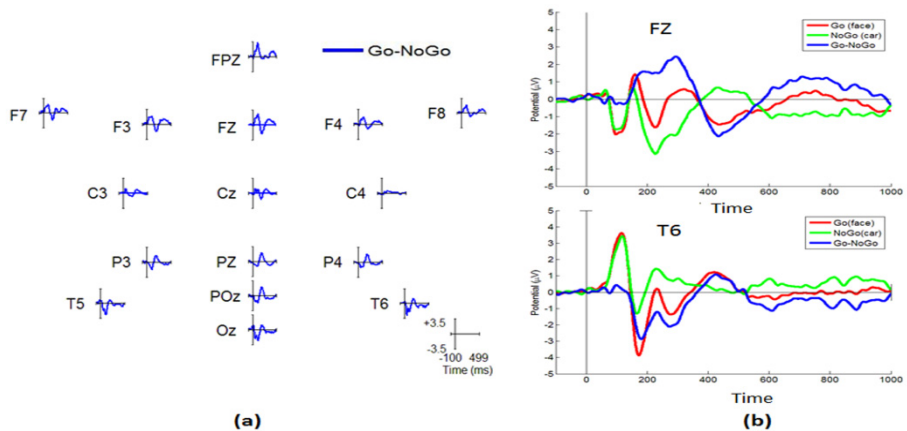


Fig. 5. Grand averaged ERPs for the task with the phase coherence value of 45%. (a) multi-channel difference waves (Go - NoGo). (b) ERP and the difference wave in Go and NoGo trials at channel Fz (top) and T6 (bottom).

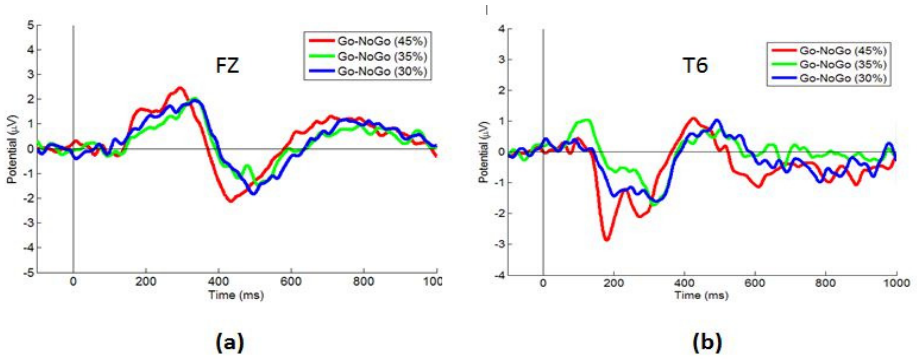


Fig. 6. Difference waves (Go- NoGo) under different difficulty levels at (a) Fz and (b) T6. The red, green and blue colors represent coherence values of 45%, 35% and 30% respectively.

Fig. 6 shows the difference waves between Go and NoGo conditions under different difficulty levels at channels Fz and T6. Intuitively, it seemed that as task difficulty increased, the amplitude of the difference wave decreased, while the latency of the difference wave increased. These response variabilities would make the EEG-based classification more difficult.

Single-Trial EEG Classification

Fig. 7 shows that the system’s classification accuracy increased monotonously with the length of time window. It is also evident that the collaborative paradigm outperformed the mean of the individuals and the best individual in the group. The classification accuracy of the system could reach about 80% with a time window length of ~350 ms.

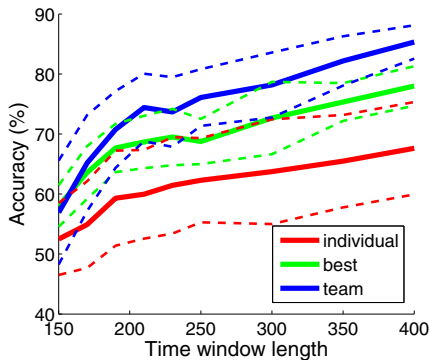


Fig. 7. Single-trial EEG classification accuracies as a function of time window length at the phase coherence value of 45% across all the six groups

Fig. 8 shows the single-trial EEG classification accuracies as a function of the length of time window at the phase coherence value of 35% and 30%, when all the 36 subjects were included in a group for calculation. Using the EEG from first 350 ms, the accuracy was 71.0% and 65.5% at the phase coherence values of 35% and 30%, respectively. These results were comparable to the individuals' behavioral results ($74.0 \pm 3.8\%$ and $64.0 \pm 3.5\%$ at the phase coherence values of 35% and 30%, cf. Fig. 4(b)). To be noticed, in the Go condition, the average response time was 461 ms and 470 ms when the phase coherence values were 35% and 30%, respectively.

These results suggested that even under very difficult decision-making situations, when the subjects failed to make an accurate and quick decision, the collaborative BCI have the potential to improve individuals' decision speed with comparable accuracy.

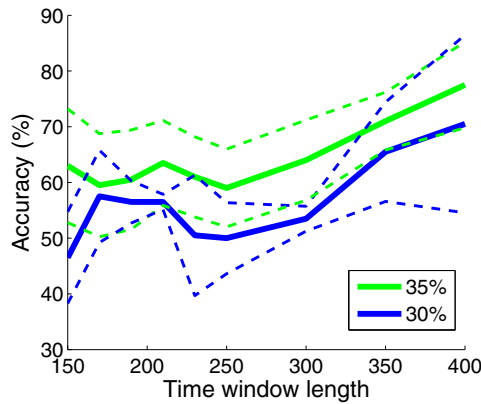


Fig. 8. Single-trial EEG classification accuracies as the function of time window length at the phase coherence value of 35% and 30% respectively

3.3 Online BCI Performance

Table 1 lists the performance of the online collaborative BCI. Consistent with the offline analysis, the online test showed that the prediction accuracy of the collaborative classification was significantly enhanced over that of the individual classification. Using EEG within the first 360 ms after the stimulus onset, which was 50 ms earlier than the mean behavioral response time (409 ± 85 ms), the collaborative BCI reached a mean classification accuracy of $78.0 \pm 2.6\%$ (range: 75%-82%) across all groups. It was 12.9% higher than the average individual accuracy ($65.0 \pm 8.1\%$, $p < 10^{-4}$), and 3.3% higher than the best individual accuracy ($74.7 \pm 4.2\%$, $p < 0.1$). These results suggest that a collaborative BCI could accelerate human decision making with reliable prediction accuracy in real time.

Table 1. Accuracy of the online collaborative BCI (%)

Group#	Sub #1	Sub #2	Sub #3	Sub #4	Sub #5	Sub #6	Team
1	63	68	51	61	63	58	76
2	62	73	68	66	52	68	82
3	79	73	74	65	72	65	80
4	79	77	56	53	64	59	75
5	73	58	58	73	58	63	77
6	63	48	68	73	76	65	78

4 Conclusion and Discussions

This study presented the design and implementation of an online collaborative BCI for improving individuals' decision making in a visual Go/NoGo task. The performances of the collaborative BCI during the tasks with different difficulty levels were also evaluated. The offline results suggested that even in the difficult decision-making situations, where the subjects were difficult to make quick and accurate decisions, the collaborative BCI can still have the potential to improve individuals' decision speed with comparable accuracy. In summary, the collaborative BCI technology provides an efficient way for achieving collective intelligence from brain activities of multiple subjects.

The proposed BCI system does have some limitations. First, the data transmission and analysis of the system was implemented in a centralized fashion. Too much data transmission and computation would affect the speed and performance of the system. In the online experiments, we found that the data transfer speed varied across trials, bringing some delays in the feedback presentation. To alleviate this problem, a distributed framework, which involves less data transmission and performs data computation in a distributed fashion, may be a good choice. Furthermore, more efficient multi-brain computing methods are also of great importance to improve the system performance. The collaborative filtering and transfer learning may be promising along this direction [13].

The proposed paradigm may also have potential in reducing errors in impulsive decision making of a group within chaotic and data-poor environments. In addition to BCI applications, the proposed framework might have potential for EEG-based group brain imaging of social processes and behavior.

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Towards Implicit Control through Steady-State Somatosensory Evoked Potentials

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Abstract. We present a reliable reactive BCI based on steady-state somatosensory evoked potentials (SSSEPs). As the stimulation frequencies are higher than 35 Hz this system ensures no interference with BCIs relying on ERPs or SMR. Hence, the presented system can be combined with other BCIs broadening the bandwidth of communication.

Keywords: Reactive BCIs, steady-state somatosensory evoked potentials (SSSEPs).

1 Introduction

1.1 Objective

The study presented here aims at extending the scope of Brain-Computer Interfaces (BCIs), by introducing an approach that is not interfering with standard BCI systems and which is not altered by signals evoked from standard modes of interaction.

BCIs were initially introduced to support severely disabled persons with providing an additional communication channel that only incorporates activity from the central nervous system [18]. Today, this technology evolved to broaden human-computer interaction in general, also including people without disabilities [20]. Such BCIs extract features from the electroencephalogram (EEG) that are functionally related to cognitive or affective aspects of the user state. Based on information inferred from these features the technical system can react or adapt itself to the current user state [20]. As the EEG has a very high temporal resolution the BCI can work with minimal temporal delay, allowing for recognizing changes in the user state even before the user becomes consciously aware of these changes [19].

BCIs for direct control of technical systems might be of interest for users who want to send commands additionally to their primary mode of interaction. For example, users might send a simple command while their hands, speech and even their gaze is occupied in other tasks. Think about a pilot in an emergency

situation, speaking to the tower and the copilot, reading the instruments and using the manual inputs of the plane. He might need to respond quickly to an urgent request of the cockpits computer systems, which might be accomplished with an additional, unoccupied communication channel provided by a BCI.

Here, we present a BCI based on high frequency steady-state somatosensory evoked potentials (SSSEP), working with signal frequencies higher than 35 Hz. Standard EEG analysis focus on frequencies between 0.1 and 35 Hz, including delta, theta, alpha and beta bands [1]. as these frequency bands are associated with human cognition [17]. Hence, the BCI presented here is based on features in the EEG that should not be modulated by such processes. The presented approach can be categorized as a reactive BCI (rBCI) [20], as SSSEPs can be modulated by attention but cannot be generated without the perception of artificial stimuli. In comparison to active BCIs where users can and need to generate a specific activity by themselves, control via rBCIs is usually less demanding. Hence, an rBCI is a good choice for application in the aimed multitasking environments.

1.2 Approach

Reactive BCIs usually make use of two different types of features in the EEG. One approach is facilitated by systems detecting changes in or appearance of event related potentials (ERPs) typically caused by the perception of discrete, relevant stimuli. Alternatively, there are systems based on the detection of steady-state evoked potentials (SSEPs). These are potentials which are evoked from perceiving a stimulus that is modulated in a specific frequency. This perception leads to differences in the spectral domain of the EEG in exactly the same frequency.

A well known example for ERP-based rBCIs is the P300-Speller [5], relying on visual perception. A rBCI based on tactile information can be found in [9].

Most of the work with SSEPs is based on visual input [8,11], but here also tactile [2] stimulation can be found next to studies involving auditory [12] stimuli. These examples give evidence that rBCI-based approaches can potentially be transferred between modalities. As the visual and the auditory domain of users in Human-Machine Systems usually are occupied during operation, we investigate rBCIs that rely on tactile stimulation. Our approach transfers the knowledge gained from the rBCIs mentioned above to this modality and investigate the reliability of high frequency stimulation.

We modulate specific frequencies in the EEG by steady-state somatosensory evoked potentials (SSSEPs) with auditory speakers as tactile stimulators. A similar approach focusing on low frequency stimulation has been applied by Mueller-Putz et al. [10] who used transducers on both index fingers with subject-specific “resonance-like” frequency, i.e. interindividually differing frequencies ranging from 20 to 31 resulting optimized SSSEPs with a BCI accuracy of between 70% and 80%.

In our approach the frequency domain of the factors is kept above 35 Hz and thereby excludes (1) interference with typical BCI-applications that are based on

evoked potentials since those usually consist of waves within a lower frequency band (0.5 Hz – 5 Hz) and (2) covering of the frequency domain which is generally assumed to be related to cognition [17].

As we are aiming to provide first evidence of a rBCI based on high frequency SSSEPs we decided to apply the tactile stimulation to the participants palms, since they are represented very prominently in the somatosensory cortex (which can be seen in figure 1), ensuring a good signal quality.

2 Method

2.1 Experiment

EEG was recorded in 8 participants with 64 impedance-optimized electrodes [BrainProducts, Gilching, Germany] placed along the extended 10-20 system. Impedances were kept below 5 kOhm. Tactors used in the experiments were developed by EagleScience [Amsterdam, The Netherlands] and are based on auditory speaker modules. Compared to tactors that are driven by unbalanced motors, the stimulation with auditory based tactors is very precise and well adjustable regarding the frequency and amplitude of the vibration. The experiment was realised within the SNAP-Framework [Swartz Center for Computational Neuroscience (SCCN), University of California, San Diego (UCSD)] and the data was recorded using the labstreaming layer [SCCN, UCSD], fusing the EEG datastream with the markerstream sent by SNAP.

At the beginning of the experiment participants were informed of the course of the experiment. Afterwards the EEG was prepared and the tactors were placed on the participants palms of the left and right hand and fixated with gauze bandages.

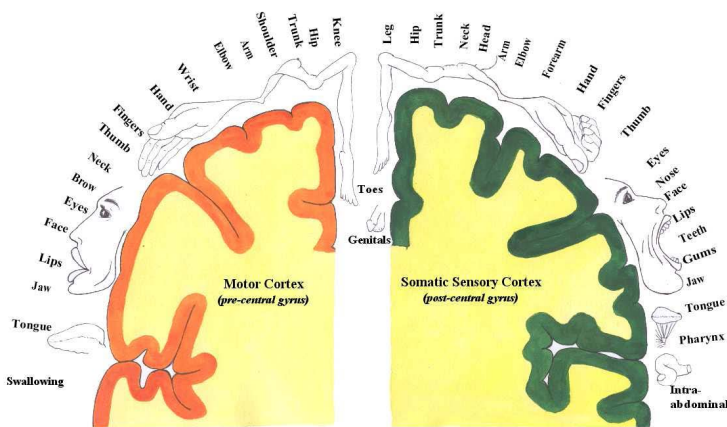


Fig. 1. Homunculus of the somatosensory cortex ([7])

Each trial started with the presentation of a randomly selected letter from the set L, R at the center of the screen for a period of 2 seconds. Hereafter, the letter was replaced by a fixation cross displayed for 3.8 seconds. Simultaneously the tactors started vibrating and participants were asked to focus their attention on the vibration on the left hand if the initial letter had been L or on the vibration on the right hand if it had been R. After 2.75 seconds the amplitude was reduced by half for 0.125 s (amplitude twitch, comparable to [10]) and then went back up to its initial amplitude for the rest of the trial. Participants completed 60 trials, with a probability of 0.5 for each side.

Stimulation was derived from [15] and [10]: each tactor was vibrating with a carrier-frequency of 128 Hz sine modulated with a sine frequencies of 41 Hz on the left hand and 59 Hz on the right hand. Prime number frequencies were used for modulation to reduce overlapping frequencies.

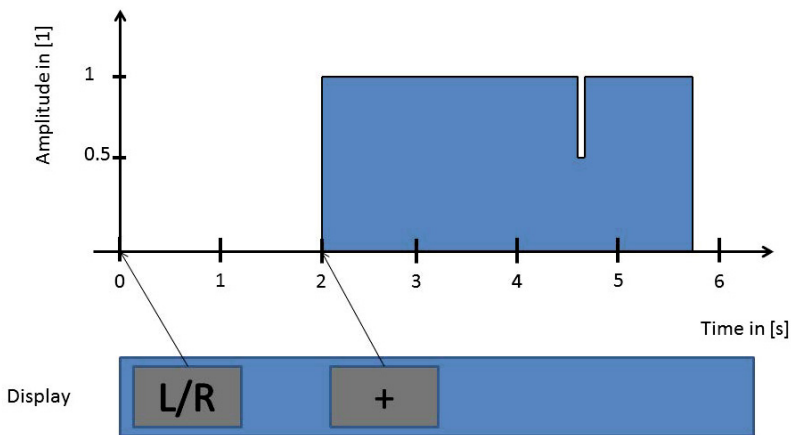


Fig. 2. Course of one trial during the training session

Markers were written to the EEG for every presentation of the stimulus and fixation-cross.

2.2 Analyses

Similar to the Common Spatial Patterns [13] approach we implemented spatio-temporal activation patterns and filters respectively. Patterns were derived for each class (attention on left or right tactor) by averaging differences between the estimated power of the frequencies of 41 Hz and 59 Hz during stimulation and normalizing it by the respective averaged bandpower derived from the 2 seconds of data before the stimulation. Filters were calculated by projecting the patterns with the inverse covariance matrix derived from the stimulation period.

Features were extracted for each channel by a similar procedure. Again, but here on single trial data of 2.8 to 3.8 seconds after the start of stimulation, bandpower was estimated for both frequencies and normalized by the bandpower of the prestimulus data. Features were then projected by the patterns and filters, resulting in a 4 dimensional feature space. Single-trial offline classification was performed with BCILAB [3], generating a regularized linear discriminant analysis for each participant by crossvalidating the trials along the aforementioned approach.

3 Results

The regularized crossvalidation of the classification procedure resulted in an accuracy of 65.3% averaged over subjects. Individually estimated accuracies can be found in table 1.

Table 1. Accuracy of classification across subjects

S1	S2	S3	S4	S5	S6	S7	S8	average
0.60	0.65	0.65	0.65	0.68	0.73	0.63	0.65	0.653

Figure 3 shows the averaged weights of the activation patterns for each class. High weights can be found at electrodes over those parts of the sensorimotor cortex related to tactile sensations at hands.

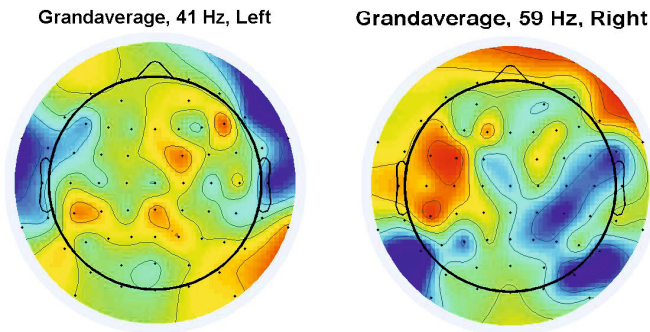


Fig. 3. Topographic scalp plot for 41Hz domain with focus on left hand and 59Hz domain with focus on right hand (grand average)

4 Discussion

The presented approach focusing on high-frequency SSSEP features indeed leads to a reliable single-trial classification. It is lower than that reported in [10], but the approach presented here ensures independence from other modes of input. Nevertheless, at the moment the reliability around 65% is not high enough for real world applications.

In this experiment the factors were located on the palms of participants. Even though it likely provides the best signal quality, this approach is hardly applicable in real world scenarios. Users might be hindered in their primary modes of interaction, if they require manual input. If the rBCI is used for directional decisions, users also might get confused if spatial locations of the hand change over time. The homunculus (figure 1) indicates that other areas (e.g. arms or legs) also could be good locations for SSSEP stimulation. Such areas might be represented prominently as well, but will be closer to each other which might complicate utilization of spatial patterns.

Nonetheless the results of this study represent a first step towards multimodal and multifunctional BCI-based control in Human-Machine Systems. It still needs to be validated in an online experiment. First pre-experiments showed a mixed reliability. Over certain periods of time participants had almost full control, while they lost it almost completely in other periods. This points at a problem with feature-nonstationarities. Hence, future research should focus on new types of feature extraction aiming to increase the robustness and accuracy OF classification. Improvement of the linear weighting to a spatial filter could be a solution, which would have to be tested on data from a higher number of participants. A hybrid application combining the approach described here with e.g. a motor imagery BCI should be promising to increase the bandwidth of information transfer in BCI-based applications.

Concluding, the study presented here has made a first step in investigating the useful applicability of rBCIs for users without disabilities. The provided proof of concept opened up the field of BCI research to new types of applications and raised questions which have to be investigated in future research.

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Designing Wearable Bio-Interfaces: A Transdisciplinary Articulation between Design and Neuroscience

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Abstract. This paper presents and discusses the rapprochement between Design and Neuroscience in the design of wearable bio-interfaces based on the contributions of studies related to the environment/behavior/neuroscience paradigm and emotional processing in the human brain, regarding the identification and recognition of neurophysiological information relevant to projectual practice in Design. The article also considers the Design-Neuroscience relationship in the projectual practice of wearable computers “BioBodyGame” (2006-2008) and “NeuroBodyGame” (2008-2010) by means of which it addresses the interaction between the body of the user (neurophysiological signals and brain waves) and the computer by the use of bio-interfaces.

Keywords: Design, Neuroscience, Wearable Bio-Interfaces, Transdisciplinarity.

1 Design-Neuroscience Relationship

Neuroscience, as a relatively new science¹, deals with the development, chemistry, structure, function and pathology of the nervous system [11]. In this perspective, cognition is investigated based on the properties of the brain, that is, by assigning specific brain structures to all forms of behavior and experience, even though approximately. Thus, changes in brain structure imply changes in behavior and experience. In this context, if on the one hand, there is the association of bio-based properties to cognition, on the other hand, mental and biological phenomena are considered as products of the cognitive system structure [18].

Researches in Neuroscience [2], [5], [7], [9], [17] indicate that the human brain is particularly able to design things - concepts, tools, languages and locations. In other words, the human brain may have evolved to be creative - to imagine new ideas, put into practice what was invented, and critically analyze the results of human actions.

The cognitive science has already uncovered cue recognition information that designers can apply, for example, “knowing that physical cues located below eye level are more readily processed and attended to than those located above it, wayfinding cues that designers place in our lower field of vision are likely to be most

¹ "Thorough scientific researches on the neural function have a relatively short history, beginning in the late nineteenth century" [11].

effective” [20]. And in this way the neuroscience literature seems to indicate that the higher purpose of the brain’s environment system is to develop a clearer sense of who we are in relation to our environment” [20].

In this context, John Zeisel proposes The Brain’s Creative Development Spiral diagram comprising that when someone has a perception, develops a plan or reacts to the environments, the mind uses the same interactive process that designers use in their design process. And, in this sense, Blass suggests that designers and researchers should take advantage of the brain’s natural creative process to achieve their ends and that understanding brain function can provide insight into the nature of research, design and creativity. Therefore, exploring the brain even further must improve design and research in practice [20]. For these researchers, the focus lies in answering “how the brain’s fundamental creative process engendered the cognitive process of design?” [20], once incorporating an understanding of the brain’s neuronal structure and processes Design leads to the most supportive setting for creation and projectual proposals. In other words, “understanding of brain capabilities employing a neuroscience approach reinforces and explains studies of users’ needs, behavior, attitude and opinion” [20]. Such understanding also supports the structuring by Zeisel regarding the Environment/Behavior/Neuroscience (E/B/N) paradigm assuming that changes in the environment change the brain and behavior and later the interaction between environmental stimulus and behavioral response in ways that inform and improve design. According him if you understand how people’s brain and mind develop and function in different situations, and how they have evolved over time to respond to physical environments, then environments designed to support these capabilities as well as tasks, activities, and user’s needs will contribute to people’s quality of life, creativity and survival [20]. Thus, while the user’s needs paradigm primarily rests on analytic interpretation of externalized data, the neuroscience paradigm rests on analysis of brain and mind based on observed behaviors and adds understanding of neurological and biological functions to traditional psychological, sociological and anthropological environment-behavior knowledge. The goal is that further neuroscience understanding of brain abilities will help designers more effectively plan their projects.

2 The Role of Emotion in Human Survival

One of the brain skills we are interested in addressing and relating more specifically to the projectual practice in Design consists of human emotions. Therefore, at first, we consider this question from the standpoint of neuroscience and neurophysiology so we can propose the articulation of this scope to the field of Design of wearable bio-interfaces in the next section. According to the biological perspective, emotion can be defined as "a set of chemical and neural reactions underlying the organization of certain behavioral responses that are basic and necessary to the survival of animals" [14]. Thus, emotions are essential so the animals can present "appropriate behavioral responses to certain situations, increasing their chances of survival" [14].

On human beings, emotions result from the activation of a complex neural network that promotes a varied repertoire of behavioral responses. In this sense, emotion reaches a subjective dimension of unique experience different from the behavioral dimension observed in other animals. Thereby, on human beings, emotion has a "neural substrate that arranges responses to emotional stimuli and the own perception of emotion" [14]. Although "the precise composition and dynamics of emotional reactions are shaped by each subject, according to the environment and singular development, there is evidence that most emotional reactions, if not all, result from a long history of particular evolutionary adjustments" [4]. As claimed by Damasio, emotions consist of actions or movements that occur on the face, voice or in specific behaviors, many of them are externalized [5]. Nevertheless, despite some of these behaviors that are not visible to the naked eye, current scientific probes such as the determination of blood hormone levels or patterns of electrophysiological waves can make them visible. On the other hand, feelings are necessarily invisible to the public because there is a private ownership of the body hidden from anyone except the one who possesses it.

On human beings, the emotions are mediated within the limbic system by the amygdala and by areas in the hypothalamus, septal area, thalamic core, anterior cingulate cortex and limbic association cortex [10]. Amygdala plays a vital role in social behavior, interpreting facial expressions and social cues [19] and triggering emotional experiences from the electrical stimulation [10]. It receives information from all sensory systems and connects with the orbitofrontal cortex and the anterior cingulate cortex. Together, the amygdala, orbitofrontal cortex and anterior cingulate cortex regulate emotional behaviors and motivation. As a result, it is possible to notice that there is no single brain center for processing emotions, in contrast, there are distinct systems related to separate emotional patterns. In other words, "different emotions are produced by different brain systems" [4].

Human emotions can be classified into three types: (A) primary emotions, (B) secondary emotions; and (C) background emotions. Primary emotions (A) are considered innate or not learned, that is, common to all subjects of the species, regardless of any sociocultural factors. Despite the disagreement among researchers of emotion, there are six primary emotions: joy, sadness, fear, disgust, anger and surprise [14], [4].

Secondary emotions (B), however, are more complex and depend on sociocultural factors. Guilt, shyness, embarrassment, jealousy or pride are examples of emotions that vary in accordance with culture, previous experience and time in which the subject lives. This type of emotion is likely to change; while some civilizations can excessively experience them, others may not even present them [14]. As a consequence, learning and culture alter the expression of emotions and give them new meanings. However, despite the endless variations found in different cultures, among subjects and over the course of a lifetime, it is possible to predict that certain clearly dangerous or valuable, internal or external, stimuli will produce certain emotions [4].

Background emotions (C), on the other hand, are related to well-being, malaise, calm or tension and are usually induced by internal stimuli of regulation of life. Such emotions can also be triggered by physical or mental continuous processes or

interactions of the organism with the environment, or by both, leading the body to a state of relaxation or tension, fatigue or energy, well-being or malaise, anxiety or apprehension. Such processes entail "continuous satisfaction or inhibition of impulses and motivation" [4]. While these emotions are expressed in complex musculoskeletal changes, such as subtle variations in body posture and global configuration of movements, the main role is played by the internal environment and viscera [14].

The understanding of emotional variants that comprise the human organism is added to the understanding of its dual biological function. The former consists of the production of a specific reaction to the inducing situation and the latter covers the "regulation of the body's internal state so that it can be prepared for the specific reaction", that is, "certain orchestrations of reactions to a given cause in a given environment" [4]. In this context, chemical and neural commands follow two routes: (D) bloodstream and (E) neurons. In the bloodstream (D), the commands are sent in the form of chemical molecules that act on receptors on cells constituting the tissues of the body. In neurons (E), the commands "take the form of electrochemical cues that act on other neurons, muscle fibers or organs (such as adrenal gland), which may release its own chemical substances into the bloodstream" [4].

As a consequence, although the origin of these commands is limited to a relatively small area of the brain that reacts to a specific content of the mental process, both the brain and the body are affected in a comprehensive and deep way by the coordinated group of these commands, resulting in a global and deep change in the state of the body and the landscape of the body and brain. In compliance with Damasio, all of these changes will constitute the substrate for the neural patterns that will become feelings of emotion, ultimately [4].

3 Designing Wearable Bio-interfaces to Organic Interactions

The transdisciplinary articulation among concepts arising from the neuroscience studies discussed above, particularly related to the environment/behavior/neuroscience paradigm and emotional processing in the human brain, and the field of Design dedicated to the design of wearable bio-interfaces presents a fruitful process to the research and implementation of direct interactions between the body of users and contemporary computing systems, herein called as organic interactions. This section discusses this potential by means of the projectual practice used in the development of wearable computers: BioBodyGame (2006-2008) and NeuroBodyGame (2008-2010) designed by Rachel Zuanon and Geraldo Lima.

According to Poissant, interfaces are becoming more natural, and may take, alternately or simultaneously, extensible, enlightening, rehabilitative and filter functions or act as agents of synaesthetic integration [15]. In the opinion of Bureau, interfaces seen as sensory organs generate a deconstruction of the usual modes of perception, as a kind of fragmentation/displacement of the body that leads to reflection on these modes of perception, to questions about the nature of space in

which this body exists and fundamentally redefine itself as human [1]. In her view interfaces also work in the "rehabilitation" of forgotten, neglected or lost sensuousness. They restore or reinstate ways of perceiving, differently inciting connection with others and with the world, but first they enable the rediscovery of dimensions and body functions that have become obsolete [15]. In this context, there are wearable bio-interfaces as "agents of stable mediations between thought and matter, thought and sensibility" [15], and the notions of complexity, affectiveness and naturalness are enlarged to an organic scale, in which the physiological information of the users act as data to configure an interaction that responds to their emotional state in order to match the state of their body specifically at that particular moment. The bio-interfaces build a differentiated condition of interaction governed by the biology of the users and include the studies related to functional biometric interfaces, as well as brain-computer interfaces, both focused on enabling communication processes between humans and machines and/or humans-machines-humans based on a co-evolutionary² relationship of biological and technological systems [21].

Functional biometric interfaces, based on checking ANS (autonomous nervous system) variability, provide information about the physical state or the behavior of those who use them, continuously gathering physiological data, that is, without interrupting the user activity. For such, biosensors are used as input channels for a functional biometry system, such as: galvanic skin response sensor (GSR); blood volume pulse sensor (BVPS); breathing sensor (BS); and electromyogram sensor (EMG) [21].

In this context, BioBodyGame [22] constitutes a wearable, wireless interface for functional biometric interaction with onboard games in the system, in which the games, as well as the wearable computer, react to the user's emotion during interaction. For such, the interactor's neurophysiological parameters are read during playability: emotional variability; anxiety control; emotional response; sympathetic and parasympathetic nervous system; functional oxygen; and cardiac variability. The mapping of these parameters is done and associated in real time to game functionalities, which begin to react in accordance with the player's neurophysiological state.

Anxiety control is the ability that the subject has to adapt to surrounding stressors, both physical and psychological. This neurophysiological parameter is directly associated with the neuro-emotional reaction and neuro-emotional response that the user of BioBodyGame shows when interacting with the game. In other words, the reaction of the interactor's autonomic nervous system to external stimuli generated by the environment in which the user is located (neuro-emotional reaction), such as sounds, noises, smells and visual and sensory perceptions, and the response of the autonomic nervous system to internal stimuli (neuro-emotional response) generated

² Co-evolution is the selective reciprocal interaction between two major groups of organisms, with a close ecological relationship [13]. According to Moraes, "the co-evolution of biological and physicochemical systems created the conditions for the development of human beings, which introduced a new kind of interaction: human interaction" [12].

by thoughts, feelings, emotions, as well as to its own stimuli generated by neuro-emotional reaction. The analysis of anxiety control, neuro-emotional reaction and response is performed according to the electro-dermal response associated with the sympathetic activity of the user, captured by the galvanic skin response sensor (GSR). The analysis spectrum ranges from 0 to 100%, and the largest percentage indicates better anxiety control by the interactor.

The measurement of the variation of functional oxygen in the blood and heart rate variability - which is determined by the activation or inhibition of the Autonomic Nervous System (ANS) of the user - and the functional analysis of the ANS are carried out by the blood volume pulse sensor (BVPS), in which the pulse, speed, frequency and variability of the optical signal are collected.

The index of baroreflex provides an analysis of the variation of functional oxygen in the blood in a range varying from 0 to 100%, given that the larger percentage indicates normal physiological variation, that is, no significant signals of respiratory changes and cognitive and/or concentration wearing of the user of BioBodyGame.

The index of heart rate variability enables the analysis of heart rate variation according to the degree of stimuli to which the subject's heart undergoes; the reference ranges from - 4 (minimum) to + 4 (maximum), taking into consideration that 0 (zero) indicates the cardio-normal functional activity.

Sympathetic and parasympathetic ranges and the sympathetic and parasympathetic frequencies altogether provide functional analysis of the Autonomic Nervous System. Considering that the indicator ranges of the individual capacity of sympathetic and parasympathetic systems for autonomic performance and the indicator frequencies of the balance between these two systems by autonomic stimulus. Sympathetic and parasympathetic ranges are the intensity of the performance of sympathetic and parasympathetic systems, respectively, and vary from 0 to 100%, where zero indicates the lowest intensity and a hundred represents the highest. While the sympathetic and parasympathetic frequencies indicate the amount of stimuli sent by ANS to trigger the sympathetic and parasympathetic activities, respectively, and vary in a range from 0 to 100%, where zero indicates the lowest intensity and a hundred represents the highest. Nevertheless, sympathetic and parasympathetic ranges and frequencies imply an inversely proportional relationship. For example, the closer the parasympathetic range is of 100%, the better the performance and/or capacity of the subject's ANS. However, the closer the parasympathetic frequency is to 100%, the smaller the stimuli sent by the ANS to the Parasympathetic System. Thus, within the frequencies, autonomic balance is indicated by index equal or close to 50%.

Therefore, in BioBodyGame, the identification and real-time analysis of all these neurophysiological indices by wearable computer are as in Table 1.

In other words, playability is facilitated or made difficult based on the user's emotional state as well as how the wearable computer interprets these emotions and reacts to them, altering their color (front/back) and applying vibrations (back). Thus, a really calm user will have its playability enhanced and the BioBodyGame will mostly

react by displaying the color blue. If the user is just calm, the color displayed is green. A tense or even nervous user will have its playability worsen and the wearable bio-interface will react to it by turning into yellow and applying a soft vibration in the back area of the user. And a really tense user will have its playability worsen and the BioBodyGame will react by changing its color to red and by intensively vibrating.

The context of functional biometric interfaces presents even more complex perspectives when brain signals are the substrate of biological information. A brain-computer interface (BCI) transforms the electrophysiological signals of central nervous system activity reflections into the products intended for that activity: messages and commands that act in the world. It transforms a signal, such as an EEG rhythm or a neural trigger rate from a brain function reflection into the final product of this function: an output that, as an output in conventional neuromuscular channels, carries out the person’s intention. A BCI replaces nerves and muscles and produces movements with electrophysiological signals associated with the hardware and software that translates them into actions [21]. In this sense, the NeuroBodyGame [23] consists of a wearable computer that allows the users to play games with their brain signals. It is a wearable wireless interface for the brain to interact with the games bundled in the system. It has an independent and non-invasive BCI integrated to its technological system in which the brain output channel is the EEG, and the generation of the EEG signal mainly depends on the user’s intention, and not on the peripheral nerves and muscles [8], [16], [6]. This BCI captures the user’s brain activity as spontaneous inputs from EEG rhythms on the frontal lobe through two electrodes disposed on F1 and F2 channels according to 10-20 Standard.

Table 1. BioBodyGame – Correlates among physiological parameters mapped, wearable computer and game

Measured Neurophysiological Indexes	BioBodyGame’s Response	Game’s Response
- Anxiety Control (Neuro-Emotional Reaction and Response): $\geq 90\%$ - Variation of Functional Oxygen: $\geq 90\%$ - Heart Rate Variability: 0 (zero) - Sympathetic and Parasympathetic Ranges: $\geq 80\%$ and $\leq 100\%$ - Sympathetic and Parasympathetic Frequencies: $\geq 45\%$ and $\leq 55\%$	Alteration in appearance, it turns blue	Easy playability
- Anxiety Control (Neuro-Emotional Reaction and Response): $\geq 80\%$ and $< 90\%$ - Variation of Functional Oxygen: $\geq 80\%$ and $< 90\%$ - Heart Rate Variability: $\geq +1$ and $< +2$ - Sympathetic and Parasympathetic Ranges: $\geq 60\%$ and $< 80\%$ - Sympathetic and Parasympathetic Frequencies: $> 55\%$ and $< 70\%$	Alteration in appearance, it turns green	Satisfactory playability
- Anxiety Control (Neuro-Emotional Reaction and Response): $\geq 70\%$ and $< 80\%$ - Variation of Functional Oxygen: $\geq 70\%$ and $< 80\%$ - Heart Rate Variability: $\geq +2$ and $\leq +3$ - Sympathetic and Parasympathetic Ranges: $\geq 40\%$ and $< 60\%$ - Sympathetic and Parasympathetic Frequencies: $\geq 70\%$ and $< 90\%$	Alteration in appearance, it turns yellow and there is a soft vibration in the back of the user	Poor playability
- Anxiety Control (Neuro-Emotional Reaction and Response): $< 70\%$ - Variation of Functional Oxygen: $< 70\%$ - Heart Rate Variability: $> +3$ and $\leq +4$ - Sympathetic and Parasympathetic Ranges: $< 40\%$ - Sympathetic and Parasympathetic Frequencies: $\geq 90\%$ and $\leq 100\%$	Alteration in appearance, it turns red and there is an intense vibration in the back of the user	Hard playability

The NeuroBodyGame (NBG) includes, as a BioBodyGame's upgrade, the mapping and the association of user's brain activity in real time to game functionalities, which begin to react in accordance with the player's neurophysiologic state. In other words, playability is facilitated or made difficult based on the user's brain wave frequencies as well as how the wearable computer interprets these brain activities and reacts to them, altering their color (front/back) and applying vibrations (back).

Specifically, the user's brain activity in a frequency period of 9 to 13 Hz enhances the user's playability and the NBG mostly reacts by showing the color blue. The detection of brain wave frequencies between 14 to 21 Hz displays the green color and for frequency periods between 22 to 30 Hz the user's playability is made more difficult and the NBG reacts to it by turning to yellow and applying a soft vibration in the back area; while brain wave frequencies between 31 to 40 Hz make the user's playability even more difficult and the NBG reacts by changing its color to red and by intensively vibrating. It is worth noting that in both wearable computers (BBG and NBG) the games are open source – a fundamental characteristic for providing full remodeling of the programming and integration with the games' controls and the neurophysiological signals and brain wave activity of users.

The design of these two wearable computers assumes that "emotion and biological mechanism are the mandatory monitoring of the behavior, conscious or not" [4]. In other words, some level of emotion will necessarily follow the thoughts that the user has about itself and what surrounds it [4]. Thus, "the thoughts and emotions affect the functions of all organs. This is due to the bidirectional communication between the nervous system and the immune system" [11]. In this regard, an individual reaction to experiences may disturb homeostasis³; and set up a response to the stress responsible for increasing strength and energy of the body in order to handle with the situation. In compliance with Lundy-Ekman, three systems create the response to stress: somatic nervous system, autonomic nervous system and neuroendocrinological system. In this condition, the motor neuron activity increases muscle tension (somatic nervous system); sympathetic activity increases blood flow to the muscles and decreases blood flow to the skin, kidneys and digestive tract (autonomic nervous system); the sympathetic nerve stimulation of the adrenal medulla causes the release of epinephrine into the bloodstream. Epinephrine increases the heart rate and cardiac contractile force, relaxes intestinal smooth muscle and increases the metabolism (neuroendocrinological system) [11]. In this context, a concept of significant importance and which also permeates the making of the four pieces as a whole is found in the possibility of it being used by bodies of diverse biotypes. It means that these wearable computers can be expanded or contracted in order to fit in the user's body. Its main challenge lies in the fact that it tries to preserve the user's comfort. Once each and every possibility of discomfort may alter the neurophysiologic signals,

³ Homeostasis describes a set of "regulatory processes and, at the same time, the resulting state of a well-regulated life"[4], such as: find energy sources; incorporate and transform energy; maintain, inside the body, a chemical balance compatible with life; replace the subcomponents that age and die in order to maintain the structure of the body, and to defend the body from disease processes and physical injury.

and by doing so, it would compromise the organic information (neurophysiological signals) acquired. And the guiding concept for distribution of all items in these two wearable computers lies in considering that its internal structure reproduces the interior of the human body, taking the brain as the main point from where the nerve stimuli responsible for the body functioning depart and arrive. Therefore, the electrodes and sensors responsible for measuring the user's neurophysiological signals are located in the front view of these wearable systems. Thus, with the human body as a reference, along the spine and medulla, the pieces reproduce the chain of electrical conductors which allow sending information to other areas of the wearable devices. "We are now providing clothes with more complex functions. Clothes become a sensor for recording body information and increasingly exchanges with the environment" [15].

Such articulations between concepts based on Neuroscience and Design to the creation and development of these four wearable bio-interfaces involve a transdisciplinary team comprised of designers, artists, doctors and engineers, which provides the encounter and unique exchange of knowledge among areas fully articulated and integrated to the product's final result.

4 Conclusion

From the Environment/ Behavior/ Neuroscience (E/B/N) paradigm it is possible to understand a closer relationship between the brain's natural creative process and the cognitive process of design. Among the brain skills, human emotions are responsible for profound and global changes in the state of the organism and the landscape of the body and brain, and therefore play a regulatory role in survival. In this sense the neuroscience understanding of brain abilities and human emotions can improve design researches and practices helping designers to plan their projects considering how people's brain and mind develop and function in different situations and then contributing to people's quality of life, creativity and survival effectively. Thus the transdisciplinary articulation between Neuroscience and Design proves to be a promising field of research and projectual development by indicating the way to an increasingly natural interaction between the human body and the contemporary computer systems, that is, in synergy with the human body - both physically and functionally. In this regard, the understandings arising from the environment/ behavior/neuroscience paradigm and emotional processing in the human brain herein addressed in the form of a dialogue with the design of wearable bio-interfaces expand the projectual potential of wearable computers as well as the future prospects of human-computer-environment communication. By offering wearable bio-interfaces for different biotypes and preserving the comfort, the wearable computers BioBodyGame and NeuroBodyGame not only provide a differentiated relationship between the subject and technology, founded on reading, interpreting and associating neurophysiological data to control commands. They allow a meeting between biological and technological systems for collaborative creation, including users with

different cultural behaviors, modes of perception and apprehension of the world, altering the expression of emotions and giving them new meanings. As a result, the collaborative work among designers and neuroscientists has proven to be crucial to support and base the transdisciplinary research that effectively cooperates and contributes to the progress of projectual solutions and development of products able to identify and respond appropriately to the organic and emotional needs of the user.

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