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Reiner Wichert
Birgid Eberhardt *Editors*

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4. AAL-Kongress 2011
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Preface

The concept of “Ambient Assisted Living” (AAL) has become a relevant factor in the research landscape over the last couple of years. A multitude of national and international R&D projects is working on specific challenges and fields of application within the thematic area of AAL. However, the goal of a realization of the AAL vision is impeded by a number of obstacles and problems, for which this conference discusses possible resorts, approaches and recommendations within numerous papers.

To confer these new approaches the AAL-Kongress 2011 brings together developers, producers, service providers, carriers and end user organisations working in the field of technologies and applications of Ambient Assisted Living (AAL).

AAL aims at extending the time older people can live in their preferred home environment by increasing their autonomy and assisting them in carrying out activities of daily living. The aim is to enhance the quality of their lives by the use of ICT products and the provision of remote services including care services that will assist them to achieve the autonomy, independence and dignity appropriate to their needs and conditions.

Since this vision is influenced by a lot of different concepts in information processing and combines multi-disciplinary fields in electrical engineering, computer science, industrial design, user interfaces, and cognitive sciences a lot of research is needed in providing new models of technological innovation within a multi-dimensional society. Thus the AAL vision relies on the large-scale integration of electronics into the environment which assist especially elderly people in all living conditions.

For this reason in 2008 a new series of events has been established called AAL-Kongress (Congress for Ambient Assisted Living) and has been organized by VDE and BMBF. The focus of this AAL-Kongress 2008 had been on applications of intelligent assistive systems within the areas of “health & homecare”, “safety & privacy”, “maintenance & housework” und “social environment”.

More than 520 participants attended the second AAL-Kongress in Berlin in January 2009. It focused on use cases to support the manufacturing of products adjusted to the needs of the user. In 2010 the third AAL-Kongress had been organized with close to 600 participants also with the focus on use cases.

In 2011 the AAL-Kongress will be organized the fourth time by BMBF und VDE. Beside economical challenges and trendsetting applications the congress will dedicate especially on innovative technology. To underline the research priority the research papers have been evaluated more restrictivly and have been published for the first time in Springer proceedings.

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Contents

Chapter 3: Platforms

Chapter 4: Activity Recognition

Chapter 5: Sensor Technology

Chapter 6: Telemonitoring

Chapter 1: Assistance Systems

Architecture of the 'Daily Care Journal' for the Support of Health Care Networks

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Abstract. The project 'Daily Care Journal' is implementing and evaluating a platform for the support of health care networks using AAL technologies. The platform enables the participants of the network to exchange information about the person in need of care and health care activities, depending on their access rights. In this way the information flow between the participants will be optimized, as well as heath care processes. The functional requirements for the platform are described in this paper by employing application scenarios. Based on those use cases a reference architecture for the implementation of the platform is described. A relevant part of the architecture is the definition and the targeted provision of service building blocks.

Keywords: AAL, Health care network.

1 Introduction

The goal of 'Ambient Assisted Living' (AAL) is to connect new technologies and the social environment in order to improve people's living quality in all life stages [1]. AAL technology can be used for example to support an elderly person to live as long as possible in his familiar home environment. Such technology can be found in home automation, ubiquitous computing or in robotics. Based on such technology AAL services can be offered which are integrated into the daily life of the user and provide intelligent support. Examples for such AAL services can be found in [2].

The aim of the project 'Daily Care Journal' (DCJ)[1] [3] is to support the coordination of care activities by relatives, friends, neighbors and professional care providers within

[1] Supported by the 'Federal Ministry of Education and Research' (BMBF) under grant 16KT0959.

the patient's home environment by providing a care network. Part of the project is the conception, development and piloting of the DCJ platform, which can be used to build such a care network. The platform includes services, which allow the participants of the care network, including the patient, to document and exchange information on the actual well-being and problems. Thereby the different points of view of the participants can be collected centrally and be used for improving the coordination of care processes within the network. For example relevant information documented by the neighbor can be provided as part of the tour information of the caregiver. Additionally the patient can be included intensively into the care process and be motivated to participate actively.

The DCJ service provides specific views on the available functionalities and information for the different participants of the care network. Using the DCJ service, the patient can define the care network and grant access rights to the different views. According to the specific requirements of the participants these views will be provided on different end devices. The DCJ service can be used by the patient within his home environment via his television using the remote control or on a home tablet PC. Additionally the patient will be assisted in the documentation of his situation and the performed care actions by selected sensors. The caregiving relatives or friends can use the DCJ service via the internet. For the professional care provider the DCJ service is integrated into his care management system.

The implementation of the DCJ platform is based on the specific goals and the requirements of the care network. Together with other relevant general conditions these lead to the resulting architecture of the platform. The necessary technical components and their interdependencies will be the defined within the architecture. The goal of this paper is to describe the application scenarios for AAL technologies to support care networks. Furthermore the resulting architecture will be described as a guideline for the implementation and assignment of existing technologies according to a reference architecture.

In the following chapter we give an overview on the state of the art. Then we describe the application scenarios. In chapter 4 we describe the architecture that results from the professional requirements. Finally we give an outlook to planned future work.

2 State of the Art

There are a number of research projects focusing on the development of AAL technologies and frameworks for the implementation of AAL services. For example in [4] sensors for reliable fall detection are explored, which also ensure privacy and user acceptance. Sensors and actuators can be inter-connected using existing approaches of home automation. Technologies from ubiquitous computing enable an intelligent and natural integration of these technologies into the natural environment of the user [5]. One aspect of ubiquitous computing is the context-awareness of services [6]. Within EU and further national research programs a number of frameworks have been developed, which can be used for the implementation of AAL services. An example is the middleware platform, which is being realized within the "PERSONA"-project [7]. Furthermore many social projects have been promoted, which deal with social structures, residential quarter neighborhoods and care structures. For example in the project "Pflegebegleiter" [8] education concepts are being developed, which support the caregiving relatives in the accomplishment of practical and daily life activities.

The objective of the DCJ project is the connection of the professional view on care networks and the usage of AAL technologies that goes beyond the state of the art. The implementation of the technical solution is based on the evaluation of already existing AAL technologies.

3 Application Scenarios

The professional requirements from the view of a care network are the basis for the conception of the DCJ platform. These have been identified through the means of expert interviews. As a basis for further discussion and documentation these results have been described in different application scenarios. At the beginning the required application scenarios are identified and described in an overview. These have been discussed in detail and analyzed according to the following aspects:

- **Objective:** What should be achieved by using the DCJ services?
- **Roles:** Which roles are needed in the achievement of the objectives?
- **Process:** What are the workflows for the different roles? For which activity is a DCJ service necessary?
- **Result:** What are the concrete results after using the DCJ services?
- **Details:** What details have to be regarded for the implementation of the DCJ services?

In the following the application scenarios that have been analyzed in this way will be described. An overview is given in the following figure.

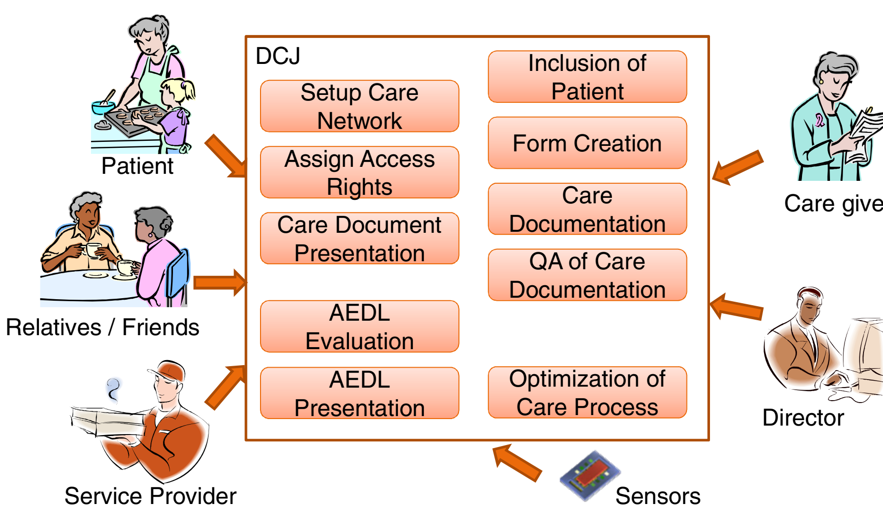

Fig. 1. Application scenarios of the Daily Care Journal

3.1 Setup of the Care Network

The patient is able to setup his care network using the DCJ platform and to include different participants therein. Potential participants are for example the professional care provider, caregiving relatives, friends or other service providers. There are two variants that have to be supported. In the first variant the professional care provider is not yet part of the care network and can be included on demand. In the second variant the DCJ platform will be provided by the professional care provider as an additional service. As a result the patient has access to the DCJ service and is able to invite further participants to his care network.

3.2 Inclusion of the Patient

This application scenario describes the inclusion of the care network into the processes of the professional care provider. This is done by using the existing care management system, where the patient's file is being recorded. Additionally further participants of the care network will be imported into the care management system. The DCJ service and the care management system have to be connected through defined technical interfaces. As a result the care provider is able to get access to the specific views of the DCJ platform and to provide information and documentation to the care network using his care management system.

3.3 Assign Access Rights

An essential functionality of the DCJ platform is the exchange of information on the well-being of the patient and the care actions between the different participants of the care network. The largest amount is personal information and needs special protection. The patient therefore must be able to assign access rights to the different participants of the network and also to withdraw them. As a result the patient is able to freely assign access rights. An exception exists regarding the professional care provider where the patient cannot withdraw access rights to information that is needed for the care process.

3.4 Form Creation

In today's existing care processes the care documentation of the professional care provider is done using paper-based forms, which stay within the home environment of the patient. The care giver is using such a form to carry out the documentation of the performed care actions and observations. These are solely available in the home environment of the patient and therefore cannot be accessed by the other participants of the care network outside of that environment. Using an electronic pen the care giver can carry out the documentation in the used manner. At the same time an electronic copy of the documentation is created and made available through the DCJ platform to the care network. For the usage of the electronic pen special forms are needed. These include additional information for the electronic pen, which allows assigning the written text to the appropriate form fields. Such forms have to be designed and provided to the care givers. By the usage of the electronic pen together with the special forms the documentation of the care giver can be made available to the care network.

3.5 Care Documentation

In this application scenario the performed care actions of the different participants of the care network are documented. The care giver is using the electronic pen to record the performed actions and observations within the special forms in the home environment of the patient. The documentation is digitalized and transmitted automatically to the DCJ platform. The other participants of the care network can document their care actions using specialized end devices. To cite an example, the client can use the remote control to affirm liquid intake. This could also be recognized by the existing sensor system and then the information could be send to the DCJ-Platform. Other participants can document their nursing activities via the internet client. As a result the entire care documentation will be available for the participants of the care network.

3.6 Presentation of Care Document

All participants of the clients care network should have an insight into already realized actions. If a caregiver or another participant delivers a care service, everybody in the network can see it. That helps to coordinate the care process. As a consequence transparency and quality of care process are enhanced. The concrete characteristic of the application scenario differentiates between the roles of observers. The director of nursing has access to care documentation by using the care management system. The care management system is the place where available documentation is provided. Other participants of the care network get access to DCJ-service through several end devices. As a result participants can view documentation according to their roles.

3.7 Quality Management of Documentation

Care documentation of a caregiver does not conform to the defined quality requirements. Examples are a poorly readable lettering or wrong information through transposed digits. With the help of digitalization a quality control of care documentation should be made possible. The care management system enables the head of the nursing service to access and control the care documentation which is digitally available. This process can be supported even more by checking other quality criteria, for example the presence of entries in mandatory fields. This information can then be used by the nursing director to take further action. An example is the training of nurses. A result of the application is the improvement of care documentation through nurses.

3.8 Optimizing Care Processes

This application scenario describes different opportunities of optimization of care processes by using the DCJ-Platform. Some of these possibilities will be described. As the nursing documents are digitally available, it can be checked weather new forms for the nursing book are required. The review can happen at the client's house.

The forms can be printed on time and can be taken to the patient by the nursing staff. The manual assessment of the client's state and the resulting care measures will be set at a fixed rhythm, for example every 4 to 6 weeks along the activities and existential experiences of life (AEDL) [9]. However, a nurse should validate the client's state. If the DCJ-Platform recognizes the need for a new AEDL assessment, this should be initiated. Because of the digital documentation of care processes and the information about client's state, medical implications can be identified and reported to the nursing service manager. One example can be the relation between new medication and changes in blood pressure. This knowledge can be used to optimize the care planning.

3.9 AEDL Assessment

The condition of the patient and his care should be evaluated by different care network participants. Each participant has different rights. The condition of the patient should be made available within the DCJ-Platform. This application scenario differs depending on the role involved. The nurse performs the assessment and types the results with a digital pen in the medical history book. Thereafter the results will be transferred by the digital pen to the DCJ-Platform. Every care network participant with rights can see the new results. Self-evaluation by the client, as well as external assessment by the relatives, friends or other service providers can be accomplished by a DCJ client. Appropriate input masks are provided. After completion of these assessments, the information is available for network participants. The sensors in the client's house can be used to obtain an objective AEDL assessment. Sensor record events and send them to the DCJ-Platform. On this basis further information can be derived. The information will also be available in the care network.

3.10 AEDL Presentation

Every care network participant should have, depending on assigned access permissions, the possibility to see the condition of the patient and his care. The nursing management can have an insight to this information and use the information to adapt the care plan.

By consulting the AEDL, the nurse should be able to quickly respond to existing problems of the client. Tour information of the nursing management system can be displayed in a mobile device. The client, his family, friends and other service providers can get access to the available assessments by the DCJ client.

4 Architecture

The technical requirements, which are included in the application scenarios, form the base for the realization of the DCJ platform. The first step is the definition of the underlying architecture. This divides the required functionality for the implementation of these scenarios and assigns it to components. At first the definition of the architecture happened independent of possible deployable products or of existing platforms in the sense of reference architecture. Constitutive on this logical architecture the observant general conditions and the products to be used will be examined and in a concrete architecture described. More extensively concepts improve this architecture.

Below a logical architecture will be described in detail. Thereafter a brief outline of the observant general conditions of a concrete architecture occurs. Finally we describe the usage of service components as a more extensively concept of the underlying architecture.

4.1 Logical Architecture

Below the components necessary to implement the technical requirements of the application scenarios are described. First an overview of the components as well as subcomponents and their dependencies is given. Then a description of these components is given in detail.

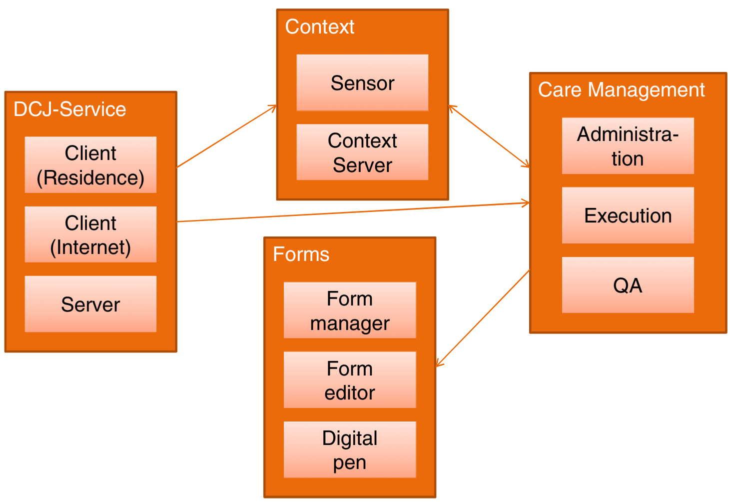

Fig. 2. Overview on the logical architecture

4.1.1 DCJ-Service

This component serves to establish and support the health care network. Functions for the documentation and presentation of the health care measures carried out by the participants are provided in the residence of the client and via internet. The same applies to the estimation and presentation of the state of the client health care based on the AEDLs. The necessary subcomponents are further divided into a client for the resident, a client for the internet and the DCJ server.

DCJ client (residence): This DCJ client enables the access to the DCJ service for the person in need of care, family, friends or other service provider in the residence of the patient. This client is matched to the needs of the person in need of care and can be handled without computer skills. Possible end devices for example are the television or the intelligent picture frame. The client provides the following functionalities:

- Management of the health care network
- Authentication of the participant with a PIN
- Views and insight of the health care documentation
- Views and insight of the AEDL rating
- Views for the provision of further care relevant information.

DCJ client (Internet): This DCJ client enables the access to the DCJ service for the family, friends or other service provider outside the residence of the person in need of care with a web browser. The client provides the following functionalities:

- Authentication of the participant
- Views and insight of the health care documentation
- Views and insight of the AEDL rating
- Views for the provision of further care relevant information.

DCJ Server: The DCJ server provides the actual functionality of the DCJ service the participants will be offered. It offers functions for acceptance and allocation of care documentation and AEDL evaluation. In addition, other care-related information and services are managed and offered. The DCJ-Server manages the authorized access to information and function blocks.

Dependencies: The DCJ-Server needs access to care management system. The server delivers and collects individual-related information of care documentation and AEDL evaluation. In addition, participants of care network are synchronized between these components. The DCJ Server needs access to context servers for applying context information.

4.1.2 Context

This component is used to detect and deploy context information. Information about the client and its environment are provided. Subcomponents are sensors and a context server.

Sensor technology: Sensor technology is used to record contextual information for residents or the environment. This information is passed on to the context server. Examples for sensor technology, used in DCJ, are:

- Sensors for the detection of apartment-related context information, e.g., water consumption.
- Sensors for detection of resident-related context information, e.g., vital signs.
- In-house emergency calls.

Context Server: The context server serves to the central provision of contextual information. Specifically, the following functions are provided:

- Collection of reported context information and association to a context model.
- Compacting the collected context information.

- Deriving situations and indications of AEDL.
- Providing context for the other components of the platform.
- Active surveillance and notification of the other components at relevant events.

4.1.3 Forms

The administration and provision of forms as well as documentations based on it is the task of a separate component. The digital pen is a special subcomponent, which converts documentations on papers into a digital form and makes it available to the subcomponent 'form manager'. Furthermore a form editor is required.

Digital pen: The digital pen allows in cooperation with special paper forms the following functions:

- Digitalization of paper-based creation of documents
- Transmission of the digital documents to the form manager.

Form editor: The form editor allows the creation of templates for health care forms for the usage with the digital pen. The editor has to provide the following functionalities:

- Creation of new and modification of existing form templates.
- Acquisition of predetermined input fields: name and example values.
- Transfer of finished arranged form templates to the form management.

Form manager: The form manager handles the management and provision of forms and documents. It has to provide the following functionalities:

- Management of created form templates
- Generation and printout of forms on base of the templates. These include:
  - Presetting of default values in the forms
  - Enhancement of the forms with meta-information for the classification of input fields for the digital pen
- Support for editorial processes for the quality assurance of form templates
- Acceptance and management of digital documents based on the forms.
- Automatic recognition of contents with OCR.
- Maintenance of the automatic quality assurance, e.g.:
  - Verification of mandatory fields
  - Identification of the filling level of a document

Dependencies: There are no dependencies to the other components identified.

4.1.4 Care Management

In this component you can find different subcomponents. These components are needed for administration, execution and quality assurance of care measures by professional care providers. The following component description is limited to functions, needed for the implementation of application scenarios.

Administration: The administration of the care management system is responsible for administrative tasks in nursing. The following features are present:

- User interface for managing form templates.
- Assigning general rules for notifying the Nursing Director and other caregivers.

Execution: The implementation of care management helps to support the operational processes of care. Following functions must be available for the execution:

- User interface for managing the care network.
- User interface for providing and printing forms.
- User interface for providing care documentation.
- User interface for providing the AEDL estimates.
- Management of care information.
- Identification of abnormalities within the AEDL assessment followed by the notification of the nursing service manager.
- Recognition of professional connections and following the notification of the Nursing Director.
- Creation of tour information

Quality assurance: The quality assurance of care management serves the optimization and quality assurance of care processes. The following functions must be provided for the quality assurance:

- Representation of a negative list with missing care documents.
- Overview of existing care documents with a label of automatically detected errors.

Dependencies: The care management system provides the views and functions required by the nursing service. For this purpose it needs access to the components of form management for opening the form editor including parameter value delivery, for reviewing existing forms, for generating and printing forms, for accessing existing documents as well as for retrieving document content. An interface to the DCJ-Server is needed for synchronization of care network and the containing views.

4.2 General Requirements of the Concrete Architecture

For the implementation of the DCJ platform the available technologies and products have to be evaluated and defined along the identified components and their functionality. In addition, other non-functional aspects have to be included in the definition of the concrete architecture. Subsequent the implementations of the data security on the concrete architecture will be examined project-specific.

4.2.1 Data Security

Due to the fact that personal data are part of DCJ, organizational and technical measures are to be taken in order to protect them against unauthorized and misused access. This counts for the following personal and health care information from DCJ:

- Health care documents
- AEDL estimation
- Context information, for example vital parameters

The consequence is that the components, which are responsible for management and delivery of these pieces of information, have to be operated in a secured environment. This needs to be protected organizationally and technically adequate. Therefore the following components must be included in this environment:

- Health care management
- Context server
- Form management

The health care service operator, which is involved in the project, already operates a proper secured environment for the software systems required in the health care. This is self-contained and only open to the internet at well-defined points. With the help of firewalls unauthorized access will be blocked. Thus access from the outside to one of the systems located inside the secured environment is not easily possible.

For connecting DCJ components outside the secured environment with components inside this environment the following architecture specifications will be made:

- The connection from outside to inside the secured environment occurs only at a central point. This collects the method calls of the other components and passes them over to the secured environment. Such a 'proxy' will be embedded in the secured environment with a VPN and a static IP-address. The proxy is responsible for ensuring that only authorized components are allowed to perform method calls in the secured environment.
- The access to the components, which exist in the secured environment, doesn't take place directly. This is preceded by a component that provides only the required functions to the proxy and forwards a call accordingly. Such a front is responsible to make the actual components invisible for the caller.

4.3 Service Modules

A key concept for the implementation of the different views of the participants in the care network by the DCJ platform is the definition and targeted provision of service modules. A service module provides a defined extract of functionality and information in the DCJ-Platform. The network participants have got the possibility to use these functions and information provided by clients. An example of such a service component is the display of the blood pressure profile for a selectable time interval. The possible view for a participant in the care network is defined by its associated set of service modules. The set of views can be restricted by the client with the definition of permissions. It will be displayed in an appropriate form on the participants' end-device. The specific needs of the participant for a service module depend on its specific objective and the particular situation. For the targeted delivery a categorization of these service modules is described. In addition, the dynamic aspects of the provision in the form of an interaction concept are described.

4.3.1 Categorization

The categorization of service modules is based on two dimensions. The first dimension concerning content assigns components to categories regarding activities and existential life experience, which were defined in the AEDL. Examples are communication, movement, vital signs, or care. The second dimension defines the purpose of such module. Consecutively, the defined types are described. In addition, examples for identified service modules of AEDL, 'food and drink' are shown.

- **Activity:** Services may be provided to support the conservation and improvement of the current situation. The user can perform following activities:
  - Nutrition quiz: Questions about nutrition will be asked and will be evaluated.
  - Reminder function 'Food intake': Particularly diabetics can use the reminder function for the food intake.

- **Service:** Services or care measures are offered, which retain and enhance the actual living situation. These services can be provided by several service providers.
  - Adding a delivery menu service to the care network.
  - Menu order from menu delivery service.

- **Information:** Information about different questions can be provided by DCJ, e.g.:
  - information on health problems and their causes,
  - information about the preservation of the life situation or information on tools to improve the living conditions,
  - product-neutral information on nutrition products or
  - recommendations for the fluid intake.

- **Reporting:** Services can be offered, with the help of which various indicators of life situation of the customer as well as the taken measures can be registered and displayed. These can be used for continuous monitoring or adjustment of health care measures.
  - Meal ingestion: Reporting of ingested meals: Kind of meal, number of meals per day, quantity of food per meal.
  - Weight/BMI: Display of the current weight and the variation in time. Display of the normal range and the mapping of the current data. Display of the corresponding BMI.

- **Deficit-oriented reporting:** Services will be offered, which allow the reporting of problems. Examples for this are pain, tumbles or insomnia. These can be used to customize the care measures by the care provider.
  - Logging of dysphasia
  - Problems with false teeth
  - Logging of nausea and vomiting
  - Problems with the compatibility of food and drink

This categorization is used for the identification and mapping of potential service modules. In addition, service modules can be registered in the DCJ-Server. This enables a dynamic extension of the available views.

4.3.2 Interaction Concept

The target-oriented delivery of these service components is part of an interaction concept which has to be adapted to the respective user groups and their terminals. Subsequent basic styles of provision are described, which are supported in the DCJ clients.

- Category selection: The service components are provided to the user according to the assigned categories. The user can navigate within the categories and select the desired component.
- Manual composition: The user or another participant of the health care network is allowed to compose service components manually. For example the nurse is able to choose the relevant components for the support of a counseling situation and makes it available to a person in need of care or to his family.
- Technical connection: Service components can be connected based on technical knowledge and provided to the user contiguous in the context of the dialogue direction. For example the detection of a tumble can lead to a connection with other components, e.g., pain registration and information of tumble protectors.
- Context-sensitive choice: The detection of events in the home can lead to automatic selection of a service component. For example if the grabbing of a drinking vessel is detected, then the recording of the drinking quantity could be recorded.
- Date book: The date book can be a starting point for the selection of a service component. Based on the date book the user can determine and view the schedule of health care measures. In addition service components can be triggered by the date book, e.g., the memory function for food ingestion.

5 Future Work

The DCJ project is currently in the phase of technical survey and design. In a next step these will be validated by user workshops with different persons involved like health care service providers and potential persons in need of care and their families. To implement the defined architecture the technologies introduced by the project partner will be used. Examples include the MILEO platform [10] for the implementation of the 'Context'- and the 'DCJ-Service' subsystem. The DCJ platform will be tested late in 2011 with selected customers of the health care service providers in the context of a pilot operation.

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Technological Stress – Mental Strain of Younger and Older Users If Technology Fails

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Kurzfassung. In einem Laborexperiment wurden bei 136 Probanden während der Arbeit mit einem PC Hautleitfähigkeitswerte gemessen, per Videoaufzeichnung Reaktionen beobachtet und mit Fragebögen subjektive Erlebenswerte evaluiert. Alle Teilnehmer hatte die Aufgabe mit handelsüblicher PC Technik an einem Arbeitsplatz, wie er bei jedem Teilnehmer auch zu Hause eingerichtet sein könnte, einen Text von einer Papiervorlage in ein elektronisches Dokument zu übernehmen. Die Teilnehmer kamen aus unterschiedlichen Alters-, Sozial- und Berufsgruppen. 32 % der Probanden waren zwischen 45 und 65 Jahre alt. Die Probanden wussten nicht, dass drei Ereignisse bei ihrer Arbeit auftreten werden, die Stresssituationen simulierten und die Arbeit beeinträchtigen. Ziel des Experimentes war es nachzuweisen, dass psychische Beanspruchung in Form von Technikstress bei unvorhergesehenem Technikversagen auftritt und subjektive Erlebenswerte von den Probanden zu erfassen. Aus den Erkenntnissen wurde ein Erklärungsmodell für Technikstress entwickelt und Handlungsregularien für Hersteller und Nutzer abgeleitet. Nachfolgend sollen einige Ergebnisse der Studie als vergleichende Betrachtungen zwischen Arbeitnehmern über 45 und unter 45 Lebensjahren dargestellt werden.

Abstract. In an experimental setting in the laboratory the skin conductive levels of 136 participants were recorded during their work with a personal computer. Additional video recordings of their reactions and questionnaires about their perceived level of strain were taken. The task the participants had to fulfil was to copy a text from a paper original to an electronic document. For this task they used a common personal computer technology, the same as it could have been situated in the participants' home. The participants had a different background concerning their age, profession and social status. 32% of them were in an age from 45 to 65. The participants did not know that certain events would take place during the completion of the task. These events simulated stressful situations and interrupted the task. The goal of the whole experiment was to prove mental strain in the form of technological stress if technology fails and to record the participants' perceived level of strain. The new knowledge derived from this experiment helped to develop guidelines of action for developers and users of technology. In the following sections some outcomes of the study as a comparison of employees under and above 45 years of age will be shown.

1 Initial Situation

In the general understanding of society, in the current life situation of older people technology is understood as a means to satisfy needs. For the industry, older people have become interesting buyers of technical products. Research and development see a new field for a gain in knowledge with the aim of improving the quality of life in old age. Due to new innovative technologies and technical products changes in the working environment, private leisure time und social environment come up to the users in quick succession. Not everybody is a enthusiast of technology, and there are also opponents and people who demand evidence [1]. For this reason, the analysis of man-machine-interfaces has to be further placed in the focus of scientific research in the recognition of the responsibility for technology which is appropriate for age, objective and activity. In doing so, a comparative consideration of employees above and below the age of 45 should be increasingly carried out so that possible differences in handling and experiencing technology can be recognised and strain can be influenced at an early stage. It is not only important to use technology as positively evaluated and to adapt the human being to the existing status, but to recognise possible strains prospectively, identify causes and develop guidelines for action for manufacturers and users of technology. For this, new knowledge from fundamental studies is required which specifically prove strains and derive explanatory models in order to be able to specifically develop guidelines for designing man-machine-interactions then. Therefore the aim of technology stress research is to collect empirical data under laboratory and vivid conditions to verify strains in the context of technology, to develop explanatory models, to analyse cause and effect complexes and to derive guidelines for action for users and manufacturers of modern technology. Here technological stress is understood as a "… special kind of stress, a specific or unspecific reaction pattern of the organism to external and internal stimuli, which directly or indirectly results from technology, i.e. already through the design of technical utilities, when using technical utilities and through the general attitude to and acceptance of technical utilities and which interferes with its physical and psychic balance as well as strains or exceeds its adapting or coping abilities" [2]. In a scientific study possible strains due to technological stress were analysed, which can occur if technology suddenly fails. Simultaneously the partcipants´ perception of the situation was evaluated by means of a two-part questionnaire and the responses were videotaped. In the following part some outcomes of the study as a comparison of employees under and above 45 years of age will be shown.

2 Research Methodology

It makes sense to carry out the analysis of strain caused by failure of technology to indicate perceived stress by collecting several data, such as by measuring and observing responses and interviewing the participants. This multi-dimensional approach corresponds with the specifications of the DIN EN ISO 10075-3:2004. An analysis of the different aspects of work strain by means of various measuring processes considering several degrees of accuracy provides a sufficient description and evaluation of the resulting strain reactions [3]. For the quantitative assessment of the mental strain in the man-machine-interaction the physiological parameters heart rate and electrodermal activity [4] are used as the most important indicators. These two indicators are well suited for the recording of short-term strains and changes in strain [5]. Problems when using these two indicators can be seen in their ambiguity and lacking intercorrelation [6]. Psychological indicators change in dependence on various influencing values (e.g. physical activity, emotion, daily rhythm etc.) so that a unambiguous allocation according to Nitsch [7] is only possible in the respective stress reaction to a very specific stressor under extremely controlled conditions at best. Skin conductivity can only be recorded at the exclusively sympathetically controlled eccrine sweat glands of the palm and the inside areas of the feet as changes of the bioelectric properties of the skin (measurable 1.5 to 6 seconds after the occurrence of the event). The psychophysiological data were collected using the Par-Port/ F device of the company PAR Medizintechnik Berlin. In the experiment described here, the electrodermal activity was derived by means of two Ag/AgCl-multiple electrodes (Ø 9mm) attached to the palm of the non-dominant hand. The Ag/AgCl- multiple electrodes were covered with electrode gel and additionally fastened by an elastic bandage in order to prevent slipping. The changes of the skin conductivity value to be expected were registered and saved as EDA. The individual reaction response to strains can occur both in the form of hyper activation and deactivation of the organism as a response reaction [7]. In principle, strain proportions in an observed situation can be identified as an erratic rise of the skin conductivity level [8]. At the same time a work-related leap can occur [9]. For this reason the changes after and the cycles between the events were recorded as measured data and correlated with response observations.

In order to create these controlled conditions in a test procedure a complex testing procedure was designed.

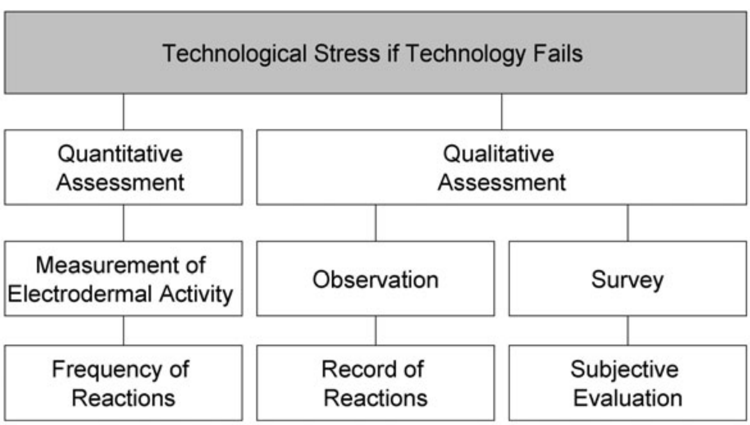

Fig. 1. Illustration of research methodology

3 Description of Experiment

For the detection of technological stress which is consequence of strain due to failure of technology a laboratory experiment was prepared which was approved by the ethics commission of the Federal State of Brandenburg. During a work phase of 15 minutes three events, two errors and a time warning were included as stressful situations in the course of the laboratory experiment. In a first test, a preliminary test was conducted with a pretest group consisting of 10 randomly chosen test persons, during which the structure, course of events, evaluation and goal check were carried out. The timing and the sequence of the error events were reviewed and the questionnaire was checked regarding its ease of understanding. The questionnaire was revised regarding its length and the electrodes were fixed by means of a gauze bandage at the non-dominant hand. Documents such as the written instructions were standardised and shortened. The collected data of the 10 test persons from the pretest were not included in the evaluation of the whole experiment.

In the ergonomic laboratory (experiment room 1), in which there is no through-going traffic, an office work station was specifically installed for the test period.

The task was the same for all test persons: preparation of a one-sided electronic technical text (description of devices, LMT – light density gauge series L 1000) from a given paper within 15 minutes. The text was of medium difficulty since coping with the task was to be possible with some effort and it was to largely simulate a daily situation (writing official papers, letters or applications). For this a work station was set up in one of two adjacent ergonomic laboratories including an ergonomic office chair, a desk, workplace technology consisting of screen, keyboard and computer, document holder, mouse and footrest. The workplace was near a window, but could also be darkened if it was desired. Every test person was allowed to use the document holder individually. A small camera in the window corner at the workplace, which was hardly seen, recorded the test persons' reactions during the whole experiment. A second camera, placed behind the work station, recorded the procedures and the activities in use of the technology. The recording technology was placed in an adjacent room (experiment room 2). The person conducting the experiment could simultaneously observe the whole experiment room on several screens and a monitor at a work station, and all other acoustic signals such as the instruction or the test persons' verbal reactions could also be simultaneously recorded. By means of recording and editing technology the reactions of all test persons were recorded during the whole experiment. In experiment room 1 there was a supervision place for a second conducting person (instructor). This was separated from the experiment work station by an opaque partition as a kind of second room. Here the instructor could monitor the skin conductivity measurements in order to be able to correct measurement errors at the beginning of the experiment and to help in case a test person did not feel well. In this separate area there were also desks to answer the parts of the questionnaires before and after the experiment and to fix the sensing electrodes. All in all, the whole experiment lasted between 30 and 45 minutes. With 15 minutes the time period measured for performing the task was fixed for each test person as a standard.

Each test person entered the experiment room 1 and was greeted by the instructor. After the task had been briefly explained orally, each test person received a test description and a written participant's declaration, which she/he signed after she/he carefully reading it and asking possible questions. Then questionnaire part 1 was presented to the test persons. After they had answered it, the participants were shown to their work stations and connected with the measuring device by fixing the sensing electrodes to the non-dominant hand. The electrodes were fixed by means of an elastic gauze bandage in order to prevent sliding and keep measurement errors to a minimum. The instructor checked the correct illustration of the measured values on his monitor. The time when the measuring technology was fixed, was determined at the beginning of the experiment in order to achieve an adaption to this unfamiliar situation. Then the work station was explained to the test persons and the text was handed over. After all questions had been answered the experiment was started and it was announced that none of the contact persons could be reached any more. The test person group without failures worked on the completion of the task with only one unforeseen event, which was the instructor's warning to stick to the time limit. For the test person group with failures two additional failures, without their own fault, were loaded from the adjacent room as unforeseen events before the warning to stick to the time. In experiment room 2 the person conducting the experiment had access to the test persons' devices and could activate standardized failures which led to the disappearance of the test person's respective result from the monitor. With some knowledge of the technology, the first failure allowed the restoration of the result, whereas the second failure could not be repaired and the result was lost. The test persons always experienced the failures as a sudden unforeseen failure of technology. The time warning was given to the test persons with failures and to the group without failures at the same time. During the whole experiment the participants' activities and the responses were recorded. After 15 minutes the experiment was finished by the instructor independent of the respective result. Then the sensing electrodes were removed and the test persons were taken to the forward area of experiment room 1 to complete the second part of the questionnaire. Then the experiment was finished by the instructor.

All test persons were allowed to stop the test during the laboratory experiment at any time. At the end of the experiment the test persons were again informed about the videotaping and they were allowed to look at the test set-up in room 2. All participants agreed again to the authorization to evaluate their recorded responses. With every participant his/her own measured values were briefly evaluated in the room. At the end it was agreed with the participants to keep silent about the test set-up and the procedure until the test series was completed.

4 Evaluation

136 persons voluntarily participated in the laboratory experiment. In a standardised interview all participants were prepared for the test procedure regarding content and organization and signed a declaration of consent. In addition, they were informed about the possibility to stop the experiment at any time. The participants came from the Cottbus region and the composition of the test person group was random after an individual address. The total number of test persons amounted to 146. The number resulted from the test persons' reply to the request. to a request asking for participants. No test person was rejected in order to achieve the greatest possible random sample. A group of ten test persons formed the pretest group. In the study 136 test persons were evaluated, where a second consideration divides the total number of test persons into a group with failures and a group without failures (every fifth test person). 15 test persons could not be involved in the evaluation of the measured data, because from 14 test persons no data could be recorded from the device during the

experiment or very serious measurement errors occurred. One test person stopped the experiment ahead of time and gave a very high stress level due to the unfamiliar technical tools as a reason. Before the experiment the test persons completed a questionnaire part 1 and after the experiment a questionnaire part 2. In order to be able to compare the answers from the questionnaires with the skin conductivity measurements when interpreting the results, the 15 invalid test persons were not included in the comparative analyses of the questionnaires regarding the skin conductivity measurements, so that the group of 121 (29 above 45 years and 90 under 45 years) valid test persons was subdivided into 23 without (7 above 45 years and 16 under 45 years) and 98 participants with induced failure events (22 above 45 years and 74 under 45 years, twice there was no data) (Figure 2).

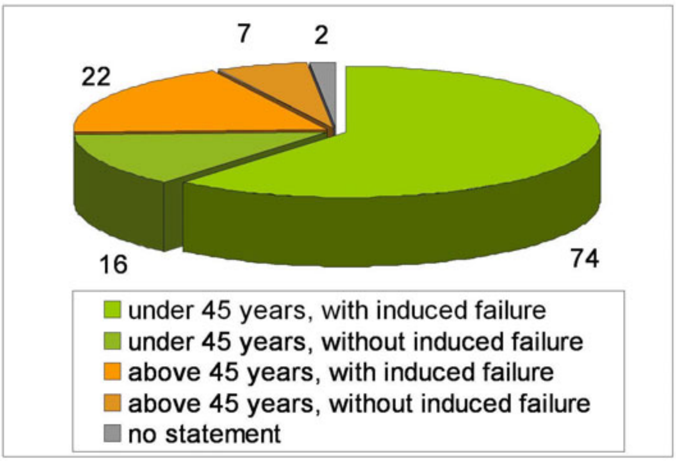

Fig. 2. Distribution of age groups

5 Results

A two-part questionnaire with five sections regarding content was used. The first part was handed out to the test persons before the task and was divided into the sections: sociographic data (items F1a/b and F2), attitude towards technology (items F3 to F7) and current individual situation (items F8 to F11). The second part of the questionnaire was handed out to the test persons after the completion of the task and was divided into the sections: statements on technological stress (items F12 to F16) and statements on subjective performance assessment (items F17 to F19). Each test person was successively assigned to a number so that an anonymous evaluation was possible. The evaluation was carried out by means of enumeration and was evaluated as percentages.

In the following section individual items will be illustrated as examples. Since the attitude towards technology has a decisive influence on the psychic strain in the form of technological stress, all test persons were asked about this problem.

The following statement resulted from the answers to the question “Do you like working with the computer?”: 83.8% of the participants above 45 years said that they "liked" and "liked very much" working with a PC, whereas 95.1% of the participants in the group under 45 years said the same. 16.1% of the older and only 4.9% of the younger test persons said they "did not really like" working with a PC. That is a representative statement because, at the time of the study, all participants in the experiment were active in professional life and, according to their own statements, worked with the computer "every day". The competence in handling technology has an influence on the psychic strain as well. In the item "How do you assess your own performance at the PC?", the subjectively assessed competence in handling technology was asked about. In percent, both groups of participants rated the competence in the "high" section. But here differences in the subjective evaluation become obvious. 60.7% of those older than 45 years rated their own competence as "high" and only 3.6% rated it as "very high". 35.7% even said it was "low". The result in the group of persons younger than 45 years is different. 72.6% rated their own competence in handling the PC as "high", 13.7% said it was "very high" and 13.7% said it was "low".

The statements on the main use of technology were also interesting. Here drastic differences in the groups considered became evident (Figure 3) as illustrated in the following part by the statements on the item "What do you mainly use the computer for?"

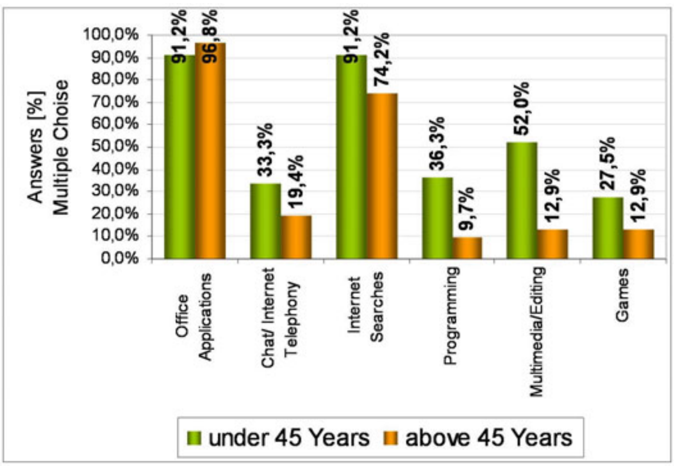

Fig. 3. Fields of application

From these statements it can be concluded that users older than 45 years subjectively assessed their own competence more critically, although, according to their own statements, a large number liked working with the PC and the main fields of application were in the office and Internet research. The measurement of the skin conductivity during the whole experiment suggested psychic strain when working with technology, when technology failed and when there was time pressure.

In the following charts the measured levels of the test persons with failures 1 (Figure 4) and 2 (Figure 5) are contrasted. In both figures it can be seen that high and very high increases of the skin conductivity levels (in percent) can be found in employees younger than 45 years, but that a reaction to technological stress due to failure of technology could be proved in all test persons.

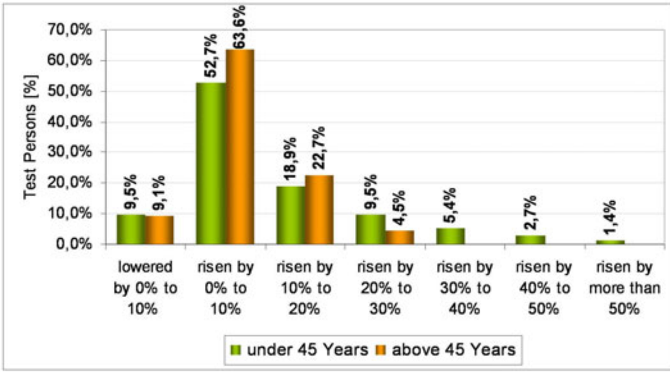

Fig. 4. Skin conductivity level after F1

In Figure 5 it becomes obvious that after the second error event a further reaction to the disappearance of the text could be ascertained by measuring the skin conductivity levels. It is important to notice here that the skin conductivity value after the first error did not go back to the starting level and therefore represents a further increase compared to the increased levels. Consequently a psychic strain is to be assumed.

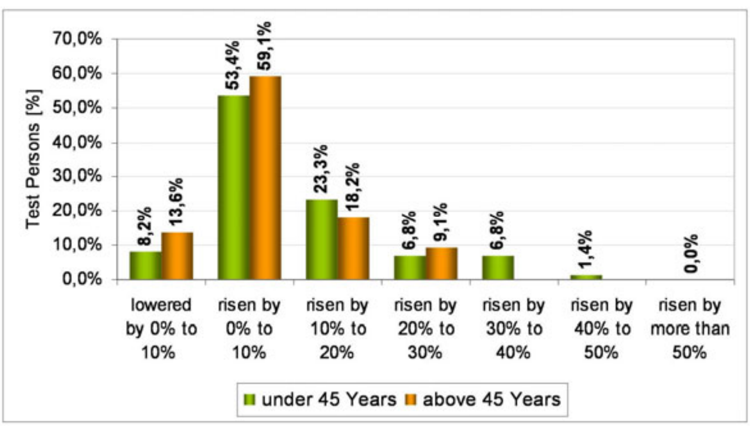

Fig. 5. Skin conductivity value after F2

An additional increase of the skin conductivity value could be measured in the test persons with failures under additional time pressure (Fig. 6). This increase is smaller than that in the test persons without failures (Fig. 7). But this can be explained by the increase because of the previous errors, because the skin conductivity value did not go back to the starting level after the error events and represents an additional strain.

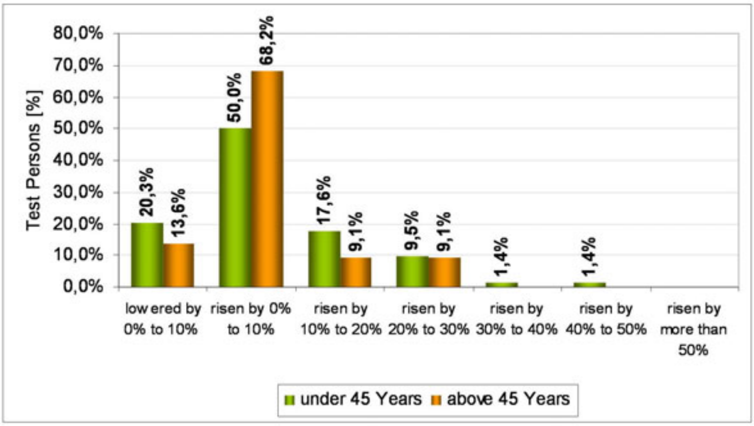

Fig. 6. Skin conductivity value after warning to stick to time (test persons with failures)

In the chart about the skin conductivity value of test persons without errors with warning (Fig. 7) it can be seen that the increase due to time pressure is higher (in percent) in the participants' group above 45 years. Therefore it can be assumed that in this group time pressure when working at the PC is perceived stronger.

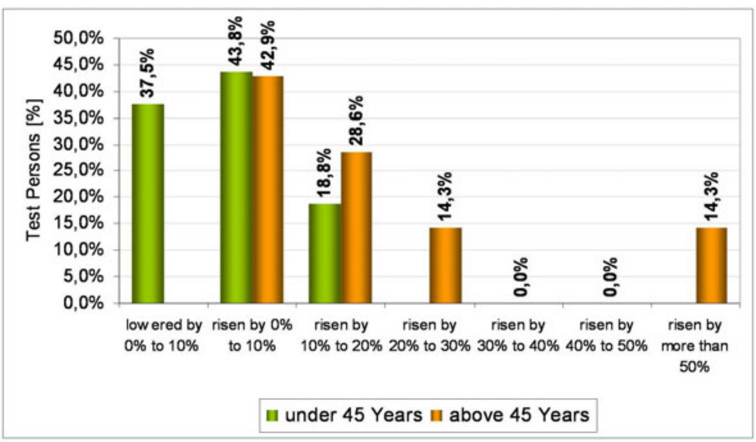

Fig. 7. Skin conductivity value after warning to stick to time (test persons without failures)

In a comparison of the statements of the questionnaires on stress perception with the measured skin conductivity levels an interesting fact could be observed. Test persons who stated a "very low" and "low" stress perception during the experiment showed an increase (in percent) in the skin conductivity value of 200% (Fig. 8). This is a clear indicator that neither group subjectively experienced a proven strain when working with technology.

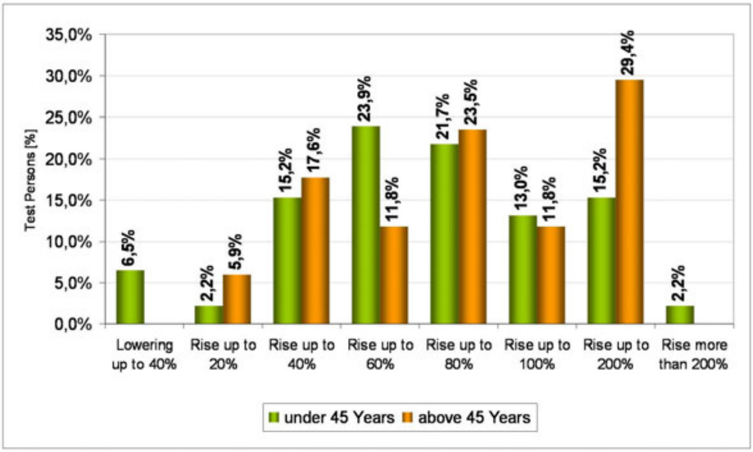

Fig. 8. Test persons with low/very low subjective stress perception in comparison to measured skin conductivity levels

The observation with the help of two cameras resulted in another interesting statement on the behavior and actions of the test persons. On the basis of search times the notional and temporal interruptions of the work can be identified. Longer search times indicate a competitive situation regarding technology, whereas a quicker start of work indicates a result-oriented approach. In this experiment, longer search times were found in the group above 45 years (Fig. 9 and 10).

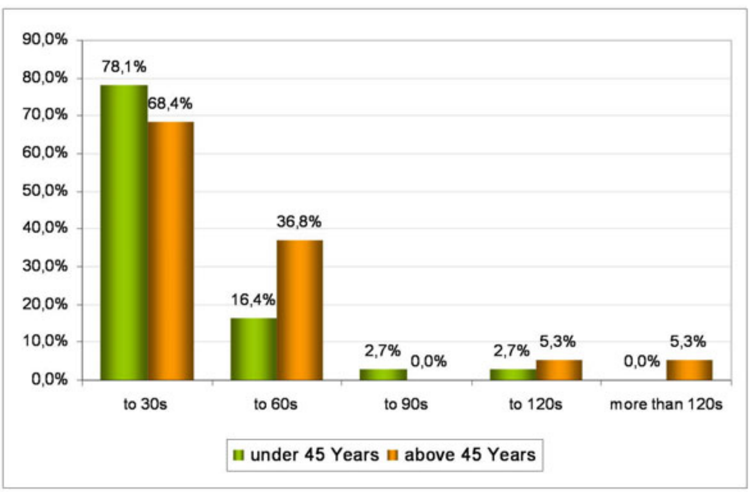

Fig. 9. Search time after 1st failure

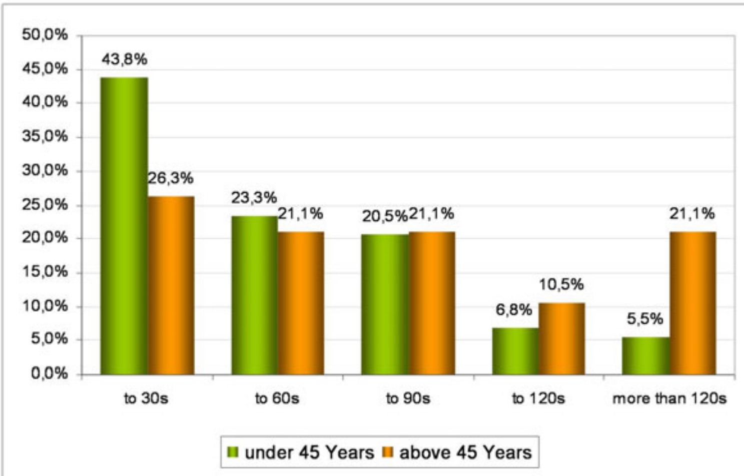

Fig. 10. Search time after 2nd failure

6 Conclusions

The experiment has shown that both groups like working with the PC and, by the majority, assess their competence as "high". In the group of participants who were older than 45 years a larger (in percent) number of people have the opinion that their competence was "rather low". The longer error search times were also found in the group above 45 years. In the described laboratory experiment an increase (in percent) of the skin conductivity levels in cases of technology failure and time pressure could be proven by measuring both test person groups (below and above 45 years of age). From the results of the additionally used questionnaires a discrepancy of the levels perceived and the levels measured could be seen. Here there could be the danger of an increased strain without value perception when being focused on working with technology. These indications must be investigated further in order to prospectively avoid possible consequences for health.

In addition, the results were prepared as guidelines for practice transfer for **users** of technology within the framework of further training in occupational seminars, in the university for senior citizens and publications, and as guidelines for **manufacturers** within the framework of design recommendations as **guidelines for action** when handling technical utilities.

Ten guidelines for action for users and manufacturers of modern technology were derived on the basis of the experiment results. Two of them should be mentioned here as examples. E.g. the 4th guideline for **manufacturers** of technology [1], which could be a great help to reduce strain especially for the group of users who are older than 45 years: **signal possible breaks to the user**.

A software that prompts a note for short, useful breaks on the screen by means of little signals after longer phases of work would be imaginable [1].

Furthermore, from the results of the study for example the 2nd guidelines for action for **users** of technology were formulated:

As much as necessary, not as much as possible
The goals of action determine the choice of technology. The user should specifically think about the question which technology she/he needs and what and how often she/he uses it for. This can be achieved by means of training.

In order to be able to recognize consequences of strain, to identify causes and to derive design recommendations, technological stress research must do more scientific research work.

Unfortunately, the future of every kind of scientific research is often not guaranteed due to financial restrictions. Nevertheless the importance of technological stress research must be increasingly placed in the focus of interdisciplinary thinking in all fields of human life.

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Ubiquitous Life Support Systems for an Ageing Society in Japan

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Abstract. Japan is hit hardly by the consequences of demographic change. The awareness concerning this problem and the accompanying social and economic problems is high in Japan. In order to increase the development and distribution of new ICT and MST-based technologies and also to maintain an international leadership here, the Japanese government deliberately increases on the one hand the awareness of future problems, and promotes on the other hand particularly "ubiquitous" high-tech-systems to solve problems arising with the demographic change. The Paper is based on a study for the German BMBF in which about 100 Japanese assistance technologies, concepts and related business models had been analyzed and categorized.

1 Japan as a Forerunner

Japan is, compared to all industrial nations, most badly affected by the consequences of the demographic change. The awareness of this problem is big in Japan, from the side of the government and the politicians as well as from the side of the economy and the company. To promote the development and the distribution of new IaC and MST-based technologies and to keep the international top position of Japan in this area, the Japanese government intervenes specifically by strengthening the awareness of the future problems and by promoting in particular “ubiquituous” technologies for the solution of the demografic change for the good of the whole society (“U Japan” Strategy). [1]

1.1 Variety of the Players

The active Japanese scenery with players in the area of “AAL”, is varied. How the following analysis will show, big manufacturers (Panasonic, DoCoMo, Fujitsu, Toto etc.) and users (apartment companies: Daiwa House, Sekisui House) are already integrated here– still more than in Germany– and the first and successful test series (Maron, YRP Location Aware Services, R-Click) and products (e.g., Intelligence Toilet, already the second product edition) were already put on the market. That means that Japan has already collected (positive and negative) experiences with the introduction of marketable products and can therefore achieve the next quality- or success-step in the upcoming researches, products and services concerning new high tech assistance systems. The national research institutes (AIST, NEDO, RIKEN) are very important in Japan. They often do research by order of the government and their national strategy plans (U Japan strategy) in basic technologies (Brain Machine interface, networks and ubiquituous access to products and services etc.) and they are important initiators. The very interdisciplinary integration of different branches under one main organisation (see AIST, chapter 4.3) and the education of interdisciplinary initiatives at universities (especially The University of Tokio)– which in Germany is still in it's infancy compared to Japan – has got a long tradition. The ability of integrated and interdisciplinary work is particularly important in the field of the assistance systems. This is why the Japanese approach can also deliver interesting indications for the development of assistive systems in Germany especially in the area of the integrated development.

1.2 Universities as the Scientific "Spine"

Universities and professors, who are playing an extremely big role in Japan, are the scientific "Spine", so to speak. On the one hand, facts are created here by analytic research concerning demography (Prof. Sonoda, Prof. Ohara) and technology (Prof. Fondling) and, on the other hand, new advanced concepts are developed (Tokyo Univ., Waseda Univ., Tsukuba Univ.). Big and widespread companies like Sekisui Chemical, Toyota and Panasonic – which are also active in house building– have recognized that particularly in connection with living space technologies, products and services can be offered, which can come from other company spheres or from suppliers close to the companies (e.g., chapter 4: "Intelligence Toilet", Panasonic products, Cyberdyne products). The modularized, major industrial production of residential space ("Open Building"-approach, Prof. T. Yashiro, Tokyo IIS University) is a special quality of the Japanese market and appears to be almost predestined for the integration of high tech assistance components in the living environment.

1.3 General Innovation Enthusiasm

In contrast to many European countries and Germany in particular, in which new and anticipated technologies are often looked at with skepticism and where they not rarely lead to big public discussions, such technologies are generally approached with enthusiasm in Japan. There is no fear at all to be felt here that these technologies might bring about damage or even "rationalize away" the human worker. Technology is seen as an "ally" in Japan, it is produced by human beings for human beings. This high technology-acceptance is based on the current political and legislative support just as on the historical development, where people were able to predominantly have positive experiences with technology. Examples for this thesis are the historical Wadokei-clocks, which could be adapted to the rhythm of person and nature, in contrast to European models. Furthermore, "Ningyo Karakuri" - early predecessors of automatic systems and robots – had initially been developed to entertain people.

1.4 Growing Old in Japan

The foundation of the esteem of old people is based on the people's religion (Shintoism/Buddhism) with the principle of worshipping the ancestor and the demand of childish piety and performance of their duty towards their parents in Japan. In comparison to European countries the formal family ties are also clearly higher [2]. In total it is easy to see that, nevertheless, the narrow family ties of older people in Japan has another, social-culturally induced quality than, e.g., in Germany. Generally speaking the traditions still play a bigger role there compared to individual preferences. And although the traditional high esteem of the elderly steps aside for a rather unemotional appraisal in Japan as well, nevertheless, the status of old people as approved and respected citizens, which are to be treated with respect, is strongly renowned. Increasingly it is recognized that their lifestyle is less a support assignment, but for the biggest part of this life period an assignment of the self-help with the aim of a long maintainance of individual capacity to act [3]. Numerous state and social institutions or initiatives offer a setting for this, which should be filled, however, to a great extent by own effords, contentual as well as organizational (self-help, help by the family background).

2 Strategies and Developments in Japan

To be able to understand the technology and products developed in Japan better, sociopolitical and research-political objectives and strategies are looked at firstly.

2.1 The U Japan Strategy – Solution of Social Problems by Information Technology

The "U Japan strategy" has got the purpose that anywhere, anytime, anyone can access the Internet and the offered services and can thereby profit from it [16]. With the realization of this vision of "ubiquituous" interlinking Japan wants to become a worldwide forerunner within the IT-society. The "U Japan strategy" is supported and carried by the government and it's umpteen institutions. The extremely low fees in Japan for the use of broadband are part of this strategy as well. The "u" in "U Japan" does refer not only to "ubiquituous" but also to "universal", "user oriented" and "unique". [4]

Ubiqituous. ICT will penetrate all aspects of our life and enclose, on this occasion, things which we have never before judged to be communicationable. The basic concept is, that "everything and everybody" it is linked up.

Universal. Everybody, including the old and affected people, should be brought into the position to be able to use ICT and MST easily. User-friendly communication, which overcomes spatial distances and language barriers and which links connects different generations with each other, should be promoted particularly.

User Oriented. Products and services go over to being determined by the ideas and individual wishes of the customers and to being strongly user-centred in future instead of being manufacturer-oriented.

Unique. ICT will also transform the society from uniformity and standardization to a society, which is based on uniqueness, creativity and new social values.

The use of Information and Communication and all the services connected to them are to be raised strongly by the implementation of networks in all areas of the everyday life. By “Inclusion” instead of “Exclusion” especially older citizens in should have the possibility of being able to catch hold of networks and services any time from anywhere through the “U Japan strategy”. The purpose of the “U Japan strategy” is also to bespeak social problems and to questions efficiently.

2.2 Microsystem and Micromachines

The public support of the microtechnology in Japan started at the beginning of the 90s. Subsequent to that the METI promotes a 10-annual program (Micromachine Technology Project) since 2001 for more than 20 companies and research institutes for the development of other bases for microsystems. In addition, it financed a program for the development of MEMS sensors between 2002 and 2005. In 2004 a program was brought to life, that should produce “Design tools” for “Open Network engineering” and for simulation and test purposes of microsystems. A program, which promotes the system integration of microsystems with other systems (e.g., nanotechnology, electronics), was issued as well. Nevertheless, most companies in Japan do not depend on public incentives. Own capacities and resources are often provided to be able to cooperate with universities and research institutes in this field.

Furthermore it is typical for the Japanese MEMS industry that it likes deriving new product generations from present developments, preferably by the usage of improved micro system technology.

Interestingly, the focus of the Japanese mike system technology to approx. 2007 lay strongly in the field of entertainment electronics. From there new developments were transferred on other applications. Position sensors, for example, which are also utilized in the service field and in the field of assistance systems originally were developed for entertainment purposes in machines like game consoles, to MP3-players, mobile phones, step counters etc. [5 [6]]

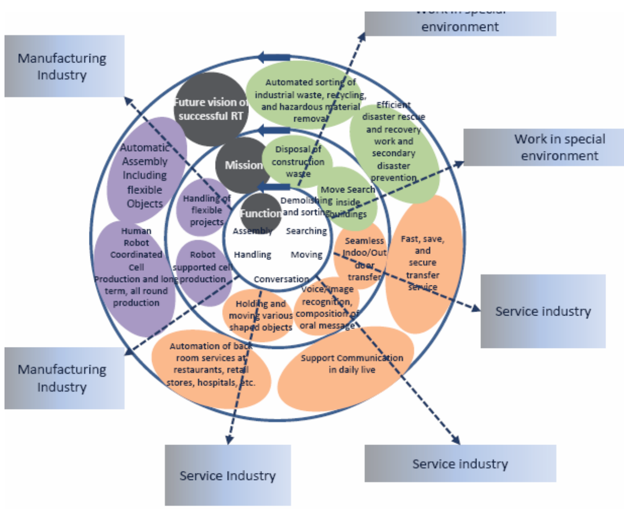

Fig. 1. Japanese automation and robotics strategy and central topics in research and development according to New Energy and Industrial Technology Development Organization (NEDO)

2.3 Robotics

Today the Japanese strategy regarding robotics focuses on three areas: "Manufacturing Industry", "Service Industry" and "Work in Special Environments". The national robotics program contains three sub-programs: [7]

- Strategical development of "Advanced Robotics Elementar Technology"
- Intelligent Software
- Open innovation by Robotics

Research is encouraged especially in the follwing areas:

- Flexible Production Systems
- Human-Machine-Communication and flexible Productions Cells
- User Interfaces particularly for Elderly.

2.4 Yaoyorozu: Technology as an Assistant in the Everyday Life

Further, the term" Yaoyorozu" (= uses 8 millions)is also used is association with the new IaC and MST based technologies. This means something like "uncountable many". Specifically the phrase "Yaoyorozu no Kami-gami" (8 million gods) is implying that "gods" do not only work in the old temples, but also in all things of life. For a research project of Hitachi this image was significantly extended and "Yaoyorozu" was used for "ubiquitous" to show that a surrounding, which is enriched with objects with "smart" and with information technology / micro system technology, can support a person and even protect him! Hence, future intelligent surroundings should not only follow the paradigm "ubiquitous" ("anytime, anyplace, anything, anyone") but also be increasingly able to focus on single individuals in a personalized way and to "protect" them. This is why "Biometrics", "Sensors", "Physiological Condition", "Wearable Devices" and especially user interfaces are forming a stronger and stronger the main focus in the micro system technology research. Traditionally, Japan is also known to offer, in the end, solutions, which are highly "adaptive" and/or "personalizeable".

3 Examples of Assistance Technologies in Categories

Within the scope of a study for the BMBF and by order of the VDI/VDE Innovation und Technik GmbH 100 technologies, concepts and research attempts from Japan were analyzed and divided into categories. In the following for every category one assistance system is described briefly and exemplarily showing the general development in Japan.

3.1 Home Care: Robotic Bed

The "Robotic Bed" is equipped with a controlling system, which ensures secure movements of the robot. It automatically makes a distinction whether between the wheel chair and the bed mode. In the wheel chair mode the robot is able to recognize people and obstacles in order to avoid collisions and to navigate securely. Besides, the

"Robotic Bed" is equipped with an intuitive control system, which enables the user to steer easily and to change between the modes. For a higher comfort the robot works with a technology, which supports the posture by adjustment and optimization of the mattress form. Moreover the user can be moved to avoid bedsores. Additionally, the stationary part of the bed possesses an information and operating module in the bed sky, which submits television, internet and the control of house-automation systems.

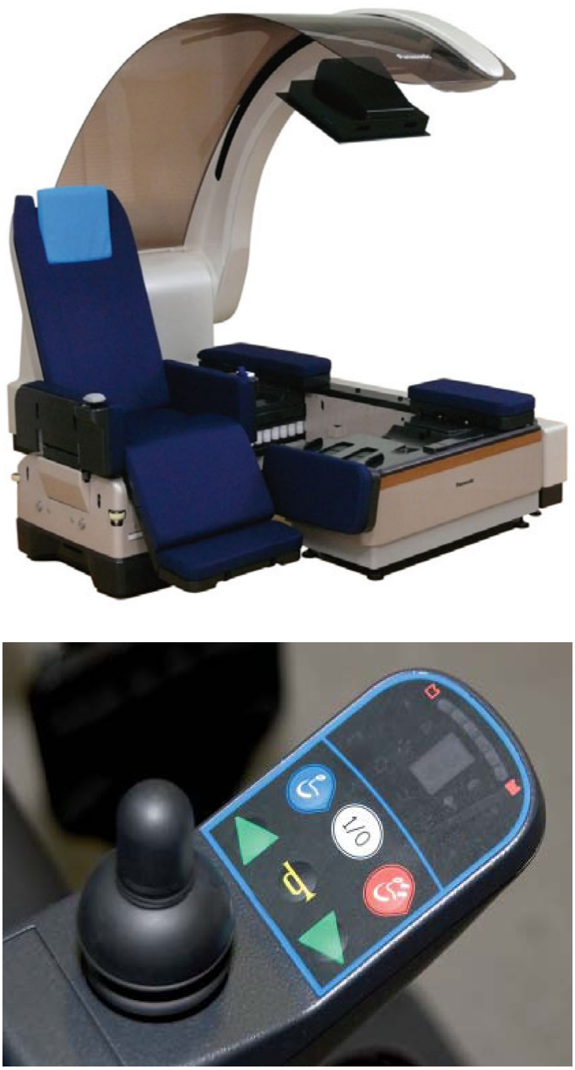

Fig. 2. Enhanced efficiency and safety of transfer processes in hospitals, homes for the elderly and private homes

Developer:	Panasonic
Business Model:	Solving the “transfer” problem and/ or making transfer more efficient and safe
Target Group:	Hospitals, Home Care
Technology Readiness:	Prototype, Research and Development Project
Commercial Launch:	--
Price:	--
Success of Product:	--
Contact:	Panasonic

3.2 Social Interaction: NetTansorWeb

“NetTansorWeb” from Bandai and Evolution Robotics is a mobile house robot and was developed for families and amateur handicraftsmen. Owners can steer the robot on the internet and navigate him through the house to supervise it, or they can program him to do that automatically. While doing that he can also take pictures or videos of his surrounding and send them to a mobile phone automatically.

Fig. 3. Communication and Interaction Gadget “NetTansorWeb”, Bandai

Developer:	Bandai und Evolution Robotics
Business Model:	Mobile Household Robot with cameras and communication functions
Target Group:	Home Owners
Technology Readiness:	Already second product generation launched
Commercial Launch:	2008
Price:	$ 500
Success of Product:	--
Contact:	Bandai

3.3 Health and Wellness: Intelligence Toilet

"Intelligence Toilet" is a toilet system, which is able to measure the sugar level in the urine, and also the blood pressure, body fat and weight. These performance features should prevent forthcoming illnesses by early diagnosis and reduce medical inspections at a doctor's office. The further developed version (version II) can additionally predict the menstrual cycle of a woman by temperature measurements and analysis of the urine. All values are collected and saved in a house-internal network on a computer, on which one can read this in form of tables and graphics. The built-in urine-analysator in the Intelligence Toilet catches 5 cm^3 urine before measuring the sugar level from it. The unit cleans itself after the one minute lasting test. The blood pressure measuring instrument is in direct reach next to the toilet bowl. Weight and "Body Measure Index" can be measured by an into the ground integrated scale in front of the sink. The results are seized over a network and they are evaluated on a computer using provided software. That allows an individual configuration for different users and proposals for diets, exercises, possible health risks or doctor's visits.

Fig. 4. The Intelligence Toilet is a seamlessly integrated assistance system. Daiwa House & Cyberdyne.

Fig. 5. "Intelligence Toilet" is a toilet system, which is able to measure the sugar level in the urine, and also the blood pressure, body fat and weight. These performance features should prevent forthcoming illnesses by early diagnosis and reduce medical inspections at a doctor's office. Daiwa House & Cyberdyne.

Developer:	Toto und Daiwa House Industry
Business Model:	Bath and Toilet-system for continuous health monitoring
Target Group:	health conscious families
Technology Readiness:	Already second product generation launched
Commercial Launch:	2005 (Version I), 2008 (Version II)
Price:	\$3.550 - \$5.230
Success of Product:	Version I had been sold 10.000 times
Contact:	Daiwa House Industries, Nagoya Toto, Tokyo; Cyberdyne Inc., Tsukuba

3.4 Information and Learning: Dr. Kawashima

The game "Dr. Kawashima" is based on the theories of Japanese cerebral researcher Ryuta Kawashima. By intensive research during the last years, he distinguished in which way the efficiency of the brain decreases within age. Through regular and specific training this process should be antagonized. Kawashima found out that with easy arithmetical problems the brain shows a high activity, while it is low with difficult arithmetical problems. Tests at a school in Scotland were apparently so promising that the pupils there are urged to play Dr. Kawashimas Brain-Jogging for 20 minutes before the lesson starts now. After regular calculation and reading, the activity of the frontal lobe could be increased with dementia patients as well.

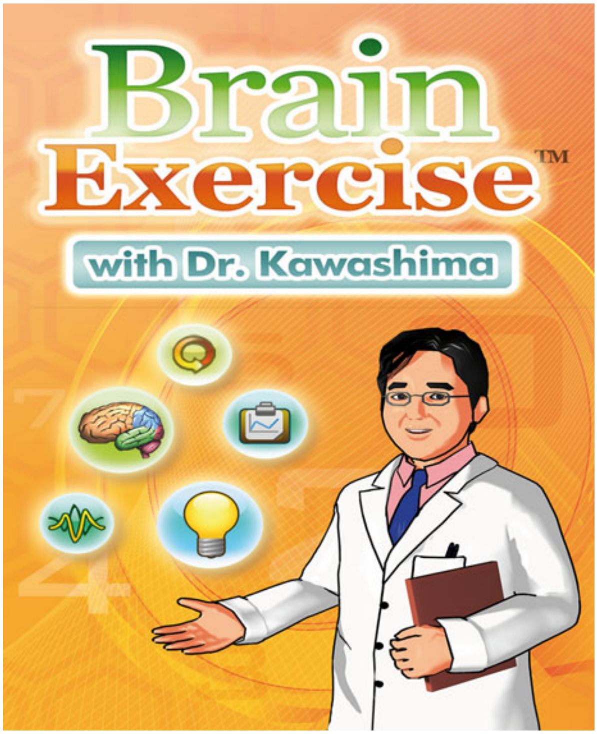

Fig. 6. The game "Dr. Kawashima" is based on the theories of Japanese cerebral researcher Ryuta Kawashima. By intensive research during the last years, he distinguished in which way the efficiency of the brain decreases within age. Dr. Kawashima & Nintendo.

Developer:	Nintendo, Ryuta Kawashima
Business Model:	Mental traning game running onNintendo DS, PCs, Pocket PCs
Target Group:	people of all ages
Technology Readiness:	Product launched
Commercial Launch:	launched in Japan 2005, launched in Europe 2006
Price:	20 € / per game
Success of Product:	in 2008 already over 23 million games had been sold
Contact:	Nintendo, Prof. Dr. Kawashima, Tohoku Univ., Department of Functional Brain Imaging

3.5 Professional Life: Stride Management Assistant

Honda began its researches regarding electronic assistants in 1999, with the purpose to help older and weaker people or factory workers who have difficulties with walking.

While walking, “Stride Management Assistant” collects information with sensors above the hip. With these an integrated computer is able to calculate when and how much support is needed. The engines are compact and allow a relatively light weight of only 2.8 kg. The used lithium ions battery allows an operating time of 2 hours with 4.5 km/h running speed.

Fig. 7. Honda began its researches regarding electronic assistants in 1999, with the purpose to help older and weaker people or factory workers who have difficulties with walking. Honda.

Developer:	Honda
Business Model:	Walking Assistance for factory workers
Target Group:	companies
Technology Readiness:	Prototype, research and Development, Evaluation and Usability Engineering in own factory environments
Commercial Launch:	--
Price:	--
Success of Product:	first promotion activities have been started
Contact:	Honda

3.6 Mobility: Toyota i-Swing

The form of the i-Swing reminds less of a vehicle, but suggests rather a new life form. “i-Swing” is“ the fourth concept study of Toyota for individual mobility after “p.o.d”, “PM” and “i-unit”. With it’s compact, flexible bodywork “i-Swing” adapts ideally to every individual life surrounding. It can be geared precisely to the personal needs of it’s driver and it offers nearly unlimited mobility.

Fig. 8. "i-Swing" is"the fourth concept study of Toyota for individual mobility after" "p.o.d", "PM" and "i-unit"

Developer:	Toyota
Business Model:	Urban and Personal Mobility
Target Group:	--
Technology Readiness:	fully functioning Prototype
Commercial Launch:	--
Price:	--
Success of Product:	--
Contact:	Toyota

3.7 Home Automation

The company Sekisui Home is a big Japanese living space provider, which offers "Customized Houses" in space cells construction method (Unit-Technology). Sekisui is doing intensive research in their R&D-Centers concerning new concepts and technologies on the subject of AAL. The completely preinstalled space cells of the company Sekisui are not only used for the establishment of single-family-houses, but also for the establishment of homes for the elderly and Japanese "Group Homes".

The Sekisui House "Sustainable Design & Technology Laboratory" for instance is a research house developeded since 2006 for tests concerning "Home Designs" and "Home Technologies" of the next generation. The equipment exists of two areas. The area interesting in view of AAL is called "Experimental Living centre"; new residential concepts and technologies are explored here. The centre is inhabited a by experimental subjects and also by the researchers themselves from time to time.

Fig. 9. Modular Buildings are fully equipped with assistance technologies in the factory. Sekisui Heim.

3.8 Smart City: Town Management System

The basic idea of this technology is based on the actual fact that robots have only a limited recognition ability and a limited learn ability of processes. Prof. Hasegawa makes clear with his research in Fukuoka, how future robots could work more efficiently. Hasegawa proceeds from the assumption that robots of today's stand (and probably also in future) can only react to their surrounding, if it makes itself recognizable for them. With this approach the complexity is outsourced, from the robot away in favor of the intelligent systems distributed in the surrounding, which then supply the robots with information. Now this approach is developed further to "Town Management System" (TMS). With this approach the town transmits information to the corresponding robot at every time and about every location in order to simplify orientation and the compliance of instructions for his. The Town Management System (TMS) is firstly to be tested in an old people's home in order to support the nursing staff.

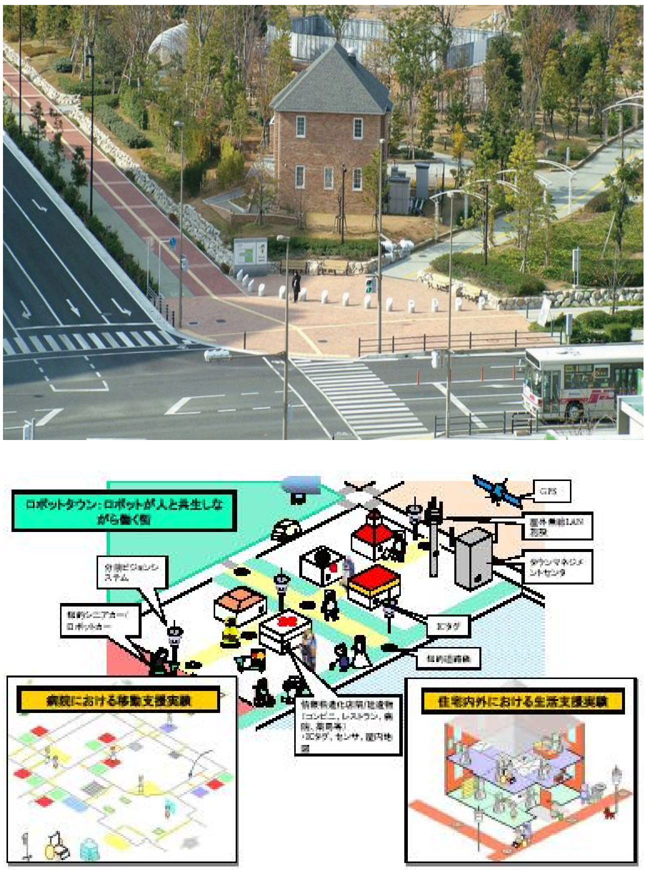

Fig. 10. Town Management System (Robot Town). T. Hasegawa, Fukuoka, Kyushu University.

4 Implementing of AAL Technologies by Means of Modularized Residential Systems

Industrialization in civil engineering is a keyword, which is all too easily associated only with deterrent examples from the 60s and 70s. At that time the impression was characterized, that industrialized construction goes along with the loss of the architectural identity of single buildings, whole ensembles or even whole public spaces. The fact that this is at odds with the truth – the fact that industrialization is no uniformist utopia in the construction process – Toyota Home proves as a real and successful company in an impressive way. After the Second World War the Toyota Motor Corporation looked for a way to multiply her productiveness. They wanted to be able to keep up with the US-American icons of the mass production. A visit of Ford and General Motors led the persons responsible for Toyota to the conclusion that a manufacture strategy based on mass production and "Economies of Scale" could never work with big success in her own social and economic system. In Japan, differentiated and quickly changing markets, which required a production within the scope of small series, already existed in that time. Also they feared the consequences of a possible worldwide recession. One supposed that the industrial undertakings, which are aimed at the production of large amounts of a standardized product, could only get over an economic crisis with immense losses (Taichi Ohno). How much Toyota has proven foresight with a strategy, which relies on sustainability and conservation of the resources, appears just now: The expected crisis has really entered, and it demands exactly the tribute one was not ready to pay in Japan. From these circumstances the Toyota Production System (TPS) was developed. The basic idea was to reform material and information streams of the mass production ("Pushing Production") substantially and thereby to achieve an industrialized manufacture, which strictly declares the demand as a starting point ("Pulling Production"). With an economy and manufacturing system, which is uncompromisingly filled with information technology, Toyota has established an infrastructure, which is able to dynamically adapt to the individual wishes of many single customers. Based on this current status of development the introduction of industrial processes into the Japanese civil engineering was a step relatively slightly to be taken. In Japan just as in Europe buildings are closely related to the thought individuality, but especially in Japan the gap between rationalization of the processes and simultaneous individualization of the end products was already overcome. Thus in the halls of Toyota Home steel frames ("Skeleton") are moving on an assembly line through the factory now and they are adapted and developed ("Infill") "precisely in time precisely in sequenz" to the demanded solutions. Each house – compound from a variable number of individualized single modules – receives it's own identity. Toyota Home is, with the help of the TPS, able to put together 200,000 single components to a finished product in the shortest time and to build a house from them (in comparison: With cars only approx. 14,000 components are processed on an average) [8]. Toyota Home provides a promising solution for the industrialization of construction processes with it's "Skeleton and Infill" system and it shows that nowadays robotics allow a financeable, customized industrial production of living space in a contemporary way. Before the houses, house modules, walls or other prefabricated parts are prefabricated industrially within the shortest time (according to the company max. 1 to 2 months of production time!), the customers are led through a multistage configuration process.

Fig. 11. Configuration and Factory Production of Individual Homes in Japan. Toyota Home. Sekisui House.

During the configuration process the house is tailor-made to the customers regarding the layouts and the contained features. For this purpose the customers are invited in a R&D centre, in which tests and simulations are run with the customers concerning the different habitation and living areas. Afterwards a "profile" of the customer is prepared, which also takes into consideration the change of the age in time and in particular the subject "Age" (or AAL). In almost all R&D-Centers bigger Open Innovation Fields exsist, in which especially in an older age appearing situations can be simulated with the customers. On the basis of this academically profound "profile" the final configuration of the residential surrounding is undertaken with the customers.

AAL feature modules (intelligent bathrooms, intelligent house control systems, emergency call systems, health care/fitness systems) in connection with age-appropriate design and age-appropriate residential surrounding-creation are offeres by all "Housing Companies". In spite of an individual configuration and the integration of numerous manufacturers the houses are produced, in the end, with industrialized means in the factory and on the assembly line ("Mass Customization) [9].

5 Conclusions

The results of the analysis are multi-layered and depicted a row of innovative attempts, trends and also suggestions for the German or European AAL program. Some of the most important conclusions are briefly described in the following.

5.1 Thematization of High-Tech-Assistance Since the Beginning of the 70s

The demographic comes especially hard to Japan and simultaneously this development takes place even more rapidly than in Germany. Therefore Japan is also some years ahead with the thematization of their "aging society" compared to other industrial nations like Germany. So-called "life support systems" are already thematized since the 1970s. Interestingly, concepts and considerations were in the early phases just like today aimed at supporting people in different situations (work, hospital, at home, everyday life). A focus on old people was broadly avoided at least in public discussions and strategies since the beginning of the development.

5.2 "Universal Technologies" Instead of Agespecific Technologies

Many of the MST based technologies, which, in Japan, nowadays are developed by companies or universities or are already on the market, have a rather "universal" claim (and emphazise this as well) than an exclusive customization to the "Silver Business". It becomes also clear that, even if a product is actually intended exclusively for the areas "old people" or "care", the versatility is always emphasized. Thus "Maron" (Fujitsu) and "NetTansorWeb" (Bandai) or also the bathing machines "Hirb" (Sanyo) and "Santelubain" (Avant) can – at least according to commercials or photos – also be used for numerous other purposes (Maron, NetTansorWeb: e.g., for the observation of children and domestic animals; Hirb, Santelubain: as wellness or massaging machines). Interesting in this context is also the fact that above all games (Nintendo, Dr. Kawashima brain jogging), which were intended officially for another target group – is it unintentional or maybe even intended – have become bestsellers just within the older population in Japan.

5.3 Technology and Status of the Elderly

In contrast to Germany old people are traditionally and mainly also nowadays cared for at home by a member of the family. In some cases a member of the family even gives up his regular work. Indeed, old people's homes and other nursing institutes are increasingly spread in Japan as well, but, in total, still clearly less respected than in Germany. Even if older people live at home alone (what still is more common than the living in so called "Group Homes", old people's homes or nursing homes), care and communication through/by a member of the family have a high value. Numerous of the eel products developed in Japan (e.g.: Maron 1 and Maron 2 of Fujitsu; Ubiquitous Monitoring system of Hitachi; NetTansorWeb of Bandai) have to be seen against this background of the "communication with family members".

5.4 Working with Preseries or Test Series

In Japan intensive research is conducted concerning the development of technologies for the demographic change since middle of the 90s. It is typical that since this time over and over again so-called preseries or test series (number of pieces between 50–1,000 pieces) are put on the market by different companies and their R&D institutes or in collaboration with universities. Thus, e.g., the Maron 1 by Panasonic, precursor of Maron 2, was firstly produced 1,000 times and was sold test-wise to private residential buidlings and dormitories. Other examples for this are also some of the mobility-studies of Toyota, PaPeRo and the "Location Aware Services" from the YRP/Sakamura Lab, which are tested in some towns at the moment.

5.5 Modularized Residential Buildings as a Sales Motor

The major industrial production of modularizede and in the factory produced living spaces is far developed in Japan. This modularized construction method is particularly suited to the dynamic integration of AAL-components (e.g., Daiwa House, Sekisui House, Sekisui home, Toyota Home, cf chapter 4.), because AAL-Technologies can be integrated step by step into residential surroundings this way, at the same time they can be assigned to certain performances and wishes and, besides, offer the possibility of changing in time ("Open Building" approach). The mentioned big living space suppliers are therefore – like OEMs (Original Equipment Manufacturers) in the automobile industry – predestined to be end integrators of high tech equipment of any kind. Also, for instance, Toyota expedites the modularization and modular openness of it's residential buildings with the brand "Toyota Home" to be able to strongly incorporate technologies from other Toyota business fields (e.g., Toyota IT, Toyota Automotives to be able to integrate Toyota Mobility etc.).

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Chapter 2: Human Machine Interface

An Intelligent House Control Using Speech Recognition with Integrated Localization

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Abstract. In the past few years great technological progress have been made in mobile devices performance and capability as well as in mini computers world. Mobile phones with wireless interface and advanced operating systems are becoming today's standard. Recent years showed, that they are going to be accepted also by elderly people and they are becoming an inseparable belonging of their every day's life. Since so called intelligent houses are moving from "special" to "common" world, together with today's mobile devices they open the door for many innovations, among others also speech recognition in the house.

In this paper, we describe our efforts towards introducing a simple speech recognition system for voice control of intelligent houses. Introduction to intelligent house environment is given with focus on elderly and disabled people. We also analyse the use of automatic speech recognition in such environments. The main focus is on the design and implementation of the simple speech recognition system and the integration of localization service in such environment.

1 Introduction

In this paper we present a user interface for controlling home equipment such as lights, blinds or heating via speech. In the research area of Ambient Assisted Living (AAL) the question of how to provide the user with an easy to accept and easy to use interface/device is still going on. Some suggest the TV as a device that is readily availbale and accepted by people [1]. But it has the draw-back that it is not mobile and it does not allow for a speech interface, which has emerged as a preferred input method for assistant systems [2]. [1] stated that assistant systems had the following requirements:

- light weighted
- simple and intuitive to use
- adaptable to physical and psychological changes
- offers various input methods like speech and touchscreens
- reliable

Therefore, we propose a speech interface for controlling home devices that runs on mobile phones. The mobile phone addresses several of the previously mentioned requirements in that it is light weighted, simple and intuitive to use and newer mobile phones, especially so-called smartphones also offer touchscreens. Furthermore, mobile phones are very common and elderly people also use it for emergency calls. In the past it has been noted that a common platform should be used or that proposed solutions should be made available on a variety of platforms [3]. As our solution is available for several different mobile phones it accomplishes the latter of these goals.

Our user interface runs on the mobile phone as an additional application that allows the user to interact with their home devices. The microphone is only activated as the respective button is pushed, which addresses another issue raised in AAL applications: privacy [4]. In environments where microphones are set to always-listening modes this is a major issue, as the microphones are constantly recording. This is avoided by giving the user the control over the microphone.

In a preliminary study we have found out that it is rather cumbersome for users to always specify the room where they want something to happen (e.g. "turn on the lights in the living room") if they are already sitting in the specified room. Therefore, a localisation method is added to the application.

This paper is structured as follows: We will first introduce the environment that our application is based on (see Section 2). Next, we will give some details on the topic of Speech Recognition in general (see Section 3) and specifically in the home environment. The next section deals with the problem of localisation in the house and our proposed solution (Section 4). Finally, we will show the setup for the technical realization and some experiments we performed both with the user interface as well as with the localization (see Section 5). A summary that contains our conclusions and suggestions for future work finalizes this paper (Section 6).

2 House Environment

So called intelligent or automated houses today are equipped by default with a central control system. Such a system is able to control and monitor many devices, like lights, shutters, doors, the heating and others. They are usually based on KNX/EIB or similar technology. The control of such a system is usually done with switches similar to those in "normal" houses[1]. Beside, there is also a graphical user interface which allows the same functionality as standard switches but also opens the door to more advanced control and monitoring features.

Such a graphical user interface (GUI) is mostly integrated in to the wall at some fixed place—for example right beside the entrance of a house. It can also be accessible with a personal computer or via some kind of tablet PC, which allows usage from almost anywhere. However, the tablet PC is not being carried all the time with the user and can still be relatively heavy for a disabled or elderly users. If they do not have a simplified user interface, they can not be considered as user friendly for elderly people even despite individual adaptation to the user. It is not possible to use them also for other purposes, such as localization, or in

[1] Recently wireless EIB/KNX switches have become available that allow upgrading existing houses with this technology without need to replace all the cabling.

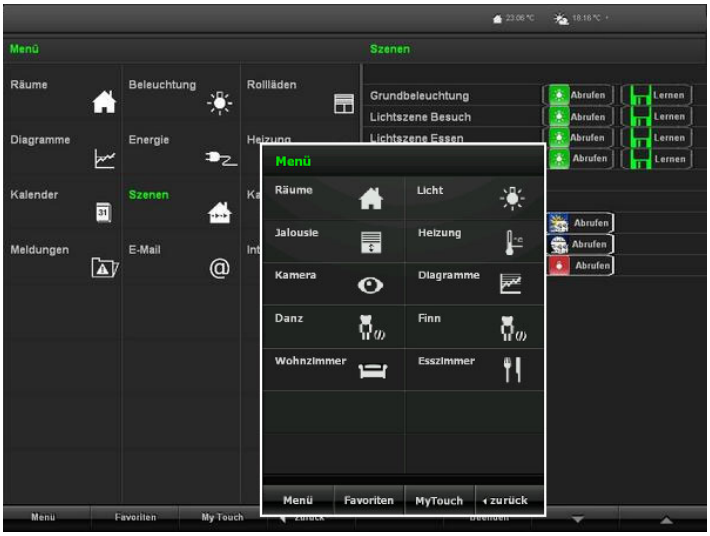

Fig. 1. Two different GUI examples for EIB/KNX system in a house.

emergencies because when they are really needed, they are very likely not with the user (see also the list of requirements presented in Section 1). On Figure 1 are two examples of such GUIs showing controls and monitoring for lights, shutters and the heating.

3 Speech Recognition in House

Speech recognition is able to minimize most of the problems mentioned in previous section. It can be used in a house with elderly or disabled people, to control different devices [5,2]. The presented solutions are usually suffering by one of the following problems:

- They are reliable, but they are very complex and expensive. Reliable systems require a large microphone array, speaker localization, echo cancellation, noise filtering and several other advanced techniques. Such complex systems are still more in a research state than reality today.
- They are cheap, but completely unreliable. A solution with one microphone in the room is usually possible to use only in a quiet room in a certain position with a strong voice. Any other louder acoustic activities in the same room make the system completely unusable.

3.1 Overall Design

To design and implement a simple, reliable, inexpensive, and especially today, widely usable speech recognition system for an intelligent house, we rely upon a

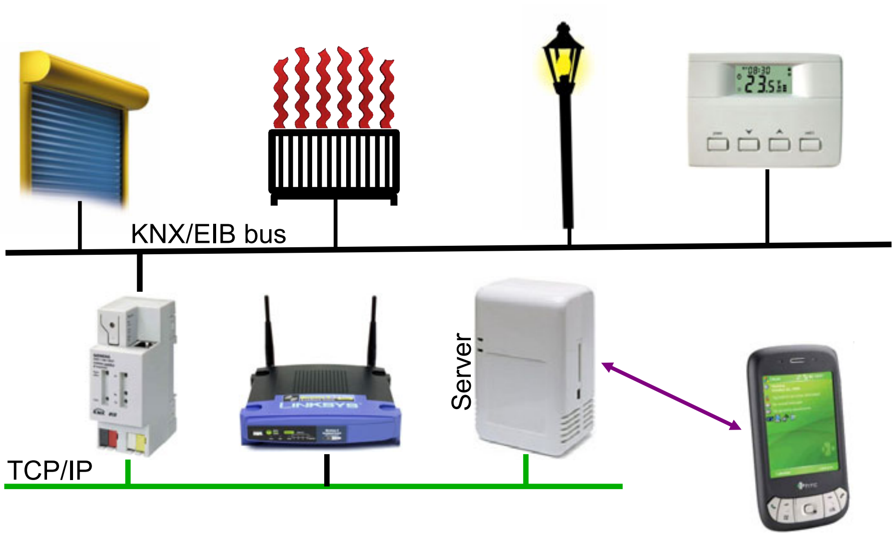

Fig. 2. Voice enabled house control architecture.

few technological achievements. For one, the significantly increased performance of mini PCs. Pocket-sized computers can today easily outperform normal desktop PCs from some years ago [3]. Most of the middle-class and state-of-the-art mobile devices today are equipped also with wireless network support. Besides that, a change in user behaviour has occurred: The mobile phones are already accepted and being used through all age groups [3].

Mobiles phones today are powerful enough to run system for automatic speech recognition. Unfortunately, the huge variety of mobile devices prevents to design a low cost speech recognition software running on all available mobile phones reliably. Indeed it is much easier to design a simple application which is just recording the speech signal. Applying a client–server approach, the recorded speech signal from the mobile device can be send to a recognition server for processing. As already pointed out such a "server" can today also be a cheap device which has a similar size as the mobile phone itself.

Such hardware equipment allows to make very quickly any intelligent house voice enabled. The entire architecture is shown in Figure 2. The user says the voice command in to a mobile phone. The mobile phone records the command and send it to the "server" using the available wireless network. The server will process the speech signal. After the recognition, the result is interpreted to generate the proper command for the house and also sent back to the mobile phone for visual feedback. The final command is sent to the KNX/EIB network via an interface. The entire system is working in real time and the action derived from the speech command takes place immediately.

3.2 Speech Recognition

Speech recognition under the technical conditions described above and controlling the utilities in an intelligent house have two important and positive features which results in high reliability of entire system:

1. The recorded speech signal has a very good quality. The mobile phone is acting as a close-talk microphone. In general, mobile phones have very good audio input hardware in contrast to many other hand-held devices where audio input is designed only as an optional feature.
2. The set of the commands for the house control is relatively small. The number of controlled utilities in average house is usually around 50. For this reason the speech recognition system can be grammar based and still very robust[2].

The grammar based recognition system obviously requires designing a grammar. Since each house is different, each house needs also an individual grammar. Fortunately, the group of the devices (lights, shutters, heating, ...) as well as group of available commands (switch on/off, up/down, dim, ...) is relatively small. Therefore we were able to design a fixed grammar, where during the adaptation for a particular house it is "just" necessary to add the existing devices with their real names (Peter's room, garden light, ...). The additional subsystem responsible for the interpretation of the voice commands is individualized in the same way.

All the changes necessary for one specific house can be done on the "server". The mobile phone is running a universal speech recording software and can be used in any house where such a server-based recognizer is installed.

The exemplified grammar in Figure 3 accepts for example the following commands:

– *"Könntest du bitte die Beleuchtung im Garten einschalten?"* (Would you please turn on the light in the garden?)
– *"Das Licht im Garten an"* (Light in the garden on)

Different mobile phones are recording the audio signal in different qualities. Although for a human ear in all cases the audio quality is very good and the differences are barely noticeable, it matters for the speech recognition process. Because the standard API for each device was used, it is not clear, if this a hardware or software limitation of the particular mobile phone. So far we tested our application on Android, Blackberry and iPhone.

4 Localization in House

As already pointed out in introduction, localization of the user is an important factor in order to create intuitive user interfaces. From the user's point of view

[2] One of the requirements for running on "small/slow" devices in real time. Language models based system require usually huge amount of memory and more powerful CPU as well.

```
[$prefix] $loc_garten $actionSchalten
   {out.device=rules.loc_garten.device; out.action=rules.actionSchalten.action;}
 | ([bitte] [$prefixMach]|[$prefixMach] [bitte]) $loc_garten $actionSimple
   {out.device=rules.loc_garten.device; out.action=rules.actionSimple.action;}
 | [$prefixMach] $loc_garten $actionSimple [bitte]
   {out.device=rules.loc_garten.device; out.action=rules.actionSimple.action;}
 ;
$loc_garten = ($lampe (im | in dem) Garten | [die] Gartenlampe)
   {out.device="L_Garten";}
 ;
$lampe = [das] Licht | [die] Beleuchtung
 ;
$prefix = (Würden Sie|Könnten Sie|Würdest du|Könntest du) [bitte]
 ;
$prefixMach = Mache|Mach | Machen Sie | drehe|dreh | schalte|schalt
 ;
$actionSimple = (an|ein) {out.action="ON";}
 | aus {out.action="OFF";}
 ;
$actionSchalten = (einschalten|anmachen|anschalten) {out.action="ON";}
 | (ausschalten|ausmachen) {out.action="OFF";}
 ;
```

Fig. 3. Example of a simple grammar for switching a garden light.

it is not very comfortable to always use the name of the room for addressing the devices in his current location, e. g. if the user is in the living room, he does not want to say: "*Lights to 50 per cent in the living room!*", but rather "*Lights to 50 per cent!*". To implement such functionality it is necessary to have a localization system available in the house.

The topic of indoor localization is still a research topic as pointed out by [6]. Various methods have been examined as for example GSM, FM or ultrasound [7,8,9]. [10] states that for localization wireless solutions should be preferred, as they are easy to install and also existing buildings can be equipped with this. Following this reasoning, we suggest to use Wireless LAN (WLAN) routers for this purpose. These are readily available and if the household should not be equipped with a WLAN router they are available at very little costs. They also do not suffer from problems stated by [10] concerning energy supply, as the access point sits somewhere in the flat/house and is directly plugged to the electricity network. Additionally, [11] showed that WLAN can also be used in environments with several floors with little additional effort. Therefore, WLAN-based positioning also supports one main goal of AAL research, namely to allow elderly to stay in their homes for as long and as independent as possible. The problem of localization using WLAN has been well researched [12,13,11] in the past years, and [12] gives an overview about the topic.

The very little costs of the WLAN-based approach is even further lowered by the fact that WLAN has become ubiquitous within the last decade. Therefore, many users already have some WLAN hardware at home (e. g. internet routers).

As reported in [12], localization by one single access point does not yield a satisfactory recognition of the room. As mentioned, WLAN devices have become ubiquitous, so in most households you can discover several different WLAN access points from neighbouring flats. For the purpose of localization it might be sufficient if some neighbours have WLAN devices, which, we assume, is the case in most urban areas today. Even if there were not enough neighbouring networks available, WLAN equipment is still cheap and easy to setup for localization. As the application recording the spoken command of the user runs on his mobile device, it is obvious to do the localization with the device itself.

The localization using WLAN relies on several measurements. During these scans the available access points and their signal strength are recorded. These so called *fingerprints* are then fed into different learning algorithms for training (*calibration*). As recording these fingerprints might be a tedious and too complex process for the user, the application needs to record these fingerprints in an intuitive and easy manner.

The signal strength recorded in the fingerprints can be influenced by various factors: People that are “in the way”, or furniture that has been moved around. If neighbouring WLAN networks are sensed during calibration, also factors out of control of the user, like new devices connected by neighbours or access points or furniture being physically moved to different places in the neighbour’s apartment, may decrease recognition performance. These changes in the WLAN infrastructure can clearly not be anticipated in advance by the user. These problems call for a *recalibration* from time to time. So the (re)calibration process must also be integrated in an intuitive way into the application.

4.1 Technical Realization

The speech recognition application is running on the mobile device and sends the recorded audio together with the deduced room to the server. Therefore, the application initiates a network scan to create a fingerprint of the current position. This activity starts as soon as the user starts recording his command. While the audio recording is running, the scan terminates. The algorithm to deduce the room from the generated fingerprint runs and the data is made available as metadata during the request to the recognition server. The server will then use this information to disambiguate the spoken command.

In case the network scan takes longer than an average spoken command, a periodically initiated scan in the background could be realized in order to decrease the delay for the user. The network is scanned every x seconds, and the most recent results will be used. However, this approach is in general not recommended as it drains on the battery power of the device.

The different learning algorithms (e. g. k nearest neighbours, Bayesian inference, artificial neural networks, support vector machines) have different requirements on computing power and might therefore not be realizable on a mobile device. In such case the raw fingerprints could be sent to the server during the calibration as well as during the recognition phases. The server, which is doing the speech recognition anyway, will then recognize the room the user is in. This could also be a solution for the aforementioned delay problems.

5 Experiments

In the following part we are presenting preliminary results from our experiments, which were used to confirm the described approach is feasible.

5.1 Speech Recognition

To test and evaluate the implemented solution we installed the entire system into real houses. After adaptation to the house environment, as described in Section 3, the system was passed to the householder for real usage. The users were not informed about the available commands. They were asked to talk to the system as they wish.

After one month we downloaded all speech commands, which were saved with the householder's consent, and transcribed them. In the Evaluation, we did not focus on the speech recognition accuracy, but on the action accuracy. For example if a user said: "*Die Beleuchtung in der Küche einschalten*" and the system recognized: "*Licht in der Küche einschalten*", then from a recognition point of view it is incorrect, but from an action accuracy point of view it is correct, as the same action would be triggered. We also analysed out of the grammar sentences to improve the grammar to be able to cover bigger variety of utterances. In Table 1 are results for out of the grammar utterances, sentence accuracy and action accuracy for an evaluation period of 1 month with 4 different users depicted.

The result for out of the grammar (OOG) utterances is high, but is caused by the fact, that users did not get any initial instructions. A closer look at the OOG utterances distribution in time, we can clearly observe, that most of them appear shortly after system installation. For more detailed results a longer evaluation period is needed. For sentence and action accuracy, out of the grammar utterances were removed from evaluation pool.

On the first look, 55.56 % sentence accuracy may seem very small, but it resulted in a 91.23 % action accuracy. We analysed the recognition errors and most of the errors in prepositions like "im" or "in" or incorrectly recognized articles. Such errors are not influencing the action accuracy rate and are mostly not noticed by the user. It is also important to note, that almost 30 % of utterances

Table 1. Out of grammar utterances, sentence and action accuracy for evaluation period one month and four different users.

Out of grammar utterances	14.93 %
Sentence accuracy	55.56 %
Action accuracy	91.23 %

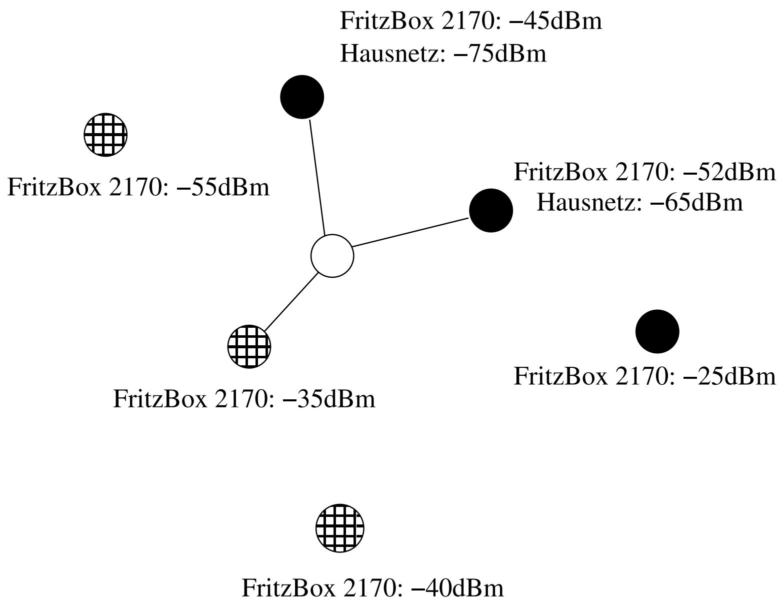

Fig. 4. Example for the *k*NN algorithm.

were spoken by a non native speaker. Recognition errors that resulted in faulty actions usually lead to the user to re-try.

Besides measuring accuracy, we asked the householder about their personal satisfaction with a free-form questionnaire. In all cases the reported satisfaction can be summarized as very high.

5.2 Localization

To evaluate the feasibility of our localization approach we used a simple Android-based application which scans the available networks. If asked, it stores the most recent scan as a fingerprint associated with the room the user selected. It then uses a simple k-nearest neighbours (kNN) approach to match a recorded fingerprint to a room. The idea behind kNN is to find those k fingerprints recorded during the calibration phase that have the closest distance to the current fingerprint. The distance is measured as a euclidean distance on the signal strength vectors (as described in [12]). If found, the room is returned as a result which was assigned to the majority of the k votes. For example, in the situation depicted in Figure 4, the reference point (white) would have been measured with -50 dbm for the access point named "FritzBox 2170" and -35 dbm for the access point named "Hausnetz". From all the recorded fingerprints available the $k = 3$ nearest fingerprints would be searched (the ones connected to the reference point). In the example the black fingerprints would be assigned to one room and the patterned for another. The reference point would be assigned to the black room

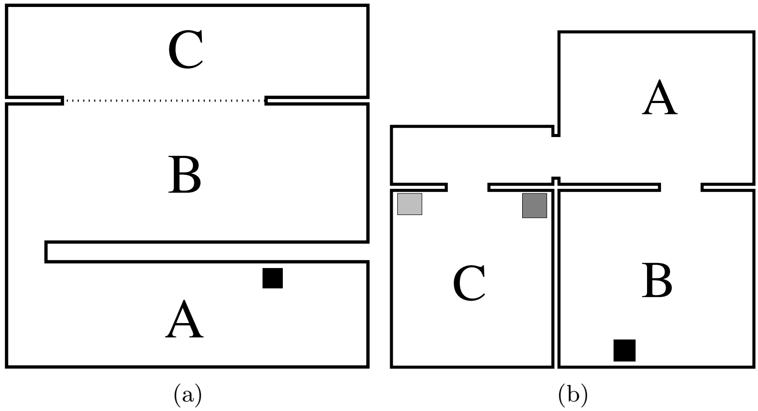

Fig. 5. Schematic floor plans of the experimental houses

as there are more black than patterned neighbors close to it. For more details on kNN see [14,12].

The results of the experiments prove that it is not problem from a performance point of view to run the room recognition on a mobile device. The chosen algorithm is not very complex and easy to apply. The performance is fine on a recently bought phone. Literature has already mentioned that one Wireless network access point is not enough to make proper localizations [12]. We observed the same behaviour under lab conditions: With rooms close by each other the error rate is quite high.

We conducted two experiments in real-world apartments, where several WLAN access points by neighbours were available. The first apartment (Figure 5(a)) consisted of tow rooms, between which there is a quite thick wall. They are connected by a few stairs, but without a door. The second room consisted of two areas which were separated by a wooden double wing door which was open. The household contains one router in room A. From the neighbours there were detected up to 6 different WLAN networks in the rooms depending on where the mobile device was located. In each room the kNN algorithm was calibrated using 4-7 fingerprints per room. As expected, the results were much better than the laboratory test with only one WLAN access point. We anticipated that the confusion between B and C would be higher than between A and B. In the other house, the situation was a little bit different. We had 3 rooms as depicted in Figure 5(b). In this household there are three routers, one in room B, one in a room below room C (lighter grey) and one in a room above room C (darker grey). In addition, there were more than 10 WLAN networks available through neighbours. We expect this to be the usual case in urban areas. There is no door between room A and B, but doors between A and C and the hallway. The algorithm was calibrated by 10-15 fingerprints per room. The observed accuracy was even better than in the first case and made it possible to clearly distinct the individual rooms.

In total the recognition of the rooms was acceptable and, as only a very simplistic implementation was used, there is much room for improvement.

6 Summary

In this paper we have described various aspects of the simple and reliable speech recognition system for the voice control of house utilities. We showed, that such system has not only acceptable action accuracy and can be easily used without any special training, but because of integratation in to the mobile phone it has potential to be used for elderly or disabled people.

By adding WLAN-based localization the ease of use for the speech control could be further improved. As the localization is only activated when the communication with the house control is activated, privacy is at the control of the user. Experiments in a real testing environment demonstrated the feasibility of our approach, but also unveiled the need for future broader scale evaluation of the localization to find out whether the localization algorithm has to be improved. In one test environment it worked very well in the current setup. Therefore, it is necessary to find out whether more sophisticated methods (e. g. using artificial neural networks) for localization, which would also be more compute intensive pay off.

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Ambient Voice Control for a Personal Activity and Household Assistant

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Abstract. Technologies for ambient assisted living (AAL) are used to increase the quality of life of older or impaired persons. This contribution discusses the utilization of automatic speech recognition (ASR) as a natural interface for control of assistive technologies in everyday life situations. We focus on the use of hands-free systems, the technical challenges for the ASR software caused by this and the benefits for older persons. Moreover, state-of-the-art approaches for improving robustness of ASR systems are presented, discussed and demonstrated by an ASR experiment.

Keywords: Automatic Speech Recognition, Acoustic User Interfaces, Hands-Free, Distant Speech Recognition.

1 Introduction

Due to the demographic change that will lead to an increased amount of older persons [1-3], new solutions are necessary to cope with the challenges that will occur e.g., in the field of social care. Assistive technologies show great potential to support older people in their everyday life situations and, by this, allow for a longer independent period of life [4]. In this context, information and communication technologies (ICT) are of high social relevance. However, especially for older people this kind of technology is often not easy to use due to its inherent high complexity. For this reason the design of simple and intuitive user-interfaces is of great importance [4-6].

The use of speech is the most natural form of human communication. Therefore, the control of assistive technologies by speech recognition software is desirable and offers opportunities for an intuitive and user-friendly navigation of assisting devices in a home environment for example. Moreover, in situations in which the hands are not free to be used, speech input offers great advantages over conventional input methods, such as a remote control or mouse and keyboard [6, 7].

However, automatic speech recognition (ASR) in combination with hands-free equipment in adverse acoustic environments is still a challenging problem [8, 9]. The reliability (i.e. 'robustness') of current speech recognition systems still is far from reaching the performance of humans [10]. For this reason, in this contribution we will describe results of a user study that was conducted and in which the tolerance threshold for erroneous recognitions was determined. Moreover, the user acceptance for such defective systems will be reviewed (cf. Section 2).

To improve recognition rates in acoustically adverse conditions several approaches exist. On the one hand concepts for improving the signal-to-noise ratio (SNR) of noisy and reverberant speech signals are applied (cf. Section 3.1 and references therein). These signal processing concepts can be used for pre-processing the speech input of ASR systems, to increase their robustness especially if hands-free equipment is used. However, it should be mentioned that these concepts may also cause distortions of the acoustic features an ASR system relies on, which can pose problems for the speech recognition algorithms even if the signal quality perceived by a human listener is improved [9]. Thus, benefits of possible pre-processing concepts must always be regarded in connection with the used speech recognition concepts.

On the other hand, in addition to an appropriate pre-processing also other concepts exist to improve robustness of the ASR system itself. Current methods are presented and discussed in Section 3.2. One common method is to use a structured dialogue for the ASR system instead of recognition of continuous speech, for example. The advantage is twofold. Firstly, the complexity of the speech recognition software can be kept small and secondly, the control of those systems by spoken commands is favoured by many users as it is shown e.g., in [11]. The main reasons that were given by users in [11] for preferring a structured dialogue are that this type of control is unambiguous and already known from other applications.

Section 4 of this contribution presents results of an ASR experiment, which was conducted in an AAL living lab that is built similarly to a conventional living room. In this living lab a distant ceiling microphone and a close-talk microphone were used for the experiments described in Section 4. The performance was compared in terms of word error rates and the used microphone for training and testing.

2 User Acceptance Study

In [11] a user study has been conducted to evaluate the user tolerance threshold and the acceptability of erroneous command recognitions. For that purpose a total of 12 subjects aged from 63 to 75 years were consulted. The experiment was made using a mock-up system, which simulated a calendar application as part of a personal activity and household assistant [12]. This means that the in- and output of the system was controlled by a human investigator, who responded to the commands of the subject. The investigator, thus, took over the duties of the ASR software, whereby previously planned failures of the system could be investigated. The output of the system was presented acoustically to the user by previously recorded speech sentences. By this approach three test phases were pre-defined to prove the users tolerance level. In each phase, the subject could enter a new appointment to the calendar application by spoken commands and after each phase the subject was asked about his or her impressions of the command controlled calendar application.

During the first test phase, the ASR system worked perfectly and didn't make any mistakes. By this, the subject could get used to the system and got an idea of how the system works in general. In the second test phase, one recognition error was introduced, which means that the subject had to correct the incorrectly recognized part of his or her speech input by repetition of the corresponding commands. In the third and final test phase continuous recognition errors were introduced by the investigator. By this, an infinite loop of corrections had to be done by the user to measure his or her frustration tolerance. A yellow and a red card were handed out to the subjects. By using the yellow card a warning could be given to the system, which was considered as a first indication of frustration and the red card stopped the test. By this procedure the subjects' limit of tolerance for mistakes of the ASR software was determined.

After each phase the attributes "user-friendliness"," intuitiveness of use", "comprehensibility", "helpfulness" and "acceptance" of the presented device were evaluated. These properties were assessed on a scale between 1 ("not applicable at all") and 5 ("applies wholeheartedly"). The result after the first phase was that the user-friendliness and acceptance were rated very well (between 4 and 5 by all 12 test persons). The result regarding helpfulness of the system was also rated well (between 3 and 5). The assessments of the comprehensibility and intuitiveness were somewhat inhomogeneous. The interested reader is referred to [11] for a more detailed discussion of these results.

The assessment of the system after the second test phase (with one incorporated error) did not change significantly.

The evaluation of the frustration threshold within the third test phase leads to an interesting result. The amount of repetitions due to faulty command recognitions ranged between 0 and 17 until the subject showed the red card to abort the test. The median of repetitions was six. As stated in [11], the high tolerance threshold for this experiment was not expected by the investigators. Nine of twelve subjects stated that they would use such a system in the future, although the willingness to use such a system in current state was rather low. Reasons to be mentioned for these findings are that the mock-up system was still quite limited in features and in possible output modalities, i.e. only acoustic output was available for instance. Reference [7] and [12] provide a more detailed overview of the multi-modal outputs of the personal activity and household assistant.

Also many users assigned that they would like to activate the system by a keyword or by clapping. Reference [13] describes event detection methods in the context of AAL, which can be used for this purpose.

3 Challenges and Demands for Voice Controlled Ambient Assistive Technologies

Robust automatic speech recognition with non-close-talk recordings, i.e. with recordings captured by distant microphones ('hands-free'), is still a major challenge for research in ASR. This is due to the spatial distance between the used microphones and the source of the desired speech signal, which is generally the users mouth. Therefore, microphones do not only pick up the clean speech signal, but also ambient noise sources and delayed copies of the original signal (reverberation), which strongly depends on the environment in which the system is used.

Fig. 1 illustrates a user scenario of a system which can be installed as an ambient assistive device at home. The provided example shows a situation in which the microphones of the device capture several signals from different sources. On one hand this is the desired signal of the user who provides speech commands to the system, and on the other hand these are undesired noise signals which interfere with the speech signal. The constituted noise sources in Fig. 1 are a vacuum-cleaner and also the loudspeakers of the device itself, that play back the acoustic output of the system. Those parts of the signal that are uttered by the loudspeakers and picked-up by the microphones again are commonly known as acoustic echoes [14]. Thus, the user's command input is heavily disrupted by (i) ambient noise, (ii) acoustic echoes and (iii) room reverberations, namely echoes introduced to the desired speech signal due to reflections at room boundaries as obvious e.g., from speech in churches.

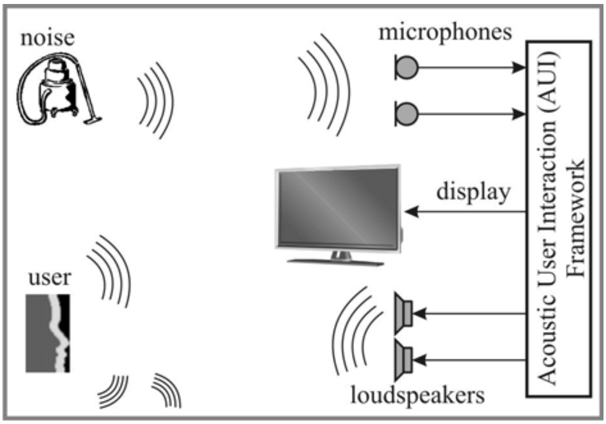

Fig. 1. Schematic of the technical structure of the personal activity and household assistant. The acoustic user interaction framework contains the ASR system and the intelligence to control the in- and outputs depending on the specific application.

Different signal processing strategies to enhance the desired signal and to suppress others are described in Section 3.1. Section 3.2 presents a common strategy for improving the recognition performance of an ambient ASR system used in adverse acoustical conditions. Furthermore, an insight to a current field of research for enhancing robustness in ASR is provided.

3.1 Pre-processing Concepts for Speech Quality Enhancement

As depicted in Fig. 1 multiple microphones as well as multiple loudspeakers can be used for sound pick-up and play back in hands-free systems. The microphone signals are processed by the signal processing unit (acoustic user interaction (AUI) framework in Fig 1), which enhances the captured signal and analyses the content of the signal by means of ASR. Feedback is given by the system acoustically via its loudspeakers.

Fig. 2 shows the signal processing unit AUI for the single-channel case in more detail. Here, the desired signal part, e.g., a spoken command, is denoted as $s_n[k]$.

Ambient noise $n[k]$ and acoustic echoes $\psi[k]$ are disturbances for the ASR system that are superimposed to the desired signal part in the microphone signal. The acoustic output of the system $s_f[k]$ is played back by the loudspeaker. Due to the acoustic coupling between loudspeaker and microphone, parts of the signal are picked up by the microphone again. Numerous reflections of the signal at the room boundaries (walls, floor and ceiling) lead to a reverberated version of the system output at the position of the microphone. Mathematically these reflections are characterized by the so-called room impulse response $h[k]$ as depicted in Fig. 2. Since the system output may contain speech information, this could heavily disturb the ASR system if no suppression filter is used. So-called acoustic echo cancellation filters $c_{\mathrm{AEC}}[k]$ estimate the signal part stemming from the loudspeaker signal contained in the microphone signal, whereby its cancellation is principally possible [15, 16]. Highly reverberant environments and multiple loudspeakers pose particular challenges to such acoustic echo cancellers. The interested reader is referred e.g., to [14-18] for a more detailed discussion of the technical challenges.

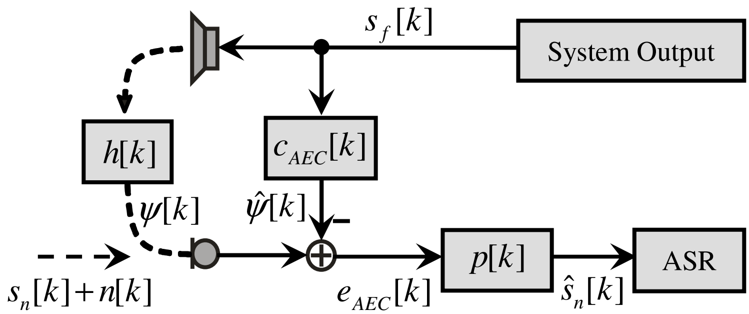

Fig. 2. Suppression of ambient noise and acoustic echoes.

Residual echoes that may remain after the compensation point of the acoustic echo canceller $c_{\mathrm{AEC}}[k]$ as well as additional disturbances $n[k]$ that are picked-up by the microphone are suppressed by the succeeding suppression filter $p[k]$ before the enhanced signal is analysed by the ASR software [9, 19]. Such suppression filters generally do not only suppress disturbances but may also introduce distortions to the desired part of the signal. Although these distortions may be small in amplitude they might heavily distort the acoustic features an ASR system relies on. Therefore, distortions of the desired part of the signal have to be kept as small as possible [9].

Spatial distortions from different directions can be reduced by the use of multiple microphones as in Fig. 1. Like humans are able to focus on a spatial direction by exploiting information from their two ears and suppress acoustic sources stemming from other directions, this is also possible with signal processing strategies based on multiple microphones [9, 19, 20].

Another signal processing concept in ASR is to spread several microphones in the room and then selecting that one, which provides the best voice quality for the recognition process [21]. This normally is the microphone which is closest to the speaker's mouth, since it generally provides the best SNR. However, the usage of more sophisticated approaches is worthwhile.

3.2 Concepts in Automatic Speech Recognition to Improve Recognition Performance for Acoustically Adverse Conditions

Besides an appropriate signal pre-processing additional concepts for improving ASR performance for acoustically adverse conditions exist. Two major concepts regarding the ASR algorithms itself are presented in the following.

The first concept is to use training data that was recorded in the same conditions as those in which the speech recognition device will be used later. By this, the acoustic models, such as the hidden Markov models (HMM) for instance, learn the noise characteristics, which may disturb the speech signal [8, 23-25]. Also convolutional noise like channel characteristics and reverberation can be learned to a certain extent by the acoustic models. However, if the acoustic environment changes (e.g., the amount of ambient noise, spectral noise characteristics or the reverberation time), benefits of this condition-adopted training can get reduced or even lost [8, 23]. Therefore, to obtain a reliable improvement, this method is only applicable if the acoustic conditions, in which the ASR system will operate, are precisely known. If the system is used in changing environmental conditions, but which are known in advance, then the ASR device may switch between different acoustic models that were trained under these different conditions. For this case a reliable detection of the current acoustic condition is needed, which can be a challenging problem as well [24].

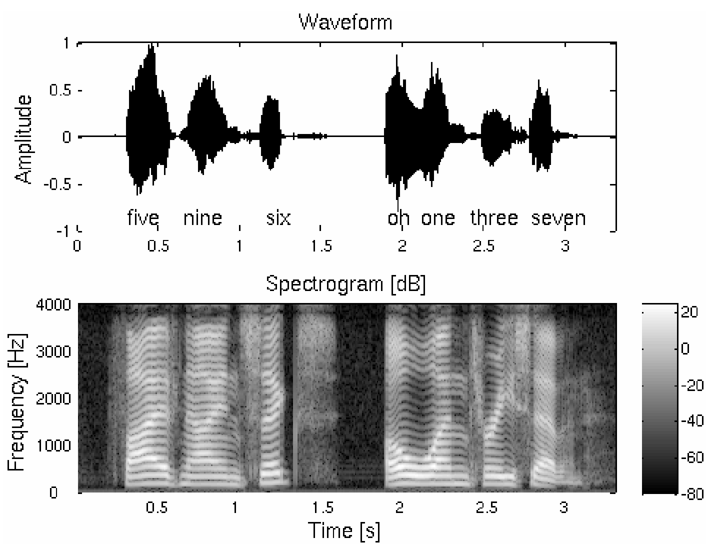

Fig. 3. Time-domain representation of a speech sequence (upper panel) and its spectro-temporal representation, i.e. spectrogram (lower panel).

Another concept to increase recognition rates in acoustically adverse conditions is a proper selection of the acoustic features that are used to represent the characteristics of speech. These have to match two important requirements. Firstly, the properties that allow for distinguishing between the decisive characteristics of the different units of speech must be mapped as well as possible. Secondly, disturbances of the acoustic signal, such as noise and reverberation, should influence the properties of interest in feature domain as little as possible.

Most feature extraction methods in ASR are based on the spectral representation of the signal's waveform. To obtain this, the acoustic signal is first divided into short overlapping segments of typically 20-30 ms duration that are then transformed to the frequency domain by a Fourier transformation. This procedure is called short-time Fourier transformation (STFT). The result is a time versus frequency representation, which is commonly known as spectrogram (as depicted in the lower panel of Fig. 3).

Furthermore, a filter bank motivated by the human auditory system, such as the Mel or Bark filter bank, is usually applied to the spectrogram [8, 22, 23]. Such filter banks group certain frequency sections to frequency bands, which shall approximate the frequency resolution found in the inner human ear. For today's feature extraction methods further computational steps are necessary, however detailed descriptions are beyond the scope of this paper. Here, the interested reader is referred to [8, 22, 23].

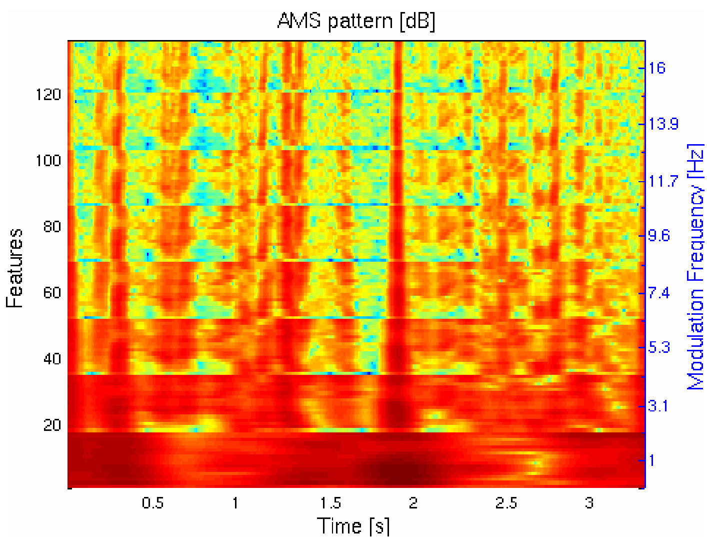

Fig. 4. AMS pattern of the signal depicted in Fig. 3. In order to make all three dimensions visible, patterns of time versus acoustic frequencies are stacked for each modulations frequency.

Instead, a feature extraction method is exemplarily presented in the following, to demonstrate which kind of approach is investigated in current research for improving robustness of ASR systems. Current research tends towards analysing longer time trajectories of spectral envelopes, which were taken from the spectrogram representation. As an example the so-called amplitude modulation spectrogram

(AMS) is introduced [26]. This feature type analyses about 300 to 350 ms long time trajectories taken from a spectrogram, which was previously half-wave rectified, squared and frequency decomposed into Bark bands [27]. By this, the amplitude modulations are analysed from the acoustic signal. Subsequently the modulation frequency domain gets filtered by a band pass filter to ignore modulation frequencies lower than 1 Hz and greater than 16 Hz. Thus, only the relevant modulation frequencies for speech are passed, whereby non-speech influences can already be reduced [28-30].

Fig. 4 shows an example of an AMS pattern for the signal depicted in Fig. 3. Since AMS is a three-dimensional representation of a signal, namely time versus acoustic frequency and modulation frequency, it is non-trivial to generate an easily interpretable graphical representation. For this reason modulation frequencies and acoustic frequencies are stacked in Fig. 4. This can be seen by the axis labels on the right, which indicates that patterns of time versus acoustic frequencies are stacked for each modulation frequency. For the example presented in Fig. 4 this results in a 136 dimensional feature vector (17 Bark band frequencies times 8 modulation frequencies) for each time frame.

It should be mentioned that dimension reduction methods (such as the principal component analysis (PCA)) are usually applied before this representation is used as an acoustic feature [8, 25]. This is done since classification algorithms, such as HMMs, are more effective if the dimensionality of feature vectors is low and if the feature components are decorrelated [8, 25].

4 An Automatic Speech Recognition Experiment in an AAL Scenario

In this section an ASR experiment is presented to demonstrate the influence of channel distortions and room reverberation on the performance of a speech recognizer. To do so, recordings of eight male speakers were collected in an AAL living lab. A room decorated like a living room was equipped with almost invisible ceiling microphones. These ceiling microphones represent the hands-free equipment for the conducted ASR experiment. In addition, a close-talk microphone was situated in front of the speaker's mouth. For the recordings the speaker was sitting on an armchair in the middle of the room turning the head towards the television screen (cf. Fig. 5).

The synchronous recordings of spoken commands with the close-talk microphone and with one ceiling microphone that was situated in the middle of the room (c.f. Fig. 5) were then used to train and test a speech recognition system. 25 different command words have been selected and recorded for the purpose to manage a calendar application of the personal activity and household assistant. Each of these commands was recorded ten times from each speaker in a silent environment. The testing was done with the so-called cross validation procedure [25]. For this, the recordings of seven speakers were used for training and the recordings of the remaining speaker were used for testing. By this, all eight possible combinations were tested and an average word error rate was determined.

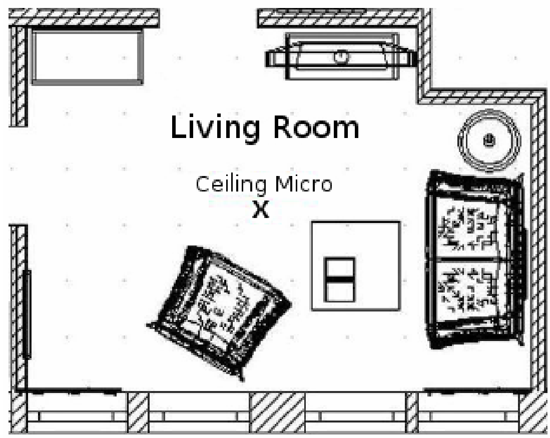

Fig. 5. Layout of the acoustic environment in the living lab. The position of the ceiling microphone, which is used for the experiment, is indicated by an 'X'. The armchair in the bottom centre of the room indicates the position of the speaker.

The most commonly used acoustic features, namely the Mel-Frequency Cepstral Coefficients (MFCCs - here including the 0^{th} cepstral coefficient plus dynamic features such as deltas and double deltas) [8, 22, 23], are also used for this experiment. The classifier relies on the statistical description by linear whole-word hidden Markov models (HMM) with 14 states each (including the two non-emitting states).

Three test scenarios were defined:

a) The recordings of the close-talk microphone are taken for training and the ceiling microphone for testing.
b) The ceiling microphone is used for training as well as for testing.
c) The close talk microphone is used for training as well as for testing.

Table 1. ASR results for the different test scenarios. SD: Standard Deviation.

Test scenario	**a)**	**b)**	**c)**
WER (SD) in %	56,9 (26,5)	2,2 (2,3)	1,1 (2,1)

Table 1 shows the results in terms of word error rates (WER). The WER is calculated by the ratio of mistakes made by the ASR system and the total amount of spoken words. Mistakes that may occur are deletions (*DEL*), substitutions (*SUB*) and insertions (*INS*) of words. Expressed in a formula that is

$$WER = \frac{\#DEL + \#SUB + \#INS}{N} \tag{1}$$

where N is the total amount of spoken words to be recognized.

The results show that the performance strongly depends on the training data. For the case that the recordings for training and testing are produced in the same way (see results of scenario b) and c)), the system achieves very low WERs. As soon as the recordings of the close-talk microphone are taken for training, which can be considered to be free of reverberation, and reverberated speech taken by the ceiling microphone is used for testing, then strongly increased WERs can be observed (see results of a)). In addition to room reverberation also channel distortions and internal noise due to different types of microphones used in the ceiling and for close-talk plays a role for the increased WERs observed in test scenario a).

The results demonstrate that it is necessary to account for the specific environmental conditions and known distortions when preparing training data for speech recognition software. This is especially a very effective concept, if hands-free equipment is used, which is permanently installed in the room since changes of the spatial conditions do not have to be expected. However, it should be mentioned that in addition other difficulties, which are not considered by this experiment, are present when using hands-free equipment. These problems result from the fact that non-close-talk microphones do not only pick up sound from the desired speaker, but also from noise sources in the vicinity and other talking people, for instance.

5 Summary and Conclusion

In this paper an overview of current challenges and demands for acoustic user interfaces for AAL technologies with a focus on automatic speech recognition (ASR) is provided. In addition, the discussed results are supported by an ASR experiment in an AAL living lab environment.

In Section 2 a user study was presented evaluating the acceptance of a voice controlled calendar application. Furthermore, the user's tolerance limit for erroneous recognitions caused by a mock-up simulation of an ASR system was evaluated for the targeted user group of age 63-75 years in this study. The result was that speech input is accepted by the older users even when the system produces recognition errors.

Section 3 presented an exemplary approach of a personal activity and household assistant. Based on this exemplary application, possible challenges for the use of ASR systems have been discussed which typically will occur when ASR is used for hands-free acoustic user interaction with assistive technologies at home. In this context, different concepts for improving robustness of ambient voice controlled devices have been presented. Also a brief insight in acoustic feature selection has been introduced as an example for a current field of research in ASR.

Finally, in Section 4 results of an ASR experiment with a hands-free system were shown. This was done to demonstrate the importance of considering the specific environment in which the ASR system will be used. It could be shown that recognition rates will considerably fall if known distortions are not taken into account. The considered distortions in this experiment are room reverberations and the microphone characteristic that has an effect in the use of different microphone types.

As an overall conclusion it can be summarized that the development of ASR as a technology for user interaction with assistive technologies has reached sub-goals, so far. The performance of state-of-the-art systems sill does not reach the recognition performance of humans. This holds particularly when ASR is used with hands-free equipment (e.g., ambient microphones) in arbitrary acoustical environments.

Since the use of ASR in combination with hands-free equipment is a very natural way to interact with assistive technologies and because hands-free ASR has a large potential to make assistive technologies unobstrusive and much easier to use at the same time, the concepts for enhancing the robustness in ambient ASR (as presented in this contribution) are promising from a technology as well as from an AAL application oriented perspective.

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Natural Gesture Interaction with Accelerometer-Based Devices in Ambient Assisted Environments

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Abstract. Using modern interaction methods and devices enables a more natural and intuitive interaction. Currently, only mobile phones and game consoles which are supporting such gesture-based interactions have good payment-rates. This comes along, that such devices will be bought not only by the traditional technical experienced consumers. The interaction with such devices becomes so easy, that also older people playing or working with them. Especially older people have more handicaps, so for them it is difficult to read small text, like they are used as description to buttons on remote controls for televisions. They also become fast overstrained, so that bigger technical systems are no help for them. If it is possible to interact with gestures, all these problems can be avoided. But to allow an intuitive and easy gesture interaction, gestures have to be supported, which are easy to understand. Because of that fact, in this paper we tried to identify intuitive gestures for common interaction scenarios on computer-based systems for uses in ambient assisted environment. In this evaluation, the users should commit their opinion of intuitive gestures for different presented scenarios/tasks. Basing on these results, intuitively useable systems can be developed, so that users are able to communicate with technical systems on more intuitive level using accelerometer-based devices.

Keywords: gesture-based interaction, computer-human-interaction, human-centered interfaces.

1 Introduction

Modern interaction systems, particularly in ambient assisted environments, are using modern interaction styles, orienting on the human factors. This allows systems to provide easy to use interfaces, which the user can use without reading manuals or documentations. A good example for this aspect is the iPhone or the iPad from Apple. These devices provide a well-designed and easy-to-use graphical user interface and an intuitive useable interaction with finger gestures. But also entertainment-based platforms and consoles are focusing increasingly on these modern styles of interaction. On the one hand it is more intuitive for the users and on the other hand it is closer and therefore more natural to the performances in the real world. The first entertainment console was the Nintendo Wii, which had an amazing success because of its innovative intuitive accelerometer-based device, with which games could played by dynamic gestures. Next to this controller also a balance board exists, using which the user can surf or ride a virtual snowboard, so that the gaming is similar to the real world activity.

In general the interaction using modern interaction methods becomes easier. In difference to the established devices like mouse or keyboard, with the new controllers every user comes clear from the first time of use. Especially computer novices have now an easier access to these systems. Next to technical aspect in using such devices, there is also a healthy once. Older people are not able to move a computer mouse as softly as needed to select icons for starting a single program. For them it is also hard to use a normal remote control e.g. for the television, because of the small buttons, which have to be pressed for changing the program channel. For those older people it will be helpful, if they can use a more natural and easier interaction style. This can be achieved with a gesture-based interaction. With gestures, seniors can interact through menus and systems in general without facing problems of small buttons or to small written channel numbers on a remote control for the television. They also do not get overcharged, because of having too much buttons for controlling a system. So the support of gestures can be a helpful development, for easy interaction with systems.

In this paper we will present the results of an evaluation, to determine gestures, which are intuitive for common interaction scenarios and tasks on computer-based systems. We will concentrate on gestures, which should be performed with an accelerometer-based interaction device, like the WiiMote. Next to computer systems, the results are also interesting for similar other systems, like televisions, because the most of the scenarios, like scrolling or zooming are also useful for those systems.

2 Overview and Related Works

In the communication between people, gestures are playing an important role. Because with gestures, the spoken word can better be pictured so that a committed aspect can better be described additionally. But the importance of gestures is also indicate able by observing the environment, where a speech communication is impossible or is restricted because of surrounding annoying sources e.g. noise on a construction area. On the role field of an airport or on a construction area it is hard to give all needed commands for a communication by voice so that for the most commands different gestures are existing and will be used. The gesture commands are understood by both communication partners and are less error susceptible than a communication only with speech.

Similar to such working areas, also the communication between computers and users can be made easier by using more intuitive interaction methods like a gesture-based interaction. Especially in ambient assisted environments a more natural form of interaction is used, so that also older people are able to communicate with the technologies and systems.

2.1 Gestures Depends on Cultural Back-Ground

Gestures are a common additive in the non-verbal communications. Next to the verbal communications, gestures will help to commit an opinion better convey to the audience, because with gestures different aspects can better be sketched additionally. A human being learns gestures during his entire life, beginning at the time when he is baby. During these learning phases a person learns a dataset of different gestures. Some gestures are used without noticing it for instance in discussions and some of them are used directly like pointing gestures to an item.

Another person is only able to understand all the gestures, if both communication partners have the same common ground [1] for the used gestures. But this common ground depends also on the cultural background [2]. Perhaps in different countries different gestures for the same meaning can be exists and also same gestures with different meaning are possible. This is a relevant fact, by designing and creating a system for different countries, which should be controlled with gestures.

2.2 Throw and Tilt Interaction

Dachselt et. al. [3] developed a system, which allows an intuitive interaction with media data. This system allows using tilt gestures for an interaction with mobile applications or distant user interfaces. The mobile phone, which contains accelerometers, acts as remote control. Furthermore, throwing gestures can be used to transfer media documents and even running interfaces to a large display like a beamer.

However, this system uses simple gestures for basic functionalities, like transmitting data to another technical device. And also the list of functions is limited to general understandable gestures, but these functions does not lean on the use of established platforms with common functions, like selecting, moving or zooming in a windowed application.

2.3 Hand-Drawn Gestures

Next to interactions by selection menu options and similar things, it is necessary to provide functionalities, using which a user can easily enter texts or edit paragraphs etc. But for a user it can be more efficiently, if such tasks can be accomplished with gestures and not by entering a command or finding an option in a menu. To enter texts with gestures, basing on traditional way of writing a letter with a pen, a lot of positive implementations and evaluations were done. But it is also possible to provide an intuitive to use of editing options with gestures for working on the text [4].

By using gestures in writing texts and also editing texts or paragraphs a user can fast create documents, without knowing much about computers or a specific writing program.

The results of such techniques are necessary, because for shorter texts it can be easier to write a text with gestures, then with a keyboard – especially for non-computer experts. The aspect of writing and editing texts is a specific field and provides no generalizable interaction for common interaction tasks with a technical system like scrolling through a document.

2.4 Postures and Gestures in Human-Computer-Interaction

Most gesture interaction technologies are basing on the idea of identifying a performed posture or gesture, which is more complex than only a simple movement. Especially in the non-verbal communication between people, gestures can be used to convey information without using words in an intuitive way [5]. Most of these interactions will be done with hands and arms, but it is also possible to interact with gestures, performed with the head or the whole body.

Because of the use of gestures in the all-day life, gestures are easy to use for users and so they are also intuitive for them. It is also intuitive, if users have to perform the gesture with a device in his hand that identifies performed gestures or postures, like the WiiMote. The challenge in using such more complex gesture lays in the high effort in developing recognition systems, which are able to detect gestures with a good recognition rate.

3 Experiment for Determining Intuitive Gestures Using Accelerometer-Based Interaction Devices

The experiment we made for this paper has as main goal to identify typical and intuitive gestures for typical interaction scenarios for instance scrolling through a presented document or text in general. Next to the gestures, we also expect to determine prevalent gestures, which are similar or equally performed. This is a relevant point, because technical systems must support those gestures, which are commonly used by users, but it is often impossible to invest the effort for regarding all possible gestures that people suggest as intuitive once.

In the following chapter we describe the evaluation environment and for which scenarios we ask the participants for intuitive gestures.

3.1 Overview

To determine intuitive gestures for common scenarios, we present such a scenario in an example screenshot to the participants. Then a participant gets time for trying different gestures. At the end of this phase, he has to commit that gesture, where he thinks it is for him the most intuitive once. As answer only gestures are allowed. The evaluation encompasses only solvable and commonly occurring scenarios.

All activities of the participant will be recorded in two different ways. At first, we store all activities with two cameras, from two different positions as an informal observation. On the other hand, we store significant peaks of the data-stream from the accelerometers of the WiiMote as formal observations. During the interpretation, with these two kinds of stored results it is possible to compare between the performances of the users with each other, whether they are the same meaning, are just looking equal (but are different in detail, e.g. one participant performed gesture with a light rotated controller) or are in fact different.

3.2 Evaluation Environment

The experiment is performed in a room, which provides enough space to perform also bigger gestures. The participant stands in front of a monitor, where an example context/scenario in a screenshot will be shown. An interviewer stands next to the monitor and describes the situation and the tasks that have to be performed.

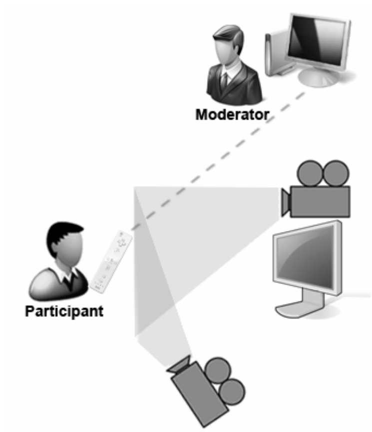

Fig. 1. The evaluation environment, in which the participant is getting observed. Furthermore all performed gestures with the WiiMote are stored on the computer.

During the evaluation, a camera next to the monitor (in front of the user) and a camera right to the user is recording all activities. The WiiMote, with which the participant is performing the gestures sends the data-stream over a Bluetooth-connection to the computer, on which the software (Figure 2) [6] records the peaks of the data-stream and store them on the computer.

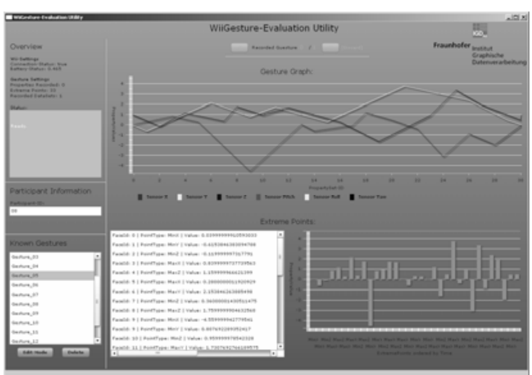

Fig. 2. Screenshot of the Evaluation-Tool, which stores the data from the accelerometers of the WiiMote to performed gestures by a participant.

3.3 Participants

The experiment was performed with 26 participants with European cultural background. The participants were middle-aged people. Because of the fact that we were going to determine intuitive gestures for common interaction scenarios on a technical system, it was not required to evaluate older people e.g. seniors. The described tasks were also abstract and so also older people would be able understand them. Eight of participants had major experience in playing and using the Nintendo Wii and its controller. 10 of the test persons had less experience and 8 did not have any experience with the Nintendo Wii. By making the evaluation with participants who have no or only fewer experiences with the WiiMote, we regard that the participants are open-minded and are not influenced by the default used gestures in Wii-games etc.

All the test persons were regularly working with a PC, thus they knew the presented situations, for which they should find intuitive gestures.

3.4 Evaluation Tasks

During the evaluation, several interaction situations were presented, where the participants have to perform a gesture by interacting with the WiiMote-controller. The gestures which can be performed were not restricted so that the test persons could use the same gesture in more than one task and with an unlimited complexity.

Graph-Navigation

In a presented relation graph (e.g. for presenting semantically information), the participants had to move between different nodes along presented edges. The nodes were placed in a square-layout. The tasks were:

1. Select the node right to the actual selected bottom-left node.
2. Select the node above to the actual selected bottom-right node.
3. Select the node left to the actual selected top-right node.
4. Select the node below to the actual selected top-left node.

Simple Dialog

In the next situation the participant had to choose an option in a simple dialog. In the dialog the participant had only two options, like it is normally used in small requests e.g., “Do you really want to delete the selected items?”:

5. accept the dialog
6. decline the dialog

Zooming Function

In the next two situations, a very small and an oversized visualization were present. The participants had to perform the following tasks:

7. enlarge the visualization (Zoom-in)
8. minimize the visualization (Zoom-out)

History/Undo Function

Some applications provide the possibility to undo actions or e.g., in web-browsers the user can go back to a previous visited website. So the participants get the tasks:

9. go backwards / undo
10. go forwards / redo

Scrolling in Windows

To present more information on small physical screens like on mobile devices, most application use scrollbars. This is a widely used feature with a well understood metaphor. So the participants had to perform the following tasks:

11. scrolling to the right
12. scrolling to the left
13. scrolling to the bottom
14. scrolling to the top

3.5 Accomplishment

Before performing gestures, the participants had to fill out a form for socio- and demographical information and questions about their experiences, especially with the Wii and the WiiMote, because this could influence the performances of the gestures and therefore it is important for the later analysis.

After that, the participants got some screenshots to the tasks, to allegorize the situation and what is mentioned by the tasks. The participant then had to perform the gesture most appropriate to solve the task. All of the tasks and performed gestures captured by the two cameras and also the data-stream of the accelerometers of the WiiMote were stored on a PC. The above-mentioned tasks are in a special order, so that similar tasks like navigation within visualization and scrolling in applications will noticed as completely different tasks by the participants. This avoids unintended dependencies in the gesture performances.

At the end of the practical part of this evaluation, the participants appraised the practical part and estimated the appropriateness of a gesture-based interaction for the different situations.

Fig. 3. Screenshot of the Analysis-Tool for the data-stream of the WiiMote.

At last, all of the recorded information was analyzed. For a better understanding of some gestures, the data-stream from the WiiMote helps to image, how a gesture was exactly performed by the participant (Screenshot of the Analysis-Tool is presented in (Figure 3). The data-stream also helps to see, if gestures were performed equally or if they are only similar.

4 Results

After the evaluation was finished, we analyzed the results, if performed gestures to the same task were equal or similar. If so, they will be summed. In the following we want to show the results of the performed gestures. To present the performed gestures, we sketch the gestures in 2D-graphs. So it is possible, to understand the made performances. As orientation how a gesture was performed in the room in real and later sketched in 2D-graphs, the mapping is shown in Figure 4.

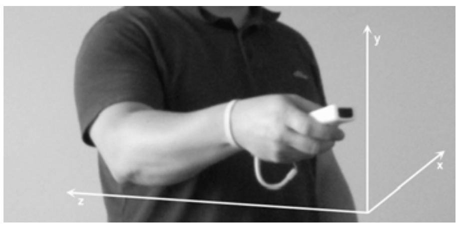

Fig. 4. Interpretation of performed gestures, which are sketched in the follow graphs.

Next to sketch of the performed gestures, the distribution is calculated absolutely and relatively. Especially for the complex tasks, more different gestures could be identified. Also during the evaluation the participants needs more time in cogitation for an intuitive gesture.

The detailed results are presented on the last pages of this paper, because of the needed space.

5 Discussion

The results of this evaluation show, that the numbers of different gestures increases if the tasks become more complex and allow a wider space for more creativity. So for example, if the user wants to scroll, the gestures are limited to gestures orientating to the side, in which they should be scrolled. In comparison by the gesture for accepting a dialog, there is wide range of possible gestures, like the side-position of the button or an abstract metaphor like check. It will be interesting to analyze, if it is possible, to determine on which degree of complexity the users will commit different gestures for the same command.

In focus of creating systems for a user-centered interaction, it is necessary to support those gestures, which users suspect they are intuitive for them. But especially for the more complex gestures many gestures have to be regarded for only one command. The higher the possibilities of gestures that have to be recognized, the effort increases too. So it is important to find a weighted solution between supported gestures and an acceptable essential effort. For that, further researches are required to identify the satisfactory level. Next to this question, it is also useful to solve, if it is useful to support more complex gestures – because by giving the user the freedom for performing personal intuitive gesture it can also happened that users spending more time in thinking for gestures, than using them for an easier interaction. This circumstance can also end in overstraining the users.

Another aspect is to support only one gesture for each command, like it is applied by mobile devices or multi-touch interaction under Microsoft Windows 7. So an evaluation will be useful, if such a limited predefining comes along with a user-centered interaction or maybe it will be a break. And furthermore, if it is really useful for providing a free and individualize interaction by let defining gestures depending on the users' perception.

6 Conclusion

In this paper we presented the results of an evaluation, to determine intuitive gestures for different common interaction scenarios on computer-based systems. The users were asked to define intuitive gestures for different interaction situations. After that, all the performed gestures for a single situation were analyzed, if they were similar. The results are presented in an overview, categorized by the different tasks. With these results a system can be created, which will support intuitive gestures for typical scenarios. It is also possible to identify that more effort is need in supporting and implementing gestures, where the scenario has a potentially wide range of possible gestures. Especially if the gestures becomes more general and allow more freedom in the performance, the number of different gestures increases.

We also noticed that in this area many further questions comes up, especially in defining general rules for good implementations of gesture-recognition systems. But to spend this effort in answering these questions is useful because most of the participants have answered that they imagine that a gesture-based interaction will make the interaction with technical systems easier. In perspective to the older people this is an approach that provides simple interaction interfaces to seniors and provide them so the possibility of using modern technical systems intuitively thus making their all-day life easier.

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A Result Details

Like it was described in chapter 4, the details for the results are presented here in this section. The results are categorized into the different kinds of tasks, which were described in chapter 3.4. For all performed gestures to a single task, we analyzed the absolute and relative distribution.

A.1 Graph-Navigation

Move from bottom-left node to the bottom-right one:

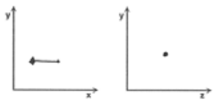
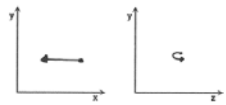
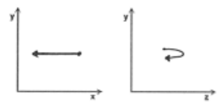
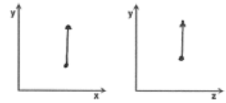
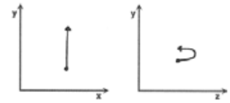
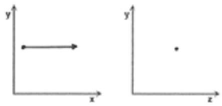
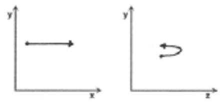
Gesture #1a	Gesture #1b	Gesture #1c
		
18x	6x	2x
69%	23%	8%

Fig. 5. Two gestures performed differently for the same sub-task: movement to the right-side.

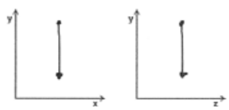
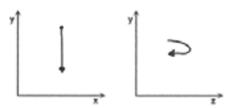
Move from bottom-right node to the top-right one:

Gesture #2a	**Gesture #2b**
	
23x	3x
88%	12%

Move from top-right node to the top-left one:

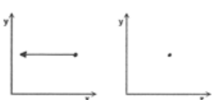
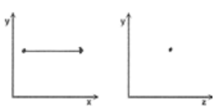
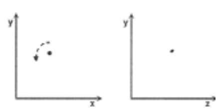
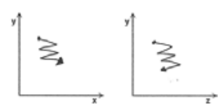
Gesture #3a	**Gesture #3b**
	
22x	4x
85%	15%

Move from top-left node to the bottom-left one:

Gesture #4a	**Gesture #4b**
	
23x	3x
88%	12%

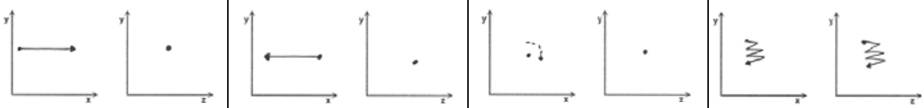
A.2 Scrolling in Windows

Scrolling to the right side (Scrollbar move rightwards):

Gesture #5a	**Gesture #5b**	**Gesture #5c**	**Gesture #5d**
			
16x	5x	3x	2x
62%	19%	11%	8%

Scrolling to the left side (Scrollbar move leftwards):

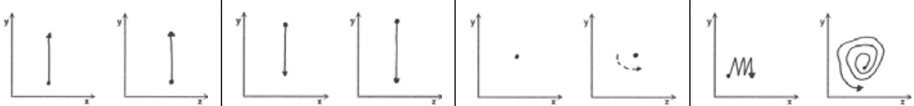
Gesture #6a	Gesture #6b	Gesture #6c	Gesture #6d



16x	5x	3x	2x
62%	19%	11%	8%

Scrolling to bottom (Scrollbar move downwards):

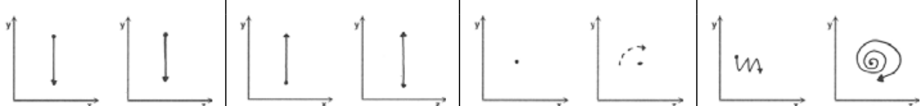
Gesture #7a	Gesture #7b	Gesture #7c	Gesture #7d



12x	10x	3x	1x
46%	38%	12%	4%

Scrolling to top (Scrollbar move upwards):

Gesture #8a	Gesture #8b	Gesture #8c	Gesture #8d

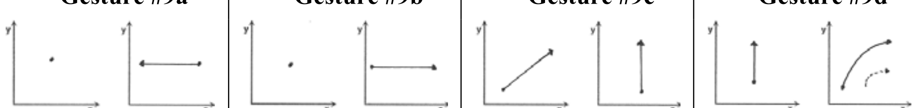


12x	10x	3x	1x
46%	38%	12%	4%

A.3 Zooming Function

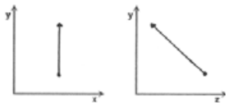
Zoom-in a visualization (enlarge it):

Gesture #9a	Gesture #9b	Gesture #9c	Gesture #9d



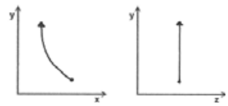
12x	5x	3x	2x
46%	19%	11%	8%

Gesture #9e



2x
8%

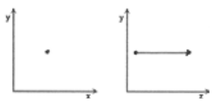
Gesture #9f



2x
8%

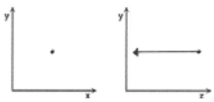
Zoom-out a visualization (minimize it):

Gesture #10a



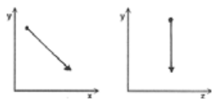
12x
46%

Gesture #10b



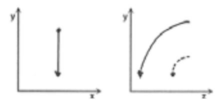
5x
19%

Gesture #10c



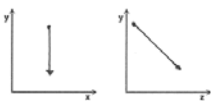
3x
11%

Gesture #10d



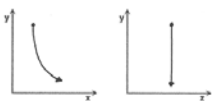
2x
8%

Gesture #10e



2x
8%

Gesture #10f

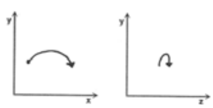


2x
8%

A.4 History/Undo Function

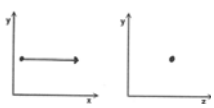
Go back in history/undo an applied action:

Gesture #11a



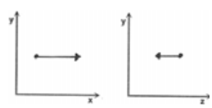
8x
30%

Gesture #11b



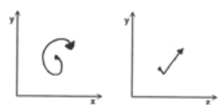
6x
23%

Gesture #11c



3x
11%

Gesture #11d



2x
8%

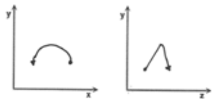
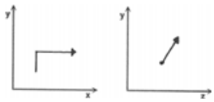
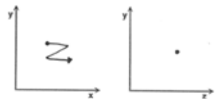
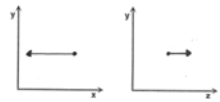
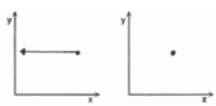
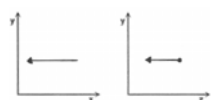
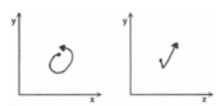
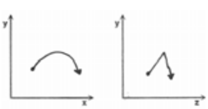
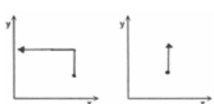
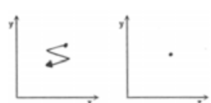
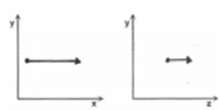
Gesture #11e	Gesture #11f	Gesture #11g	Gesture #11h
			
2x	2x	2x	1x
8%	8%	8%	4%

Fig. 6. Three of eight performed gestures for the sub-task "back-in-history"

Go forward in history/redo an action:

Gesture #12a	Gesture #12b	Gesture #12c	Gesture #12d
			
8x	6x	3x	2x
30%	23%	11%	8%
Gesture #12e	**Gesture #12f**	**Gesture #12g**	**Gesture #12h**
			
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A.5 Simple Dialog (Accept/Decline a Request)

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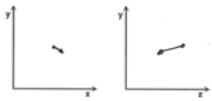
Gesture #13a



pointing gesture

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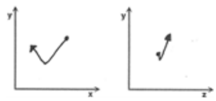
Gesture #13b



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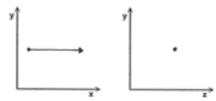

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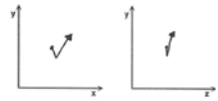

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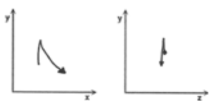

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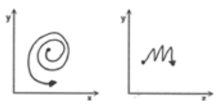

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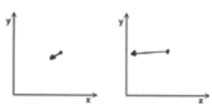
Decline the dialog:

Gesture #14a



pointing gesture

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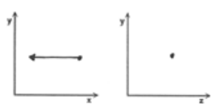
Gesture #14b



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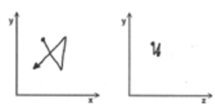

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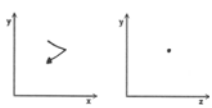

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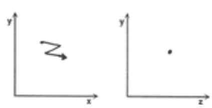

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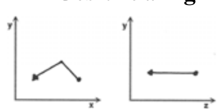

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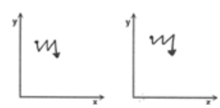

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An Elderly-Oriented Platform to Simplify the Use of Physical Activity Controlled Game Consoles

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Abstract. In this paper, a new method to facilitate the performance of physical activity in the elderly is proposed. The rising number of retirees needing assistance from social security systems makes it necessary to focus resources rather on prevention than in treatment of illnesses, to allow a longer independent life in the home environment. The proposed system is based on the implementation of modern game consoles, which demand body movements to control the player's performance in a highly-motivating context. Previous studies suggest that these virtual game environments could contribute to increase physical activity. Goal of this project is to simplify the use of these new technologies for senior people, paying special attention to an elderly-oriented design both in mechanical and functional aspects. Test sessions with potential users have been performed to test whether the functionality of the developed device effectively increases the interest of the elderly in motion-controlled virtual games. Further experiments are being planned in order to receive more feedback and accordingly refine the development process.

1 Introduction

In this paper, a new method to increase physical activity of senior people is proposed, which aims to help increasing the possibilities of a longer independent life in the home environment and consequently relieve social insurance systems, overburdened due to demographical change.

The prosperity and optimism after the Great Depression and World War II led to an unusual boost of the birth rate in developed countries through the following decades [1]. The so called "Baby Boomers" generation reached his peak in the late 50`s, where only in the United States more than 4.2 million babies were born every year between 1956 and 1961 [2]. The low level of fertility during the Great Depression and this boom in births, which lasted from 1946 to 1964, combined to produce a sharp step in the population structure [3]. The migration of this step over the last six decades, together with the increase of life expectancy during the 20th century, has considerably amplified the number of retired people needing assistance from the social security and health insurance systems. Only in Germany, 20% of the population is currently older than 65 years, with an upward trend to ca. 30% expected for the year 2030 [4] (see Fig.1). This tendency, also observable in other countries of Western Europe, North America, Asia and

Australia, sets the need of focusing resources rather on prevention than in treatment of illnesses, allowing the elderly to live independently as long as possible in their home environment and, thus, contributing to relieve the already overstrained health insurance systems.

Regular physical exercising is known to be one of the best ways to prevent cardiovascular diseases [5]. However, sedentary lifestyle is unfortunately one main characteristic through the elderly that attempts against a sufficient amount of corporal activity. Professional assistance is mostly not affordable and the motivation to exercise independently decreases considerably in time due to the monotony of standard routines and the lack of new challenges according to the training progress. An interesting proposal to overcome these inconveniences is the use of modern game consoles.

2 State of the Art

During the last years, a tendency has been established in the game console's market to develop newly interactive control interfaces that demand body movements of players in order to interact with the virtual situations presented in the game. The most known example of this trend is the Nintendo Wii[1], which uses an accelerometer-based wireless controller to recognize and use the player's movements as control commands. The worldwide success of this motion-concept has motivated other market-leading companies to develop newly high-tech solutions. One example is an accurate tracking system based on a fixed camera and a sensor-packed wand including a glowing sphere, which follows the hand movements of the player and reproduces them[2]. A fixed camera is also used in a gesture recognition system that detects and utilizes whole-body movements instead of a classic game controller[3]. A more classical example of physical interaction with game consoles is based on a stationary bicycle equipped with rotation sensors connected to the handlebar and pedals that let players control games by pedalling and steering [6]. The possibilities offered by such systems have widened their use into other areas. As seen in [7], [8] and [9], the potential of modern game consoles together with some goal-oriented hardware enhancements has been exploited for rehabilitation of patients with hemiplegia or post-stroke disabilities. At the Glenrose Rehabilitation Hospital, Canada, the use of the Nintendo Wii has shown that patients work longer at therapy as they enjoy playing, focus less on the affected limb and engage in social interaction [10]. In Germany, a group of students have been taking the Nintendo Wii to diverse retirement homes throughout the country, organizing, with great acceptance, virtual sport competitions between residents[4]. A comparison study between the execution of standard routines on a Footstepper and

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[1] Nintendo, "Nintendo Wii," wii.com, 2008. [Online]. Available: http://wii.com [Accessed: July 26, 2010].

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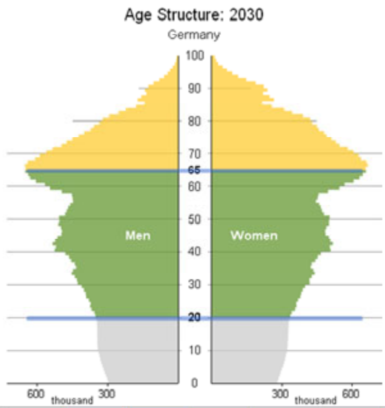

<20	20–64	65+	Total		AQ
12.9	42.1	22.3	77.4	Mill.	53
17	54	29	100	%	

Fig. 1. Expected demographic distribution in Germany in 2030 [4]

equivalent routines on the Wii Balance Board showed that interactive multimedia training methods are quickly adopted and enhance the motivation to improve physical performance [11]. Moreover, the American College of Sports Medicine (ACSM) and the American-Heart-Association (AHA) give advice that balance exercises on the Wii Balance Board help train the body perception, with a consequent reduction of fall risks in people over 60 years old [12].

The experience gathered in these studies suggests that virtual game environments are a perfectly suited approach to successfully increase physical activity. Due to their recreational characteristics, they could also contribute to enhance group activities and social relationships, not only within the retirement home environment but also inside the family circle, helping to bridge the generation gap between the elderly and the technology-adapted youth. However, initiatives are still missing that aim to provide an easy-to-use, cost-effective and elderly-oriented platform to improve fitness in the home environment and, therefore, prevent diseases.

3 Challenges

The advantages of game consoles have been mainly used in rehabilitation scenarios. But, when aiming to develop a technological, game-console-based solution, whose purpose is to allow the elderly to perform physical activity in a homely environment, different aspects missing in the referenced projects have to be considered:

3.1 Self-explanatory Human-Machine Interface

The main goal is to focus on simplifying a new technology for the elderly by making things easier to do without underestimating their abilities. The referenced projects show the permanent need of a support person when introducing elder people into handling a new system. Not only to explain how it works, but also to assume the sometimes tricky manipulation and solve the annoying technical difficulties that may occur, situations that could end up fading the user's motivation Therefore, a simplified human-machine interface is needed in order to allow seniors to interact with the system independently and whenever they want to, not sporadically when personal guidance is present. This interface has to be self-explanatory and provide just the necessary functions.

3.2 Elderly-Oriented Design

Since game consoles are designed for a younger target population, the appearance and functionality have to be adapted to meet the requirements of an elderly audience. Important aspects are simple and precise written hints with big sized fonts, high contrast colours, the use of few big distinguishable buttons and a robust construction.

3.3 Wireless Operation

An elderly-oriented device must cause as less inconveniences as possible in everyday life. A battery-powered system and wireless communication between components are essential to assure the absence of surrounding cables that difficult its installation and limit its employment.

3.4 Record of Activity

A chronological register can show if a person has been doing enough exercise according to its individual requirements and give advice about anomalous routine alterations that might predict a change in health status. Relatives or nursing care may profit of this record to perform periodical evaluations. In addition, the system itself should be able to customize the difficulty level according to the progress or regress of every user, assuring to maintain the will to exercise for a long period of time.

3.5 Low System Cost

As the final product should be as inexpensive as possible, design and development have to be economically carried out and the whole system has to be based on an existing commercially available platform, avoiding software and hardware modifications.

All these considerations have to be borne in mind during the development process, in order to allow spreading the use of the created solution.

4 System Description

The developed system is based on the Nintendo Wii; however, the concept has been developed to be applicable to any similar game console. This choice was made due to the project-well-suited console's intrinsic characteristics, such as intuitive playing modalities, continuous storage of the player's progress and the stimulus to improve one's performance thanks to comparison and competition with other users. The main input device of the game console is a wireless remote-control that detects the player's hand movements using an acceleration sensor and an IR-Tracking system. These movements, together with the pushing of several buttons, are then interpreted by the game console for the needed set-up steps and to accordingly move the avatar representing the user in the virtual world.

Elderly people are mostly not used to handle with new technologies and the learning process for it, if carried out, is frequently overwhelming. Usually, when using the game console, playing with body movements is easily understood after a few tries. Yet, the numerous set-up steps needed before actually getting to play increase the difficulty and might diminish the will to play. The constructed solution has been conceived as an enhancement accessory for the Nintendo Wii to help simplify and automate the game-loading process. The so called Simple-Use-Wii (SUW) unit performs all the required configurations and game relevant choices following a unique user instruction. A scheme of the whole system arrangement is shown in Fig. 2.

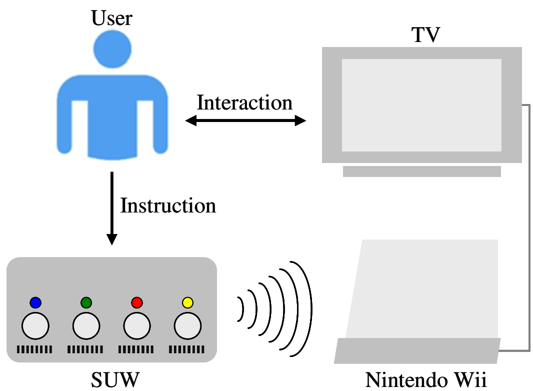

Fig. 2. Diagram of the system's configuration

4.1 Hardware and Construction

The internal architecture is based on an Atmel AVR ATmega 644V microcontroller and a proprietary radio-frequency transceiver working on the 2.4 GHz band. A microSD card is included as a removable non-volatile memory expansion for the microcontroller to save relevant user data. A built-in real time clock serves for precise time-logging of the system activities and a Bluetooth adapter is incorporated to achieve the communication between the SUW and the game console. The power supply is attained thanks to a 3.7 Volts and 1600 mAh rechargeable lithium-ion polymer battery, which lasts approximately 6 days in stand-by modus and about 20 hours when used continuously. Thanks to the wireless communication, battery-powered electronics and since no hardware modifications of the game console are required, the device can be directly used with any Nintendo Wii without complicated installations. The SUW unit measures 15x9x3 cm (HxWxD) and has only four buttons located on top of it, each one of them with a coloured LED over it and a written label under it, indicating one of four predefined sport games that can be played: Tennis, Bowling, Golf and Box.

4.2 System Operation

When a user presses the button corresponding to one of the four available sports, the SUW assumes the loading process by first turning on the game console and then performing the configurations that are normally supposed to be carried out by a person by means of the remote-control. In order to achieve all this, the device sends, via Bluetooth, the proper formatted data of IR-Tracking (pointer position) and confirmation commands (remote-control buttons) to the Nintendo Wii. During this process, the user just needs to wait for his chosen game to be loaded, what takes about one minute depending on the selected sport. At this point, the player can take a normal Nintendo Wii remote-control and play, following the Nintendo's original play modality. If the game has ended or the person wants to end it, pressing again the button causes the SUW to take over the control of the console and turn the whole system off.

4.3 Record of User's Activities

There are two methods to record and quantify the amount of physical activity executed by a person using the system.

The first one is based on the console's intrinsic evolution of the avatar (Mii) that characterizes the user in the virtual world. Each one of these virtual players has his own identity and different users are represented by means of different avatars that can be configured in the game console, which are then selected during the game loading process. If the Mii succeeds or regresses in a certain sport, i.e. the real person as well, the difficulty level is correspondingly adjusted. In this manner, the system encourages the user to improve his performance as the difficulties are neither overwhelmingly high nor boringly low, helping to keep the person motivated for a long period of time. The progress and usage frequency are registered for each Mii, serving as a record of the physical activity of a person using the system. Since the SUW unit automatically performs all the configurations when loading a game, the person is not able to directly choose his own virtual player. Therefore, the link between the avatar and the real user is periodically saved in the SUW μSD card, guaranteeing the accordance in the progression of both of them.

The second method is based on the storage of user related information in the μSD card. Data are saved in form of text files in three different types of files. The first one, named "SUW.txt", is unique and contains system-relevant values associated to the total number of users, the link between them and the distribution of the Miis in the Wii selection Menu and the last game played. The second file, "TIME_LOG.txt", saves the time and date information of all the last SUW activities by means of the integrated real time clock chip. There is one text file in the μSD card, "ID_Nr.txt", associated to every registered player in the system, where "Nr" is replaced with a number ranging between 1 and the total number of users. An example of the internal structure of this file can be seen in Fig. 3.

Every player has a distinctive numbered user identity that is consistent with the value of "Nr" in the file name. The last game played is saved with a number, where 0 represents Tennis, 1 Bowling, 2 Golf and 3 Box. The amount of times each one of

ID_01.txt

MiMed - SUW User Record	
User_ID:	001
last_game:	000
nTennis:	013
nBowling:	017
nGolf:	008
nBox:	002
T_last:	14
T_total:	087

Fig. 3. Example of a text file with user information

these sports has been loaded is recorded, together with the duration in minutes of the last game played and the total play time. Since data are stored as text files in a removable unit, it can be easily accessed using any computer by relatives or nursing care, allowing effectively, periodically checking to see if a senior has been exercising enough or if his activity routines have suffered unexpected alterations that might predict a change in health status.

5 Experiments

5.1 Test Sessions with Potential Users

To analyze the acceptance and functionality of the SUW unit, two test sessions with different groups of seniors were performed. For the first one, 48 volunteers (16 women, 32 men, age range from 59 to 85 years, mean value 68.4 years) were recruited through local press. All of them used lenses, four needed a hearing device and none of them required walking assistance. 44.9% had practiced technique-oriented jobs in their professional life and a bigger percent of them employs daily common technologies (see Fig. 4). A personal computer is often used in 83.3% of the cases, Internet in 75% and TV in about two-thirds of them. A considerable difference regards the use of a game console: 68.8% of the volunteers don't even have one, while a 27.1% never uses it. During five three-hour sessions, groups of 9 to 10 participants were initially introduced into the Nintendo Wii, without using the SUW unit. Their mission was to turn on the system, start and try one of the different sport games and finally change to another sport program. Once the subjects were familiarized with the game console, the SUW unit was introduced and put into practice. They had to start a game with it, play for a while, and then turn the system off. The evaluation of the experimentwas done by observing how the volunteers coped with the different tasks and, in a group discussion at the end of the session, each person had the chance to express his opinion about the experience.

The second test session was performed with 10 residents of a nursing home (6 women, 4 men, age range from 72 to 96 years, mean value 82.9 years), recruited by

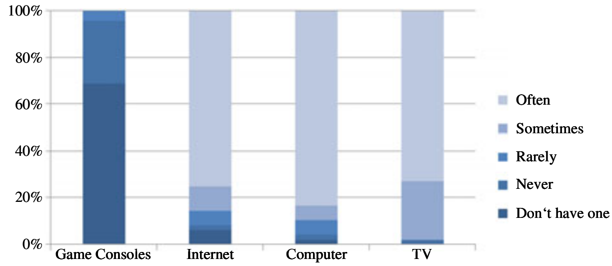

Fig. 4. Volunteer's employment of daily life technology

the home's administrator. All of them used lenses, one needed a hearing device and four required walking assistance. Only one had practiced technique-oriented jobs in his professional life, eight of them use regularly a TV and one uses a computer and Internet. None of them has a game console. In one two-hour sessions, each person had the chance to individually test the SUW unit and to use the Wii console "normally". For each trial, the task consisted of starting a game, play for a while and shutting the system down. The evaluation of the experiment was done by observing how the volunteers performed the assigned tasks and also by responding a specially designed questionnaire. 2 participants left the session before its end due to health reasons and another 2 questionnaires weren't evaluable.

5.2 Test Results

A recurrent observed conduct was that the volunteers gradually learn how to use a game console after repetitive indications and with immediately available assistance. Yet, they tend to forget it when not using the system continuously by themselves, a behaviour that strongly accentuates in the second group. The most critical factor was to identify the buttons on the remote control and to recognize when and which one of them had to be pressed. Independent of the volunteers age, they were initially reticent to perform real sport-like movements, what gradually changed with the familiarization with the game.

Opinions of the first group, like *"this is good for lonely living people"* or *"this would be a proper way to spend the free time in a nursing home"*, propose that the use of a game console could be accepted by an elderly audience. Some inherent game characteristics were evaluated as irritating or confusing (automatic replays, screen splitting), and the Wii's navigation menu was generally stated as understandable but to long before a game could be started. Regarding the SUW unit, the handling of it was easily understood and performed straightforward. Some opinions, like *"it's more suited for people with cognitive impairments, since fit healthy persons would want to perform the configurations by themselves"*, suggest that people around the mean age of the first group, a generation more used to daily life technologies, would still be able to learn how to successfully use a new system like a game console.

According to the 6 valid questionnaires of the second group, 4 users found the SUW unit helpful and 2 of them considered it as a determinant factor for a more frequent use of the game console. Although 4 players said that they would be able to perform the initial configurations by themselves, the test experience showed that this would be inconceivable without permanent personal support.

A significant finding of the test sessions is the importance of the target population, exemplified by the age difference between both groups (ca. 15 years in average). Generally speaking, people around 75 years old or more weren't used to deal constantly with new technologies during their lives, which now affects their ability to get along with them. In contrast, the "now-aging" generation, around 55 years and more, has faced constant new technology developments during the last 30 years, broadening their acceptance to the implementation of new systems like the one proposed. However, the development process should not ignore the requirements and characteristics of the older group, as it represents the most important reference for aspects like design, usability and functionality.

6 Conclusions

In this paper, a new method to facilitate the performance of physical activity in the elderly, based in the implementation of a modern game console, was proposed. The Simple-Use-Wii (SUW) unit is a tiny microcontroller-based device that simplifies the use of the Nintendo Wii. It was developed to allow senior people to profit of characteristics like intuitive play modality through body movements and continuous storage of player's progress. The SUW has only four clearly labeled buttons, each one of them representing one possible sport game. When the user presses one, the unit automatically performs all the necessary configurations to start a game. By doing so, the person just needs to exercise itself while playing, without needing to repeatedly navigate through the console menus by means of the not-elderly-conceived remote control. The unit works with an internal rechargeable battery and every data communication within the whole system is performed wirelessly. Since no hardware modifications of the game console are required, the SUW unit can be used with any Nintendo Wii without complicated installations, while leaving untouched the original play modality. A removable µSD card saves the user's progress in time, permitting relatives or nursing care to supervise eventual change of activity routines over time.

Test sessions with more than 50 potential users showed that game consoles could be accepted by the elderly as a suitable way to perform physical activity in the home environment. The observed behaviours and the volunteer's opinions suggest that the SUW unit, by simplifying the usability of such systems, would boost this acceptance. The tests elucidated the need to focus the system's improvement on the target population (above ca 55 years) that would most profit of its benefits according to the demographical change trend.

Acknowledgment

Within the research consortium of the Bavarian Research Foundation (BFS) "FitForAge" a team of scientists and engineers affiliated to 13 departments of the Bavarian universities Erlangen-Nürnberg, München, Regensburg and Würzburg works together with 25 industrial partners on the development of products and services for the aging society.

The scope of the research consortium is to develop technology based solutions which will help elderly people in their future living environment comprising home and workplace as well as in communication and transportation. Eventually not only elderly people but also all social groups should profit from these solutions.

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Chapter 3: Platforms

System Architecture for Palliative Care in the Home Environment

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Abstract. To establish modern technical communication and monitoring systems also in the private homes of patients with palliative care needs a special and complex architecture behind. With the help of modern communication technology the existing social network such friends, family or social services will be strengthened. Additionally a monitoring system helps to detect an upcoming crisis of the patient at an early stage to defuse the situation betimes, or - in case of eventuation - to cope with a crisis in an appropriate way with the help of a well elaborated information forwarding system. On that way depressive and unnecessary hospitalizations should be avoided, if possible. Medical care and business models in the sense of end-of-life-care will be evaluated within the PAALiativ project. The models will be developed with two groups of patients exemplarily, patients with pulmonary cancer and patients with Chronic Obstructive Pulmonary Disease (COPD).

1 Introduction

Background of the demographic change is a double-ageing-process of the society. On the one hand there are an increasing number of elderly persons, while on the other hand the number of new born children is decreasing. Due to the advances in health treatment, many previously fatal diseases have been turned into chronic diseases and the lifespan increased. The consequence is a growing demand for care, especially for elderly persons or persons with a disability. The objective of the PAALiativ[1] project is to improve the palliative care of patients with end-stage pulmonary diseases by integrating modern assistance and medical monitoring techniques in their home environment. Within the PAALiativ project we address the health care and business cases of the two patient groups: Chronic obstructive pulmonary diseases (COPD) and lung cancer. Two disease patterns which currently show the highest accession rate [1].

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2 Motivation

Patients with palliative care needs often wish to stay at home instead of being cared for in a hospital or another specialized institution . They want to stay close to their partners, relatives and friends and they want to keep going in their normal life as long as it is possible [2]. However, a number of measures have to be taken to make sure that care at home really is an improvement or at least a positive aspect for the patient and his affiliates. In home care, conflicts may arise because the patient feels him- or herself to be a burden for relatives and friends; especially the partners of patients often have to live with a double pressure of on the one hand having to continue with their life and work to keep up the (financial) provisioning, and on the other hand having to care for a loved one, who is dying. In case of lung cancer and patients with COPD occurrences of acute dyspnoea may result in emergency calls followed by hospitalization even though it could have often been treated on the spot. This is because the emergency staffs have no or few information about the patient's disease history, which plays an important role for an adequate evaluation of the situation. Unnecessary hospitalization can be very wearing and stressful for the patient and his or her affiliates. It also produces avoidable costs for the health system.

To address these problems the following measures should be taken: Monitoring, supporting medical decisions, and creating and supporting a social network.

2.1 Monitoring

The disease pattern of patients with lung cancer and COPD is known and to some extent predictable. Continuous monitoring of selected parameters like pulse, pulmonary function, of the patient and his or her environment and providing this information to the care personnel can help them to refine the treatment of the patient. Figure 1 shows two kinds of typical illness trajectories for people with progressive chronic illness. Patients with cancer have a long period of preserved function followed by a precipitous drop that starts within a few months before death (top). Patients with COPD have an overall gradual decline in function punctuated by periods of exacerbations with acute drops in function followed by a return to near their previous level (bottom). The intent is to predict and deescalate bad trends, and to avoid periods of exacerbations best possible. Based on single vital parameters as well as composite disease markers (e.g., Bode Index, [4], result of data aggregation, consisting on weight, dyspnoea, obstruction, and the physical capacities/ exercise), and further assessments, upcoming crises should be detectable and can be medicated at an early stage. Crisis is here defined as any change of the situation which makes intervention from outside necesnecessary. It includes physical as well as psychological or psychosocial developments. The patient might also perceive the fact that the data is taken and forwarded as a reassurance that he or she is under the surveillance of professionals while at his/her home.

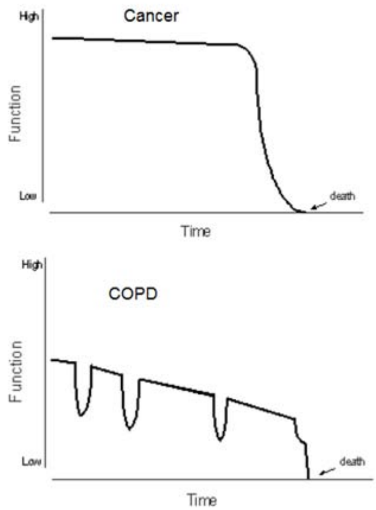

Fig. 1. Typical illness trajectories for people with progressive chronic illness. Top: Patients with cancer have a long period of preserved function followed by a precipitous drop that starts within a few months before death. Bottom: Patients with COPD have an overall gradual decline in function punctuated by periods of exacerbations with acute drops in function followed by a return to near their previous level [3].

2.2 Supporting Medical Decisions

In case of an emergency or a crisis as much relevant information as possible about the patient and his or her situation should be accorded to the emergency decision maker. Relevant information includes the medical history as well as current values of selected vital and environmental parameters, supplemented by subjective self evaluations. Short term as well as long term changes in behaviour or variations in the health status of the patient can be a meaningful instrument for deciding the right measure. Based on diverse information the emergency physician has the possibility to assess the situation correctly and to decide, if there is really the need to send the patient in the hospital, or if it is possible to treat the patient at home.

2.3 Creating a Social Network

To address the psychological and psychosocial conflicts that can arise for the patient and his or her affiliates, it is important to structure a close net of formal (professional) and informal support groups [5]. These groups differ a lot. Formal, professional groups include the medical professionals in the general practitioner (GP) practice or in the hospital, as well as the home care nurses and the medical decision makers in case of emergencies. They are trained, often specifically for palliative care and have formal ways to obtain and manage information. Informal groups can vary from voluntary groups, carers and relatives, to close and distant friends and neighbours, who come to visit and talk, or e.g., to take over some work in house or garden or supporting the patient in any other way. All these different groups build the social network of the patient. To make them work effectively, it is necessary to link them. E.g., if the home care nurse knows about the volunteer, who is dealing with the authorities in the patient's name, she might ask him or her to help with upcoming insurance issues; if the operator in the emergency centre knows about the neighbour, who has got a key to the patient's house, he or she can contact him or her to quickly check on the patient, if a situation is unclear; if relatives have knowledge about the situation, they can offer to help with household work or other tasks, possibly relieving some of the pressure from the patient and his or her partner.

3 State of the Art

' "Palliative care is an approach that improves the quality of life of patients and their families facing the problem associated with life threatening illness, through the prevention and relief of suffering by means of early identification and impeccable assessment and treatment of pain and other problems, physical, psychosocial and spiritual"' defined the World Health Organisation [6]. Today the main par of the day to day palliative home care is undertaken by close relatives and professional home care nurses, ideally ones specifically trained for palliative care. Nurses visit a patient two to three times a day, according to a care plan and support e.g., the daily hygiene, and they take care of medical provisions such as infusions. Nurses document their visits in care protocols, which are seldom electronic based. These care protocols are then used for the accounting at the insurance. The medical responsibility for the patient lies with the family GP, supported by the applicable specialists. He or she might also be specifically trained for the palliative treatment of terminally ill persons. The GP keeps a record of the medical history of the patient, as far as it is known to him or her. He or she gets records of the findings of the specialists and keeps them with the patient's data. How the data is organized and stored varies a lot between the practices: There are still many paper based file card systems, but there are also a number of software systems available. In-house emergency call systems enable emergency calls from a fixed base station and a corresponding radio calling device in the patients' home. In case of an emergency call, the patient's system is uniquely identified and the operator in the call centre receives previously stored patient information on a computer screen, when he or she takes the call. This information includes name, address, age, general medical status (i.e., care level, diseases, allergies), address of the GP and contact numbers of affiliates. It also comprehends the call history of the patient. Based on the call and the information in the system the operator decides on his next steps [7]. Due to the technical development in the past few years especially regarding wireless data transfer, and in the area of disease management, a number of telemedical approaches emerged, which aim to support patients and their GPs in the management of chronic diseases. Bolz et al. present some examples where vital parameters of patients are monitored continuously or discretely and are analysed either at the base station or transmitted to a remote server for evaluation there [8]. In both cases a health professional is contacted if the parameters violate a predefined range of values. The information is presented to support the diagnosis of the situation. The data is stored in a patient health record and therefore also available for further or long term analysis. Telemedical approaches including remote monitoring like these have been evaluated by Clark et al. and their findings show that they have a positive effect on the management of a chronic condition like chronic heart failure [9]. Social networking in the area of palliative (home) care has also grown in the past few years, mainly probably owed to the fact that new guidelines in some countries [10] call for the development of new and multi disciplinary ways of care for patients at the end of life. The WHO describes the content of palliative care as holistic, i.e., integrating the psychological and spiritual aspects of patient care, and advocates that palliative care should be applicable early in the course of life-threatening illness, for all patients and any setting [11]. There are also special Care Pathways for dying patients, like i.e. the Liverpool Care Pathway, that is used at the bedside to drive up sustained quality of the dying in the last hours and days of life [12]. Cities and communities are looking for ways to link the different care providers like hospitals, hospices, medical practices, ambulant nursing services, psycho-oncological services and so on, voluntary, non-profit organizations, affiliates, friends and even neighbours, who offer their support. An example is the ‘ “Palliativstuetzpunkt Oldenburg” ’ [13], where different relevant institutions within the city work together to provide a central point of contact and coordination for palliative (home) care for the city of Oldenburg and the surrounding area.

3.1 Limitation of the State of the Art

The main limitation of the previously described state of the art lies in the consequences of the lack of information and information exchange between the different stakeholders in palliative homecare, which is the base of coordinated, linked care cooperation. As can be drawn from the previous sections, the number of stakeholders is bigger than two; the communication between parties is seldom more than a two-way communication though, with the patient and his or her partner being on one end. The different groups of formal and informal carers are not linked and the information exchange between them is rarely and seldom structured. E.g. there is no formal way in which the ambulant nursing service receives relevant information about the patient’s visit at the GP’s. Information could therefore be lost to the nurse, if the patient him or herself does not convey it. Also in-house emergency call system operators do not receive updates of important information like a change in the general medical status. Medical professionals in hospital or GP’s practice often have only got their own documentation [14] of the patient’s history and a GP’s letter as information about the patient’s treatment at other institutions, but no continuous documentation. Miller and Sim found a lot of key barriers to physicians’ use of electronic medical record instead of paper based documentations [15].

The patients themselves often have none or only an incomplete documentation of their illness, even though the institutions are obligated to provide all information if patients want to give it to another institution. As with the current approaches to telemedical systems, they are often focussed on one or two aspects of a condition, e.g., oxygen saturation and heart frequency in a system, which detects cardiac problems like atrial fibrillation. When dealing with patients with palliative care needs, who suffer not only from sensor-measurable, physical problems, but also very often have to deal with psychological and psychosocial problems, this approach to monitoring is too limited. More integrative monitoring is called for:

– Objective (vital) parameters like weight or temperature and also aggregated composite markers should be monitored along with subjective ones like the patient's perceived level of pain or degree of dyspnoea.
– Assessment of mobility and activity values could be used as indicators not only for the physical but also for the psychological state of the patient [16].
– Environmental parameters like meteorological or indoor air quality parameters [17] should also be included. For patients with lung diseases the air quality is quite important [11].

4 Approach

Our new approach to support patients with COPD and lung cancer in their home environment is to compose a system which provides a collective source of information and a central linking point for all groups and persons involved in the care process. Keeping information up-to-date and distributing this information between the different parties is one focus of our system. Since all of the information in question is directly related to the patient, and especially because care for the patient is very individual the installation of a supporting system in the home environment is the only reasonable way:

– One of the most important data sources of the system, the monitoring of vital and environmental parameters, must be located in the patient's home. Storing and processing the data where it is collected, requires less effort in enabling and especially securing data transfer to external systems.
– The patient is the owner of all data and he or she is the only one who can allow or disallow access to the information or part of the information. Keeping all in the home further supports this ownership.
– Most of the care, especially the day-to-day care by the ambulant nursing service, is carried out in the home of the patient.

The information derived from the monitoring system combined with an up-to-date patient's medical history and up-to-date information about the patient's social network (e.g., continuously updated in-case-of-emergency contacts) should be presented to the emergency call operator as to facilitate his decision process. Figure 2 illustrates the medical decision support: The collected medical data are

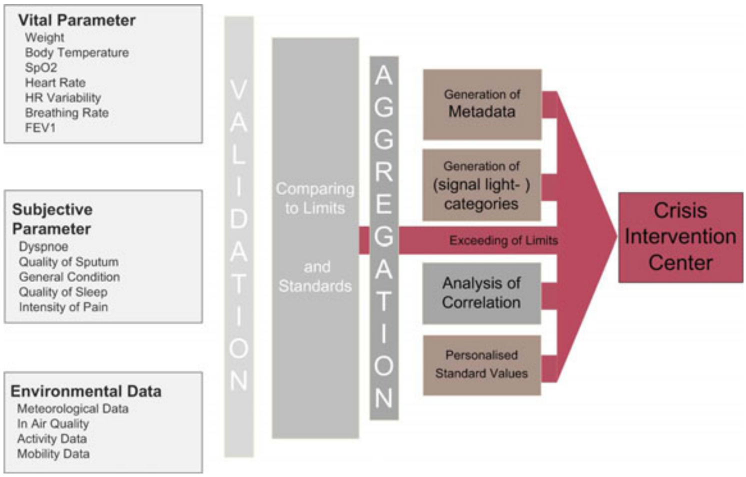

Fig. 2. Illustration of the medical decision support. The collected data are validated, compared to standard and extreme values, aggregated and compacted to metadata, categories and personalised standard values. If the data exceed some limits, the Crisis Intervention Centre is informed immediately.

validated and compared to medical standard and extreme values. If the data exceed some limits, the Crisis Intervention Centre is informed immediately. In a second step the data are aggregated and compacted to personalised standard values, metadata (like the Bode Index [4], a composite disease marker, aggregated from several single parameters to a composite index), and categories (like signal light categories, green means ‘ “all seems to be alright” ’, orange means ‘ “better avoid every kind of stress” ’ and red describes an ‘ “acute serious health state” ’). Again, if these aggregated data exceed some limits, the Crisis Intervention Centre is informed immediately.

- The monitoring data are interpreted, aggregated and concentrated for meaningful metadata
- Exceeding of medical limits is reported immediately to the Crisis Intervention Centre.
- Changes of the monitoring data will be evaluated and graphically prepared for easy perceivable views
- Data and metadata can be used to identify changes in behavior as well as in well-being; emergencies can be prevented while a crisis will be recognized earlier within the Crisis Intervention Centre.

All involved medical professionals and the nurses of the ambulant care services should be able to view and review the patient's status and his developments which are both derived from monitoring and metadata, and thereby receive access to the complete patient's history. The establishment of super ordinate boards, where stake holding institutions work together is only one step to link all the different support groups. Voluntary groups and also informal supporters, relatives, friends, neighbours should be involved in such a way that information exchange and mutual, unbureaucratic support is possible. Keeping all information at and distributing it from one central point also ensures that all parties share the same information. The possibility to integrate all the different data can enhance the value of the information in such a way that a crisis and even a growing risk of a crisis can be conveyed to a crisis intervention centre by the system itself. Along with the notification of the crisis or of the change of the risk of a crisis, relevant, aggregated data can be sent to the operator, who can be sure to have up-to-date information about the patient. The requirements, the realisation and the concept of our in-house communication platform are described in detail within the next section.

5 Architecture

The designed architecture of our approach follows the suggested user centralized approach with the main data storage and processing located in the patient's home. Requirements derived from the centralized approach are kept in mind during the realisation phase.

5.1 System Requirements

Installing the system in the home environment leads to a number of requirements, some of which are:

- The system needs to be usable for technical non-professionals.
- It has to be robust and low-maintenance, because service technicians will not be available quickly at all times.
- It has to be low cost to account for the fact that patients at the end of life often have to deal with a financially difficult situation, when the patient has to stop work
- Especially the hardware of the system has to integrate itself smoothly in the home environment. A system which blends in with the patient's familiar surroundings is more likely to be accepted.
- In case of COPD and lung cancer the decline is following a pattern over time, in case of COPD it is also peaked by exacerbations. Hence the system should be adjustable to the patient's growing needs.

5.2 Realisation

Television means a well accepted, quite popular medium. Germany's residents watch TV for about 188 minutes per day, the elderly for 273 minutes [18]. The number of households owning set top boxes (STB) is still increasing, especially since the change to DVB standards. Additionally the trend of high definition television (HDTV) is followed by improved performance of the STBs. A STB for receiving HDTV typically works with 256-512 MB RAM, whereby about 30% are preserved for decoding the TV signal. CPUs show 300-400 MIPS. The characteristic of the processing unit is the ability to deal with encryption algorithms like AIS and 3DES. The normal use is decoding the TV signal, but it also enables to encrypt local data. The size of the flash memory where the system software and the applications are preinstalled are very variable and range between 16 MB to several GB. Interfaces as USB and RJ45 allow the exchange to other devices, as well as home net and internet. But rarely the systems are used to capacity. The system software is increased Linux. STBs show a lot of advantages against commercial PC:

- An everyday accessibility in all age classes is warranted by the constant use of the TV set
- The acquirement is cost-effective, the power consumption low
- STBs are made for continuous duty and are nearly maintenance-free

As a closed system and with the ability to support actual encryption algorithms hardware sided, the STB features increased safety. Sensors and devices can be adapted to the In-House Communication Platform with Zigb?e or Bluetooth wireless. The data exchange between the In-House-Communications System and the ‘ “Out-House”’ can be realized via a secure internet access.

5.3 In-House Communication Platform

Figure 3 shows the system architecture for an In-House Communication Platform for palliative home care. Located at the patient’s home is the set-top-box. The sensors for the monitoring are connected to the In-House Communication Platform through a device abstraction layer, which abstracts the platform from the underlying sensor system hardware. On top of the device abstraction is a database and backup, base services for the management of the data. Some of the sensor data is stored here directly. Other data is taken by the monitoring system, which also takes and writes data from and to the database to fulfil its tasks. Data processed by the monitoring and master data - basic information about the patient, including e.g., the medical history, are both used in the medical decision support system, which calculates the risk of a crisis, or respectively detects a crisis. A communication system provides the basis for communication services like video telephony or other messaging services. Information going out of the monitoring, the medical decision or the communication system is encrypted through the hardware encryption services of the set-top-box, where applicable. The next layer presents the different ways of information distribution and reception. A (web) server provides access to the data. For the patient this is realized through the display and manipulating of the data in a browser applicationwhich runs on the TV. Keeping all information at and distributing it from one central point also ensures that all parties share the same information. Any persons outside the patient’s home can access the information through a web browser. In that case a user has to identify him or her with personal login data, which also identifies

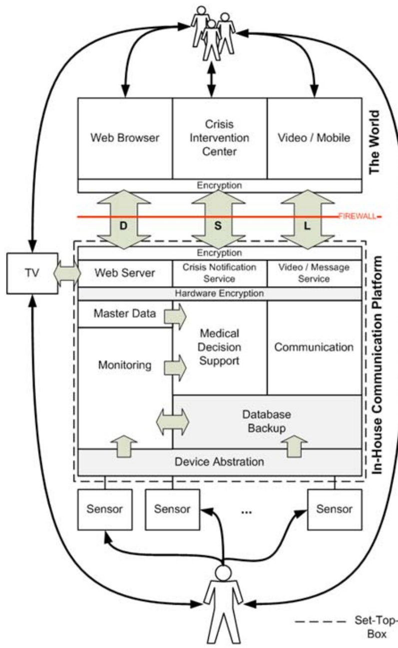

Fig. 3. System Architecture for an In-House Communication Platform for Palliative Home Care.

him or her as belonging to a user group. His access to the information will then be restricted to the information available to the respective group. The diverse accesses show not only different information availability, but also different possibilities of data inputs. E.g. to change some medical instructions is only allowed to medical professions, to comment or estimate some situations or processing is allowed also to family members or friends. The use of the calendar functions is allowed to all parties. All data input and reading rights are assigned from the patients themselves and can be updated if required.

5.4 Medical Decision Support

The monitoring provides different kinds of data. In case of objective vital parameter like heart rate, blood pressure, body temperature, the interpretation is quite clear: there are existing standard parameter ranges, between the values have to be. Comparing these metered or computed values with the standard ranges allows estimating a first impression of the patient's health status. Furthermore some metadata or collections of several data like Bode Index are computed. If the data exceed some maximum or minimum values, the Crisis Intervention Centre will be informed immediately. This kind of rule based evaluation is realized with the help of Medical Logic Modules (MLM), which include medical knowledge and standards, implemented in the Arden Syntax [19]. Over the time the general medical standard values will be supplemented by personal or typical values for the patient himself, medians or means of the monitored parameters; deviations within these personal standard values can be evaluated additionally, especially over time, to detect individual trends and histories.

Subjective data are collected via digital questionnaires and the replies can be evaluated as necessary amendment, to monitor i.e. the success of certain medication (pain/ dyspnoea) or therapies.

Some others of the collected data are less univocal, like mobility or activity values. These parameters have to be evaluated in the individual context. To evaluate these values there have to be some initializing working theories defined first, such as ' "if the patient doesn't move, he or she suffers pain"', but they have to be examined and enhanced continuously over monitoring time. Last but not least there are data whose influence we do not know for a fact, but we assume they must have influence, i.e. meteorological data. For these kinds of data the observations are initially necessary to determine correlations between the meteorological data and the status of the patient. These can then provide a basis to find a correct individual interpretation. Based on these findings the system can warn the patient, if there are special circumstances which might impair on his or her health status.

Example: *patient with COPD since 25 years, age of 68 years, living at home with his wife. The system gives notice that the heart rate and breathing rate of the patient is ascending; the actual heart rate is about 26% above the mean rate of the last three weeks, the breathing rate about 31% above the personalized standard. An accurate sight in the electronic health record of the home platform shows more detailed information: The patient's normal temperature is on average 36.2 degree, today his temperature is about one degree higher, but still in the normal range. The sleeping quality is not as good. The patient describes his perceived vitality as normal to low, and ranked the actual dyspnoea as rather wearing. The sputum colour has changed, from a transparent pertinacious to a slightly yellow-green. The activity values show that the patient was very immobile during the whole morning and the Medical Decision Support-Report attests an orange signal light category and an actual downward trend over the last three days.*

The operator in the Crisis Intervention Centre calls the patient to ask him some more details and to tell him, that he wants to send the GP to him, because he is assuming that an infection is on the way. The patient appreciates this approach that the operator is attending to the doctor's visit directly. In the afternoon the GP is coming and diagnosing an infection. The GP brought the antibiotics with him because he already assumed its need based on the information the operator in the Crisis Intervention Centre gave him.

The GP tries to prevent a hospital admission in treating the infection early in the home care setting. After this intervention, the patient is getting better after three days in close assessment and supervision by the CIC and the GP. He is back to a normal health status after a week without the need of hospital support.

6 Conclusion/Discussion

The presented system architecture confirms not only the networking and the information exchange processes. It also allows conducting and organising the diverse stake holders' engagements and medical applications. The electronic medical health record helps to collect and manage the health data in a manner also laymen have access to their medical data at any time and are able to comprehend. With the help of the system the success of therapies can be examined. The system gives the possibility to study the changes of the patient health to evaluate correlations between single symptoms and to develop a more patient centred treatment in this way. Combining objective, subjective and environment data helps to find more indicators for a crisis and enable the medical team to react not only immediately, but also in time. Emergency situations and hospital stays, which are very exhausting for patients and relatives can be avoided. Based on the collected knowledge of personalised long term vital parameters, subjective self-assessments, and environment parameters, it should be possible to model the patients behaviour related to certain changes of these parameters. Especially with a view to the meteorological and indoor air quality data the system can help to bring some interrelations in the awareness of the patient. A behaviour change in easy all-day operations like proper heating and ventilation can help to reach adequate air moisture and can prevent infections and therewith exacerbations particularly during times with high risk of infections, e.g., during the winter months.

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openURC: Standardisation towards "User Interfaces for Everyone, Everywhere, on Anything"*

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Abstract. As a consequence of the large interest in standardized, open, scalable and interoperable platforms that can implement scenarios and requirements posed by the AAL and eInclusion communities, the ISO/IEC 24752 standard Universal Remote Console (URC) has emerged from a single project infrastructure within the FP6 eInclusion project i2home into a steadily growing ecosystem with parties ranging from more technology oriented over business but also stakeholders that represent users. In order to coordinate and make transparent activities as well as provide a meeting place for different stakeholders, we have started building up the OpenURC Alliance. This paper presents the URC technology, the timeline and construction of the Alliance and, finally, point at some current and future activities.

Keywords: OpenURC, Alliance, Platform for Accessible User Interfaces, ISO 24752.

1 Introduction

One of the holy grails of Artificial Intelligence is to implement intelligent environments where persons are intelligent supported by the environment in various ways. We witness instant improvements but at the same time a diversification in different areas where different stakeholders focus on and implement specific aspects of such environments, such as *intelligent assistance while driving* which has additionally become an affordable technology. The development within other areas of daily living, e.g., smart homes,

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or smart working places have not advanced in the same way. Really smart homes are today either practically nonexistent in large parts of the world or very expensive. The latter hinges on the fact that we still lack agreed-upon technological platforms that are capable of implementing the diversity of technology needed for realizing smart homes. Moreover, the “smartness” of the smart home is limited to the smart home itself and typically vanishes as soon as we leave our home and close the door.

Imagine instead a world where your are on business travel checking into a hotel in a foreign city. You enter the room and the air conditioning automatically sets to your preferred daytime room temperature. The TV displays a welcome screen. You pull out your smart phone and use it to switch to your favourite news channel. Even though all products and systems in the room are new to you, they or more precise the interaction with them is familiar since you use the same interfaces on the smart phone that you use for your home appliances. As this is your own personalized interface, the controls are shown in your native language, so you don’t have to decipher the labels on the systems in the room which may be in a language foreign to you.

Imagine additionally that you are buying to your home, a new TV since your old one broke along with a falling detector service since you have lately started to suffer from dizziness. Rather than throwing away your old remote and learn a new one, you simply replace the old TV with your one. The user interface remains the same as before. The falling detector service contains four sensors that you can even mount yourself in your flat and that seamlessly integrates with your existing environment. The appropriate user interface and additional software is installed automatically in your smart home.

Imagine finally elders or users with mild cognitive disabilities, some of whom would like a much simpler interface than that offered to the general public. They would no longer have to learn how to use a new interface each time a device has to be replaced or when they are travelling or visiting family and, more relevant even, at their very homes. They too would become more autonomous.

The conclusion is more or less evident: the evolution toward more and more devices and services in all aspects of people’s lives—home, work, leisure, travel, etc.—logically create demands for

1. services that are truly ubiquitous and/or pervasive;
2. architectures that can integrate new services and corresponding user interfaces on the fly as they are discovered
3. user interfaces that can be personalized, namely, being adapted to the capabilities of a specific user.

The reality, however, is that up to today, UIs tend to represent the “stepdaughter” of many products and services. Typically dominated by concerns of brand protection, marketing, and focus on the “sweet spot” of mainstream users, UIs frequently lack the ability to adapt to a specific user’s needs. Indeed, we find well-functioning island solutions—there are in fact several which are concerned with controlling light and heating, e.g., Zigbee[1], enocean[2], knx[3] just to mention a few. However, since these

[1] http://www.zigbee.org
[2] http://www.enocean.com
[3] http://www.knx.org

technologies do not work together, or are unable to work with other equipments or services, the world increasingly become a sea of island solutions.

On a political level, Europe has started to implement the "Convention on the Rights of Persons with Disabilities"[4]. This convention is based on eight principles of which two are particularly relevant for the work described here: "3. Full and effective participation and inclusion in society" and "6. Accessibility". These principles have or will have very large impacts on different parts of the society not only in the areas of architecture and city planning but also on Information and Commmunication Technologies (ICT). Consequently, information and services made available by particularly government but also ideally hotels, shopping malls etc will have to be made accessible for everyone. This work describes an open, scalable architecture based on industrial standards that meets all these requirements and desires.

2 The Universal Remote Console Standard

Technology enabling wireless connectivity and networked computing is already available, providing methods for seamless discovery, controlling and eventing. But at the moment, user interfaces still have to be authored separately for each controller platform. Furthermore, many existing interfaces are neither intuitive nor easy to understand for many users. What is needed is a standardized, versatile user interface description for products. A kind of "user interface socket" to which any personal device or "URC" (Universal Remote Console) can connect to discover, access and control a device, system or service. A solid user interface description alone could support diverse URC technologies—including direct manipulation techniques via desktop computers and personal digital assistants (PDAs), TV-based UIs [6], voice recognition and natural language technologies used by PDAs and wearable computers, or even Brain Computer Interfaces (BCI) [7]. Such an approach could also enable older products to be controlled with new user interface technologies, e.g., speech-based UIs [9].

In early 2008, subcommittee SC 35, User Interfaces of ISO/IEC JTC1, Information Technology, published a new multi-part International Standard, promoting interoperable and personalizable user interfaces, ISO/IEC 24752, Information technology—User Interfaces—Universal Remote Console (URC), see [2].

One intuitive view point of the URC technology is the middleware approach called Universal Controle Hub (UCH) as depicted in figure 1. In line with many other middleware solutions, the UCH includes the heterogeneous appliances and services, called *targets* and make them available as abstract user interfaces ("UI Socket Layer" in the figure). A socket can be thought of as an abstract description of the input/output behaviour of the target. Furthermore, we say that socket is rendered or made concrete by typically running some user interface on some *controller*. To enable controllers to access and control a target without any prior knowledge of each other, some "common understandings" need to be in place. The first part of ISO/IEC 24752, Part 1: Framework, defines the components of the URC framework and specifies the "common understandings" between them as conformance requirements, stated in terms of

[4] http://en.wikipedia.org/wiki/Convention_on_the_Rights_of_Persons_with_Disabilities

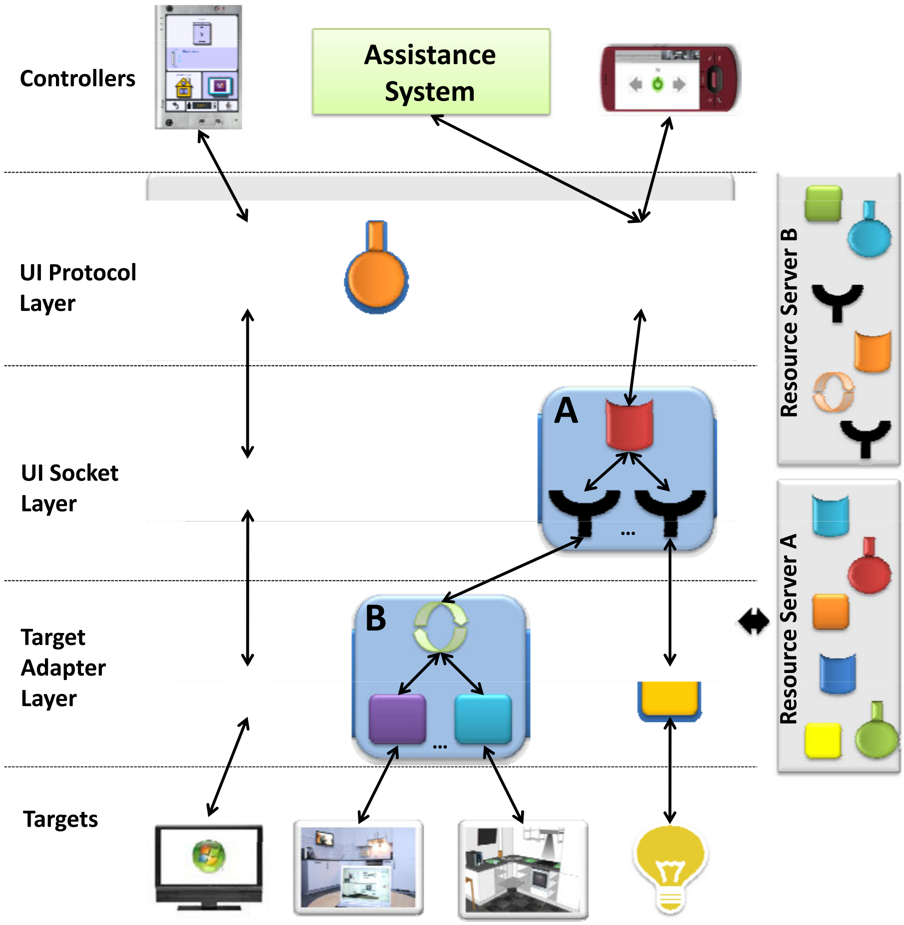

Fig. 1. The URC framework with its different layers (from the bottom): Target Adaptor Layer, Socket Layer, UI Protocol Layer. In the figure, two additional plugin extensions are depicted: A) A CEA-2018-based Task-Model Engine; B) A Synchronization Module used for implementing synchronized scenarios.

high-level interaction. A key part of this interaction is the sharing of control and access information through XML documents.

The URC technology does not pose any requirements on the targets other than being controllable over a network. Currently, UCHs can interact with UPnP devices, ENOCEAN, WSDL services, ZigBEE, bluetooth just name a few technologies. Integrated user interfaces range from simple automatically generated HTML pages, accessible HTML pages, flash-based UIs, multimodal speech- and gesture-based UIs. Appropriate controllers have been iPhones, Android phones, TV + Remote Control, touch-screen based computers and even Brain-Computer Interfaces (BNCs) etc. The URC technology has been applied in diverse scenarios, like comfort, security, information services, peer-to-peer gaming within the Smart Homes, i2home implementations of the UCH approach additionally allows for plugins, e.g., a CEA 2018 task model engine [8] which can be used to combine services forming compositions thereof.

The two USPs

Apart from the separation of concerns which allow user interface developers to focus on the development of user interfaces rather than technical issues, there are two unique selling propositions of the URC technology not present in most other frameworks:

- *Pluggable user interfaces* meaning that there is a clear separation between the appliances and services on the one hand and the user interfaces on the other. With this approach it is possible to dynamically install UIs with the same functionality depending on the user's profile and the context.
  We strongly believe that this approach should be incorporated into ICT in general since it provides the necessary ingredients for personal and thus potentially accessible user interfaces.
- *Resource Servers* A resource necessary for connecting a target with a UI is available via resource servers. In the last years, special forms of this concept have received a lot of attention, such as Apple's App Store. The URC approach, however, allows sharing arbitrary resources necessary for connecting a target with a user. Also, a UCH can interact with several resource servers thus allowing providers to maintain their own resources on own resource servers.
  The Resource Server is instrumental in providing the benefits of the URC framework regarding user interfaces, such as personalization, accessibility, context-awareness, openness for 3rd-party contributions, support for agent-based user interfaces, and support for management of user interfaces [10]. Currently, a pilot Resource Server is being operated by the US-based company dotUI, see `http://www.dotui.com`

Current status

Today, besides the aforementioned Resource Server, a variety of platforms and tools are already available to the person or entity that is interested in evaluating the standard and/or decided to apply it, both in a research context or for the development of real products or services. More is already in the development pipeline:

The central element for any URC driven infrastructure is the already mentioned UCH. The TRACE Center distributes Open Source reference implementations in Java and C++. Meticube offers a range of UCH variants based on MS .NET, Java and C++. These are available in so-called Starter Kits (Basic, Professional, Enterprise). All versions are optimized concerning robustness, performance and scalability, equally suited for R&D and professional usage in real applications and production environments. Meticube's UCH also features a special Cascading Mode that allows to interact with devices and services which are connected to a remote UCH and that supports a wide range of deployment scenarios (hierarchic, mesh, P2P, proxying, ...).

DFKI provides an implementation based on the OSGi platform. This implementation is scheduled for being re-implemented according to the common criteria methodology in order to receive a level four certificate. This correspond to the security level of today's home-banking systems. Furthermore, DFKI has developed a rapid-prototyping tool for drag-and-drop creation of UIs.

Furthermore, Meticube's .NET implementation provides a range of tools and add-ons, like an Activity Management Extension Kit (EK), based on CEA 2018, a Load Balancer for deployment of the UCH in cluster / cloud environments, and a "UCH Workbench", a graphical tool that supports the development, installation, configuration, operation and control of UCH driven systems and applications, from small local installations up to large scale deployments with thousands of UCHs operating in parallel.

VICOMTech provides three EKs. First, a MS Windows Media Center (MCE) Extension Kit that allows to use MS MCE both as Target and Controller. The Avatar EK allows designing and deploying UIs that incorporate 3D avatars in combination with speech driven interaction. Last but least, a Video Conference EK provides support for UIs that integrate video based user interaction, both on the Controller and Target side.

From Czech Technical University comes the UITV EK. Its purpose is the rapid development of UIs specifically designed for usage in conjunction with TV sets. UITV also features configurability and dynamic rendering of UIs.

Finally, C-LAB GmbH from Germany provides a simple but efficient GUI Tool EK solely based on JavaScript.

A large number of additional resources are available, such as several UI Protocal implementations, e.g., URC-HTTP modules, TAs for ENOCEAN, MonAMI residential gateway (including ZigBEE), google calendar, PICASA, Windows Media Center, etc.

3 Injecting the URC Ecosystem

During the course of the project, i2home [3] provided parallel running EU-funded projects, such as, the VITAL [5,11] and MonAMI [4] projects with access to the URC implementation. In fact, MonAMI's field trials (50 flats) include the i2home URC implementation. But also industry has started showing interest in the URC technology and so at this year's CEBIT, German Telekom demonstrated their Universal Service Gateway (USG) where the URC technology serves as a middleware for three different UIs (in car, PC-based and mobile-phone based) within a traveling scenario. In addition to India and the US, we also observe an adoption within academic research in Australia. Accumulated, we count projects using URC technology with about 120 partners and EURO 100 Mi, see figure 2.

This has encouraged us to initiate the international OpenURC Alliance, see `http://www.openurc.org` as an international platform for fostering the ecosystem that will be necessary for broadening the knowledge about and usage of the URC technology. The OpenURC Alliance provides a meeting place for different stakeholders interested in this technology.

A key objective of our strategy is to avoid "reinventing the wheel". Hence, the openURC Alliance is seeking cooperation with complementary standards as much as

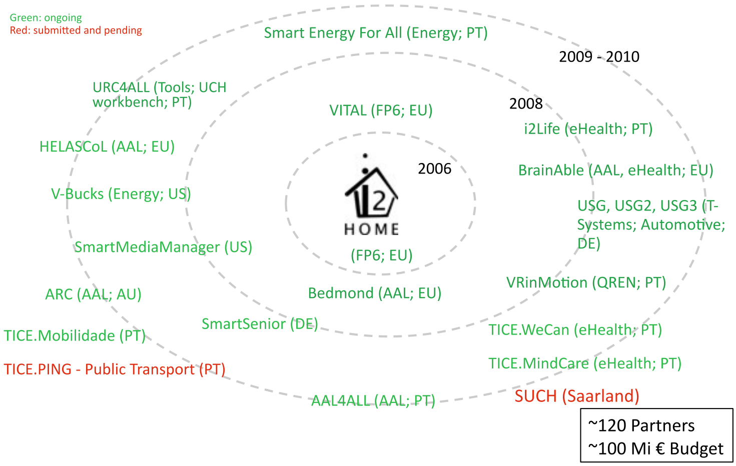

Fig. 2. International projects using URC technology.

possible. For that purpose, the Alliance is developing relations with a series of other standardization initiatives.

4 Structure and Timeline of the OpenURC Alliance

At the time of writing, the OpenURC Alliance consists of four Committees:

Governance: Here, the work consists of structuring the alliance as a whole. Also, work includes the writing of membership rules and By-Laws. We have developed four different membership categories: “Charter”, “Core”, “Associate” and “Basic” which all have different benefits. Additionally, experts might get invited in order to resolve or work on some issue(s).

Marketing: This committee develops material for presentation and marketing, organizes presentations at conferences and fares.

Technical: The technical committee further develops the URC technology by producing technical documents and perform standardization work. This committee also maintains open-source reference implementations and technical documentation of the URC standard, see section 5

User: We are currently developing a fourth committee called the User Committee whose purpose is to add to the alliance the perspective of the users, such as ethical considerations and how to execute user-centred design for persons with special needs, e.g., within gerontological scenarios. An important topic will be to host and develop personas [1].

4.1 Time Line

The OpenURC is already up and functioning as an ad hoc group performing meetings on weekly or bi-weekly basis. We are targeting a launch of the OpenURC Alliance as a non-profit legal body within 2011. The launch of a new web site is planned for late 2010. We are currently moving the content of the current Universal Remote Console Consortium web site `http://myurc.org` to the web site to the new new OpenURC Alliance web presence `http://www.openurc.org`.

5 Current and Future Technical Work

The OpenURC Technical Committee is working on technical specifications that provide precise descriptions of implementation aspects of the URC ecosystem. Examples of these technical specifications are the UCH specification, the URC-HTTP protocol specification[5] and the resource property vocabulary[6].

For an ecosystem to be fully functional, various tools need to be available for authors, publishers and installers. Plans for the development of various tools are being pursued in existing projects and projects that are being applied for. Examples of such tools are URC runtime support for Android, plug-ins for mainstream application development frameworks and workbenches like Eclipse, MS Visual Studio and Flex and diagnostic and reporting tools, just to mention a few.

We are currently working on an integration of the URC technology into the Web service world. Here, the goal is to allow for the design of personalized user interfaces and their substitution as web service front ends. Here, RESTful services and a WSDL interface play an important role.

Another vital challenge is the standardization of user interface sockets. Currently, an author can design their own user interface socket as needed. This results in different sockets for targets that may have many functions in common. Possible solutions is to publish "upper models" of prototypical sockets that can be used as a basis for new sockets. Extensions can be modelled by inheritance.

6 Conclusion and Outlook

We have argued and showed that the Universal Remote Console approach should play a role in any framework that takes accessibility seriously in the area of ICT. The URC approach provides an open standards-based fundamental functionality for any framework or platform where the diversity of users are to be supported and where accessibility is addressed. In order to provide a platform for different stakeholders within the AAL community to communicate and collaborate in this area, we are starting the OpenURC Alliance. The Alliance will provide a meeting place for providing information about the URC, exchanging ideas, meeting other stakeholders interested in the URC technology and, finally, manage open source resources.

[5] http://myurc.org/TR/urc-http-protocol2.0/

[6] http://myurc.org/TR/res-serv-http1.0/

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universAAL – An Open and Consolidated AAL Platform

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[6] CNR-ISTI Consiglio Nazionale Delle Ricerche

Abstract. Due to the demographic development towards an ageing society AAL technologies will play an important role in the future. There has been a lot of work done in the field of AAL, but most of the project outcomes are proprietary and thus impossible to be combined. Accordingly, there is a need for an universal and open platform, which can be used as a starting point for further developments or just as an integration and standardization tool. For future service platform related research projects reference use cases as well as a reference tool set and framework would help to ensure a reusable and expandable platform, which is wide spread and therefore ensures a quality of service. The aim of the universAAL project is to combine the advantages and strengths of still ongoing or already finished research projects to create an universally applicable platform. The focus thereby is on interoperability and standardization to ensure a broad range of applicability and to develop an open platform that will make it technically feasible and economically viable to develop AAL applications. There are two tools for spreading the outcomes and ideas of the project planned: On the one hand the establishment of a store providing plug-and-play AAL applications and services that support multiple execution platforms and can be deployed to various devices and users, and on the other hand the AAL Open Association (AALOA) with the mission to create a platform for identifying key research topics in AAL, and to reach agreement on prioritization of these and to design, develop, evaluate and standardize a common service platform for AAL.

Keywords: AAL platform, interoperability, open source, reference architecture, platform consolidation.

1 Background and Motivation

Recent European population projections have underlined demographic developments towards an "ageing society". A challenge of the future is "ageing well at home" assisted by technology, while maintaining a high degree of independence, autonomy and dignity. Ambient Assisted Living (AAL) technologies try to follow this objective by integrating intelligent assistance-systems in people's homes.

Looking at the AAL solutions currently offered, one can find different proprietary and non-standardized solutions. There are solutions like home emergency call systems designed as capsulated alarm systems, domotic sensors for in house light control or very specified interfaces to single devices. A lot of these proprietary and single solution devices and applications can only be combined to a more comprehensive solution with a lot of technical development effort. Data formats as well as protocols are mostly incompatible and simple adaptations and integrations need the knowhow of an IT specialist or system integrator. which leads of course to high costs for the user himself. Often components like sensors or different functionalities have to be installed and paid multiple times, because systems are proprietary and only work if distributed as complete package [1].

Additionally, AAL is an application domain with a lot of overlapping subdomains, like the eHealth domain, the home entertainment domain, the home automation domain, the household appliance domain, the energy control and saving domain and many more. Accordingly, the AAL domain has to deal with conflicting versions of standards as well as conflicting implementations thereof. Furthermore, existing standards, like the ISO/IEEE 11073 standards for domotic sensors, have so far not been used and implemented in many applications and cases. Thus, there is little experience regarding missing parts and, overall, not many lessons have been learned from usage. Consequently, there are not many examples to show how to implement these standards in practice. Of course, there is also a lack of standards in some fields of AAL applications like remote maintenance, terminology and ontology, emergency and alarming calls and procedures and in some extend middleware architectures etc. This lack of standards is also amplyfied by the lack of certification and also labelling processes of devices and modules in the AAL domain [2].

Ideally, AAL applications and technologies should be based on a middleware, which is open to the public and which works as an intermediate layer between the operating system and the application itself. The middleware has to be adaptable in terms of services that can be implemented. Furthermore, it should be flexible and freely configurable to consider user needs in the development of applications and user interfaces. Moreover, it should be a good starting point for rapid development of applications and services; making the development process more cost- and time-efficient. A realization as an open source project would help to spread it in a big community, with the benefit of increased reliability and security in all development stages. To ensure the usage of the platform, the architecture should be open and adaptable to other overlapping domains of services and applications. This would overcome interoperability problems of many stand alone solutions currently available. Furthermore, all services must be able to be easily controlled and maintained, which could be achieved by running them in one defined framework. This will also ensure a better interoperability and quality for the user. On the other hand, a combined platform for services will also lead to a cost sharing for the different services. As an example leisure services can be financed by the end user itself, health related services through health insurances and energy controlling services through a public grant. Lastly, the platform should provide an ecosystem for a lot of different stakeholders including developers, application and service providers, research groups as well as end users of the application.

The aim of universAAL[1] is to establish exactly such a cross application platform for AAL, health, home automation, entertainment, energy efficiency applications and services. Any service based application, which is thinkable, should be realisable on this platform. Beyond that, universAAL will also provide combined and validated reference use cases, and a tool chain for extending platform capabilities. Additionally, with the universAAL Developer Depot and uStore, two tools are available that will support different stakeholders in creating AAL services and applications.

universAAL's development approach for such a platform is described in the next section; including an overview on the input projects that have been considered. Distinctive features of the universAAL platform compared to existing solutions are summarized in Section 3. Section 4 gives a concrete example of the consolidation work and establishes, as a first result, universAAL's layered architecture. In Section 5 the consolidated Reference Model is described, which is another result of the first iteration of the universAAL consolidation process. Section 6 introduces the AAL Open Association (AALOA), which is universAAL's idea to establish a technical AAL community and ecosystem. The last section concludes with a summary and outlook. Since universAAL is an ongoing project all results presented here must be considered as intermediate results that might change during the course of the project.

2 Development of an Open AAL Platform

Fortunately, some already finished or nearly finished mostly public-funded AAL projects have already tried to tackle some of the issues derived above. Apparently though, no solution has been able to overcome all the relevant issues including the initiation of an active technical AAL community. Therefore, universAAL's goal is to tackle all of these issues resulting in a combined flexible, interoperable platform based on standards, which can be adapted and extended through a modular architecture.

In order to do so the universAAL platform will be based on different approaches from various input projects (either still running or already terminated) combining several aspects, advantages and learned lessons that emerged so far [5]. Some of these input projects are described in the following sections.

[1] http://www.universaal.org/

2.1 The Input Projects

AMIGO

The AMIGO[2] architecture follows the paradigm of Service Orientation, which allows developing software as services that are delivered and consumed on demand. The components in the AMIGO Open Source Software can be divided into three main parts (the Base Middleware, the Intelligent User Services and the Programming and Deployment Framework).

The aim of application development has been to extend the home environment for both interpersonal communication and shared activities, using the generic AMIGO platform (Middleware and Intelligent User Services). Two subdomains have been addressed: the Ambience Sharing, Social Radio and parts of the Feeling @ applications are oriented towards new forms of interpersonal communication, whereas the Activity Sharing, Board Game and Feeling@ sketch sharing applications provide means for sharing activities with remote people.

The main benefit of the AMIGO project for universAAL can be the provision of seamless interoperability of services and applications. Furthermore, user requirements study results could be used as an input while AMIGO OSGi bundles and some service components can potentially be used for the universAAL platform implementation.

GENESYS

GENESYS[3] [6] has been a FP7-STREP project, which has provided a cross-domain architectural framework for embedded systems development that can be instantiated for different application domains (e.g. consumer electronics, mobile systems, automotive, avionics, industrial control). As a candidate for the ARTEMIS European Reference Architecture for embedded systems it has been designed to meet the requirements and constraints that are defined within the ARTEMIS Strategic Research Agenda [7]. The development of GENESYS has been driven by a list of challenges of embedded systems design: composability, networking, security, robustness, diagnosis, maintenance, integrated resource management and evolvability.

The design principles of the GENESYS architectural style facilitate the development, certification and integration of robust systems that are composed of several individually developed subsystems. The main benefit for universAAL and the specific concerning the other projects is solid formal specification of requirements for distributed systems.

OASIS

The characteristic of the OASIS[4] platform is an architectural development based upon ontologies and semantic services, which allow plug and play and cost-effective interconnection of existing but also not yet existing new services domain comprehensive.

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[2] http://www.hitech-projects.com/euprojects/amigo/

[3] http://www.genesys-platform.eu/

[4] http://www.oasis-project.eu/

The approach of OASIS is simple in conception: direct reusability of information is to be provided across heterogeneous services and devices. In order to achieve interoperability of services and sharing of contextual information between different services and objects, it is necessary to model them first, by extracting each services individual structure up to its most primitive level. In current approaches, this can lead to more or less ad hoc solutions. The OASIS solution is to provide foundational ontology components, specifically tailored to the requirements of the applications to be covered and the services provided.

The benefits for universAAL can be that OASIS can provide a comprehensive view of the interoperability between services and applications as well as an excellent background in the integration of different application domains.

MPOWER

MPOWER[5] is based on service oriented architectures (web services, WSDL and SOAP) and uses no semantic services or ontologies. That in itself is an interoperability enabler, as the web service front ends allow heterogeneous platforms to interoperate (e.g. .NET and Java). The platform consists of several middleware building blocks with coordinated interfaces based on the IBM Service-Oriented Architecture (SOA) approach.

MPOWER has done a lot of work in applying software engineering methods and tools. The architecture is based on a good described method by IBM. The modelling and software creation follows defined processes based on tools and established technologies like Enterprise Architecure, Netbeans and the Glassfish application server. The aim has been to not only provide the platform but making it also feasable for developers to reuse and extend the platform with new services through a Model Driven Architecture approach. A lot of this toolchain can be reused in universAAL.

MPOWER has also tried to integrate standards. Thus the medical and information data sharing has been implemented through HL7 and the sensor connection has been realized with a so called Frame Sensor Adapter which has implemented the ISO/IEEE 11073 standard.

There is one central database for each MPOWER platform. These specifications lead to the fact that there is only one physical server for a particular MPOWER platform installation where all components are hosted and provided. This coordinated approach avoids many interoperability problems which automatically arise when different systems are used in a distributed environment. In contrast, a central installation on one server makes it difficult to adapt the modules to their special requirements in runtime, e.g. the hardware or software environment. For installation and integration of course the all in one installation is a benefit and makes it easier to setup.

PERSONA

The requirements of PERSONA[6] have been to put the platform focus on an open distributed selforganizing system that evolves over time according to individual

[5] www.mpower-project.eu

[6] http://www.aal-persona.org/

needs as they arise. Therefore PERSONA also uses semantic services. The platform modules have been structured in a way that individual parts can be improved and substituted. The PERSONA platform is based on a distributed architecture based on a bus communication system.

The PERSONA platform comprises the PERSONA middleware and a set of mandatory functional components consisting of a context history storage, a situation reasoner, a profiling component, a dialog manager, a service orchestrator, a gateway, and at least one I/O handler.

Benefits for universAAL can be the whole conceptual design of AmI systems as self-organizing systems with the appropriate UI framework and a set of mandatory platform components.

SOPRANO

The SOPRANO[7] technical core is SAM, the SOPRANO ambient middleware, which is installed in each home and provides its intelligence by receiving user commands and inputs from sensors, enriching them semantically and providing appropriate reactions via actuators in the house (more on SAM can be found in [9]).

SOPRANO uses a very straigth forward reflection of *sensing* ⇒ *reasoning* ⇒ *acting*. This has been achieved through a scalable but still configurable solution and an intelligent and modular approach of configuration. Accordingly, SOPRANO works on different layers of abstraction. This enables devices to work on a rather low semantic level, whereas administrators can set up procedures on a fairly high semantic level. The SOPRANO ambient middleware mediates between these abstraction layers.

Additionally, SOPRANO is an ambient system, i.e. it primarily works in the background by understanding the current situation in the house via the connected sensors and influencing it via the connected actuators. Thus, the focus of SOPRANO is different to many design projects, since it assumes that the system is not necessarily driven through user input. Ambient system behavior is achieved by a set of procedures that provide the intelligent reactions of the system to certain situations. These procedures are defined by domain experts. Therefore, the behavior of the SOPRANO system does not stem from a black-box inside the system, but the system will deterministically react according to the rules that are manually entered. As a consequence, SOPRANO is self-learning only in well-defined borders (i.e. it does not change its rules autonomously) to ensure its reproducible behavior.

2.2 The Consolidation and Development Approach

In order to achieve a high acceptance of the emerging open AAL platform, the results of several input projects and standards are consolidated into the universAAL platform. Most suitable architectural designs and components are selected for universAAL to obtain an optimal solution and to reduce the effort of development compared to implementing a completely new platform. Unaddressed open

[7] http://www.soprano-ip.org/

issues within the input projects are identified and can be solved by the adaption of solutions of other projects or by finding a new solution. The process of consolidation and development in universAAL - presented in figure 1 - is an iterative approach that consists of four phases: Analysis and Consolidation, Design, Implementation and Standardization, and Evaluation. These phases are described in detail in the following:

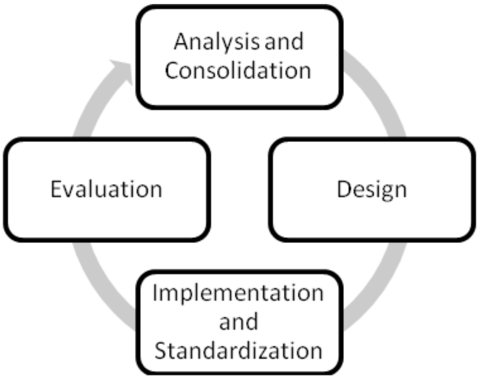

Fig. 1. Process of consolidation

- In the *Analysis and Consolidation* phase existing AAL platforms from the input projects and standards are analyzed and compared. Architectural designs of the different platforms are mapped to the universAAL reference model. This allows a conceptual comparison of heterogeneous architectures, while strengths and weaknesses of different concepts are determined. Furthermore, use cases covered by each platform are merged and the implementations of software and hardware components are ranked based on the requirements they fulfill.
- During the *Design* phase the universAAL reference architecture is designed. Architectural decisions are based on the results of the analysis step, while the obtained ranking criteria for components help to select existing components for the reference architecture. This phase especially targets interoperability between platforms and components.
- The *Implementation and Standardization* phase implements the platform middleware, services and tools. It has a special focus on the reuse of existing implementations from input projects. Thus, the main effort can target at the development of new innovations.
- Within the *Evaluation* phase the reference architecture and the implementation of universAAL services and tools are verified and validated in order to comply with the requirements. The results of the evaluation are input for the next iteration of the consolidation process.

3 Benefit of the Project

The vision of the consortium of the universAAL project is that it should be as simple for users to download and setup AAL services as it is to download and install software applications on a modern operating system. universAAL will establish a store providing plug-and-play AAL applications and services that support multiple execution platforms and can be deployed to various devices and users. Finally, the allocation of local human resources is also supported in the store.

Seen from the end user's view, universAAL provides the uStore, which gives the end user (elderly users or their care providers) a simple way to find and acquire AAL services. The uStore provides a service that can consist of software, hardware, and human resources (service providers). By acquiring an AAL service, required software (applications and device drivers) will be deployed to the user's hardware, access will be provided to required remote software services, and agreements will be made with (local) service providers to reserve required human resources both for deployment and use of the service. If necessary, new hardware will be ordered and installed in the end user's residence. While in some cases the end user or their care providers can download and install the services themselves, in more complex cases (typically involving hardware installation) the service provider will be involved in the installation (either guiding the installation remotely or at the installation site).

Seen from the developer's point of view, universAAL produces several results, which simplify the development and marketing of AAL services. Through the Developer Depot, the developer can find development tools, reference architectures, and guidelines which simplify and streamline the development of AAL services. Also, the depot links to facilities for hosting the development of AAL services in teams, and for sharing models of (public parts of) the AAL services in the wider community. Through the uStore developers can deploy and sell their AAL Services or make them available for free to the users.

Considering this, universAAL is different from other AAL platform projects, since it focuses on dedicated tool support for different stakeholders as well as on building of communities and provision of an open service platform.

4 Consolidation of universAAL's Layered Architecture

Towards consolidation of the universAAL's layered architecture, universAAL compared the layer models of the input projects along with the universAAL Description of Work (DoW) [10] in a common diagram (see figure 2).

This work revealed that the model used in universAAL DoW and the models introduced by GENESYS and PERSONA are very similar. Furthermore, most of the other layer models have a good mapping to these models. The alignment lines in the figures were added to help to visualize this mapping.

Based on the mapping between the layer models of the input projects, the consortium has designed a first version of the universAAL layered architecture

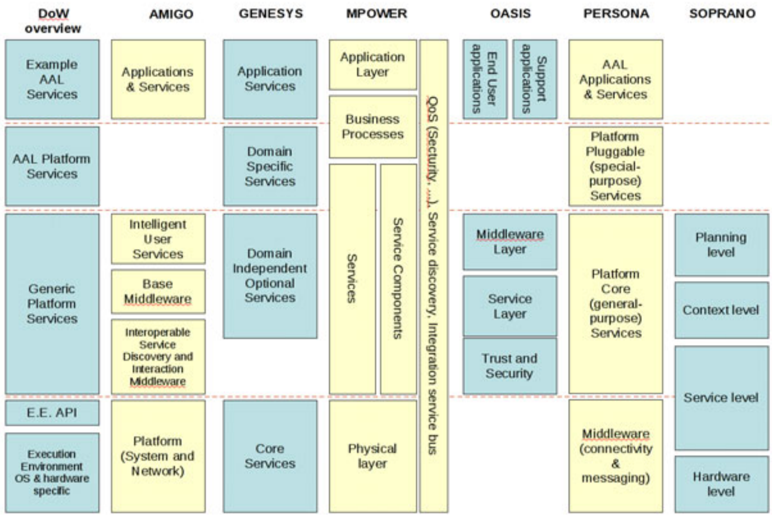

Fig. 2. Consolidation of layer model

mostly based on the GENESYS and PERSONA project. The platform is divided into four layers, namely the Middleware, the Generic Platform Services, the AAL Platform Plug-Ins and the AAL Applications and Services.

The Middleware layer is assumed to extend the native system layer of the different physical nodes participating in an AAL system and hence hide the distribution of these nodes as well as the possible heterogeneity of their native system layers. In addition to that, this layer is supposed to act as a container for integration of all components from the above layers and facilitate the communication among them.

The Generic Platform Services layer provides basic platform services, like context management, service management, and a framework for supporting complex user interactions.

On the AAL Platform Plug-Ins layer special platform services can be introduced to extend the basic functionality. This might be needed in case high-level services have specific demands on, for example, data-mining of context reasoning.

The AAL Applications and Services layer encapsulates all applications and services that directly provide support and assistance to the end user.

5 The Consolidated Reference Model

To understand the consolidated Reference Model the universAAL project team has created graphical representations of concepts and their interrelationships within concept maps which are assumed to help different types of stakeholders to quickly learn about the understanding of the AAL domain based on which universAAL started to work. The set of concept maps representing this understanding reflects the "spirit" of the input projects.

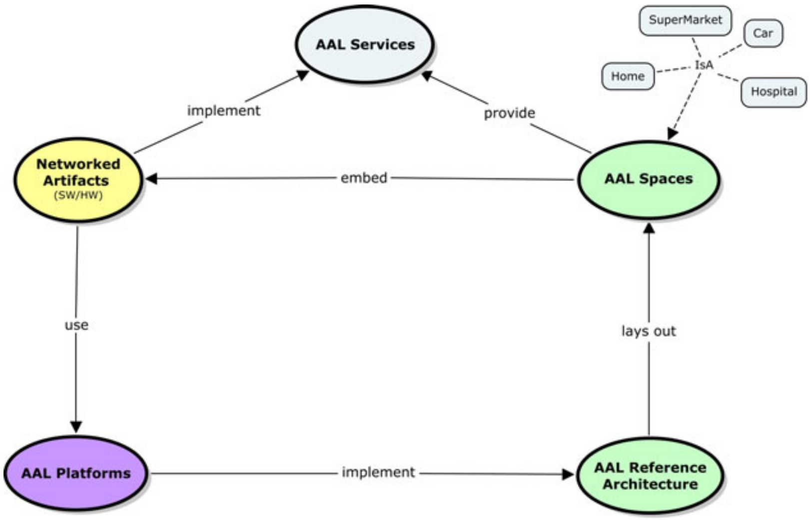

Fig. 3. The Root Concept Map of the universAAL project

The *Root Concept Map* - see Figure 3 - presents the consolidated understanding of AAL systems in a single picture using the fewest possible set of concepts. AAL systems are all about the provision of *AAL Services*. The importance of ambient technologies in the provision of such services is highlighted by putting the concept of *AAL Spaces* and the underlying technologies (*Networked Artefacts*) right in this top level. The *AAL Reference Architecture* and the compliant *AAL Platforms* incorporate the engineering challenges beyond single technologies towards reconstructable infrastructures. The *AAL Reference Architecture* identifies the basic building blocks necessary for constructing an *AAL Space*, such as *Home, Supermarkets, Cars or Hospitals*. Such an AAL Space provides *AAL Services* with the help of embedded *Networked Artefacts* that implement (or contribute to the implementation of) those AAL Services. The cooperation between Networked Artefacts distributed in an AAL Space is facilitated by an *AAL Platform* that implements the previously mentioned reference architecture in order to provide resource sharing and let users experience an integrated world easy to interact with based on natural communication. The concepts from the root concept map are further detailed in six second level concept maps.

One of these concept maps tries to clarify the notation of the term *service* and the relation to an AAL service and the *Service Component* which is a software component, e.g. a Web service or a plain old Java objet, which provides a set of service utilities in the virtual realm. And on the other hand the *Service Utility* which represents a utility in virtual realm, such as an exported method of an object or an exported operation of a Web service, which makes it possible to utilize a service from within the virtual realm. A service utility may directly trigger the process of providing the underlying service or just lead to an arrangement for starting the process at a later point in time.

A domain-specific context of AAL service - which is presented in another concept map - helps to better understand the essence of these services as well as the different interests and concerns that various individuals or organizations might have in providing or using such services.

In a domain-specific context of AAL services the stakeholders are of big interest. For universAAL especially the technical stakeholders. For this purpose, we first emphasize that the networked artefacts referred to so far comprise both, networking enabled hardware nodes and software components loadable by certain types of such hardware nodes. This helps to identify manufacturers (as producers of hardware) and developers (as producers of software). We also highlight that setting up a complex AAL space consisting of specialized hardware and software requires certain expertise and knowledge about the available hardware and software. The stakeholders that have this expertise and provide the service of setting up AAL spaces by using appropriate artefacts are called deployers. Manufacturers, developers and the deployers have to work under the boundary conditions defined by the Authorities.

Ambient Intelligence (AmI) is the science of creating intelligent environments. And, as AAL Spaces are supposed to be smart environments, we can make use of progresses made in AmI for further understanding the characteristics of AAL Spaces. These characteristics have been analysed a *Smart Environment*. According to AmI, this setup is expected to result in characteristics, such as context-awareness, personalization, reactivity and pro-activity in smart environments. That is, smart environments must provide support for acting in a context-aware and personalized way so that responses can be considered to be adaptive. Reaction and pro-action are the two examples of adaptive response that must be emphasized in order for smart environments to live up to what AmI requires. Experience shows that the quality of these four central characteristics can be improved if some sort of reasoning backs them. A supplementary concept map highlights the notion of sensor and actuator always referred to in the context of AmI. However, we would like to emphasize that in addition to sensors and actuators, there are also I/O devices realizing channels between the physical world and the virtual realm that aim at facilitating the interaction between smart environments and humans. This helps to highlight natural interaction as one of the major criteria posed by AmI.

The concept of middleware, which is a central concept for the development of the universAAL platform, has been described in another concept map. It highlights the importance of providing for mechanisms that allow distributed and heterogeneous networked artefacts to interact with each other. The middleware is understood as a software component, which ideally resides on all of the networking-enabled nodes. It provides common interfaces that facilitate the integration of other software components and the communication between them. As the middleware hides the distribution and heterogeneity of networking-enabled nodes, developers of software components need not care about the whereabouts of resources they need.

6 universAAL and the AAL Open Association (AALOA)

Since universAAL aims to develop an open platform that will make it technically feasible and economically viable to develop AAL applications it also is in the interest of the project to support the platform after the project end. This can best be done through an independent, non-profit association open to individuals, institutions and industry with a clear process definition to join the organization and to be nominated for the various elective offices. Such an "ecosystem" of users and developers has been established around the universAAL platform with the AALOA (AAL Open Association) to ensure continual support and ongoing refinements.

The mission of the association will include provision of a shared open framework for developers, technology and service providers, research institutions, and end-user representatives to discuss, design, develop, evaluate and standardize a common service platform in the field of AAL, where the framework - as a combination of resources, tools and people - is supposed to facilitate concluding provisions both inside and outside the association. Furthermore it aims to identify key research topics in AAL, and to reach agreement on prioritization of these and to design, develop, evaluate and standardize a common service platform for AAL.

To reach this goal AALOA invites everyone to participate in the activities of the association, to bring fresh ideas, to propose workshops and projects, and to contribute actively to the growth of the association. For universAAL, the role of the association will be to promote, support and continue the work initiated by universAAL - even after termination of the project itself. Since AALOA has been founded as an open association it is serving as a consortium for various projects and involving individuals as well as organizations, and is forming an AAL community with broad involvement from all types of stakeholders. AALOA is intended as an invitation to join in the mission of bringing together the resources, tools and people involved in AAL in a single forum, making it much easier to reach conclusions on provisions needed to design, develop, evaluate and standardize a common service platform for AAL.

The not-for-profit organization AALOA is being structured as a federation of projects. Projects are supposed to be organized by a project management committee that is autonomous with respect to the association's governing board, which uses the best practices of open source communities. Additionally an Advisory Board composed of industry and user communities is organized in working groups whose duty is to advise AALOA's open source community about emerging technical and market challenges. As a not-for-profit organization its costs are covered by donation and sponsorship.

To establish a technology neutral platform AALOA looks for the best technological solution independent of the interest of any technology provider. It should be transparent regarding the technological solutions provided and promoted and in respect to the governance and strategic choices. Member of a research project can release a piece of software using an open source license. Academics can help by proposing PhD theses, or by having students develop and release code for the association. Industry can advise the adoption of standards, provide marketing insight or contribute with code. All supporters can help by creating liaisons with other communities, organizations and research projects.

The first step in making the Association a reality will be to issue a manifesto. This call for action will declare the intention of consolidating efforts in the AAL field in order to reach real AAL breakthroughs, and call for foundation of an open association - with a first definition of its proposed structure and open source policies. It will invite active participation in formation of the association. As the association grows, the manifesto will be updated to reflect new developments in the AAL field, and evolution of the association itself.

To overcome the problems hindering progress in the area of AAL the signatories of the manifesto consider that the time has come to find a common solution for transcends individual projects or organizations. It needs a long-term approach, with broad involvement from all types of stakeholders. This manifesto is intended as an invitation to join us in our mission, which brings together the resources, tools and people involved in AAL in a single forum that makes it much easier to reach conclusions on provisions needed to achieve AAL progress. All technology providers, service providers and research institutions involved in AAL should either be directly involved in AALOA or aware of decisions it promotes. Especially end user representatives will be involved in all work of AALOA.

As a few projects and standardization bodies have also expressed an interest in joining AALOA, it seems that we have come a significant step closer to the vision of an universal platform. Parallel to working on community building, there is a clear and present need to convince the technological industry of our vision. Only when the industry is ready to develop products and services based on a common platform AAL and AmI will really get their first chance for having success.

7 Summary and Outlook

Today many implemented solutions for AAL applications in residential houses as well as smart home applications are proprietary solutions. Future developments should be developed and designed in a way that they can be integrated and combined with existing solutions and products. Therefore, the interests of the end users but also of the developers and service providers have to be taken into account. Although there have been a lot of AAL projects and a lot of prototypes of AAL applications exist, the integration to adaptable and reusable complete solution has not been found yet.

The universAAL project aims to combine lessons learned from eight FP6 and FP7 AAL research projects and to provide an open and adaptable framework for all kinds of AAL, eHealth, social services and energy saving services. Additionally, the project will establish a community for all relevant stakeholders with the aim of delivering a sustainable platform also over the project runtime itself.

Since universAAL aims at providing the open AAL solution framework to be reused in other projects, all interface descriptions and components are open source. We hope that the reuse of universAAL results in other projects could ensure a sustainable use of research funding and is able to speed up the process of rapid development of adaptable and individual AAL solutions.

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Towards a Unified Ambient Assisted Living and Personal Health Environment

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Abstract. Due to the changing demographics, residing and being cared in the own familiar environment is becoming the more attractive alternative for an ever increasing portion of the population in contrast to an institutionalized inpatient setting. Despite its tremendous market potential, AAL (Ambient Assisted Living) is still on the cusp of a mainstream break-through. A lack of viable business models is considered almost unanimously to be the greatest market obstacle to a broad implementation of innovative AAL systems. This paper highlights possible explanations for this deficit and shows why the AAL community has yet to arrived at joint solutions based on a unified AAL reference platform. Furthermore, this paper describes the enormous potential of AmI and AAL, as the first real opportunity for their success is provided through universAAL and AALOA.

Keywords: Ambient Assisted Living, Ambient Intelligence, market potential of AAL, business model, self-organization, software infrastructures, AAL reference platform, standardization.

1 Demographic Challenges and Technology Concepts

Delivery of social support, health and care services will be increasingly affected by ongoing socio-demographic and economic developments in all European countries. In particular, the fraction of individuals aged 60+ is continuously growing. While aging is not generally associated with need for care, however, this portion of the aging population is increasingly dependent on assistance, support and medical care. 96 % of individuals aged 70+ have at least one medical condition requiring treatment while 30% have five or more [3].

In future, this (multi-)morbidity will lead to massive costs for care giving while the shrinking younger population will be even less capable of caring for the older generation: On one hand, financial resources to cover care giving costs will continuously decrease, on the other hand, the lack of qualified caregivers (shrinking workforce) will continue to grow. Simply put, the intergenerational pay-as-you-go pension plans in Germany and Europe will be no longer practicable in their current form. It is obvious that future demands for social support, health and care services can only be satisfied with supporting application of technology.

Since the early 90s, terms like “Smart Home”, “Intelligent House” or “Intelligent Living” mark concepts for communication and computer-supported cooperation among components, devices and systems of home automation (appliances, heating and air, etc.), which normally operate independently in a private household [1]. Fundamentally, the use of resources like energy and water is consequently minimized while the inhabitants’ comfort and security are increased. In addition, support for independent living is provided especially for older individuals who may be limited in their mobility, cognitive abilities and/or motor skills. Following the needs of particularly elderly users, inclusion of health-related or medical aspects and applications is frequently seamless, various motivational or usage aspects of “intelligent” environments often overlap. This can be illustrated e.g., by the real life example of automatic opening and closing of windows and blinds that – in combination with turning on and off lighting – increase the overall comfort level of inhabitants as well as the home’s security level by reducing the chances of burglary. Further combined with adequate control of heating and air condition, home energy savings are increased, and, last but not least, preconditions for ill or handicapped individuals to remain living in their own private surroundings are like-wise improved [2].

Due to the cost and resource problem, but also reflecting changing lifestyles preferences, the idea of living and being cared for in one’s accustomed home environment versus as an inpatient in a treatment facility is becoming increasingly attractive for a growing number of affected individuals [4]. Opinion polls reveal that elderly individuals prefer to remain in their accustomed living environment for as long as possible, even in the eventuality of increasing reliance upon assistance services and caregivers [5].

These findings have motivated a number of recent research projects providing prototypical singular solutions. In particular, they motivated the exceedingly complex, highly dynamic information and communication technology domain usually referred to as “Ambient Assisted Living” (AAL). In the last years, AAL has developed to a decisive paradigm for the scientific and market-oriented research aiming at the aging population. While there is no functioning market for AAL applications yet, related marketing activities now appear to be ready to start.

2 Limitations of Isolated AAL and Personal Health Solutions

A lack of business models to motivate cooperation between ICT developers, service providers, medical device manufacturers and housing industry is almost unanimously named as the greatest market barrier to a broad implementation of innovative assisted living systems [6]. This deficit is caused by the high costs of singular solutions which dominate current practice. Their very unfavorable cost-effect ratio is shown in a BMBF-sponsored study of AAL market potential and development opportunities. For cardiac insufficiency (heart failure), e.g., costs of 17,300 Euros per additional year of life expectancy were calculated [7].

Elderly individuals, however, particularly those in need of care, usually have not one medical illness or deficiency requiring compensation, but rather are confronted with numerous, sometimes mutually exacerbating symptoms and medical requirements [3], which regularly coincide with multiple restrictions in everyday life that motivate additional assistive functionalities. Hence the only realistic option to minimize overall costs is to cover the aging person's entire clinical picture and individual needs by a unified extensible system. Thus really enabling to keep individuals remaining longer in their home, related savings for extended nursing home stays (room and board, care and supervision) can be included in the overall tally. To create an adequate system platform, existing singular applications and products must become part of this overall solution, albeit considerable effort and expense.

Currently dominating singular solutions use incompatible data exchange formats and protocols, the components of one application cannot be used by another without modification. Configuration by an expert system integrator is required to combine new and existing partial solutions, thereby making the total end solution prohibitively expensive [8]. Additionally, using combinations of singular solutions that are only available as complete packages, it is evident that sensors and other hardware components, as well as individual functionalities, must be frequently installed and paid multiple times. Fundamentally, current AAL solutions, such as building infrastructures with sensors and actuators, require detailed planning and installation by specialist experts. This level of expertise required significantly contributes to the high costs currently prohibiting a successful market launch. In general, singular solutions are too expensive for private buyers as well as health and care insurance providers. The resulting costs even appear not to be acceptable for the society as a whole, also if they were shared between different payers, e.g., health and care insurance, state / public social system, and self-paying consumers / healthcare recipients.

3 Current Platform-Based Comprehensive Concepts

It is obviously essential to abandon monolithic proprietary concepts for complete, comprehensive solutions in favor of an overall approach, where various technology and service providers develop individual products that can be easily integrated into an existing platform. This very vision of complete AAL solutions was the impetus towards six Fraunhofer Institutes joining forces in 2007 to form the Fraunhofer Alliance Ambient Assisted Living [9]. However, it quickly became obvious that such complete solutions would imply conjunction of “Assisted Living” and “Personal Health” domains. “Personal Health” systems and applications were enabled by recent technological achievements like ubiquitous wired and wireless communication and information infrastructures (Internet, GSM), low cost smart devices (smartphones, PCs) and miniaturized biosensors. Besides numerous systems and applications for telemonitoring, disease and lifestyle management, “Personal Health” also indicates a change of paradigms introducing personalized, individually controlled and organized forms of prevention, diagnostics, therapy and care that complement ongoing developments towards integrating professional healthcare stakeholders by e-health infrastructures.

Accordingly, the Fraunhofer Alliance AAL was extended to 13 member institutes in November 2009. As a primary objective of the Alliance AAL the development of a unified universal modular platform for AAL and Personal Health applications to be used in a variety of future projects was identified. As motivated above, future AAL solutions supporting elderly and care-dependent persons must be based on a flexible platform that allows for modular expansions to achieve customization to the individual's needs, lifestyle and health progression. For interface definitions ensuring ad-hoc interoperability at the semantic and process levels, recognized international standards or industry agreements, in particular from the ongoing EU-IP project universAAL [10], where several Fraunhofer Alliance AAL members participate, and the Continua Health Alliance should be leveraged.

The Continua Health Alliance [11] was formed 2006 to develop interoperability guidelines for the emerging personal telemonitoring and telehealth ecosystem (see figure 1). Currently more than 200 companies and organizations, including the Fraunhofer AAL Alliance, cooperate in the definition of common Personal Health guidelines, related development and test tools based on a comprehensive set of international standards, predominantly from ISO TC215WG7 /IEEE 11073 and HL7, where members of the Fraunhofer AAL Alliance in different positions significantly contributed to standards definition and standard process administration. The organization is also increasingly active in the development of related regulatory frameworks, markets and business models.

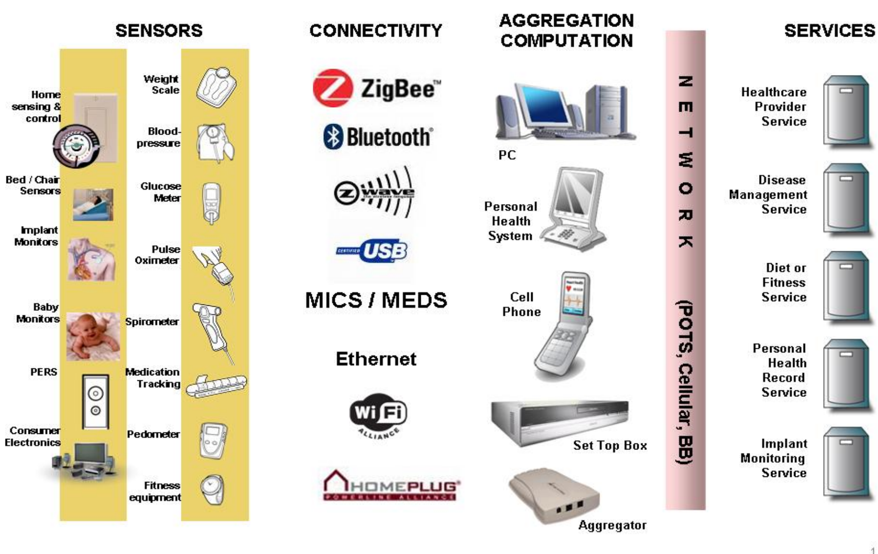

Fig. 1. The Continua ecosystem.

Continua aims to enable the alignment of different vendors and domains, focusing on management of chronic diseases outside of clinical settings, personal health and fitness applications, and last not least technologies and services for aging independently in home environments, thus clearly addressing the "classical" AAL domain. Continua-defined standard-based interoperability profiles also serve as a basis for product certification. To ensure compatibility, Continua established a certification and testing program that includes a detailed set of test specifications and testing tools so that candidate vendors can verify compliance. Additionally, interoperability events are organized to ensure that products from different vendors work together. Products that pass the certification and testing program receive certification and can display the Continua interoperability logo. The establishment of an integrative platform requires some control of creating incompatible AAL projects, where each project develops its own proprietary platform. There is an analogy in the IT domain, where only a very limited number of predominant de-facto-standardized operating systems actually come into operation.

Any additional components and devices must be capable of self-integrating into these infrastructures. Various EU projects with participation of Fraunhofer AAL Alliance Institutes already issued validated project results with a focus on dynamic distributed infrastructures for self-organization of devices, sensors and services. For instance, the SOPRANO project targets at an open platform which is flexibly configurable and customizable to individual needs in order to create a functioning market "ecology", where no single provider is developing every function and service, but different players cooperate and contribute their particular strengths. In the AMIGO project, however, a service-oriented approach and service composition techniques are utilized in a way that each component implements its own integration strategies [12]. The PERSONA Project, on the other hand, is based on a bus technology in order to connect intelligent devices on an ad-hoc basis to ensure the interoperability of devices, components and services. There is a further focus on the seamless integration of multimedia functions and the investigation of innovative interaction options for AAL/AmI environments [13].

Unfortunately, all these solutions have not achieved the desired breakthrough, although each of them provides substantial benefits as an AAL infrastructure. Hence for the current framework program the EU decided to support only one single research project developing a unified European platform for AAL systems. The universAAL project selected started in February 2010 with a total budget of approximately 15 million € and a consortium of 17 institutions from 10 countries. Within a four-year time frame, universAAL will develop an expanded open source platform with open protocols and interfaces to ensure the interoperability of sensors, devices and services along with the groundwork for respective standardization to be performed in stages throughout the project. The resulting platform shall serve as runtime environment for a variety of different AAL use cases and applications. To this end, eight of the most attractive middleware platforms to emerge in the past several years shall be analyzed and evaluated regarding important criteria like interoperability, ease of use, dynamic expansion, integration of new components and elements as well as aggregation of user interaction results and options, and shall finally with industry assistance (PHILIPS, IBM, Ericsson) be incorporated into an AAL reference platform bundling the essential benefits of the platforms mentioned above.

The project strategy encompasses an array of activities for the participation of numerous AAL stakeholders and activists. Calls for proposals combined with respective money awards shall motivate scientists and companies worldwide to develop plug-ins to promote the platform's distribution. In various project-related workshops, experts shall be consulted to early unveil deficits in the ongoing work to continuously improve the platform. Developers can find or share specifications, development tools, sample programs, and add-ons in an online developer depot. Additionally, the AAL community will be provided with AAL services through an online "uStore". The application options made available by universAAL will thus be enriched by numerous new contributions from the community, from which developers can also profit monetarily. For end users the uStore will become a kind of market hall, where they can search for suitable solutions and compare them with other users at their leisure. Utilizing the close ties of project partners DKE and Continua Health Alliance to the relevant standardization bodies, platform-related standardization should be initiated promptly. The establishment and distribution of this AAL platform with reference implementations of essential AAL basic services is the overall goal of the universAAL project. The platform will be available under "Open Source" license to enable the broadest possible use and ease further development by research and industry. This should also support simple integration of current project results and their further use in new projects. Fraunhofer as the second largest project partner acts as a driving force behind community building activities and assumes a leadership role in project-related technological activities, especially in the architectural specification of the platform and the intelligent middleware.

4 Evaluation Results in universAAL by Consolidation

The number of research projects and industrial labs dedicated to the area of Ambient Assisted Living (AAL) is constantly increasing. It becomes more and more crucial to identify reusable results in different areas of architecture, technologies, protocols, and standard building blocks. Apart from those domain-specific solutions for rather constrained scenarios, there have also been general-purpose results coming from several research projects in the field of AAL. It seems to be high time for an evaluation of significant existing solutions in order to foster the identification and re-usability of domain-independent units in an AAL environment and avoid re-inventing the wheel over and over.

Hence, universAAL decided to be a pioneer in reusing existing AAL technology by identifying and utilizing available solutions in a consolidation process. These include the results from the projects Amigo, GENESYS, MPOWER, OASIS, PERSONA, and SOPRANO, as we believe that well-founded work based on software engineering techniques has already been done in those input projects and we should benefit from it. By reusing such results, we are basically able to achieve a higher level of parallelism in several threads; work on use case and requirement analysis, design and implementation, and evaluation and feedback can be done in several (more or less) parallel threads, each collecting, categorizing, comparing, harmonizing, merging, and prioritizing one of the engineering results from the input projects that are eventually leading to several early results. The consistency and traceability of those results is then guaranteed by mapping them to each other. It turned out as more practical to use the mapping to requirements as the main utility for consistency check. That is, the consolidated set of use cases, architectural building blocks and software modules are all mapped to the consolidated set of requirements so that, e.g., the mapping between a use case and the architectural building blocks involved in its realization is derivable if needed.

The concrete steps towards consolidating reusable results in the above-mentioned parallel threads do follow a certain pattern. As illustrated in Figure 2, they mostly start with an agreement on a template to be used for collecting the underlying info while also defining a set of categories that should be used to organize the bunch of the gathered data in several smaller groups. In this way, info gathered from each input project is already forced into a harmonized frame that makes it easier to compare them with each other. The consolidation process then continues by forming a small group of interested / expert people per category that then compares and merges info in the same category coming from different input projects. This step may lead to eliminating duplicates, merging similar info into a generalized form, or even splitting complex info into several specialized sub-entries. The latter restarts this step in order not to lose new chance for reducing the number of the entries in the consolidated set.

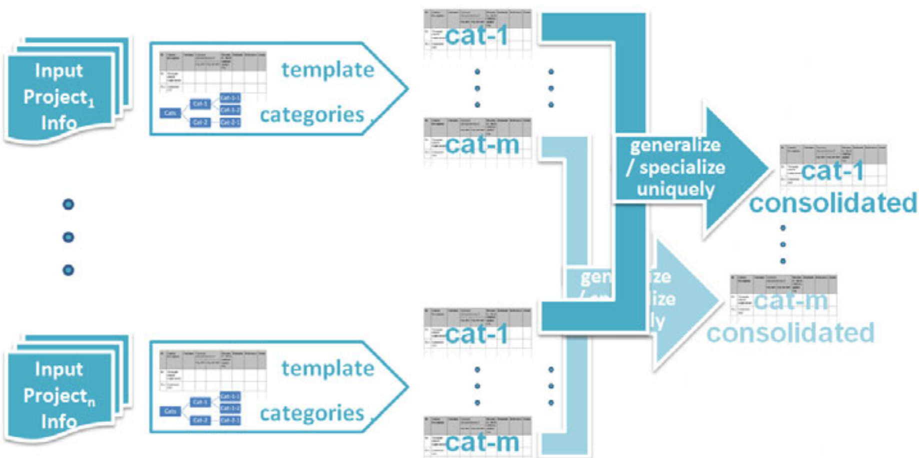

Fig. 2. The general approach for consolidation in universAAL

One of the parallel threads mentioned above is dedicated to the architectural design of AAL systems. In the following section, we provide a partial overview of the consolidation process in case of the architectural design in universAAL.

5 Examples of the Consolidation Process

Principally, there can be as many (parallel or sequential) consolidation processes as there are models. In the following, we investigate the case of a so-called System Decomposition Model at two different refinement levels, first for identifying architecture layers and then for deriving the set of architectural building blocks.

5.1 Consolidation Process When Decomposing the System into Layers

Following the consolidation pattern, the collection of the info about the logical layers in the input projects was based on a template and a set of categories. The template used was a simple table with the columns "Layer/sidecar" (the name used for the layer), "Description" (a description of what the layer does and/or contains), and "Project use" (an explanation of how this layer was used in the input project). The set of categories were simply the layers used in the universAAL Description of Work (DoW) for grouping the different sets of components comprising the runtime environment of universAAL. However, as we arranged the layers of the input projects along these categories (see Figure 3 – the alignment lines in this figure were added to help visualize this mapping), we realized that in this case, there is no need to perform the consolidation in each category separately because the resulted mapping was already very compact and allowed direct conclusions. The mapping revealed that the model used in the universAAL DoW is very similar to the models introduced by GENESYS and PERSONA. Furthermore, most of the other layer models have a good mapping to these models. Hence, these three models were used to derive the logical layers of the universAAL architecture.

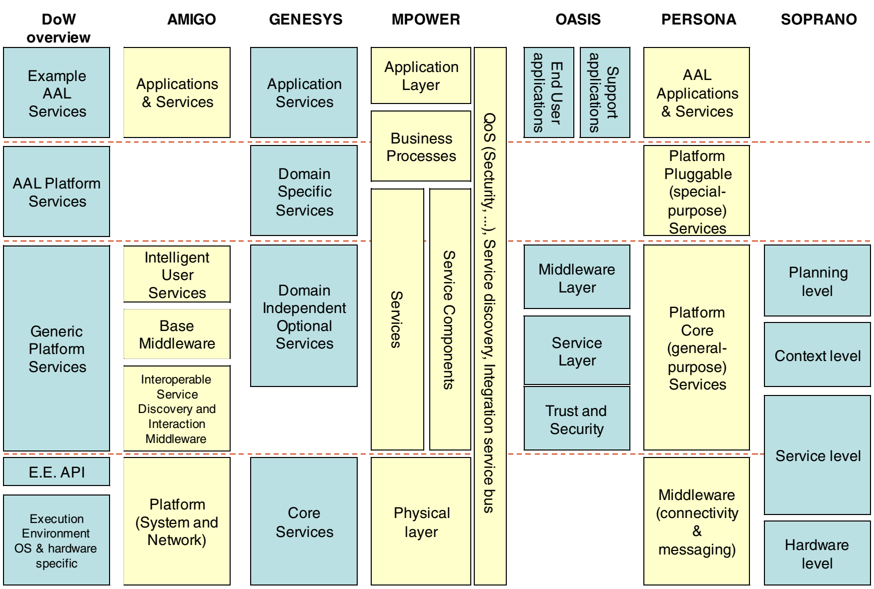

Fig. 3. Consolidation of layer models

Figure 4 shows the derived layer model for universAAL. As the focus of this paper is on the consolidation process, we avoid here including explanations about the rationale behind the selected names or the relationships between the layers and refer the interested reader to www.universaal.org, in particular the project deliverable

D1.3-B. However, as can be seen by comparing the two figures, the selection of the names has strongly been under the influence of the names used in PERSONA. It is also worth to mention that this layer model is supposed to provide a logical grouping of possible system components and should not be interpreted as a protocol stack as it is not following any strict layering but allows components residing on all layers to directly access the functionality supposed to be provided by the components on the middleware layer.

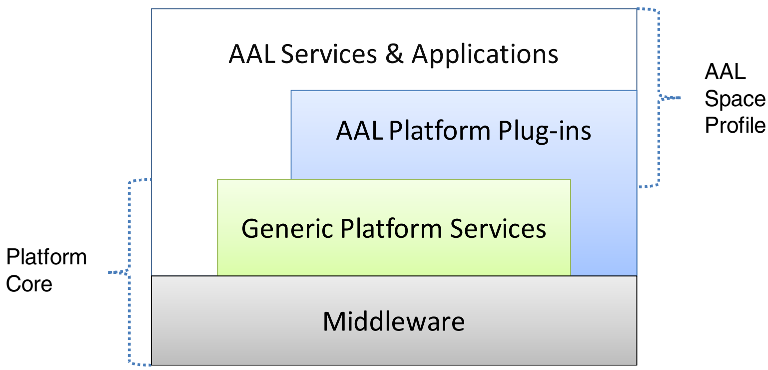

Fig. 4. The consolidated layer model for the runtime environment in AAL Spaces

5.2 Consolidation Process When Decomposing the System into Building Blocks

To derive the set of system building blocks, universAAL used a bottom-up approach: For the sake of determining reusability of software modules, the project was collecting the set of software modules developed within the input projects. Hence, the architecture group decided to group those software modules based on their similarities into building blocks. This means that the input to the consolidation process was given by the set of software modules. The idea was to use the above consolidated set of layers as a first set of categories[1], and also provide a mapping between the software modules and the consolidated set of requirements to facilitate their grouping based on coverage of similar requirements.

The template for collecting relevant info about the software modules was a table with the following columns: (1) original ID - any ID that can be used to identify a software module uniquely; (2) development status - closed or ongoing; (3) description - general role of the module in the input project; (4) functionality - more info about the functionality provided by a module; (5) technology - any technology used in the implementation, e.g., programming languages and frameworks, such as OSGi, .NET, Web Service, etc.; (6) software dependencies - any dependency to external libraries or the other software modules in this table; (7) execution / test environment - hints about runtime and testing configurations; (8) documentation link - preferably to public documents shared within universAAL; (9) source code link - if applicable; (10)

[1] The diagrams created later are using the same colors *gray*, *green*, *blue*, and *white* beside the layer names.

license - needed to be able to decide about reusability and license compatibility; (11) original classification - if applicable, e.g., the original layer to which the software module belongs in the input project; (12) universAAL layer - mapping to a universAAL layer as shared means for categorizing the software modules and (13) a set of (req#, req^) pairs - mapping to universAAL requirements, where '#' stands for the requirement ID and '^' stands for the priority of that requirement in universAAL.

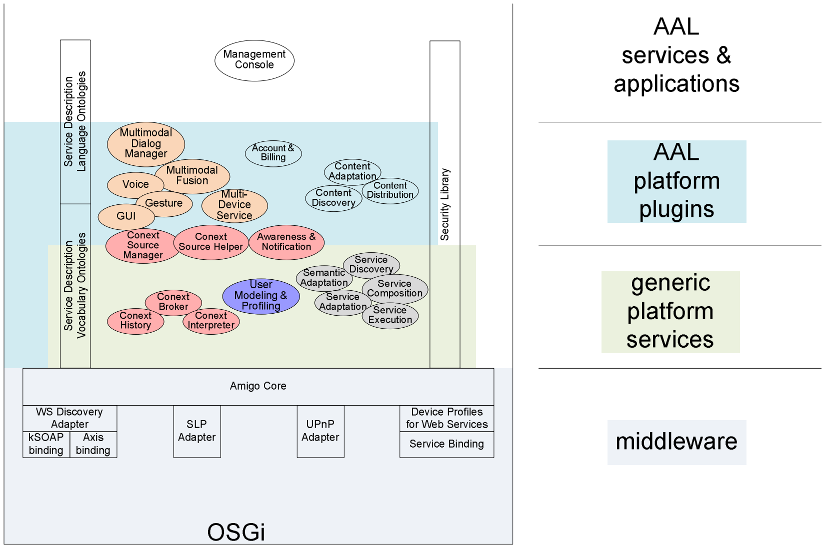

Fig. 5. Mapping software modules to universAAL layers – Amigo example

Although using the layers for categorizing the software modules could reduce the mess in dealing with the large number of software modules at hand, it was still difficult to proceed with the consolidation. Hence, the mapping to requirements was used to create several groupings of components as a topical set of categories, each associated with a color so that they are reflected directly in the mapping diagrams:

- the group of components supporting context-awareness; color *pink*
- the group of components dealing with profiling and supporting personalization; color *dark blue*
- the group of components dealing with the automatic situational reactivity of smart environments; color *yellow*
- the group of components providing a service infrastructure; color *gray*
- the group of components relevant for user interaction on the side of platform; color *orange*
- the group of components dealing with gateways and interoperability with the external world; color *green*
- all the other components; color blank, hence always taking the background color depending on the layer on which they appear

Using the above two sets of categories (layers and component groups) with their associated color-codes, a visual mapping of the software modules to the layers was provided, two of which are included here as examples (if a certain module could be assigned to several of the above categories, then mixed coloring was used).

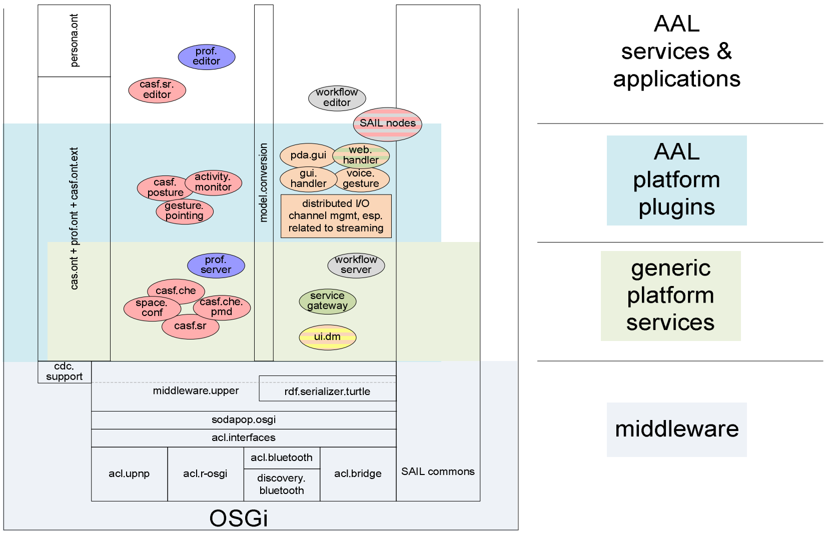

Fig. 6. Mapping software modules to universAAL layers – PERSONA example

As indicated in the consolidation pattern above, universAAL decided to create expert groups that consolidate components in the same category towards a set of building blocks for the runtime support of the universAAL platform. The creation of the expert groups, however, matched only partially the color-codes used in these diagrams. This was partly under the influence of the intermediate results from other parallel threads, such as the reference model. The created expert groups are:

- Middleware (sub-part of the blank color-code): this is equivalent to the lowest layer from the final consolidated set of layers that deals with the issues of distribution and heterogeneity and facilitates the integration of software components and the communication between them.
- Context and profile management providing for adaptability (merges the color-codes pink, yellow and blue): all software modules that support context-awareness and personalization.
- Service infrastructure (equivalent to the gray color-code): deals with abstracting shareable functionality as service and providing for service brokerage, chaining, composition, and orchestration.
- User interaction (equivalent to the orange color-code): deals with explicit interaction between human users and AAL spaces.

The Expert Group "Middleware"
This group must identify platform tasks related to the middleware as described in the context of the "Abstract Physical Architecture Model" in the universAAL deliverable D1.3-B. It is also responsible for examining possible solutions for such tasks.
D1.3-B summarizes the notion of middleware the following way:

The Expert Group "Context"
Context group deals with the handling of the information that represents the state of the environment, either physical or virtual (the context, as stated in D1.3B(II)), and makes it available to the rest of components that are interested in analysing, processing and interacting with this information, and also provides a basic common set of these components...

The Expert Group "Service"
Identifies platform tasks related to service-based interoperability and examines possible solutions for those tasks. They might fall into one of the following categories:
1. Service Model: questions related to data representation, such as service profiles, service requests, service responses, and the language for the definition of composite services

The Expert Group "User Interaction"
This group is going to analyze those platform tasks that are relevant for the explicit interaction between human users, on one side, and uAAL-based systems, on the other side, but are not covered by the other groups, especially not by the more basic ones, the context-awareness group and the service infrastructure group. "Explicit user interaction" refers here to the following

The Expert Group "Local Interoperability"
Binds special-purpose nodes that are not "universAAL-aware" but are networking-enabled and use specific standards, such as KNX, Athena, ZigBee, IEEE 11073, etc. For this purpose, it must define an integration model based on an abstraction framework with a standard way of providing the needed metadata. More concretely, the tasks of the EG fall into the following

The Expert Group "Remote Interoperability"
Analyzes those platform tasks that are relevant for the interactions between an AAL space and the world outside the space. This includes the interoperability between humans and software residing in the AAL space, on one side, and humans and software outside the space, on the other side. In particular, this group handles tasks in the following categories:

The Expert Group "Security"
Provides for trust, privacy-awareness, and access control. An artefact that joins an open system like AAL systems must possess a certain level of trustworthiness and hence the question here is about the right balance between the openness of the system and the level of control needed. At the level of joining the system, the level of trust needed is that the artefact at hand does not

Fig. 7. Expert groups responsible for system decomposition at several refinement levels

- Local interoperability (another sub-part of the blank color-code): deals with binding nodes (mostly embedded sensors and actuators) that must be used as packaged by their manufacturers without much further manipulation possibilities.

- Remote interoperability (equivalent to the green color-code): deals with the communication between AAL spaces and the world outside them.
- Security (a third sub-part of the blank color-code): deals with the topics, such as trust, access control and privacy-awareness.

The expert groups started their work by first defining themselves (see excerpts from those definitions in Figure 7) and are responsible for making any design decisions that influence both the further refinement of the reference architecture and the selection of software modules to be reused in the AAL-Platform. The result of their work on a consolidated version of the system building blocks has now been described in universAAL's newest deliverable D1.3-B. Here, we just provide the corresponding illustration that summarizes those results (cf. Figure 8).

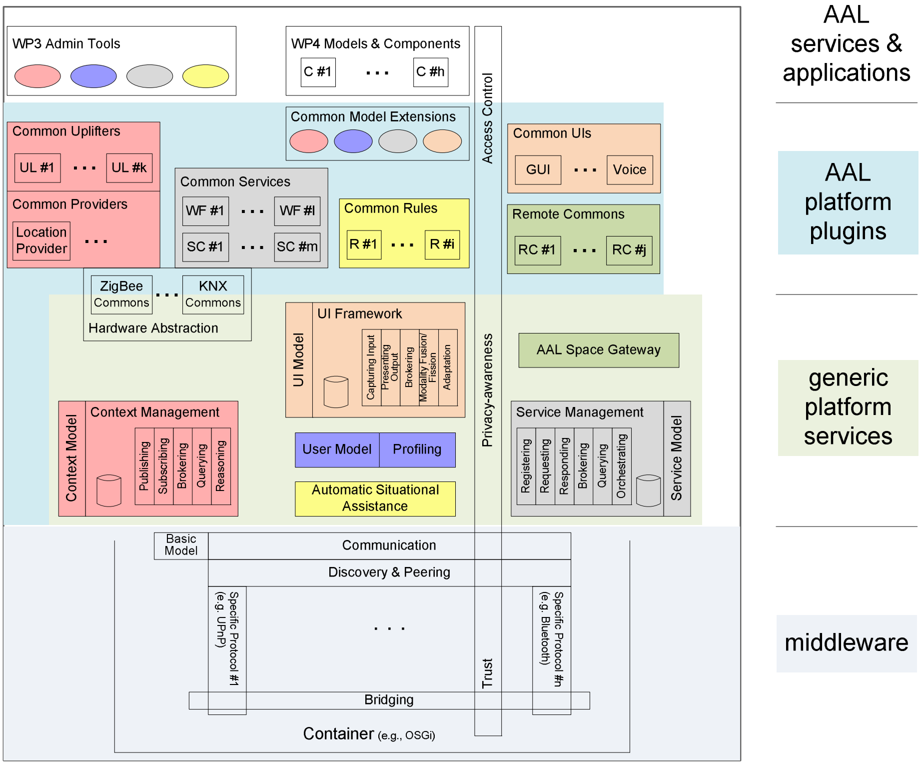

Fig. 8. The consolidated decomposition model at the level of abstract building blocks

6 Towards a Joint AAL and AmI Platform and Community

It is of vital importance that an "ecosystem" of users and developers is established around the universAAL platform to ensure continuous support and persistent ongoing refinements. This will be facilitated when the supporters of the universAAL platform accept it as an organizational framework for their activities.

Understanding that these "early adopters" can be a stimulating part of a greater AAL community which manages all open processes for the establishment of AAL solutions, efforts are being made in an open process involving all interested parties to found an open organization that can act as a repository for such activities. Such an AAL Open Association (AALOA), serving as a meeting point for various projects, individuals, and organizations, should form an AAL community with broad involvement from all types of stakeholders. AALOA is intended as an invitation to join the mission of bringing together the resources, tools and people involved in AAL within a single forum, making it much easier to reach conclusions on provisions needed to design, develop, evaluate and standardize a common service platform for AAL.

A broadly disseminated AAL platform unfortunately still bears a certain risk that the relatively high costs currently associated with AAL complete solutions are not acceptable for large parts of the society. Therefore, business models based on a distribution of costs must be developed. Such models should integrate long term care insurance providers and health insurance companies offering special AAL tariffs, complemented by substantial private investments. Unfortunately private consumers (potentially benefitting from AAL services) are hesitating or refusing to allocate any substantial sum of money to AAL technologies. Therefore, the Fraunhofer AAL Alliance is favoring an approach that the open AAL platform must be prepared for not only AAL applications for assisting elderly or handicapped users, but also for all other applications of Ambient Intelligence (AmI). The unified AAL platform should consequently only mandate a few selected components and basic functionalities that are required for all AmI-related scenarios, while all domain-specific components can be integrated as plug-ins to expand the platform towards assistive AAL enabling a step-by-step expansion. Users can hence motivate their own investments in their younger years, e.g., by a focus on energy conservation, home automation or leisure and games. Within an open platform, the sensors, devices and services that are already installed can later be used for assistive AAL applications without the need for repeated investment. This combinatory approach is crucial to avoid redundancy and to reduce costs to a manageable level.

However, to reach this goal, Fraunhofer Alliance AAL must intensify its efforts to convince the AAL community of the mentioned concepts and benefits. The universAAL project, for instance, has resources allocated to community building and together with PERSONA has agreed to join AALOA as one of the first member projects. As indicated by also other projects and standardization bodies having expressed their interest in joining AALOA, the vision of a unified universal platform seems a significant step closer to reality. Extending community building efforts, there is a clear and urgent need to further address and integrate the technological industry into the joint effort. Only when industry is ready to develop products and services based on the common unified platform, AAL and AmI really will get their chance for success.

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Chapter 4: Activity Recognition

Preventive Emergency Detection Based on the Probabilistic Evaluation of Distributed, Embedded Sensor Networks

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Abstract. To antagonize the outcome of the demographic and the appending structural change also, a human centered assistance system, that means an assistance system, which is completely user orientated, is introduced. The assistance system is realizing a predictive situation recognition with the aid of the evaluation of embedded, local actuators and sensor networks, to regulate and even if necessary to initiate preventive interventions in the user's environment. The key part of the assistance system is a hierarchical arrangement of functional layers with different capabilities; a main role is taken by the probabilistic modeling of system inherent activities through stochastic processes. This is demonstrated by a simplified example of emergency case detection including a following diagnosis process, to clarify the excellence and the current weakness of the assistance system.

1 Introduction

The unprecedented demographic change confronts the saturated societies in most of the Western industrialized countries with outstanding societal and structural alterations – already noticeable in many rural regions in eastern Germany – which engender extraordinary threats and challenges for governmental and non-governmental institutions. Henceforth, an aging society entails not only political and economical innovation deficiencies but also induces expansive cost dynamics in the health sector and increasing financial impacts for welfare institutions and retirement funds.

Studying existing shrinkage regions, which succeed from domestic migration, structural demise and low fertility rates, we obtain a deeper insight to the most crucial questions and difficulties elderly people will be confronted with in near future [1]. This includes coherent effects like unmet medical need – in particular in the area of geriatric care – insufficient area-wide provision of governmental and non-governmental services also and in addition, a rise of individualization of elder people. In summary, the demographic prognosis for Germany (refer to figure 1) presupposes extraordinary technological and socioeconomic arrangements to keep the society sustainable. Against this background, assistance systems – classified by the term AAL – Ambient Assisted Living – augur success for providing elderly people to live independently in their familiar environment under inclusion of kin-people, doctors and

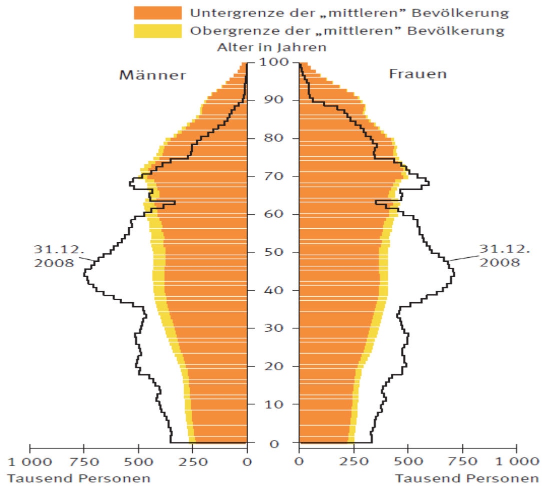

Fig. 1. Demographic trend until 2060 [2]

care personal. Therefore, this paper proposes a human centered assistance system, which combines a predictive situation recognition based on probabilistic methods with regulatory interventions through intelligent agents.

1.1 User Related Restrictions

The assistance system, that has to be integrated amidst the anthropsphere, must consider user preferences on the one hand and regard general characteristics, limitations and restrictions and user-group-specific global objectives on the other hand in order to achieve a technical solution that gains product acceptance. Over and above to usability, robustness, safety and data privacy protection, the aspect of stigmatization takes an important role; the user wants a discreet, unobtrusive support at the accomplishment of his daily tasks under guarantee of his informal self-determination. Therefore, the evaluated hardware components of the assistance system like sensors or actuators need to be installed invisible within the habitat e.g., the home of the user.

1.2 Medical Challenges

Considering the designated main application area of the assistance system – geriatric and home care – it is obvious, that the assistance system requires an implementation of a preventive medical monitoring mechanism for the postoperative or therapeutic field in order to support and enforce e.g., the compliance of the patient. Another aspect deals with the preventive detection of disease pattern for the initiation of early rescuing or recovering interventions. In this way, the hospitalization rate can be lowered. Regarding their role as outperforming cost drivers, cardiac diseases such as heart failure, cardiac arrhythmias, myocardial infarction or cerebral insults take an exposed position (refer to figure 2). The prevalence and incidence of these affections increased significantly in the recent years [3].

rank	illness cases (men)	Number of patients	∅ hospital stay in days	∅ age
1	neonates by birthplace	245838	3.8	0
2	behavioral disorder by alcohol	233278	8.6	44
3	angina pectoris	177595	5.2	65
4	heart insufficiency	156893	11.5	73
5	Hernia inguinalis	148363	3.7	56
6	chronic ischemic heart disease	144579	6.1	66
7	myocardial infarction	134721	8.8	66
8	virulent neoplasm of bronchia	131461	8.2	66
9	Intracranial harm	123417	4.3	33
10	Pneumonia	112508	9.9	56
11	Atrial fibrillation	107623	5.6	65
12	Cerebral insult	101254	12.9	70

Fig. 2. Most common diagnoses 2007 [3]

Thereby, atrial fibrillation – AF – is the most common heart arrhythmia, which is a predisposing factor for apoplectic stroke with a fivefold increased RR in relation to other diseases. Furthermore, there is a twofold lethality of these insults, caused by AF [4]. A primary obstacle for an early detection of AF is the idiopathic occurrence of AF; the first incidence of AF is usually not recognized. In addition, AF behaves in many cases asymptomatic; the patient is apparently free of any disorders. In this paper, cardiovascular diseases, particularly AF, are in the focus of further considerations in order to reflect the intention, arrangement and the mode of operation of the integrated diagnosis system.

1.3 Technical Challenges

Human centered assistance, which are integrated within the user's living environment and implementing a continuous vital sign monitoring, are subject to numerous restrictions:

- denial or exceptions by the user if camera based systems conciliate a impression of observation
- restricted mobility and autonomy if body attached sensor components are applied for data acquisition
- Concerns about data privacy protection if external services are connected with the assistance system

Clinical trials with prevailing telemedical devices reveal an increased rate of detection in the context of cardiovascular disease pattern – especial paroxysmal AF or the first appearance of AF is more often detected, proven through a successful survey of supraventricular heart arrhythmias at 94% of patients with palpitations over an evaluation interval of 40 days [5]. However, these promising devices bare a great lack when they are used in the area of home care by care institutions or family doctors, because they fail as body attached applications in reference to the introductory elucidated aspects. Therefore, telemedical solutions such as ECG-recordings, dealing with the diagnosis of palpitations, presyncopes and syncopes, are constricted to therapy control after the treatment of heart arrhythmias or limited to technical solutions like implanted cardiac pacemakers, ICDs and Event-recorder [6].

2 Methods and Techniques

2.1 Characteristic of the Assistance System

As a hierarchical composition of probabilistic methods and description logical techniques, the architecture of the assistance system provides the basement for decision-based regulatory interventions regarding evaluated sensor and actuator networks (refer to figure 3). Thereby, the classification of the different layers is predicated on the degree of system abstraction and their functionality [7].

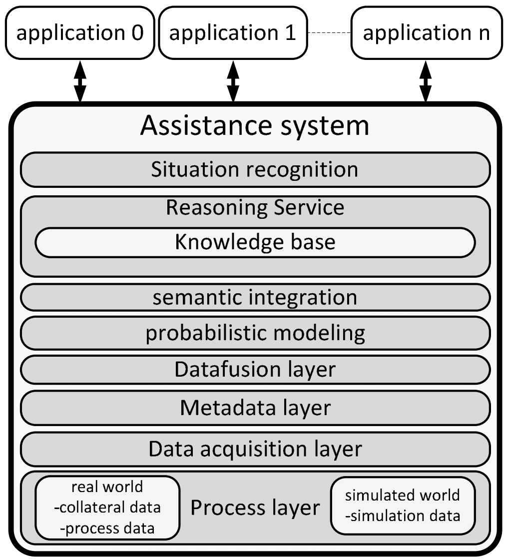

Fig. 3. Architectural model of the assistance system

Thus, the data acquisition layer melds concepts and techniques for the gathering, detection and the standardized transformation of the process values from

$\{y_n(t)\}, n \in \mathbb{N}, t \in \mathbb{R}_+$

respectively

$\{\theta_{Body}(t), p_{air}(t), \dots\} \rightarrow \{y_1(t), y_2(t), \dots y_n(t)\}.$

Considering measurement uncertainty and appearing measurement fault under inclusion of sample rate T_s

$$u_y(nT_S) \text{ and } e_y(nT_S),$$

we obtain following terminology for the discretized process data

$\{\hat{y}_d(nT_s)\}, d, n \in \mathbb{N}, T_s \in \mathbb{R}_+$

respectively

$$\{\hat{\theta}_{Body}(nT_s), \hat{p}_{air}(nT_s), \ldots\} \rightarrow \{\hat{y}_d(nT_s)\}.$$

In the metadata layer the collected process information are packed and expanded with additional adjuncts like sensor location, resolution, attenuation, unit or others, and conveyed to the data fusion layer in order to extract features or more clearly, the emissions for the probabilistic modeling. This concept and the layer of the semantic integration are in the focus of further considerations of this paper.

2.2 Process Data Acquisition

Modeling the user situation needs three fundamental types of devices to gather the process information $\{\hat{y}_d(nT_s)\}$:

- Evaluation of telemedical devices
- Evaluation of home automation components
- Evaluation of contactless measurement devices

Thereby, the patient uses the telemedical equipment in self-reliance at determined points of time, which relate to the anamnesis of the patient. The assistance system gains the vital parameters via interfaces like Bluetooth at T_s. Actuators and sensor components of the home automation are accessed by the standardized interface BACnet-IP.

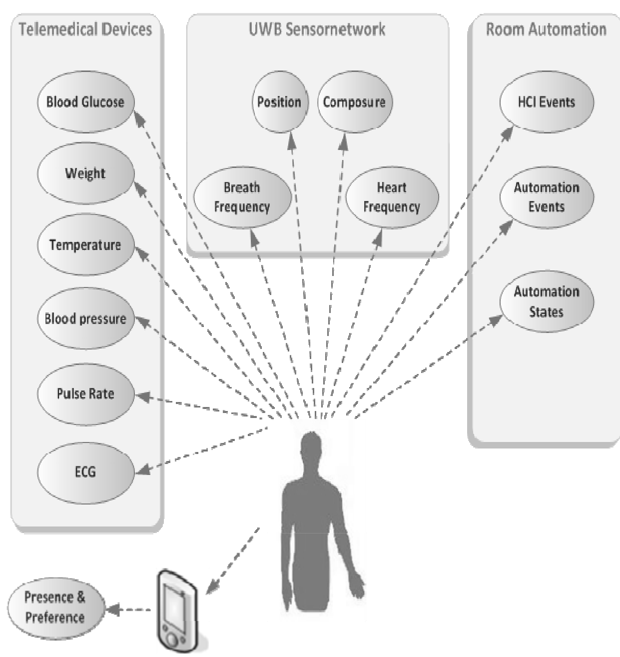

Fig. 4. Relevant parameters of the process environment

One accentuated role takes the contactless measurement of health signs. To realize a suitable solution for this approach, an UWB-radar device was implemented, which has been proposed for the measurement of respiratory and heart rate [8]. The detection of composure and position by UWB-sensors is part of the work if [9]. In order to model the patient's situation, it is essential to evaluate the process data

$$\{\hat{y}_d(nT_s)\}_{Diagnose}$$

resp.

$$\{y_{Diagnose}\} = \{\{y_{Telemed}\}, \{y_{UWB}\}, \{y_{Automation}\}\}$$

concerning

$$\{y_{Telemed}\} = \{\theta_{Body}, m_{Body},, (mm\ Hg)_{systolic\ Blood}, \dots\}$$

$$\{y_{UWB}\} = \{f_{Heart}, f_{Breath}, (x, y, z)_{Position}, \dots\}$$

$$\{y_{Automation}\} = \{e_{HCI}, e_{Automation}, X(t)_{Automation}, \dots\},$$

used to extract the single emissions $o_{t=nT_s}$.

2.3 Probabilistic Modeling

Hidden Markov Models (HMM) combined with Relational State Descriptions are a successful approach to design software agents addressed to temporal and spatial environments [10]. An alternative approach deals with the sensor based activity recognition utilizing Relational Markov Network (RMN) under inclusion of the MCMC-algorithm for inference [11]. The works of [12, 13] deal with the implementation of RMNs with the aid of undirected graphical models i.e., Markov Nets.

Furthermore, the hierarchical expansion of dynamic Bayesian Networks is a probate resolve for probabilistic modeling [14]. The work of [15] reinforced the theoretical aspects of HMMs and their benefit for technical solutions in the context of statistical modeling. A Hidden Markov Model, representing a stochastic process like a time corresponding motion pattern, may be described by the quintuple

$$\lambda = \{X, A, Y, B, \pi\}$$

with the state space X, the alphabet Y, the relating characteristic emission and transition matrices B and A, and finally, the initialization vector π. The HMM λ is adequately described by the quintuple. The hidden states of the automata, representing the invisible states of the system like user situation or the health status at the point of time t, can be expressed by the state space

$$X = \{x_1, x_2, \dots\}.$$

The transitions between the single states refer to the relationship

$$a_{ij} = P(X_{t+1} = x_j | X_t = x_i),$$

described by the stochastic matrix

$A_{(|X|,|X|)} = \{a_{ij}\}, A \in \mathbb{R}^{X \times X}$

with

$$\forall_{i,j}\ a_{ij} \geq 0, \forall_j \sum_{j=1}^{N} a_{ij} = 1$$

for the sum of all possible state transitions. As a matter of principle, the temporal devolution of an exemplary state sequence Q_T including the coherent emission sequence O_T is shown in figure 5.

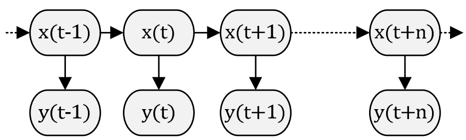

Fig. 5. Processing of a HMM

The respectively engaged hidden state X_t depends only to the preceded one – Markov property. Through the evaluation of the emitted symbols it is possible to infer the most likely state. In state $X_t \in X$ emitted symbols

$y_t \in Y, Y = \{y_1, y_2, \dots\}$

refer to the relationship

$$B_{(|X|,|Y|)} = \{b_j(k)\}, B \in \mathbb{R}^{X \times Y}$$

considering

$$\forall_{i,j}\ b_j(k) \geq 0, \forall_j \sum_{k=1}^{|Y|} b_j(k) = 1.$$

According to the in matrix B stored discrete distribution the symbols are state dependently emitted as depicted in figures six and seven.

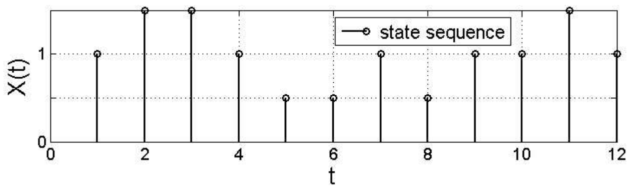

Fig. 6. State sequence for a HMM with $|X| = 3$

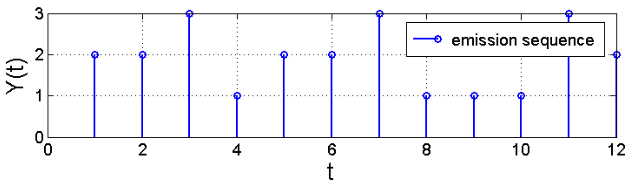

Fig. 7. Corresponding emission sequence with $|Y| = 3$

The determination of the probability of a specific emission sequence O_{T_o} for an interval $T_o = mT_s$ may be expressed by the matrix

$$C_{(|X|,m)} = \begin{bmatrix} \alpha_t(i = x_1) & \cdots & \alpha_{t+T_o}(j = x_1) \\ \vdots & \ddots & \vdots \\ \alpha_t(i = x_{|X|}) & \cdots & \alpha_{t+T_o}(j = x_{|X|}) \end{bmatrix},$$

with the initializations

$$\alpha_t(i) = \pi_i b_i(o_i)$$

and the recursive equation

$$\alpha_{t+1}(j) = \left[\sum_{i=1}^{N} \alpha_t(i) a_{ij}\right] b_j(o_{t+1})$$

concerning the initial distribution expressed by

$$\pi = \{\pi_1, \pi_2, \pi_3, \dots \pi_{|X|}\}$$

for the begin of the state sequence. The probability of the occurrence of a specific sequence O_{T_o} meets the summation of the column vector of T_o

$$P(O_{T_o}|\lambda) = \sum_{i=1}^{|X|} \alpha_{T_o}(i).$$

In the first approach the examination of real observation sequences

$$O_{T_o} = \{o_1, o_2, \dots o_{t=T_o}\}, o_t \in Y$$

over a finite interval $T_o \in \mathbb{R}_+$ is realized through the Viterbi-Algorithm (refer to. 3.1). In the first approach, the awkward problem of learning under consideration of unknown distributions relating to transition- and emission probabilities is solved by the implementation of the Baum-Welch-algorithm (refer to 3.1).

2.4 Semantic Integration

The layer of the semantic integration comprehends operations for the transfer of the explicit and implicit knowledge about the structure and the condition of the addressed domain into a representation of description logic. Hence, the knowledge base may be arbitrarily extended through individual user preferences stored in e.g., mobile knowledge bases. The implemented reasoning service deduces with the aid of the associated knowledge bases and the inference machine higher knowledge for the situation recognition, respectively procures conclusion mechanisms founded on description logic. This procedure is accessed and executed within a cyclic query by the prior situation recognition module. To represent the gained knowledge, OWL is an appropriate solution and therefore used. The specification of OWL (Web Ontology Language) was adopted in 2004 by the World Wide Web Consortium (W3C) as an enhancement of RDFS – RDF Vocabulary Description Language [16]. The W3C proposed three dialects of OWL with gradual expressiveness for the modeling of description logic. For the modeling example, OWL description logic – OWL DL – is used which is a subset of OWL full, based on description logic [17]. The semantic of OWL DL cares about the description logic SHOIN (D) which comprehends ALC (Attributive Language with Complement) and transitive roles (r+). ALCr+ is abbreviated by S; further elements are H (role hierarchy), O (nominals), I (inverse roles), and N (cardinality restrictions and D (data types).

3 Example of Implementation

The implementation example can be split in two main parts: the modeling of the user situation including emergency detection and the adherent diagnosis mechanism, which affords the estimation based recognition of disease pattern through probabilistic modeling, in particular with partial HMMs. In the modeling example the diagnosis mechanism is restricted to the approximation of the risk for cerebral insults.

3.1 Partial Model Emergency Detection

The probabilistic model for the situation recognition should map the behavior of the target person, the patient, whereat a stationary characteristic is assumed. Therefore, a Hidden Markov Model $\lambda_{sit.}$, reflecting the state space

$$X_{Sit.} = \{Sleep, Read, TV, BathShowering, Yoga, Standing, Danger, no\ emergency, Emergency\}$$

should be sufficient to map the various activities of the user such as showering, sleeping et cetera, directing towards

$$\{1,2,3\ \dots |X|\} \rightarrow X_{sit.}\ .$$

This relationship, considered by the $\lambda_{Sit.}$, is described in figure eight.

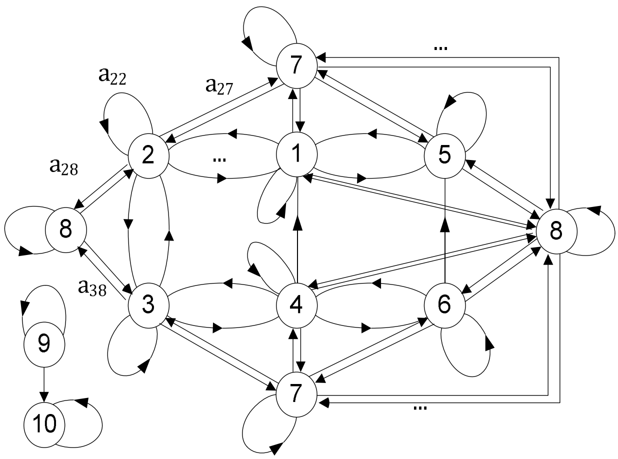

Fig. 8. Situation recognition model

Thus, the user can switch from state 'Sleeping'

$$X_t = x_1 = Sleeping$$

to the state 'Showering'

$$X_{t+1} = x_5 = Showering,$$

but not directly to the state 'TV'

$$X_{t+1} \neq x_3 = TV \text{resp.}\ x_5 \nrightarrow x_3\ ,$$

because it must be assumed, that a mean user usually heads for the bathroom after getting up, before he is watching TV. To store the probabilities of the transitions, a square matrix

$$A_{(m,m)} = \{a_{ij}\}_{Sit.} = \begin{bmatrix} a_{11} & \cdots & a_{18} \\ \vdots & \ddots & \vdots \\ a_{101} & \cdots & a_{1010} \end{bmatrix}, \{a_{ij}\} \in \mathbb{R}^{X \times X},$$

is used. Regarding the incomplete, uncertain knowledge about the observed area, a default distribution is used, which relates to presumed equal weights of the different transition options. If an acute emergency case occurs, the HMM $\lambda_{Sit.}$ changes to an absorbing state as retainable from the matrix

$$\{a_{ij}\}_{Sit.} = \begin{bmatrix} 0.2 & \cdots & 0.0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1 \end{bmatrix}$$

and the graph in figure 8. The absorbing state may be expressed by the following circumstance:

$$X_t \in J, J \subset X_{Sit.}, J = \{ x_{10} \} = \{Emergency\}$$

with the coefficient

$a_{1010} = 1.$

Due to the fact, that always emission sequences of a length nT_s are being evaluated, the time T_J for admission may be expressed by this equation.

$$T_J = n_J T_s, n_J \in \mathbb{N} \cup \{\infty\}.$$

That means, either an event occurs within a finite number of n_J observation intervals or it happens never. For the analysis of the model, following matrices

$$\{a_{ij}\}_{1.} = \begin{bmatrix} a_{11} & \dots & a_{18} \\ \vdots & \ddots & \vdots \\ a_{81} & \cdots & a_{88} \end{bmatrix} \text{ und } \{a_{ij}\}_{2.} = \begin{bmatrix} a_{99} & a_{910} \\ a_{109} & a_{1010} \end{bmatrix}.$$

result from the approach allegorized in figure 8. In respect to the partial HMMs, the absorbing states are expressed by

$$J_{1.} = \emptyset, J_{2.} = \{x_{10}\}.$$

For the detection of the states, emission sequences with elements of $o_t \in Y_{Sit.}$ are being evaluated. The set $Y_{Sit.}$ is a subset of all the emissions which may be gathered and examined by the assistance system at all.

$Y_{Sit.} \subset Y_{Assistenzsystem}$

$Y_{Assistenzsystem} = \{Y_{Sit.}, Y_{Diagnosis}, Y_{Energymanagement}, \dots\}$

The several emissions follow from the evaluation of the diverse acquired process values. For example, the symbol $Fever$ is ascertained if the filtered sampling value exceeds an individual, user related boundary:

$$\hat{\theta}_{Body}(nT_s) > \hat{\theta}_{Body}(Param) \rightarrow o_{t=nT_s} = Fever$$

In analogy, we obtain the emission $Overweight$:

$$\hat{m}_{Body}(nT_s) > \hat{m}_{Body}(Param) \rightarrow\ o_{t=nT_s} = Overweight$$

In coherence with the cardiovascular disease heart insufficiency, the temporal change in weight takes a central role as an emission (refer to figure 9).

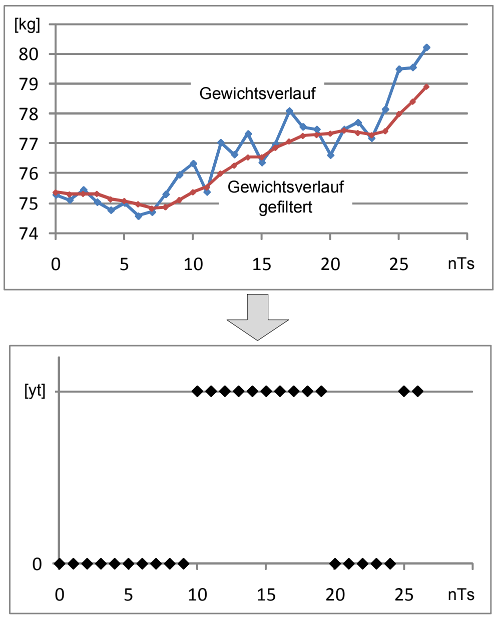

Fig. 9. Emission: significant changes of weight

The premature detection of edema as an indicator for a lurking decompensation is done through the examination of a partial HMM under inclusion of the following emission

$$\Delta\hat{m}_{Body}(nT_s) > \widehat{\Delta m}_{Body}(Param)$$

$$\rightarrow\ o_{t=nT_s} = SignificantMassIncrease.$$

The several alphabets of the assistance system are accumulated with the single elements as well as with the catenation of them even if single symbols are detected concurrently within an interval T_s

$$Y_{Body} = \{Fever, Overweight, HeartRate > 160, \dots\}$$

$$Y_{Room} = \{Bathroom, Kitchen, Living\ Room, \dots\}$$

$Y_{Composure} = \{Laying, Sitting, Standing, ..\}$

$\Rightarrow (Fever \wedge Laying) \in Y_{Sit.} \subset Y_{Assistenzsystem}$

$\Rightarrow (HR > 140 \wedge Fever) \in Y_{Diagnosis.} \subset Y_{Assistancesystem}.$

Every partial HMM λ_n addresses its own alphabet Y_n, which is a subset of all possible symbols and the concatenation of them. In every state $X_t \epsilon X_{Sit.}$ is an observable $o_t \in Y_{Sit.}$ emitted from a set with the cardinality $|Y_{Sit.n}| = 12$, considering the corresponding emission matrix $B_{Sit.}$. In respect to studies and surveillance, the coefficients are estimated and embodied in the following form

$$B_{Sit.} = \{b_j(k)\}_{Sit.} = \begin{bmatrix} 0.6 & \cdots & 0.0 \\ \vdots & \ddots & \vdots \\ 0.00 & \cdots & 1.0 \end{bmatrix}, \{b_j(k)\} \in \mathbb{R}^{X \times Y}$$

The symbol y_{11} of the partial HMM $\lambda_{2.}$, which is emitted in the state $X_{t_{2.}} = x_9 = no\ emergency$, is applied to

$$(y_{11} \in \left\{ Y_{Sit.} \middle| \bigcap_{t}^{t+n_{eva}} (X_{t_{1.}} = x_8) = \emptyset \right\}, n_{eva} \in \mathbb{N}.$$

While the model does not remain longer than an evaluation interval with the length n_{eva} in the state

$X_{t_{1.}} = x_8 = Danger,$

every emission of the sub-graph is accepted as an emission with the probability one. And vice versa, the emission y_{12} correlates to

$$(y_{12} | X_t = x_{10}) = \left(y_{12} | \bigcap_{t}^{t+n_{eva}} (X_t = x_8) \neq \emptyset) \right).$$

If the model persists in the state $x_8 = Danger$ over an interval of $n_{eva}T_s$, the symbol y_{12} is emitted and the system switches to the absorbing state $X_{t_{2.}} = x_{10}$. In this manner, the error rate may be decreased and the rate of detection of real emergency cases may be developed to the maximum. Coherently, with a growing n_{eva} the assurance of detected emergencies increases also. For the evaluation interval $T_o, T_o \in \mathbb{R}_+$ with samplings $t \in \{nT_s\}$ an observation sequence

$O_{T_o} = \{o_1, o_2, ... o_T\}, o_t \in Y_{1.}$

is gained, which is a direct result from the state sequence

$$Q_{T_o} = \{X_t, X_{t+1}, ... X_{T_o}\}, X_t \in X_{1.}.$$

The relationship between the observation sequence and the state sequence depends on the conjugated probability according to

$$P\left(O_{T_o}|Q_{T_o},\lambda\right) = \sum_{f\ddot{u}r\ alle\ Q} P(Q|\lambda)\, P(O|Q,\lambda)$$

with the initializations

$$\pi_{X_1} b_{X_1}(o_1)$$

for the start of the sequence. Due to the complexity *O(T,N)*, the enormous, sumptuary computation load of the mathematical operations can be calculated with

$$O(T,N) = 2TN^T.$$

The computation load is a restricting, not maintainable effort und leads under consideration of an abundance of $N = |X| = 6$ and a length $T_o = nT_s$ with $n = 50$ to $\approx 8 \times 10^{40}$ calculations. This is not a manageable approach for the assistance system. The model for the situation recognition should be initialized with the default state $X_t = x_7$, which means that the user stands without any precise activity or task within the room. This leads directly to the initialization vectors

$$\pi_{1.} = \{0,0,0,0,0,0,1,0\}$$

and

$$\pi_{2.} = \{1,0\}, \pi_i \notin J_{2.}$$

The determination of the most likely path through the Trellis structure, which is identical with the most likely state sequence, is accomplished by the utilization of the Viterbi-algorithm. Due to the invalid or respectively the estimation based coefficients of the matrices a_{ij} and $b_j(k)$ a low detection rate for real state sequences is expected.

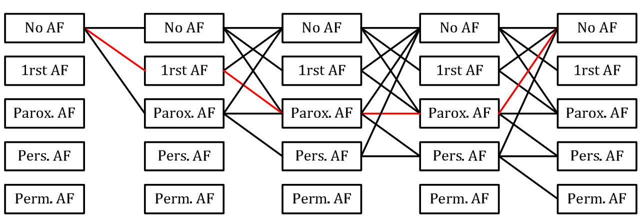

Fig. 10. Trellis-diagram for $\pi = \{1,0,0,0,0\}$

In general, the implemented Viterbi-algorithm is expressed by the equation:

$$\delta_t(i) = \max_{q_1,q_2,\ldots q_{t+1}} P\left[X_t, X_{t+1}, \ldots X_{T_o} = i, o_t \ldots o_{T_o}|\lambda\right]$$

relating to the initializations

$$\delta_1(i) = \pi_i b_i(k = o_i), 1 \le i \le |X|$$

$$\psi_1(i) = 0$$

through the recursive functions and procedures

$$\delta_t(j) = \max_{1 \le i \le |X|} [\delta_{t-1}(i) a_{ij}] b_j(o_t),$$

$$\psi_t(j) = \operatorname{argmax}_{1 \le i \le |X|} [\delta_{t-1}(i) a_{ij}]$$

for

$$2 \le t \le T_o \text{ und } 1 \le j \le |X|.$$

The recursive function is terminated after the determination of the most likely final state:

$$P^* = \max_{1 \le i \le |X|} [\delta_T(i)] \text{ and}$$

$$X^*_{T_o} = \operatorname{argmax}_{1 \le i \le |X|} [\delta_{T_o}(i)].$$

And by the use of backtracking

$$X^*_t = \psi_{t-1}(X^*_{t+1}), t = T-1, T-2, \ldots 1$$

we obtain the most likely state consecution. In order to get the real coefficients of A and B, which includes the optimization of the model approach $\lambda_{sit.}$, training data is collected, which relies directly on the process environment as sketched in figure 4. Thus, the observed system emits during the evaluation interval pairs of states and coherent emissions like

$$\{x_n, y_n\}_{(nT_s)} \in \{\{x_n, y_n\}_{(nT_s)}\}, 0 \le nT_s \le T_{Evaluation}$$

e.g.,

$$\ldots \{x_7, Kitchen\}_{(Ts)}, \{x_2, Kitchen \wedge Sitting\}_{(2Ts)} \ldots,$$

which are exploited with the aid of the Baum-Welch-algorithm – an instance of the EM-algorithm. The tweaked model $\lambda_{sit.}$ is used to realize calls of the implemented diagnosis functionality, a separate system of partial HMMs.

3.2 Partial Model Diagnosis Assistance

If the probabilistic model for the situation recognition detects some case of emergency and skips to the absorbing state $X_t = x_{10}$, a call of the diagnosis functionality, a separate module, is executed. The module $\lambda \in \{\lambda_n\}_{Diagnosis}$ comprehends partial HMMs, reflecting different kinds of diseases, which approximate the best fitting model resp. the best suitable diagnosis based on the gathered symptoms resp. emissions. Vicarious for this methodology stands the diagnosis model λ_{AF} for atrial fibrillation, introduced in 1.3, which is as a Subgraph from $\lambda_{CI-Risk}$ essential for the estimation of the risk for cerebral insults.

The HMM for AF consists of

$$\lambda_{AF} = \{X_{AF}, A_{AF}, Y_{AF}, B_{AF}, \pi_{AF}\}$$

with the state space

$$X_{AF} = \{\textit{No-AF, 1st-AF, Paroxysmal-AF, Persistent-AF, Permanent-AF}\}.$$

The Markov Model (refer to figure 11) starts in dependency to the anamnesis, which is a key element of the digital health record (DHR). Considering the DHR, we obtain a initialization vector π_{AF}. For the modeling example it is assumed that the system starts at $t = 0$ relating to

$$\pi_{AF} = \{1,0,0,0,0\}$$

in the state $X_t = x_1 = NoAF$. The partial HMM λ_{AF} uses the alphabet

$$Y_{AF} = \{\textit{SignificantHeartMurmur, Heart Rate>140,...}\}$$

and the partial model for CI

$$\lambda_{CI} = \{X_{CI}, A_{CI}, Y_{CI}, B_{CI}, \pi_{CI}\}$$

uses the alphabet

$$Y_{CI} = \{\{\textit{CheynesStokesBreath, Dizziness,...}\} \cup X_{AF}\}$$

with the state space

$$X_{CI} = \{\textit{No-CI-Risk, Low-CI-Risk, Medium-CI-Risk, High-CI-Risk}\}.$$

$$\{1^*, 2^*, 3^*, 4^*\} \longrightarrow X_{CI}$$

In summary, the states of the HMM for AF are used as emissions in the model of higher order, the HMM for CI or resp. for the estimation of the concrete risk for apoplectic stoke.

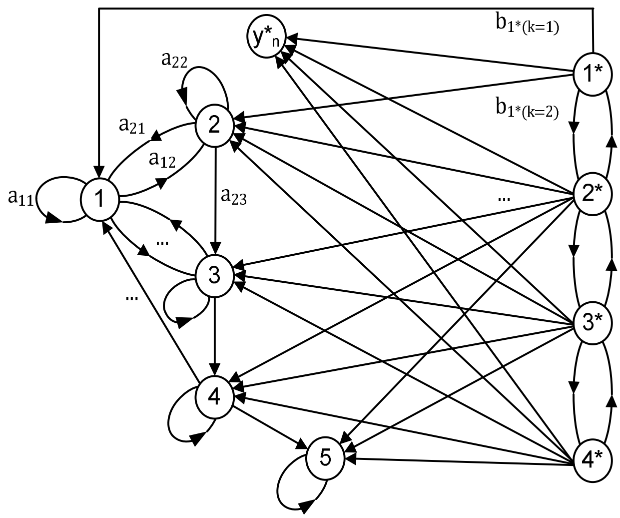

Fig. 11. HMM for CI-risk estimation

If characteristic emissions are detected which refer AF, just such as an increased heart rate

$$y_t = (HR > 160), y_t \in Y_{AF} \subset Y_{Body}$$

or typical heart murmurs,

$$y_t = Significant\ Murmur, y_t \in Y_{AF} \subset Y_{Body},$$

the model takes either the state *1st-AF* or the state *Paroxysmal-AF*. Paroxysmal AF is a stadium of AF which lasts up to seven days. If the disorders continue, the AF may be classified as persistent atrial fibrillation, represented by the state *Persistent-AF* in the model. If medical interventions like a cardioversion fail, the model switches to the state *Permanent-AF*. Apart from the state duration there exist some more relevant emissions, which are influential for the placement of AF in various states or stadiums. In accordance to the adopted state of the AF-model, the risk for the apoplectic stroke varies. Additionally, further emissions of a HMM of higher order are evaluated to estimate the most likely risk for cerebral insult. In respect to the classification of the actual risk, different reactions of the assistance system are initiated which are aligned to the gravity of potential harm. If there is a slight risk for cerebral insult – maybe only some indicators are detected – the assistance system originates only some kind of warning or messages to the responsible doctor or connected medical institutions. Otherwise, if there is spotted a high potential for apoplectic stroke, the prior regulatory mechanisms in the top layers of the assistance system initiate forthwith measures such as emergency calls including invasive, direct interventions like the application of anticoagulants.

3.3 Ontology of the Implementation

In consideration of the emergency detection model, a suitable partial ontology was developed, i.e., essential for the further progressing processing of the results of the probabilistic layer (refer to figure 12). The image reflects how atomic concepts, roles and individuals can be used to shape an emergency detection through an approach like OWL.

Partial ontology for the emergency detection module
Atomic concepts:
Person, *CIRisk*, *AFRisk*, *HealthStatus*, *Emergency*, *Situation*
Roles:
hasCIRisk(*Person*, *CIRisk*),
hasAFRisk(Person, *AFRisk*),
isInSituation(*Person*, Situation),
isInEmergencyCase(*Person*, *Emergency*),*hasHealthStatus*(*Person*, HealthStatus)
Individuals:
Person(*XYZ*), CIRisk(LowCIRisk), *AFRisk*(1*st*), *Situation*(*WatchingTV*) , *Emergency*(*Normal*), *HealthStatus*(*Normal*), …

For the implementation example, the ontology was scaled down and is restricted to the context of the probabilistic layer. Therefore the ontology does not reproduce an universal valid solution for emergency detection in general; it can be configured and adjusted congruently to the needed complexity. The reasoning service of the assistance system offers services, which are accessed and used by the prior situation recognition procedures. Addressing this layer, the information, extracted from the process environment by methods in the lower layers and embedded through semantic integration, is appropriated by the inference mechanisms based on description logic in order to gain novel knowledge about the system.

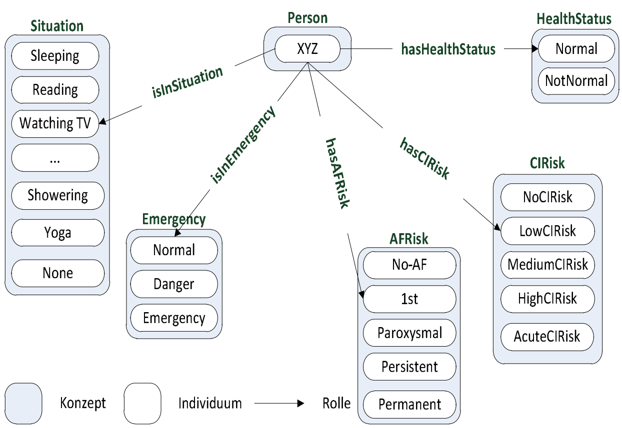

Fig. 12. Ontology for the modeling example

From a sophisticated point of view, different situations can be analyzed in their particular context in order to deduce valid conclusions for the situation recognition module. Thereby, the cross linking of different knowledge bases as collateral data takes crucial part for the quality of the prior situation recognition layer: Ontologies, referring different models like the derivative of the home automation, can be correlated with each other through description logic. In this manner, the precision of the situation recognition procedures can be improved.

4 Discussion of the Results

Due to the preliminary state of research, simulations were applied to validate routines and procedures, which are implemented within the probabilistic modeling. The determination of the coefficients of the diverse matrices was done by established methods like the Maximum-Likelyhood-technique. Precondition of this methodology was the manual acquisition of motion tracks and activity patterns via state-emission pairs over a defined interval. Because the primary coefficients were reflecting a rectangular distribution, which is not conform with real environmental system properties, only a weak detection near about 30% was feasible. Utilizing obtained parameters which are corresponding with the simulation ambience, the rate of detection rose to 71%. After an adjustment of the matrices through the evaluation of observation sequences by the Baum-Welch-algorithm, the rate achieved 76%. A rate of 97% was reached if simulation data generated in order to imitate serious events and emergency situation was evaluated. This is a contribution to the typical, most characteristic dependencies within the model which is reflected in the matrices themselves. In order to increase the amount of detected situations, it is most necessary that the model is rarefied through the identification of typical sequence patterns. Moreover, it is important to reduce the widespread extent of the different models through an appropriate classification. In order to gather the most likely state of a system, the Viterbi-algorithm has proven success in the first approach.

One primary issue of this methodology is the usage of non-equidistant process values which relate to an irregular sample process. Exemplary, the weight of the patient or user is not sampled and processed within constant intervals. This fact spawns effects to the occurrence probability of the several emissions like overweight or significant mass increase considering heart insufficiency. In addition, the modeling of the health state is afflicted with the difficulty of large numerical time constants and the occurrence of stochastically dependent parameters, which influence each other. Therefore, the system is not able to gain knowledge about medical interrelations through the usage of standardized learning algorithms for the analysis of the emission- and state sequences in the context of disease patterns. The modeling example documents how a complexity reduced and application focused ontology can be used if distributed knowledge needs to be aggregated within one knowledge base. This is a promising approach for a valid inference mechanism considering emergency detection as an integral part of the situation recognition. Furthermore, it is obvious how a context sensitive emergency detection can be modeled via description logic and how inferential processes are involved during the run-time of the assistance system in order to estimate the most likely health state of the user. OWL DL is a distinguishable subset of description logic and enables the modeling of more complex environments if it is necessary to obtain conclusions about the inner, hidden system states. Thus, extraordinary dynamic state changes can be factored in the assistance system topology through an abstraction in roles, concepts and classes.

5 Conclusion and Outlook

5.1 Résumé

In this paper it was shown that temporal sorted sequences of system states, which consider in this context human behavior during a well-defined evaluation period nT_s, can be described through stochastic processes with the benefit of Hidden Markov Models. The implementation of a probabilistic modeling is a beneficial approach for the integration within an assistance system. This is recommended if uncertain knowledge, including stochastic independent parameters, is being evaluated. This requires a reduction of system states by the classification of the model and further, appropriate trainings procedures like Baum-Welch for the adjustment of the transition and emission matrices. The investigation of the system properties is the main aspect in this relation. The integration of learning techniques enables the assistance system to regulate systems with common parameters and to evaluate systems and environments whose properties are unidentified at all. The learning process approves the assistance system some kind of self calibration, in relation to the conditioned cognitive situation recognition ability.

5.2 Next Steps

In order to improve the assistance system it is necessary to obtain valid data through randomized, multicenter clinical studies. In addition, it is an appropriate approach to examine existing data sets just such as the Framingham heart study offers. The integration of time dependent matrices for the transition and emission distributions is also part of the next stage of research. This is mandatory to customize the probabilistic modeling in orientation to real environmental properties if the assistance system should integrate within the rhythm of the user's life. The realization of a_{ij} and $b_j(k)$ as an output of a function $f(t)$ offers a dynamic identification in respect to the temporal environment. Another work package deals with the modeling and implementation of adaptable situation recognition for different environments which can be pillowed by valid data material. The presented research is an integral part of the cooperation project AAL@home, which is subsidized by the BMBF.

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Detection and Classification of Acoustic Events for In-Home Care

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Abstract. Due to the demographic change, the number of older people will grow steadily within the next decades [1]. Technical systems, methods and algorithms developed in the context of Ambient Assisted Living (AAL) aim to enable these people to live self-determined and safe in their own homes as long as possible. To ensure this, these homes may have to be equipped with e.g., a health monitoring system, special sensors or devices for gathering and evaluating individual information. In this paper, an acoustic monitoring system for evaluation of acoustic cues is presented and tested exemplarily on four acoustic events (cough, knock, clap and phone bell). The acoustic monitoring includes several consecutive signal processing steps: the audio signal picked up by a microphone is transformed in a psycho-physiologically weighted domain using a gammatone filterbank, resulting in a so-called *cochleogram* [2]. From this cochleogram, background noise is estimated and eliminated. Further signal processing determines partitions of the cochleogram which are considered to form acoustic events. Each of these events is then evaluated with a classification algorithm. In this classification step, class membership is determined by comparing the event under inspection to representatives which have been calculated during a training phase utilizing a self-organizing map [3]. It is shown that a true positive rate from over 79% can be achieved where the false positive rate is smaller than 4% except for the event knocking.

Keywords: acoustic event detection/classification, acoustic monitoring, auditory scene analysis, self-organizing map, cochleogram.

1 Introduction

The demographic change in industrialized countries leads to an increasing amount of older people [1]. Model computations show that by 2030 half of the population in Germany will be older than 47 years [4]. Already today one eighth of the persons having accidents in the house hold which are treated in hospitals are older than 65. The risk of such accidents increases by age [4]. Nevertheless, more than 73% of the older persons want to stay in their familiar environment and live independently as long as possible [5]. Moving to a care institution is perceived as a loss in autonomy and reduction in quality of living [6].

To allow older persons to live a secure life in their own, familiar homes, the health status of older people has to be monitored, and support in every-day life has to be ensured. However, this results in a considerable effort and may be too costly to be done by nurses alone.

An automatic monitoring can support older persons as well as care personal. A monitoring device such as a video camera may be considered to be a severe break of privacy and, thus, is judged critically by the users. A possibly more accepted alternative is acoustic monitoring. If the analysis of the acoustic signal is done automatically by the system without storing acoustic data and without the possibility that other persons may listen to the signals without permission of the owner, this perhaps would not be considered as a break of privacy at all. Another advantage of acoustic monitoring is that microphones can be integrated easily and ambiently in a home.

In the following sections such an event detector/classifier based on acoustic signals and with low computational effort is presented.

In Chapter 2 of this contribution the algorithm for the detector and classifier is described. Here, a distinction will be made between the detection of an event, i.e. the case that a sound not belonging to the background noise is present, and the classification step which assigns a detected event to a previously learned class. Prior to detection and classification, a psycho-physiologically motivated pre-processing of the microphone signal is used, resulting in the so-called cochleogram. From this, background noise is removed.

Chapter 3 describes the experiments and the real environment in which the detector/classifier is evaluated. Four sounds have been selected for classification. Coughing and knocking sounds have been tested exemplarily because they may be indicators for the health status of a person: Coughing for indicating respiratory diseases and knocking for dementia.

Another tested sound is hand clapping. Clapping could be used to control and interact with technical devices as demanded by older persons, cf. [7, 8]. The developed detector/classifier is used in [9] to start a personal activity and household assistant (PAHA) which can be controlled by an automatic speech recognition (ASR) system (beneath other input and output modalities) [10].

As a fourth sound, phone ringing was tested. An acoustic detection of phone ringing could be visualized for hearing impaired persons as an additional visual alarm e.g., on a TV. More than 40% of old people report that they have difficulties in hearing such alarms from household appliances [11]. In Chapter 4 results of the detection/classification experiments are shown and Chapter 5 concludes the paper.

2 Detector and Classifier

The acoustic detector/classifier has to be trained on example data before it can be used in the system to *learn* those events that have to be classified afterwards. In the training phase, the detector/classifier will be trained on correctly labelled example data in order to extract the model parameters of the classes which represent the specific acoustic events.

In the test phase, correctly labelled new example data are classified using the class parameters found in the training. Fig. 1 schematically illustrated the training and classification process. In both phases a continuous signal is picked up by the microphone. A pre-processing transforms the signals into a representation i.e., used by the successive detection and classification stage. The detector selects events from the continuous signal before each event is forwarded to the classifier. In the training phase a model is developed from these events. In the test phase the classifier uses the previously trained models to decide to which class a single event belongs to.

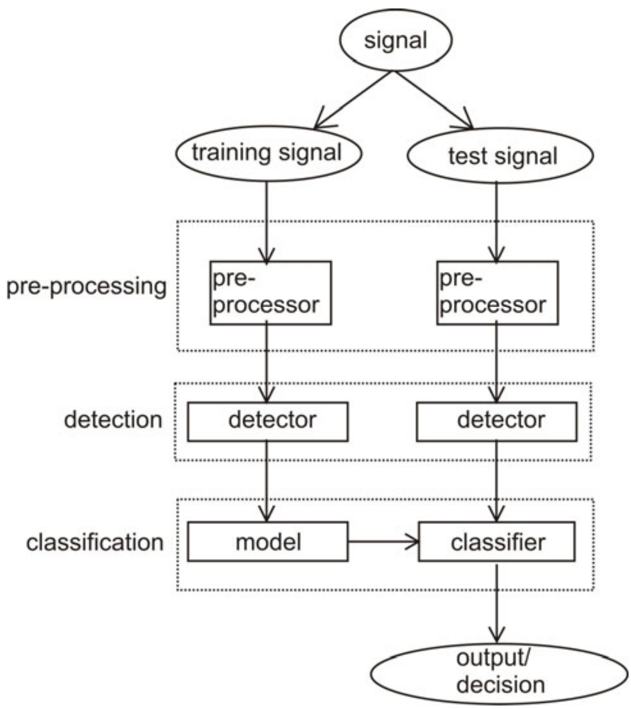

Fig. 1. Sketch of the detection and classification algorithm for training and testing.

2.1 Pre-processing

The pre-processing consists of two main steps: A transformation of the recorded time signal to a frequency-time-pattern called cochleogram and a foreground/background separation. This is done in a similar way to the aggression detector described in [2].

2.1.1 The Cochleogram as a Time-Frequency Pattern

To detect and classify an acoustic event it first has to be picked up by microphones and converted to the digital domain by an analog-digital converter. After this, it can usually be described by a quantized amplitude over time representation. For our purpose, this might not be the best representation for a sound for several reasons. The human ear has evolutionary developed a strategy to deal with sounds which are necessary to be perceived. Inside the human ear a sound signal is amplified in the middle ear. Then, the signal is separated into overlapping frequency groups in the inner ear (cochlea). These frequency groups are not linearly distributed in the frequency domain. To account for this processing model of the human cochlea, a gammatone filterbank is used [12]. For the presented algorithm, a gammatone filterbank with $M = 93$ frequency bands is implemented. The center frequencies of the bands ranged from 20 Hz to 8 kHz in 2.85 ERB distances distributed around 1 kHz. Because the phase of a signal is irrelevant in most cases, only the logarithmic magnitude of the signal is processed. The time resolution of the filterbank output is reduced by down-sampling, i.e. each down-sampled filterbank output sample represents 5 ms.

Because the resulting frequency-time-pattern is motivated by the cochlea processing it is called cochleogram. In Fig. 2, a cochleogram of a series of coughs is shown exemplarily.

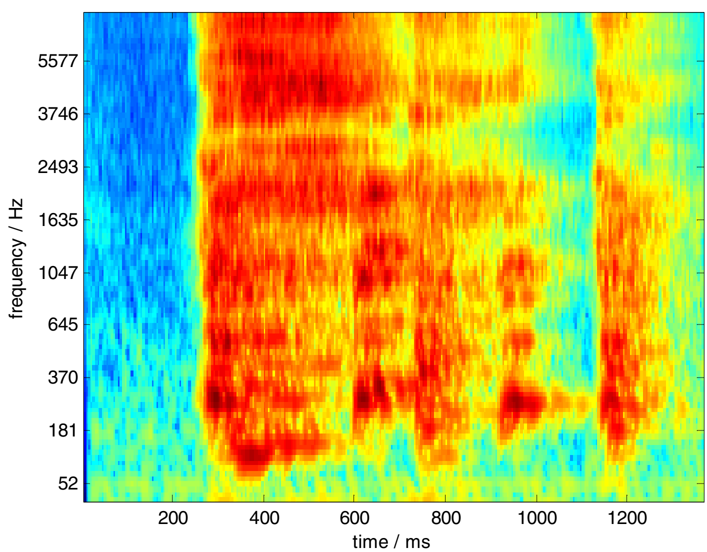

Fig. 2. Cochleogram of a series of coughs

2.1.2 Separation of Fore- and Background

A cochleogram which is denoted here by $c(m,n)$, with m being for the number of the frequency band, M the total number of bands and n the time frame, can be interpreted as a composition of foreground sounds (to be detected) and background noise. In real-world environment which do not allow control of the kind of background noise, only very weak assumptions on frequency content or time development are possible. The only assumptions made here are that background noise level varies more slowly over time than the sounds of interest, and that no sharp frequency peaks are present in the background noise.

To separate the foreground sounds from background noise, a dynamic background model is developed which estimates the level of the background for time frame *n* by the model level of time *n*-1. This model will be described in the following.

To initialize the model, the first *I* time frames (25 frames, representing 125 ms) are averaged.

$$bg(m,0) = \frac{1}{I}\sum_{i=1}^{I} c(m,i) . \tag{1}$$

For all following time steps the background model at time frame *n*-1 is used as a predictor for the next time frame *n*

$$p(m,n) = \sum_{i=1}^{M} \sigma_m(i) \cdot bg(i,n-1) \ , \tag{2}$$

where $\sigma_m(i)$ is a weighting factor, that smoothes the energies of the frequency bands.

$$\sum_{i=1}^{M} \sigma_m(i) = 1 \tag{3}$$

has to be fulfilled for normalization. Usually

$$\sigma_m(i) = 0 \qquad \forall\ i < m-2 \wedge i > m+2 \tag{4}$$

holds and

$$\sigma_m(m) >> \sigma_m(i) \qquad \forall\ i \neq m . \tag{5}$$

Using the previous definitions, a probability mask can be generated, which weights the differences between the predicted background noise *p(m,n)* and the cochleogram *c(m,n)*.

$$\mu(m,n) = 2^{-(((c(m,n)-p(m,n))/\alpha(m))\wedge 6)} \quad . \tag{6}$$

where $\alpha(m)$ is a parameter to allow for an independent weighting of the frequency bands. This is necessary because the gammatone filters include different band widths. The mask is used to dynamically adapt the background model.

$$\begin{aligned} bg(m,n) = \quad & (1-\beta)\cdot\left[\mu(m,n)\cdot c(m,n)\right. \\ & \left. +\left(1-\mu(m,n)\right)\cdot p(m,n)\right] \\ & +\beta\cdot p(m,n) \end{aligned} \tag{7}$$

β represents the degree of dynamic adjustment. If the cochleogram *c(m,n)* is predicted well by the predictor *p(m,n)*, i.e. the difference

$$c(m,n) - p(m,n) \approx 0\,, \tag{8}$$

the mask $\mu(m,n)$ will be approximately one. In this case the new background model consists of the predictor *p(m,n)*, which is mainly the old background model *bg(m,n*-1*)*, and a certain amount of the current cochleogram c(m,n). If on the other hand the predictor *p(m,n)* is very different to the current cochleogram *c(m,n)*, the mask $\mu(m,n)$ will have values close to zero. This is the case when a foreground sound is dominant. The new background model *bg(m,n)* then mainly consists of the previous model *bg(m,n*-1*)* . In Fig. 3 the background model of the cough series from Fig. 2 is plotted.

The foreground energy is

$$f(m,n) = \left(1-\mu(m,n)\right)\cdot c(m,n) \ . \tag{9}$$

Because the background energy has been modified due to dynamic adaption, the foreground energy has to be chosen as the energy higher than the background energy

$$fg(m,n) = \begin{cases} f(m,n) & \forall f(m,n) > bg(m,n) \\ -\infty dB & otherwise \end{cases} \tag{10}$$

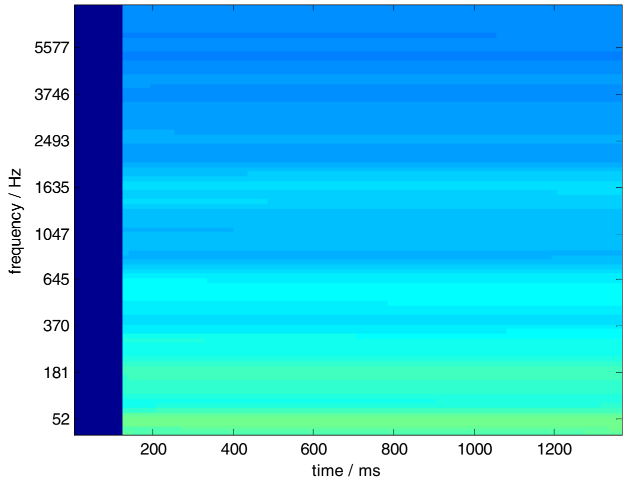

Fig. 3. Background model developed for the series of coughs from Fig. 2

The separated foreground of the cough series from Fig. 2 is plotted in Fig. 4.

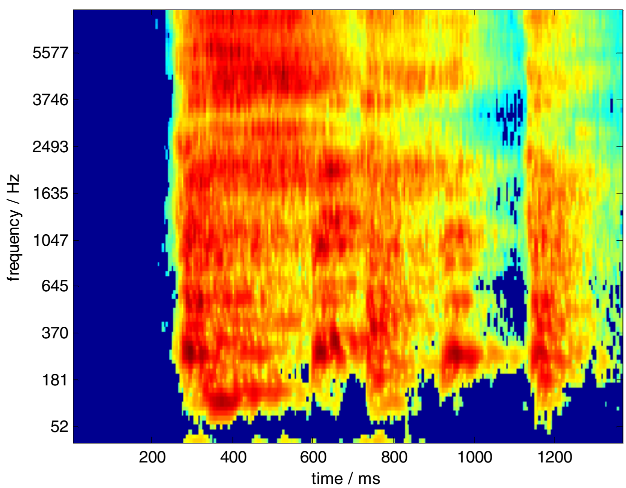

Fig. 4. Separated foreground of the cough series shown in Fig. 2

2.2 Event Detection

The detection of an event, i.e. knowledge that any sound present that does not belong to the background, is done by evaluating a threshold. If the ratio of the energy between foreground and background is higher then a defined threshold at some time frame, this time frame is marked as start of the event. The end is marked when the energy ration drops under the threshold again.

To deal with short fluctuations of the energy around the chosen threshold, a hysteresis in time is used to determine the start of an event. The start of an event is defined when the energy ratio is larger than a chosen threshold for a pre-defined time interval which is larger than the rise time. Similar to this, the end time of an event is defined when the energy ratio falls below the threshold for a time interval larger than a defined fall time. An example is plotted in Fig. 5.

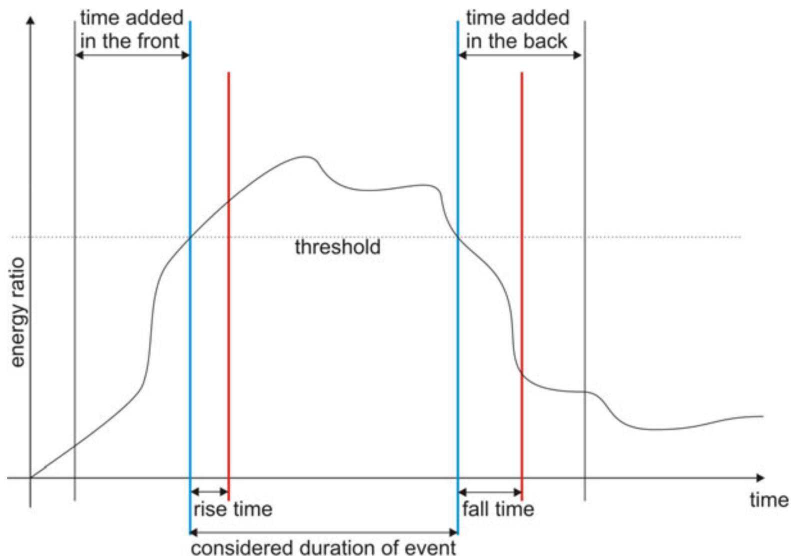

Fig. 5. Sketch of the decision step of the event detector. If the ratio between foreground and background energy stays longer than the rise time, respectively fall time over/under the threshold the start and end points of the events are marked

2.3 Classification

The two different phases for the classification process were already shown in Fig. 1: the training phase and the testing phase. During the training phase a model of the training data is developed. Afterwards, this model is used during the testing phase for decision to which class a test date belongs.

In both phases the pre-processing is the same. In this paper the separated foreground cochleograms are used. Futhermore, the means are been subtracted to achieve level independent patterns.These level independent foreground cochleograms are cut to the same length by only considering the first 180 ms (N = 36 time frames) of an event.

In the training phase each class is trained independently from the other classes. Certain amounts (about one half) of the pre-processed training data were clustered using a Self-Organizing Map (SOM) [3]. The size of the Map was 3x3. By this the whole amount of training data was reduced to nine centroids $fg_i(m,n)$ representing the data. Centroids representing less than one date were neglected.

To evaluate a value on how much a test date differs from a centroid i, the normalized L1-Norm was chosen:

$$d_i = \frac{1}{M \cdot N} \sum_{m=1}^{M} \sum_{n=1}^{N} \left| fg(m,n) - fg_i(m,n) \right| . \tag{11}$$

The minimal distance was kept as a measure of difference between the test date and the class membership.

The not yet used training data were used to calculate a threshold whether the minimal distance is small enough for a positive classification, i.e. checking if the test date belongs to the tested class. The threshold was taken as the minimum that classified all training data (except some outliers with distances > 10 dB) positively.

During the testing phase only the difference between the minimal distance and the threshold has to be checked for a positive classification (member of tested class) or negative classification (not member of tested class).

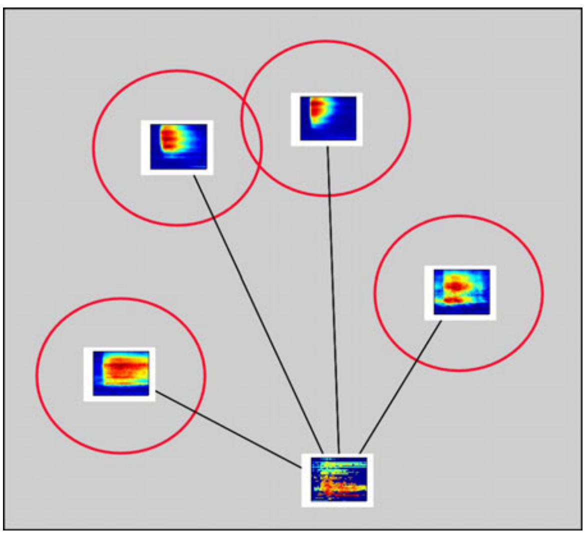

Fig. 6. Sketch of the classification algorithm. The nine centroids representing one class are placed in a high dimensional event space (gray). They are surrounded by spheres (red) representing a threshold. If a test cochleogram is inside of one of the spheres, the test date is classified positively, otherwise negatively.

In Fig. 6 a sketch represents the classification task. Nine centroids of a class (four shown here) surrounded by their threshold spheres (red) lie in the event space (gray). If the test cochleogram is inside one of these spheres the test date is classified positively otherwise negatively.

3 Experimental Setup

For evaluation of the classifier, recordings in a real environment were made. Within the Lower Saxony Research Network "Designs of Environments for Ageing" [9], a completely furnished flat has been set up where Ambient Assisted Living (AAL) technologies can be tested. For this purpose, microphones are installed in the ceiling of the living room. Different sounds produced at different positions in the room were recorded with one of the installed microphones. The recordings were made in a relatively quiet environment. The following sounds were recorded at a sampling rate of 48 kHz: coughing (two persons), hand clapping (two persons), knocking (at door, table, etc.) and phone ringing (one phone). Additionally, some every-day life recordings (conversations, bag rustling etc.) were made. The recordings of each person and each event class were labelled. Each recording session was processed by the event detector which produced the separated foreground cochleograms for each event. The detector found 33 coughs by one person and 38 by the other, 48 respectively 63 claps by both persons, 65 knocks, 9 phone rings and 36 every day life sounds.

The data were separated into training and test data to evaluate the classifier. For the two sound classes clapping and coughing, which seem to be very specific for each person, the events for one person were used for training and the remaining events for testing.

4 Evaluation

Different ways to validate a classifier are commonly used in the literature. For this paper, we chose to calculate the true and false positives and negatives.

A true positive result means that the event under test and the class on which it is tested correspond, and the classification result is correct, e.g., it is checked whether a cough signal is recognized as a cough using the cough classifier. If the classification is correct, this result is counted as a "true positive". If the event does not correspond to the classifier (a cough is evaluated with a knock classifier) and the result is negative, it is counted as a "true negative". Both classification outcomes so far have been correct. The two other possible classification outcomes are false: a cough event classified by the cough classifier to be something else would be called a "false negative"; a knock event to be classified by the cough classifier to be a cough would be called a "false positive".

In Figs. 7 to 10 the relative number of events is plotted over the minimal distances to the tested class. In Fig. 7 the classification is done on coughs, in Fig. 8 on knocks, in Fig. 9 on claps and in Fig. 10 on phone rings. The data belonging to the tested class (called test class data in the following) are displayed in black and the other data in gray. The estimated classification threshold is plotted as a vertical line. Data with minimal distances left of the threshold are classified positive and right of it negative.

In the legend the percentage of positively classified data is printed.

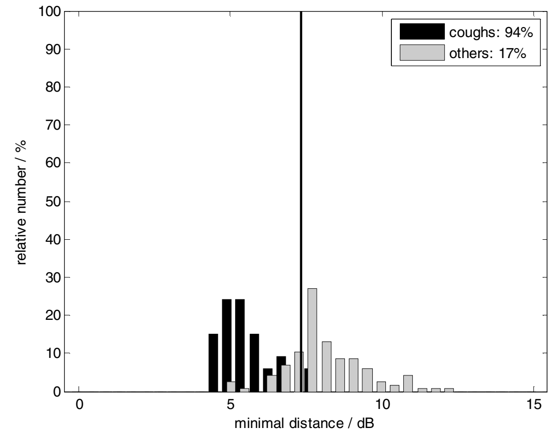

Fig. 7. Histogram of minimal distances to the cough centroids of the test class data cough (black) and the other data (gray). The vertical line shows the classification threshold at 7.3 dB. In the legend the positive rates of the data are printed in percent.

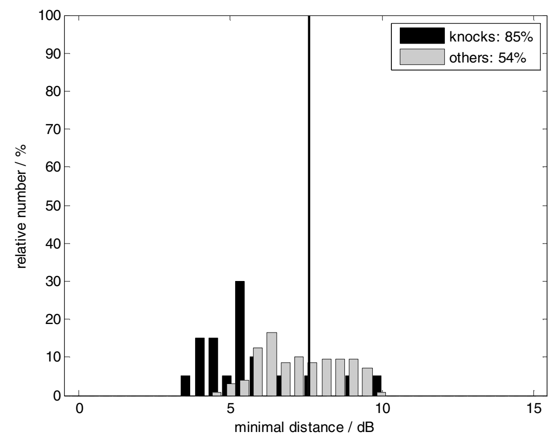

Fig. 8. Histogram of minimal distances to the knocks centroids of the test class data knocks (black) and the other data (gray). The vertical line shows the classification threshold at 7.6 dB. In the legend the positive rates of the data are printed in percent.

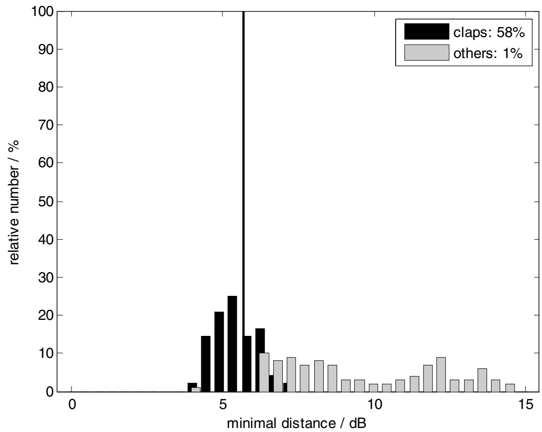

Fig. 9. Histogram of minimal distances to the clap centroids of the test class data clap (black) and the other data (gray). The vertical line shows the classification threshold at 5.7 dB. In the legend the positive rates of the data are printed in percent.

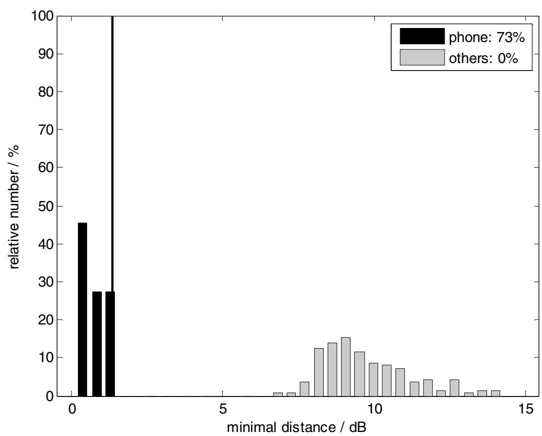

Fig. 10. Histogram of minimal distances to the phone ring centroids of the test class data phone (black) and the other data (gray). The vertical line shows the classification threshold at 1.3 dB. In the legend the positive rates of the data are printed in percent.

It can be seen that the test class data (black) in average have smaller minimal distances than the other data. A separation between these groups is possible. But the estimated classification thresholds from the training phase do not separate the classes optimal.

For phone rings the classification threshold is very low (1.3 dB) though the gap between the test class data and the other data is large enough to allow a higher threshold.

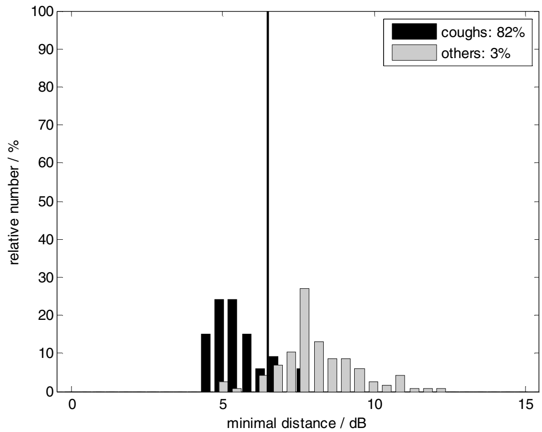

Fig. 11. Histogram of minimal distances to the cough centroids of the test class data cough (black) and the other data (gray). The vertical line shows the classification threshold at 6.5 dB. In the legend the positive rates of the data are printed in percent.

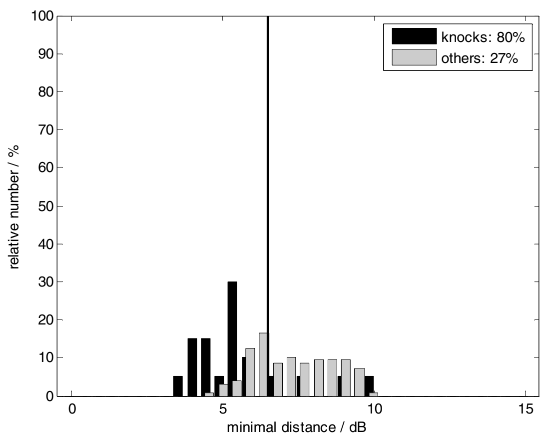

Fig. 12. Histogram of minimal distances to the knocks centroids of the test class data knocks (black) and the other data (gray). The vertical line shows the classification threshold at 6.5 dB. In the legend the positive rates of the data are printed in percent.

A fixed threshold of 6.5 dB for all experiments results in a better classification as it can be seen in Figs. 11 to 14. The true positive rate for all classes is greater than 79%, the false positive rate has been lower than 4% for all sounds except knocking. Knocking seems to have a bigger inner-class spreading due to different audio material and whether a knock was done with the open hand, the fist or the knuckles. Here, a representation by only nine centroids seems to be too few.

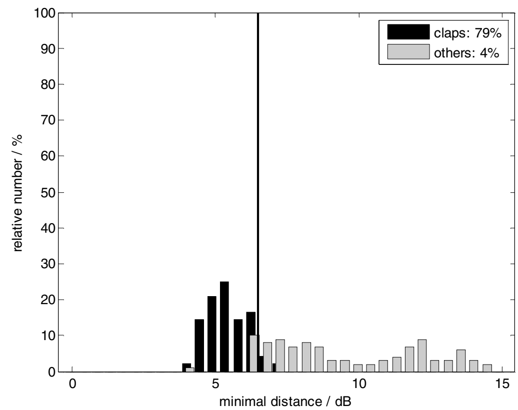

Fig. 13. Histogram of minimal distances to the clap centroids of the test class data clap (black) and the other data (gray). The vertical line shows the classification threshold at 6.5 dB. In the legend the positive rates of the data are printed in percent.

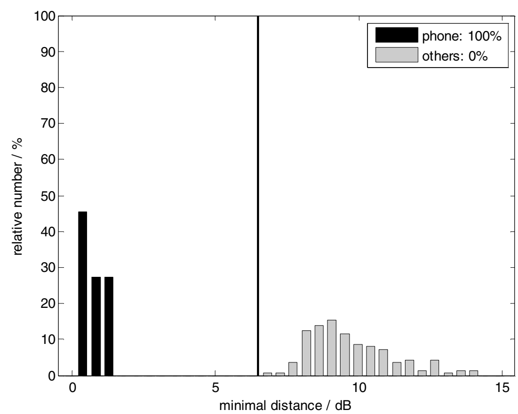

Fig. 14. Histogram of minimal distances to the phone ring centroids of the test class data phone (black) and the other data (gray). The vertical line shows the classification threshold at 6.5 dB. In the legend the positive rates of the data are printed in percent.

5 Summary

In this paper an algorithm for detection and classification of acoustic events under real conditions was presented. The pre-processing is based on the psycho-physiological motivated cochleogram. The foreground is separated from background noise. By measuring the level, a single event is marked in a continuous, acoustic input stream. The distance to representatives of a class generated from a SOM is computed, and if the minimal distance is lower than a chosen threshold, a positive classification is done.

Experiments were done in a real environment with a free field microphone installed at the ceiling of the room. It was shown that a true positive rate of 79% could be achieved for all classes where the false positive rate was lower than 4% (except for knocking).

Acknowledgements

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An Approach to the Fusion of Probabilities of Activities for the Robust Identification of Activities of Daily Living (ADL)

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Abstract. This paper describes how the precision of a system, which detects the activities of daily living (ADL), can be increased using the fusion of different sensors. Since many of the same activities can be detected by different sensors simultaneously, the use of fusion is predestined to increase the overall accuracy. The fusion can be used at various points in the data flow. If the fusion is used in the data flow at an early stage less information is lost, but higher effort is necessary for the implementation. In a first approach it is investigated how well the data at the highest level can be fused. At this level the classified activities can be found. The method Dempster Shafer was used to merge the uncertainty of data from different sources. The activity "knitting" could be recognized by the fusion with the data of a study significantly better than without the fusion with the individual classifiers of the sensors (fusion: sensitivity = 83.5%, before: sensitivity = 32.5%).

Keywords: Fusion, AAL.

1 Introduction

The existing system for activity recognition, which is developed in the project GAL[1] (Design of Environments for Ageing), uses different sensors. Currently the activities of each sensor type are detected by a separate classifier. Decision trees are used as the classifier. The recognition of activities is based on a realized study. Since many sensors detect the same activities on the same time, the use of fusion is predestined to increase the overall accuracy. Furthermore it can be determined by the fusion which sensors in which activities increase the accuracy. For the fusion different approaches are available. It is necessary to investigate which approach provides the best result for the given sensors and activities. In the first approach the method "Dempster Shafer” is

[1] http://www.altersgerechte-lebenswelten.de

used to fuse classified activities. Since this statistical approach expects probabilities as input, these are calculated using the naive bayes classifier.

The paper is organized as follows:

In chapter 2 an overview of the principles in sensor data fusion is given. Different approaches and their advantages/disadvantages are explained. In chapter 3 the Dempster-Shafer method is described which supports the combination of uncertain data. In the fourth chapter, the implementation of the fusion is described, which is based on the collected data of a study. In chapter 5 the results of the fusion are presented and in the second last chapter the results are evaluated. In the last chapter an outlook of the future work is given.

2 State of the Art

Aim of sensor data fusion is to enhance the accuracy of object recognition using multiple sensors. Furthermore, a sensor data fusion can increase the system's reliability and decrease costs, because an expensive sensor may be replaced by cheaper sensors [12], [7], [5]. In this case, additional work and expense have to be done to synchronize the sensor data. The applications of sensor data fusion can be divided into the military field and into the civil field. In the field of military applications the fusion is mainly focused on problems facing the localization and identification of dynamic units [3]. In the civil sector sensor data fusion will be used in the area of academic, commercial and industrial applications. These especially focus on the development of robots [1], smart homes and in medical applications [9]. The fusion approaches can be divided into two main classes according to the view on the main criterion. The first class can be identified according to the levels in the data flow on which the fusion may be performed [9]. There are three different levels:

- At the lowest level, "data level fusion" (figure 1), the sensor data will be fused at first. After that, features were extracted from the fused data and finally a classification will be carried out. This kind of fusion assumes that all sensors provide data of the same object to be classified. For the classification usually neural networks, clustering and template matching methods are used.

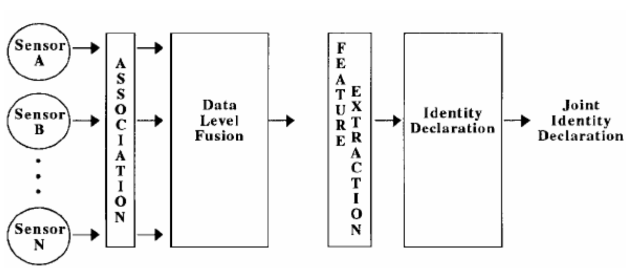

Fig. 1. Data level fusion [9].

- The second possibility is to fuse the features extracted from the different sensors. This level will be called "feature level fusion" (figure 2). The features were fused by generating a feature vector. The classification will be carried out using the feature vector, where mainly neuronal networks and clustering method are used.

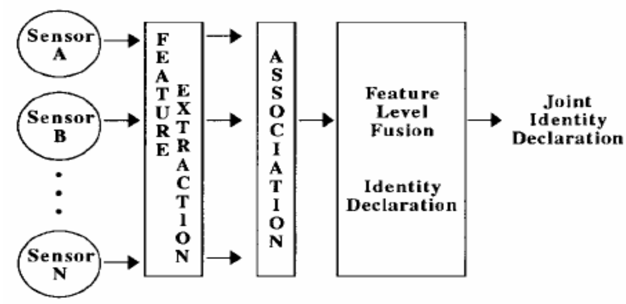

Fig. 2. Feature level fusion [9]

- At the third level, “decision level fusion” (figure 3), the data of each sensor were processed and classified separately before fusing the classified data. For this kind of fusion, mainly Bayes‘ theorem [6] or the theory of Dempster-Shafer [4], [11], [2] will be used.

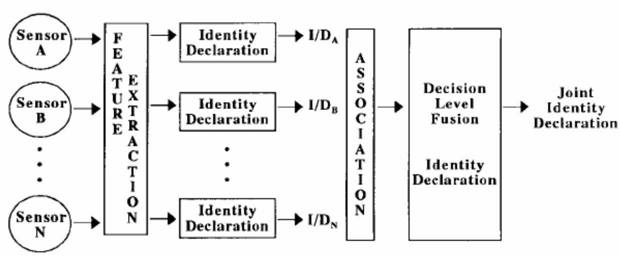

Fig. 3. Decision level fusion [9]

The fusion at the lowest level in the data flow is the most accurate, since no information will be lost. But at this level the complexity of implementation is the most extensive. In summary, the lower the level, the more accurate the fusion and the higher the implementation effort.

The second class of view on sensor data fusion is the functional aspect. Klein identified the following types of fusion [8]:

- Complementary/cooperative fusion: The object to be classified will be detected by sensors with different detection ranges. Aim of this approach is to enhance the coverage of the collected data.
- Concurrent fusion: The object to be classified will be detected by sensors with detection ranges that are related to each other. Aim of this approach is to increase the accuracy of object recognition.
- Hybrid fusion: a composition of both types of fusion.

3 Dempster Shafer

This approach was chosen, because on the one hand this can simply be applied to our data and to the other hand this is often used in the fusion at the highest level. In the following this will be presented shortly.

The probability is used for the representation of uncertainties but not necessarily for the representation of ignorance. This is needed for the fusion of uncertain information from different sources. Therefore evidences [11] were introduced, which can be understood as an extension of probabilities. Now the masses "believe", "plausibility" and "doubt" can be calculated by the evidence which is presented by a function called basic belief assignment (bba) (Figure 4). With these masses it is possible to determine the ignorance. This considers conflicting information. Thus a hypothesis can be determined more accurately.

Belief is the mass of belief that a hypothesis is true. Plausibility is the mass of belief that a hypothesis may be true if the facts are good (greatest possible probability). Doubt is the mass of belief that the hypothesis is wrong. The difference of the intervals "belief" and "plausibility" is the area of ignorance. In the interval [Bel (X), Pl (X)] is the "true belief" to find whether a statement is correct or not.

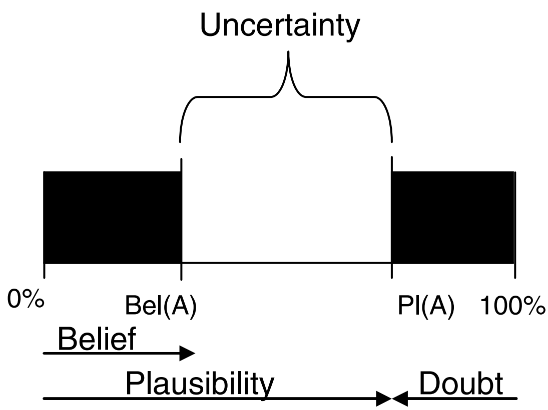

Fig. 4. Overview of evidence

Given is a set of e.g. activities (A={A1,..., A2}). If the set is complete and the singleton subsets are mutually exclusive, then A is called perceptual framework. To calculate the probabilities of the activities the bba function is defined as follows:

$$m : 2^A \rightarrow [0;1] \ . \tag{1}$$

This function has the following two conditions (the empty set is zero and the sum is one):

$$\begin{gathered} \mathrm{m}(\phi) = 0 \\ \sum_{X \subseteq A} \mathrm{m}(X) = 1 \end{gathered} \tag{2}$$

The belief function, which computes the sum of all the masses of subsets of the set of a hypothesis, is defined by a given bba function as follows:

$$\mathrm{Bel}(X) = \sum_{Y \subseteq X} \mathrm{m}(\mathrm{Y}) \;. \tag{3}$$

The plausibility function, which computes the sum of all the masses of the sets Y that intersect the set of the hypothesis A, is defined by a given bba function as follows:

$$\mathrm{Pl}(\mathrm{X}) = \sum_{Y:Y \cap X \neq \phi} \mathrm{m}(\mathrm{Y}) \;. \tag{4}$$

The doubt function is defined by a given belief function as follows:

$$\mathrm{D}(\mathrm{X}) = 1 - \mathrm{Bel}(\overline{\mathrm{X}}) \;. \tag{5}$$

Two bba functions (m_1 and m_2) can be fused using the combination rule.

$$\mathrm{m}_3(\mathrm{X}) = \mathrm{m}_1 \oplus \mathrm{m}_2(\mathrm{X})$$

$$\mathrm{m}_3(\mathrm{X}) = \begin{cases} 0, & X = \phi \\ \dfrac{\sum\limits_{\substack{Y \in A, Z \in A \\ Y \cap Z = X}} \mathrm{m}_1(\mathrm{Y}) * \mathrm{m}_2(\mathrm{Z})}{1 - \sum\limits_{\substack{Y \in A, Z \in A \\ Y \cap Z = \phi}} \mathrm{m}_1(\mathrm{Y}) * \mathrm{m}_2(\mathrm{Z})}, & X \neq \phi \end{cases} \tag{6}$$

The combination rule is commutative and associative.

$$\begin{aligned} \mathrm{m}_1 * \mathrm{m}_2 &= \mathrm{m}_2 * \mathrm{m}_1 \\ (\mathrm{m}_1 * \mathrm{m}_2) * \mathrm{m}_3 &= \mathrm{m}_1 * (\mathrm{m}_2 * \mathrm{m}_3) \end{aligned} \tag{7}$$

Furthermore two bbp functions can’t be merged if the denominator is zero. The result of the combination rule is again a bbp function m_3, with which the hypothesis probabilities for belief, plausibility and doubt can be calculated.

3.1 Example

As an example four activities M={A, B, C, D} should be considered. Furthermore there are two sensors, (S_1, S_2) with which the activities are determined. The goal is the fusion of the activities. This requires a total of two bba functions. For example:

bbp function m_1 for S_1:

$m_1(\{A, B\})=0.6$;
$m_1(\{A, B, C, D\})=0.4$

bbp function m_2 for S_2:

$m_2(\{B, C, D\}))=0.3$;
$m_2(\{A, B, C, D\})=0.7$

The two bba functions satisfy the condition that the sum of the probabilities is one (eq. 1). To determine the probabilities of the individual bba functions, it is sufficient to take the singleton subsets of the perceptual framework. For the fusion of the two existing bba functions the combination rule is applied (s. table 1).

Table 1. Results of combination rule

$m_1 \oplus m_2$	$m_1(\{A,B\})=0.6$	$m_1(\{A, B, C, D\})=0.4$
$m_2(\{B,C, D\}))=0.3$	$m_3(\{B\}))=0.18$	$m_3(\{B, C, D\}))=0.12$
$m_2(\{A,B,C, D\})=0.7$	$m_3(\{A, B\}))=0.42$	$m_3(\{A,B,C, D\}))=0.28$

After the bba function m_3 was calculated, the ignorance of various hypotheses can be calculated. Therefore it must be calculated the values of the belief function and of the plausibility function. In this example these values are calculated for the hypotheses {A}, {B} and {A, B}.

Interval of ignorance (A)=[Bel(A), Pl(A)]=[0,0.7]
Interval of ignorance (B)=[Bel(B), Pl(B)]=[0.18,1]
Interval of ignorance (A,B)=[Bel(A,B), Pl(A,B)]=[0.6,0.7]

The hypothesis {A, B} has the largest belief value (60%) that means this hypothesis is available with certainty to 60%. The probability of ignorance is 10%. That means the true probability is found in the range between 60% and 70%. For the other two hypotheses the belief value is much smaller. Thus the hypothesis {A, B} is the most probable activity from the calculated hypotheses.

4 Experimental Setup and Study

4.1 Sensors

The system for activity recognition uses different kind of sensors with different ranges of detection. First, the system includes state sensors such as motion detectors, door and window contacts and switches. These sensors are integrated into a home automation system. The advantage of these sensors is their pervasive presence and their unobtrusive appearance. The home automation system collects the data produced by the state changes of the sensors which can be used for activity detection. Second, a power sensor [10] [13] was used, which was installed into the fuse box. This sensor identifies electrical devices due to their characteristic switching patterns using pattern recognition techniques. The advantages of the sensors are the pervasive and unobtrusive measurements and the feasible installation in retrospect. Third, two vision sensors were installed in the kitchen and the living room. The advantage is their high information gain with respect to other sensor systems. Additionally to the stationary sensors mentioned, an accelerometer[2] was worn by the subjects. The advantage of this sensor is that it measures movements of the subject directly.

[2] http://cache.freescale.com/files/sensors/doc/data_sheet/MMA7260QT.pdf?pspll=1

4.2 Study

The study was performed in two stages: in the first part healthy, younger adults were monitored and sensor data were recorded to train a classifier for each sensor and older subjects were measured in the second part to provide an independent test set for these classifiers.

During the first part of the study 6 healthy, younger adults were monitored. The subjects were between 25 and 40 years old (mean: 30 years). During the second part 5 subjects were monitored, age between 72 – 84 years (mean: 75.3 years).

The subjects were studied in the IdeAAL laboratory of OFFIS in Oldenburg, Germany (Figure 5). The laboratory is a living environment equipped with sensors mentioned above. The subjects received a list of tasks they should perform in the laboratory. The order of carrying out the activities played no role. Actually, it was highly appreciated that the subjects chose the order individually. This point may be interesting for future sequence analyses of the data.

The subjects were asked to perform the following activities:

- preparation of meals and beverages
- consumption of meals and beverages
- washing dishes
- reading book or newspaper
- watching TV
- using the bathroom and
- knitting

We designed the setting so that we could test our classifiers under conditions that were as real as possible. I.e., the subjects should make and eat meals with different degrees of difficulty (e.g. some ate just a yogurt and others made pasta). The ethics committee of the University of Oldenburg has approved this study.

Fig. 5. Pictures of the laboratory taken from the first part of the study with healthy, younger subjects

4.3 Available Results

The classification models were generated using the C4.5 tree induction algorithm implementation of the WEKA[3] machine learning software.

The activities within this study were identified for each of the used sensor systems, whereas the activity was one of the following: preparation of meals and beverages, consumption of meals and beverages, washing dishes, using the bathroom and knitting.

In table 2 the sensors with the best recognized sensitivities per activity are listed. As expected, the power sensor can only recognize those activities that use electrical devices. Therefore the current sensor is combined with the home automation to simplify the fusion.

Table 2. Best sensitivities per activity of decision trees

Activity	Sensitivity	Specificity	Sensor system
Food preparation	74.7%	84.2%	Vision
Food intake	69.5%	93.0%	Vision
Hot Beverage preparation	73.1%	87.0%	Power
Cold Beverage preparation	0.0%	93.6%	Home automation
Beverage intake	2.2%	99.7%	Vision
Washing dishes	73.5%	85.8%	Vision
Using the bathroom	82.8%	97.6%	Home automation
Knitting	0%	94.7%	Vision

4.4 Probabilities of Activities

For the fusion of Dempster Shafer the probabilities of each recognized activity from each sensor must be computed. But until now only decision trees for classification have been used. Since the decision trees do not provide probability values, they are computed by the classifier naive bayes from each sensor. The result of each sensor is a file with the structure shown in table 3.

Table 3. Structure for Dempster Shafer

Time	Food preparation	Food intake	Hot Beverage preparation	Knitting
1268213325	0,12	0,01	0,07	0,05
…	…	…	...	…

Cold Beverage preparation	Beverage intake	Washing dishes	real Label
0,05	0,1	0,45	Knitting
…	...	…	…

[3] http://www.cs.waikato.ac.nz/~ml/index.html

Each line presents a labeled activity with the probabilities. The time is specified in the unix format. This structure is then applied to the combination rule to calculate the bba function for the fusion. Then the belief values and the plausibility values can be calculated. To determine the quality of the fusion the sensors with the best recognized sensitivities (naïve bayes classifier) per activity have been summarized in the Table 4. As mentioned in section 4.3 the two sensors, home automation and power sensor, can be combined for the fusion. Thus one classifier is used for the two sensors.

Table 4. Best sensitivities per activity of naïve bayes

Activity	Sensitivity	Specificity	Sensor system
Food preparation	86.9%	77.9%	Vision
Food intake	40.8%	95.1%	Vision
Hot Beverage preparation	70.1%	87.0%	Home automation/Power
Cold Beverage preparation	0.0%	93.6%	Home automation/Power
Beverage intake	0.9%	99.8%	Accelerometer
Washing dishes	50.0%	90.7%	Home automation/Power
Using the bathroom	77.6%	97.7%	Home automation/Power
Knitting	32.1%	94.3%	Vision

5 Results

The sensor-based estimated probabilities of the activities (see sec. 4.4) are hierarchically fused using eq. 6. Since the combination rule is commutative and associative the result of the fusion depends just on the number of sensors and not on the order. In table 5 one can see all valid fusion combinations of the three sensors. Here, the fusion results are based on 2424 labeled items, which have the structure as in table 3. These labeled items are the test data for the fusion.

Table 5. Combinations of sensors and non-fused data sets

Combinations	Non-fused data sets
$\{\{S_1,S_2\},S_3\}$	6,65%
$\{S_1,S_2\}$	0,40%
{S2,S3}	0%
$\{S_1,S_3\}$	3,78%

S_1=Vision-Sensor

S_2=Accelerometer

S_3=Power/Home automation

The following tables give an overview of the sensitivity and specificity per activity for the different sensor combinations. Since the combination of the two sensors {S_2, S_3} achieves a classification accuracy far below the other combinations (under 20%), this combination is not shown.

Table 6. Combination {{S_1,S_2},S_3}

Activity	Sensitivity	Specificity
Food preparation	31.7%	97.9%
Food intake	46.6%	95.2%
Hot Beverage preparation	70.9%	86.2%
Cold Beverage preparation	0%	99.1%
Beverage intake	0%	99.2%
Washing dishes	6.9%	94.8%
Using the bathroom	0%	94.7%
Knitting	83.5%	65.4%

Table 7. Combination {S_1,S_2}

Activity	Sensitivity	Specificity
Food preparation	28.1%	98%
Food intake	35.4%	96.2%
Hot Beverage preparation	41.9%	86.4%
Cold Beverage preparation	0%	98.8%
Beverage intake	0%	99.3%
Washing dishes	7.3%	94.4%
Using the bathroom	0%	92.5%
Knitting	83.5%	62,00%

Table 8. Combination {S_1,S_3}

Activity	Sensitivity	Specificity
Food preparation	29.5%	98.3%
Food intake	37.1%	95.7%
Hot Beverage preparation	71.4%	89.0%
Cold Beverage preparation	0%	98.5%
Beverage intake	0.9%	99.7%
Washing dishes	6.1%	95.4%
Using the bathroom	0%	94.6%
Knitting	83.5%	63.3%

When comparing the sensitivities of the various combinations of fusion (tables 6-8) it can be seen that the sensitivities differ significantly only in the activities of "Hot Beverage preparation" and "food intake". The sensitivity in the activities "Cold Beverage preparation", "Using the bathroom" and "Knitting" is the same in all combinations of fusion. Through fusions the overall accuracy has been increased, but the activity “Using the bathroom” is one exception. In the case of the sensor system, "Home automation/power", the activity "Using the bathroom" is detected with a sensitivity of 77.6% (see table 4). With the fusion the sensitivity of this activity is 0%. The main reason for that is that we avoid an installation of a vision-sensor in the bathroom. Since that, the vision-sensor cannot support any reasonable information and thus a brute force fusion of the sensor information fails in this situation.

6 Discussion

Overall, the accuracy was been increased by the fusion of 5%, but the sensitivity of some activities is much worse than before the fusion. For example the activity "Using the bathroom" is no longer recognized. Therefore it is useful to apply the fusion only to some activities. The reason for the bad fusion at some activities is a conflicting recognition of activities at the individual sensors. The detailed comparison of the results of the various fusions (table 6-8) with the results of the decision trees as classifiers (see table 2) shows that only the sensitivity of the activity “Knitting” could be significantly improved by the fusion (Fusion: 83.5%; decision trees: 0%). When comparing it must be considered that another classifier, naive bayes, has been used for the fusion. Therefore the quality of the fusion cannot be directly compared with the individual results of the decision trees. Since the various sensor data have good results in depending on different classifiers/fusions, different classifiers should be used for the recognition of activities. The activity "Knitting" can be best detected by the fusion. The fusion (S_1, S_2) can be used, because this has the smallest proportion of non-fused data sets (s. table 5) and the sensitivity is the same as in the others combinations of fusion.

7 Outlook

In our future work we will investigate an extended version of the proposed fusion model. The new model will be based on a set of subspaces, where each subspace defines a closed space in the monitored environment. For each subspace a combination of sensors is defined, where the combination must satisfy the requirement, that all of these sensors are able to measure the same activities. Furthermore, each subspace has a number of activities that can occur in the associated subspace. Let us e.g., consider the study in chapter 4. Here, an appropriate separation of the IdeAAL laboratory would be that each room simply represents one subspace. While in the kitchen subspace a valid combination would be $\{\{S_1,S_2\},S_3\}$ including all activities except "Using the bathroom", the bath subspace would just contain $\{S_2,S_3\}$ including the activity "Using the bathroom". The proposed fusion approach is finally applied to each subspace. This concept avoids the problem of wrong sensor predictions since it estimates for each subspace just the activities that really take place at an associated location in the living space. The results of the fusions in the subspaces represent local activity estimations. In order to get the global activity we are using an additional fusion where the activities of the subspaces are combined. This second fusion step regards the problem that e.g., the activity "Reading" can take place in the subspace "Kitchen" as well as in the subspace "Living room".

Furthermore it can be investigated, whether the fusion could be improved, if it is operated in the data flow at a lower level. It would be useful to do this on the level "feature level".

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A Gesture Based System for Context – Sensitive Interaction with Smart Homes

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Abstract. This paper introduces a system for gesture based interaction with smart environments. The framework we present connects gesture recognition results with control commands for appliances in a smart home that are accessed through a middleware based on the ISO 24752 standard URC (Universal Remote Console). Gesture recognition is realized by applying three dimensional acceleration sensor information of the WiiMote from Nintendo. This information is trained to a toolkit for gesture recognition that implements machine learning algorithms well known from speech recognition. Our study focuses on two interaction concepts with the aim to exploit the context and special home scenarios. This serves to reduce the number of gestures while in parallel retaining the control complexity on a high level. A user test, also with older persons, compares both concepts and evaluates their efficiency by observing the response times and the subjective impressions of the test persons.

1 Introduction

Life expectation in Germany is rising by three months every year and researchers predict that in 60 years most people will be living to 100 years and longer. Conversely the number of younger people is dramatically dropping compared to the increase of the older population. This demographic shift leads to an imbalance between elder and young people. This and the circumstance that older people need more support in their everyday life, invoked by physical and cognitive impairments, lead to the problem that not enough caregivers will be available to support the older generation. One solution to face this problem of the near future are age appropriated assistance systems for smart environments. A smart home that supports its aging residents in everyday life activities raises their life quality on the one hand. On the other hand, it extends the time elder people can live an autonomous life in their own four walls without being dependent on human support.

One important task is to design new interaction concepts based on different modalities like speech or gestures. We introduce a system for gesture based interaction with smart environments. The framework we present connects dynamic hand gestures with control commands for appliances in a smart home that are accessed by a middleware based on the ISO standard URC. The URC technology provides an approach called "pluggable user" interfaces allows for interfacing arbitrary networked appliances or services with personalized, accessible and adaptable user interfaces [1]. One challenge of gesture based interaction is to keep the gesture space as small and easy to remember as possible. Especially the elderly or people with cognitive impairments are overwhelmed by the task to remember a higher set of - in the worst case - complex gestures. This paper focuses on this problem by presenting two interaction concepts with the aim to exploit the context and special home scenarios in order to reduce the number of gestures while retaining the control complexity on a high level in parallel. For this, two gesture interaction concepts have been implemented and tested with a heterogeneous user-group focused on the elderly. The first one takes the interaction context into account by interpreting the performed gesture with the appliance in context as additional information. Thus we can deduce that one and the same gesture can trigger different events on different appliances although in the understanding of a person it has the same interpretation: E.g., lifting the hand stands for increasing a setting. However, on TV it has the effect to increase the volume and on the extraction hood, it increases the fan speed. The second concept combines multiple smart home functionalities of different appliances to several scenarios. Thus a complete room or even the complete house can be adapted to a special state that is achieved by performing only one gesture, e.g., we use a phone scenario that mutes the television or radio but also loud appliances such as the extraction hood.

The next section gives an overview on related work about gesture controls in smart environments and identifies some findings that influenced our study. After that we introduce our smart home infrastructure and our technology for gesture recognition. Subsequently the two examined interaction concepts are explained in detail. The final user test section deals with the test scenarios, test results and their analysis.

2 Related Work

Diverse researchers develop smart home environments with a special focus on personalized user interfaces for multimodal interaction. Burzagli discusses the challenges of designing multimodal interfaces in ambient intelligence scenarios giving main attention to speech interaction [2]. Machate focuses on multimodal interaction concepts for the elderly [3]. Similarly, Song [4] developed smart environments for the elderly and also disabled persons. In this approach voice and hand gestures are the modalities to control wheelchairs, transferring and bed robots. He installed cameras to recognize simple hand gesture patterns. In [5], hand movement paths recorded by cameras and image processing are applied to detect gestures in order to control a lamp and a movie player. For each functionality one gesture is used, four for the lamp (on, off, dim lighter, dim darker) and two for the movie player (play, pause). It is observed that users need some adjustment period with the effort to increase detection precision from 32% to 97%. Blumendorf [6] also addresses the fact that interaction commands for smart home environment must be learnable both easily and quickly. In user tests he found out that users are willing to learn easy commands for both speech and gesture input. Moreover the user appreciates multimodality and prefers short commands over more complex sentences in speech interaction. Furthermore, help for more complex commands is needed and users like to chain multiple commands to speed up interaction. In [7] they record gestures with the accelerometers of an iPhone and use them to control household appliances. The controllable appliances were TV, HIFI-system, lamp and a window shutter. In user studies with 27 persons the system was trained with 110 gestures, 42.31 per person. As expected, a correlation between recognition precision and quality rating was found.

3 Smart Home

3.1 Smart Kitchen

The smart kitchen (figure 1) at the German Research Center for Artifical Intelligence in Saarbrücken is a completely equipped kitchen with the feature that all appliances are accessbile via network. The type of connection and protocols are a various set of different technologies. Hood, oven, hob, fridge and freezer are connected via powerline technology and can be controlled by a WSDL interface. The light in the kitchen and additional sensor technology like movement, light, temperature or contact sensors for windows and doors are accessed by the battery and wireless radio technology EnOcean[1]. A television, in form of the Windows media center, runs on a desktop PC. The portfolio of appliances also includes technology for health care as bloodpressure and blood sugar measure meter.

The heterogenous number of different technologies complicates the rapid development of new user interfaces for an interaction with the smart home. This problem is faced by using the ISO 24752 standard URC (Universal Remote Console) realized with our own middleware framework UCH (universal control hub) that provides a consistent homogeneous solution to access the functionalities and states of all appliances.

Fig. 1. The smart kitchen at the German Research Center for Artifical Intelligence Saarbrücken

[1] http://www.enocean.com/

This installation serves as a test environment for different interaction concepts, e.g., a multimodal dialogue system [8] or a task based calendar that assists people with mild cognitive disabilities affecting their concentration and memory [9].

3.2 Gesture Recognition

3.2.1 The Input Device: WiiMote

Our input device is the WiiMote (figure 2) that was developed by Nintendo in 2006 as the main controller for their game console Wii. Besides normal controller attributes like buttons and a directional pad, it introduced the innovative concept of using three dimensional accelerometers for game control. Thus hand movements of the user are directly transfered to the game. With the Nunchuk controller, that contains three further accelerometers, this can be extended to a two handed control.

3.2.2 Classification

For gesture recognition we use the classification framework TaKG that was developed at our lab for recognizing gestures recorded by 3D-accelerometer-signals [10]. The framework provides several common classifiers for learning and recognizing signals of an arbitrary number of dimensions, such as Multilayer Perceptron Neural Networks (NN), Support Vector Machine (SVM) and multidimensional Dynamic Time Warp (DTW) [11]. Furthermore several methods for feature extraction are provided. In [8][10] we used the framework in different application scenarios to recognize pantomimic gestures performed with the WiiMote-Controller by exploiting the accelerometer signal of the WiiMote. TaKG is responsible for learning new gestures and organizing them into user specific training sets. Within a set, the information for every trained gesture is listed including the measured signal data and a gesture tag denoting the gesture. The main API contains the following functionalities: Load data for a special user, learn and delete gestures and classify new recorded gestures. A gesture classifying request returns the gesture tag of the gesture in the training set with the highest similarity to the gesture which has been provided together with the request. Another option is to ask for a ranked list of all trained gestures. SVM and NN provide just a ranking, the DTW algorithm

Fig. 2. Right: The WiiMote controller and Nunchuk. Left: Accelerometer axes.

describes similarity based on Euclidian distance which gives the advantage that an ill performed gesture can be dismissed.

4 Interaction Concepts

In the related work [5][7] we observed that for any single interaction with a home appliance a distinct gesture was defined and trained to the interaction system. This inevitably leads to a very large set of gestures to remember and to a difficult and unintuitive interface. Goal of this study is to find appropriate concepts to reduce the amount of different gestures a user has to learn and to remember for his interaction with the smart home environment. This is crucial, especially for the elderly and people with a reduced cognitive capacity. The basic idea to achieve this goal is a context sensitive system. A system that knows the appliance that is actually in the user's focus needs a much smaller number of distinct gestures than a system without this information. With this additional information only one gesture, if you just consider the hand movement, can result in different interpretations, depending on the appliance that is controlled in the moment of execution: e. g. a gesture for the interpretation of activating something can switch on the television or the lamp in the living room. A gesture that is a metaphor for switching through different selections of a setting can be used to zap through television channels but also to increase the ventilator speed of a kitchen hood: One gesture - Several meanings! This is the idea our first interaction concept is built on.

4.1 Gesture Control in Context

Gesture-control in context offers the advantage that one gesture can trigger functionalities on several appliances. These functionalities have a similar meaning and can be grouped in function categories. Typical function categories we applied are listed in table 1:

It remains the task to indentify the appliance that is actually in focus. Originally the plan was to take advantage of the infrared-sensor of the WiiMote and a special flashing - pattern of infrared LEDs that are assembled at the different appliances. With a specific flashing frequency for every appliance it would be possible to detect the appliance a user is pointing at with the Wiimote. Unfortunately this installation was not ready early enough for the evaluation and remains an open task for future work. To simulate this system behavior the user is able to select the appliance that is actually in focus by switching through the devices with the directing-pad of the WiiMote. Speech synthesis gives feedback about the actually selected appliance that is then in the user's focus.

4.2 Gesture Triggered Scenarios

In [7], it is discussed that a speech controlled system should provide the feature to chain multiple commands in order to speed up the interaction. We wanted to adopt this idea for gesture controlled systems and created scenarios that can be triggered by a single gesture. One scenario exactly describes a situation in which a special behaviour of the smart environment is expected. For example, a gesture to instruct silence has influence

Table 1. Predefined categories

- turn on	turn on television turn on standard light turn on fan turn on light of the hood	(impact: appliance turned on)
- turn off	turn off television turn off standard light turn off fan turn off light of the hood	(impact: appliance turned off)
- increase	increase television volume increase fan speed increase light setting	(impact: appliance setting increased)
- decrease	decrease television volume decrease fan speed decrease light setting	(impact: appliance setting decreased)
- next choice	television channel	(impact: switch to next channel)
- previous choice	television channel	(impact: switch to previous channel)
- toggle mute	television	(impact: toggle between mute/unmute)

on different appliances, e. g. a running television is muted and the speed of a fan with a high noise level is lowered. Another gesture that stands for 'go to bed' switches off all running appliances that are not needed while the user is sleeping or that would even be annoying. Obviously the idea of scenarios is also a benefit for other modalities. They could also be triggered by voice commands or GUI interactions.

5 User Tests

The user study compares the two interaction concepts we introduced in section 4 in practice. The test users have to solve a number of interaction tasks with the smart home that are embedded into an everyday life story. During these tests we measure the users' response times separated into cognitive and physical parts. The time the user needs from hearing the task until performing the gesture is the cognitive response time. The time need for performing the gesture is the physical response time. Additionally, we assessed the users' subjective ratings of the system through a questionnaire.

5.1 Test Scenario

For the evaluation we invented a story of typical everyday life situations and confronted the test persons with the exercise to operate the appliances in our smart environment according to the situation in the story. The involved appliances are television, hood with fan and light setting and a floor lamp. Every test takes around 90 minutes and is separated into three phases.

1. Test of the context sensitive interaction concept. In this phase the test person is instructed to devise personalized gestures for every single function category. There are a total number of 7 categories (table 1 gives an overview of the categories used and their influence on the different appliances). First the test persons paint the movement path on a paper and additionally describe it with words. Then they try to rank the difficulty of devising the gesture. After defining the gestures the system is trained with three performances of every gesture, so the total number of trained gestures per person is 21. In order to get the user familiarized with the interaction concept all trained gestures are tested with some exercises. Here we have the possibility to detect confusions between gestures for different categories that are too similar and in case of a confusion, replace them. After this adaption phase the user has to solve tasks that are embedded into the following everyday life story (parts of the story that require a user reaction are underlined):

   It is 7 o' clock p.m. I returned home from work and I am tired. Now I would like to relax, watch television and enjoy life. I enter the kitchen. The kitchen is dark, so I switch on the floor lamp. I also turn on the television. I take a drink out of the fridge and watch the TV program. I do not like what is on so I switch to the next channel. This program is better and I increase the volume.
   20 minutes later, I get hungry. Today I will prepare spaghetti Bolognese. I fill the pot with cold water and put it on the hob. I spend the waiting time watching TV. After some minutes the water is boiling. I would like to put the spaghetti into the pot. The steam is very strong and the light at the hob is too low. I can barely see what I am doing so I turn on the fan and the light of the extension hood and set the fan to maximum speed.
   The spaghetti are in the pot. I wait and continue to watch TV. Suddenly the phone in the kitchen is ringing. I pick up the phone. Because of the noise of the fan and the TV I can hardly hear the person at the other side of the phone. I lower the fan speed to level 1 and mute the television. After five minutes the phone call is over. I set everything back to the previous state so I unmute the TV and increase the fan speed. Finally the spaghetti are ready and I turn off the extraction hood.
   After the meal I am tired. I switch off all the devices in the kitchen and go to bed.

2. Test of the shortcut interaction concept. The procedure is very similar to the previous one. We predefined five shortcuts for the story (see table 2). In the beginning, the test person is introduced to the interaction concept of shortcuts and has to devise personalized gestures for the six scenarios. Again, the gesture is documented by painting the movement path and describing the gesture with words. Then every gesture is trained to the system three times resulting in a total training set of 15 gestures per person. The user plays the story again with the instruction to use shortcuts this time.

Table 2. The six control scenarios for our story

Amusement	Turn on television and floor lamp
Start Cooking	Turn on the light of the hood and increase the fan speed to maximum
Finish Cooking	Turn off the light and fan of the extraction hood
Silence/Stop Silence	Mute the TV and decrease the fan speed of the hood/Reset TV and hood to previous settings.
Go to bed/leave home	Turn off all appliances.

3. In the last phase the user has to answer a questionnaire. Here we want to find out the subjective impressions of the test persons. We asked for the cognitive and physical challenge of the tasks and difficulties during the test. Furthermore we wanted to know, whether it is more difficult to devise gestures for the context sensitive or the scenario based interaction concept. A last part collects statistical information like age, gender and technical affinity.

5.2 Evaluation

The user test serves primarily to compare both introduced interaction concepts and evaluate their efficiency by observing the reaction times and the subjective impressions of the test persons. A total number of 13 test persons took part in the test, six were male and seven female. Eight persons were between 18-30 years, two between 31-60 and three persons older than 60 years. The questionnaire revealed that 84.6 % of the test persons were convinced by the context-sensitive interaction concept. 69.3 % rated the shortcut based system as helpful or very helpful (figure 3).

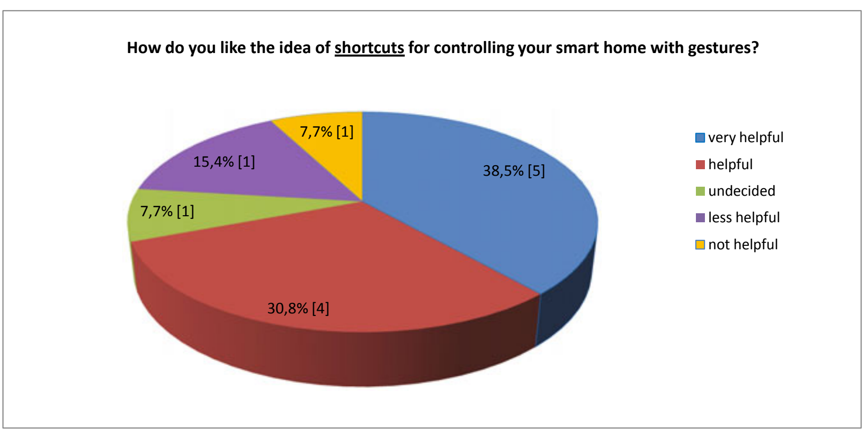

Fig. 3. How do you like the idea of shortcuts for controlling your smart home with gestures?

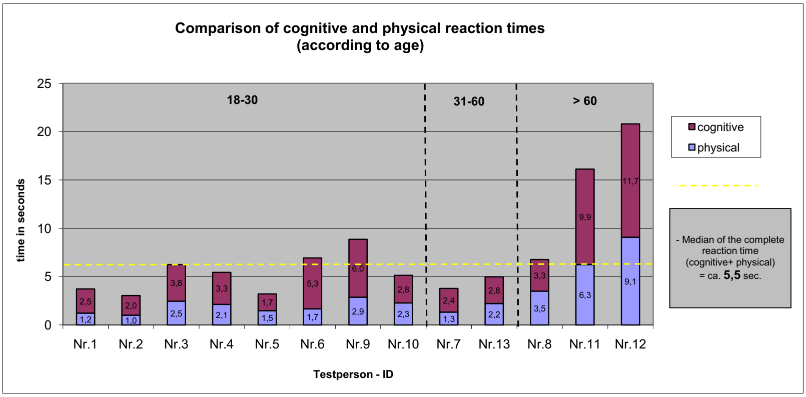

Fig. 4. Comparison of cognitive and physical reaction times according to age

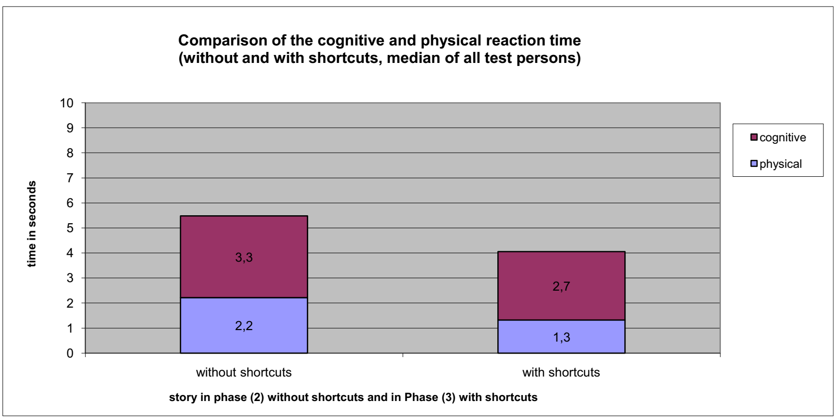

Fig. 5. Comparison of the cognitive and physical reaction time according to interaction concept

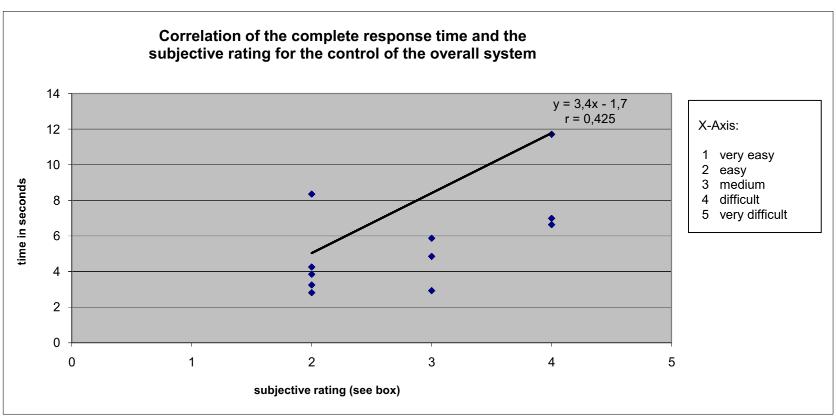

Fig. 6. Correlation of the complete response time and the subjective rating for the control of the overall system

Comparing the response times according to the age of the test users (figure 4) reveals that there is no gap between users younger than 30 and younger than 60 years. Nevertheless, it is worth mentioning that the users between 30-60 were technology-friendly. The users older than 60 years took significantly longer to solve the tasks with response times twice as long as the times of other the users. One reason for this is that the older users never have seen or used a gesture based control before.

Figure 5 compares the response times for both interaction concepts of our user study. It depicts the median of all measurement. Generally, it is clear that both, the cognitive and the physical reaction time, are shorter at the scenario based interaction concept. The observed time is the time needed to execute one shortcut which already contents multiple commands of the context based approach. So shortcuts already solve problems faster naturally because several commands are chained together to one. Finally, we examine the correlation between the user's efficiency in using the gesture based smart home control and their subjective rating of the control method. For this, the user should rank their confidence with the system on a scale from one to five (very easy to very difficult). The graph in figure 6 charts this subjective rating related to the response time of the users. The result is a marginal correlation of 0.425.

6 Conclusion and Future Work

In this paper, two interaction concepts to simplify the gesture based interaction with a smart home environment are presented. For hand movement recognition we exploit the three dimensional accelerometers of the WiiMote from Nintendo and use machine learning algorithms to learn and classify performed hand gestures. The result of the classification process is used to control appliances in a smart home, in detail an extraction hood, a floor lamp and a television. The priority of the interaction concepts is to reduce the number of gestures a user has to learn and to remember without constraining the number of control functionalities. To this end, the first concept takes the actual control context into account and the second introduces scenarios to combine simple control commands to one. Integration is realized with the ISO 24752 standard middleware Universal Remote Console (URC). Both implemented interaction concepts are evaluated in a user study with 13 test persons of different ages. The result of the study shows that 85 % of the test persons are confident with the first concept and 70 % persons with the second one. During the study we measured the cognitive and physical response time of the users and found that the median of the reaction time in the second concept is slightly smaller than in the first one. Additionally, a correlation between response time and subjective user confidence with the system was found.

In the future, we would like to develop better methods to detect the appliance that is actually in the user's focus, e.g., eye tracking, pointing gestures or context reasoned from the interaction history.

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Chapter 5: Sensor Technology

Enhancing Mobile Robots' Navigation through Mobility Assessments in Domestic Environments

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Abstract. A new concept to enhance mobile robot navigation in domestic environments by the use of mobility assessment data is presented. The concept is part of our overall approach to enabling more precise and reliable mobility assessment by the use of a mobile monitoring platform i.e. a mobile service robot equipped with a laser range scanner. We are basing our new approach on our previous work on the application of the potential field method to mobility trend analysis and the precise measurements of human movement trajectories by a laser range scanner. The enhancements to the robot's navigation enable more precise assessment results while ensuring to not hinder or endanger the human. While navigating the robot moves from one to another observation location and tries to avoid the user's movement paths whenever possible. Additionally, it adapts its own driving speed to the human's. We call these secure observation locations which provide better assessment results Optimal Observation Lots (OOL). The concept's algorithm, which was only implemented partially yet, contributes to our ultimate goal to develop an "off the shelf" robot that is placed in the user's home and is able to find its own observation spots and movement paths without further pre-programmed knowledge of the environment.

Keywords: mobile service robot, mobility assessment, domestic environments, ambient assisted living.

1 Introduction

Industrial countries have to deal with various problems caused by the demographic change. While the birthrate decreases, modern medical care and health improvements extend the lifetime expectation of the population, leading to an aging society. Concurrently, age-related medical conditions will pose a growing problem, but without large numbers of younger people in the role of caretakers or forming the financial base, health care systems will have to cope with major logistical and economical challenges. A key to overcome these problems could be the use of assistive technologies [1]. Advanced systems could assist caretakers with their task, provide assistance to elderly for an independent life up to a high age, and may help recognizing early signs of age-related diseases, thereby reducing costs and manpower demands. With concepts like smart environments [2] elderly people could use technology in their daily lives, assisting them as far as it is necessary with components integrated in their domestic environments. Actuators and sensors can provide service features to the residents as well as they can record health-related data about the residents. However, upgrading existing residences might be costly. With technological advancements on the sector of service robotics, robotic systems are intended to play an important role helping to manage the demand of caretakers by assisting elderly in their daily life [3]. Service robots could provide aid in housework or support rehabilitation and other task throughout a whole day that are currently carried out by a caretaker for only a fraction of the time. However the user acceptance of these systems has to increase. Equipped with an array of sensors, service robots could help reducing the potentially high efforts of installing smart environments. Instead of static components, with limited point of views and ranges, a mobile platform provides services in-place and simultaneously gathers information. With further development mobile robotic platforms designed for elderly may be available as ''off the shelf" products. Such upcoming technologies can be used to implement long-term monitoring of residents. The major merit of technological monitoring is to enable early diagnosis and to identify and possibly prevent imminent dangerous situations [4]. Current applications are fall detection and activity monitoring. By combining the approaches of smart environments and service robotics, we think it is possible to deliver services (e.g., reminder, cleaning help, coaching and safety in critical conditions) in-place as well as to perform medical monitoring and assessment (e.g., tele-medical consultation, trend analysis, medical assessments), increasing the quality of life. The following chapter will give further medical motivation, followed by the state-of-the-art in domestic robotics and assessments. Afterwards we will present our general approach to mobility assessment in domestic environments, describe previous work published, and draw a new concept on how mobility assessments may be implemented on a mobile robot platform while enhancing the robots' navigation utilizing the assessment results. Finally, we will conclude our paper.

2 Medical Motivation

A person's mobility is closely connected to his or her perceived quality of life. Additionally, being able to move around and to keep up certain body positions is a fundamental requirement for an independent lifestyle [5].

Mobility normally changes during age without any pathological reason. Starting at the age of 60 years, elderly peoples' mobility characteristics change [6] i.e., self-selected gait velocity decreases each decade by 12%-16% during self-imposed activities. The decrease is often caused by a reduced step length whereas the step frequency remains stable. This age-related change in gait patterns contributes to a more stable gait and it is not pathological [7].

Impairments of mobility due to pathological reasons lead to more significant changes in parameters of gait than age-related changes [7]. One of the most frequent pathological reasons for mobility impairments are neurological diseases, especially dementia. In general, severity of gait and balance disorders increases with severity of neurological disorders [8]. Mobility impairments are also an early indicator in dementia [9]. Additionally, gait and balance disorders have shown being related to a higher risk of falling. Especially slow self-selected gait velocity has found being related to an increased risk for falls and need of care [10]. Due to their often severe gait and balance disorders dementia patients suffer from an increased risk of falling [4].

Costs due to the high need of care of demented people [11] and fall-related costs are two of the major factors influencing the proportionally higher costs to the health care system caused by elderly people. From a clinical perspective long-term monitoring of changes in mobility has a high potential for early diagnosis of various diseases and for assessment of fall risk [12]. This may help delaying need of care or preventing acute incidents like falls and may thus help saving costs. On a more personal level early detection may help supporting an independent lifestyle by enabling early and purposeful prevention and may therefore increase quality of life for affected people, relatives, and carers. In today's health systems the potential of frequent mobility monitoring is most often not exploited. Rather, mobility assessments are only applied infrequently or after an acute incident like a fall took place. This is mainly due to missing technical capabilities.

3 State-of-the-Art

Large-scale and long-term assessments of people could be done best in their domestic environments remotely. The long-term collected data will build a basis for early detection of changes in the mobility which can be compared with results from previous clinical assessments in order to e.g., estimate risk of falling or to enable early diagnosis. Telemonitoring systems for the home environment seem to be a good solution to transfer assessments from clinical to domestic environments. Especially mobile robots performing monitoring offer promising opportunities for precise long-term assessments.

3.1 Mobility Trend Analysis in Domestic Environments

Several approaches to mobility telemonitoring or remote assessment have been developed utilizing either wearable sensors or ambient sensors [13]. However, most wearable sensors are not suitable for unsupervised use by layman since they require daily handling of the device.

Ambient sensors e.g., belonging to home automation or security technology systems seem to be most suitable for long-term unobtrusive mobility assessment in domestic environments. Approaches presented by Cameron et al. [14] and Pavel et al. [15] employ optical and ultrasonic sensors as well as passive motion sensors placed in door frames or various rooms of a flat in order to repeatedly measure transitions times and thus compute self-selected gait velocity. Placing three passive motion sensors in a sufficient long corridor makes those computations more reliable [16].

Large arrangements of pressure sensors can be used to locate a person and to monitor gait when placed under the floor. Steinhage et al. [17] introduced a system based on a smart underlay with capacitive proximity sensors consisting of conductive textiles. An approach presented by Poland et al. [18] utilizes a camera attached to the ceiling recording a marked floor evenly divided into rectangles called virtual sensors. For persons within the covered area the approach computes the virtual sensor in which they are currently located. However, despite privacy issues raised, the approach does not consider covering issues.

Correlating sensor-events from ambient sensors to persons triggering these is often difficult. The problem has been addressed by utilizing e.g., RFID technology [19], height recognition [20], and Received Signal Strength Indicator (RSSI) information [21].

3.2 Precise Gait Analysis

Laboratory equipment for mobility monitoring provides the most precise measurements of mobility, so far. Examples of such equipment are marker-based camera systems or fluoroscopy systems for cinematic gait analysis and force reaction platforms for analysis of kinetic aspects of movement. Nevertheless, the equipment is too large or complicated for being applied outside of a large laboratory and can only be handled by experts. Some systems require the patient to perform difficult calibration tasks which are not suitable for cognitive impaired or elderly people [22].

Recently, 2D laser range scanners, previously e.g., applied in robot navigation and pedestrian detection systems for cars, have first been used in the domain of gait analysis. Pallej et al. [23] utilize such a device to determine the length of stance and swing phase within each gait cycle and then compute the additional gait parameters average step width and average body speed. However, applicability of the approach is limited by requiring people to walk straightly towards the scanning device during the measurements. Both feet have to be kept on separate sides of drawn line which will be very difficult to apply in domestic environments and especially with mobility-impaired or elderly people. Thus, Pallej et al. have only applied their approach in a robotic laboratory.

3.3 Service Robotics

Service robotics itself is a combination of different fields of robotic research into systems that are specifically targeted at an application; it is not a basic research topic. Already over 20 years ago, Engelberger classified service robotics into different application fields [24]. Amongst them are

- Medical Robotics
- Health Care and Rehabilitation

– Aiding the Handicapped and the Elderly
– Commercial Cleaning, Household Tasks
– Military Services
– Construction or Surveillance

As technology advances, more fields of application will be made accessible. In case of health care, robotics research started with fixed workstations [25], going over wheelchair mounted systems and intelligent wheelchairs [26], [27], to autonomous mobile robot systems [28]. Today there are multiple mobile robots for health assistance available (commercially or for research purposes). Such systems like Nursebot [29], Robocare [30], Wakamaru [31], or Care-O-bot [28] deal with helping, guiding, and assisting people at home. They are mainly targeted at providing services like tele-presence (video conferencing based), automatic reminders (food, drug intake), automatic emergency notification (detecting harmful events, notifying doctors or care providers) and companionship (conversation, playing games). Most of these platforms are still in (advanced) research states. Acting autonomously in home environments [32] and learning of environmental factors and user behavior [33] are intensively developed at the moment, as well as robot design itself [34].

3.4 Limitation of the State-of-the-Art

As shown in section 3.1 most of the telemonitoring systems providing data about mobility by use of ambient sensors do not continuously observe the person concerned. Only presence at specific known points is measured. Thus this kind of monitoring is measuring mobility on an indirect way and can therefore only be an analysis of trends instead of a precise assessment to determine the mobility of a person.

Laboratory equipment for precise assessments of the mobility is too large or complicated for being applied in domestic homes. It is often bound to a specific place due to the large setup and difficult to use for the non-professional. The prices for such systems are too high to bring them to home environments as well.

Within the domain of health care and rehabilitation service robotics there are quite few systems commercially available. Further, there is no robotic system that is capable of doing mobility assessments and tries to learn from such data for robotic path planning. Most of the systems are in research states. This leads to a comparably high price as well as designs that are not feasible for daily home usage (bulky, can move only on flat floor etc.).

In summary there is currently no system or approach available that is capable of doing precise and continuous mobility assessments in domestic environments and that is learning from the user's behavior to get optimal assessment results.

4 Approach

Our new approach to provide a possibility for large-scale and long-term mobility assessment in home environment will be a combination of common path planning algorithms known from the field of robotics and a precise way to measure movement trajectories of the human via a laser scanner at home. A mobile robot will thereby act as a kind of mobile infrastructure bringing the needed sensor technology to the optimal place for monitoring, as introduced in [35]. One main goal of our approach is that the robot can be delivered via postal package and placed into the environment without any installation. To perform services and assessments without compromising the safety of the owner, the robot will start with an observational phase. During this phase the robot stands at safe place in the initial room of the home environment and observes the human behavior and environment. With the gathered knowledge the robot will afterwards compute new places where it can stand without endangering the inhabitant and observe further details of the environment. On this way, the robot gets known to the environment step by step. As soon as a sufficient map of the environment has been generated, the robot may move more freely constantly updating its environmental map upon detected changes.

Within our approach a priori knowledge about the environment (floor plan, sensors, and context knowledge) will be combined with precise laser range measurements of the movement trajectories of the human. Both will be used as input to common path planning algorithms like the potential field method. Afterwards, the computed potentials are used to determine the optimal moving, parking, and observation fields for the robot without disturbing or endangering the human. From those Optimal Observation Lots (OOL) the robot is able to perform safe and highly precise mobility assessments in the whole domestic environments without any additional stationary sensor. Movement trajectories and other gait parameters will be measured with the robot's laser range scanner, and can be easily mapped to specific locations inside the home environment. Both methods, the potential field method and the measurement of the human's trajectory via a laser range scanner, have been examined apart from each other and will be summarized in the next sections 4.1 and 4.2. The main part described in this paper will be the combination of both methods to enhance indoor robot navigation and to determine the OOLs for safe and precise gait analysis in home environments. The concept will be described in detail in section 5.

4.1 Computation of Domestic Motion Patterns Utilizing Path-Planning Algorithms

Within our previous work we have presented a context-aware system for unobtrusive mobility monitoring in domestic environments [36]. The approach enables the system to adapt to different environments and sensor configurations by providing two pieces of context information: a 2D/3D floor plan of the environment and a definition of available sensors. Based on the context information the system is capable of computing all other information required for the monitoring. This may enable a large-scale application of mobility telemonitoring utilizing home automation sensor technology. The approach was evaluated within an experiment with 15 healthy participants in a living lab. The sensors used include reed contacts and light barriers previously installed for comfort applications. Results show that the approach requires minimal effort for application in a domestic

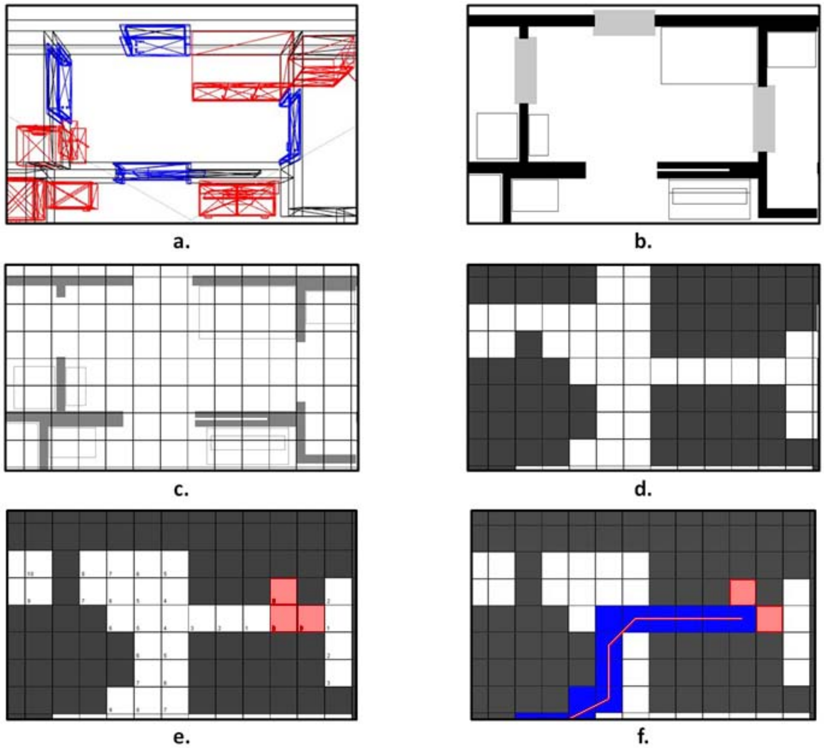

Fig. 1. Path-Planning Steps - a. 3D Floor Plan, b. Abstract Spatial Model, c. Division Into Grids, d. Assignment of Repulsive Potentials Caused by Walls and Obstacles, e. Assignment of Attractive Potentials Caused by the Goal (Red Fields), f. Resulting Path (Blue Fields) and Smoothened Path (Red Line)

environment and may be used to reliably compute self-selected gait velocity of a resident.

A path-planning algorithm is used to automatically detect possible motion patterns and their lengths within an abstract spatial model which is generated from the provided 3D floor plan (Fig. 1.a). The system currently employs a slightly modified version of the potential field method [37]. First, the abstract spatial model (Fig. 1.b) generated by transforming the provided 3D floor plan (Fig. 1.a) is evenly divided by a grid (Fig. 1.c). Every grid field has an approximated width and height of the object to be navigated (in this case 40cm). To each field of the grid a potential is assigned that is the result of the superposition of the repulsive potentials caused by existing obstacles (Fig. 1.d) and of the attractive goal potentials (Fig. 1.e). The attractive potential of a field is determined by computing its Manhattan distance metric from the goal. The Best First Algorithm is used to find a path (blue fields in Fig. 1.f). However, the implementation of the potential field method does only examine the 4-connected neighborhood of grid fields which prohibits finding bevel paths. Therefore, in order to further optimize the computed lengths a smoothing step is applied. Within this step 3-corner-fields and 4-corner-fields of the computed paths are transformed into bevel joints (red line in Fig. 1.f). Within the smoothing step it may occasionally happen that bevel joints streak (partially) blocked fields. The path planning is executed for all available sensor pairs. While analyzing relations between two sensors all other sensors' coverage areas are regarded as obstacles.

4.2 Laser-Based Precise Measurement of Human Movement Trajectories

Usage of home automation technology for mobility tele-monitoring is reasonable since sensors are already be available for other purposes. However, such sensor technologies are not very precise and do only passively measure movement by noticing presence of residents at certain places. Thus, such approach is more suitable for long-term trend analysis than for detailed gait analysis.

Furthermore, detailed gait analysis in domestic environments might provide new insights into various diseases and may provide new means for early diagnosis. Therefore, we are currently investigating the usage of laser range scanners in the field of gait analysis [38]. Such devices are much more precise than most home automation or security sensors and constantly measure distance to static and moving objects within their scanning range. By recording consecutive measurements movement trajectories of people (colored lines in Fig. 2) and their environment (black dots in Fig. 2) can be visualized.

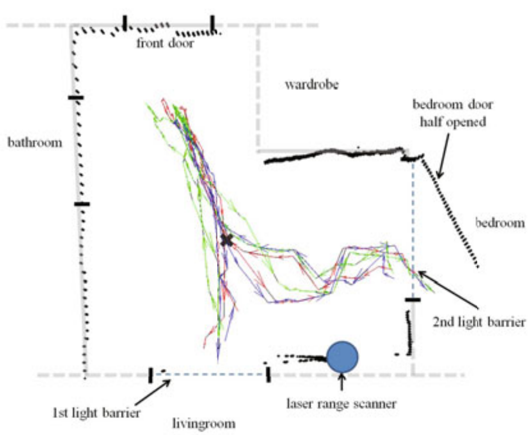

Fig. 2. Movement Trajectories Measured by a Laser Range Scanner

An experiment with five health participants has shown that these measurements allow for precise and reliable computation of self-selected gait velocity. Our approach does not restrict movement paths or placement of the scanning device, except for the device being placed approximately at the height of the probands' legs. Computation of other spatio-temporal parameters of gait is future work.

5 Concept

As a first step towards realizing our new approach to mobility assessments in domestic environments utilizing a mobile robot we present a new concept for enhancing the mobile robot's indoor navigation capabilities. Our main aim is to enable the robot to find OOLs and thus to prevent the robot from endangering or hindering the human during the assessments. The concept combines our previous work, i.e. the application of the potential field method to mobility trend analysis and the precise measurements of human movement trajectories by a laser range scanner. Thereby, the concept enables the robot to learn from human behavior while assessing him or her at the same time.

For now, the concept is based on the assumption that the robot is able to access a complete map of its environment (Fig. 4.a). In the future, this map will be created while exploring the environment using Simultaneous Localization and Mapping (SLAM) techniques. As soon as a new map or area is submitted to the robot, the whole map is divided into fields of appropriate size (see section 4.1). These fields are used within the potential field method for navigating the robot.

The overall flow of the concept has six repeating steps (Fig. 3). In short, the robot first measures the environment and second localizes itself within the environmental map. Afterwards, the third step is to measure the human's movements. Within the fourth step, the robot labels the fields of the environmental map according to whether it may hinder the human when driving there or not. Larger groups of free fields are marked as OOLs. The fifth step is the robot navigation. While navigating, the robot uses the potential field method and computed labels are used to prefer free and uncrossed fields over fields crossed by the human. Additionally, assessment results like the computed self-selected gait velocity are mapped to the environmental map's fields and are used to determine the robots own movement speed. The robot will navigate from one to another OOL as soon as another OOL enables a more precise assessment. Computation of new OOLs is repeated as long as not the whole map of the domestic environment has been evaluated by laser range measurements and afterwards in cases where changes within the environment are detected. The six steps are described in detail in the following blocks and are depicted in Fig. 4.

Step 1 - Environment Recognition: Within the first step the robot utilizes its laser range scanner in order to measure the surface of its current surroundings (Fig. 4.b). Ideally no moving objects are within the scan range during this step. Otherwise the robot has to distinguish between measurements belonging to static and moving objects utilizing one of various available approaches [39]. Measurements belonging to static objects are then transformed from the local coordinate system of the robot into the global coordinate system of the environmental map.

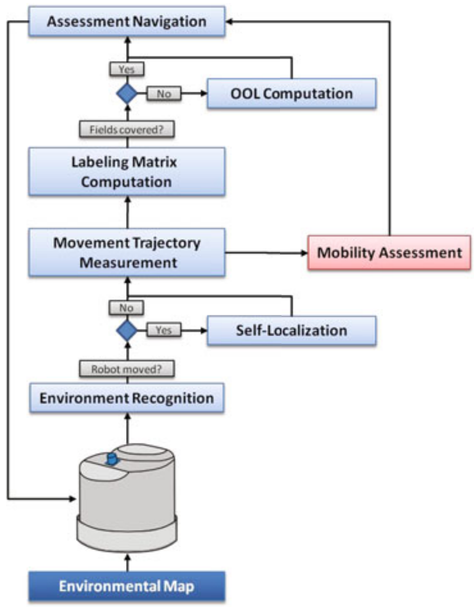

Fig. 3. Flow of the Concept

Step 2 - Self-Localization: The second step starts by dividing the measurements into segments. From these segments geometric primitives are extracted which are then mapped to the available environmental map [39]. By matching the recognized primitives to primitives within the environmental map (Fig. 4.c), the robot is able to localize itself within the environment and to compute the fields it currently occupies. The result of the self-localization is stored as 4x4 transformation matrix. This step is only performed if the robot has moved since the last pass of the algorithm. Otherwise, the computed transformation matrix is reused.

Step 3 - Movement Trajectory Measurement: As soon as a human enters the scan range of the robot its movement trajectory is measured (Fig. 4.c). Again, the robot has to distinguish the measurements into measured values belonging to the moving human and measured values of static objects. Measurements belonging to moving human are transformed into the global coordinate system of the environmental map. These measurements are then used to compute the movement trajectory of the human. Additionally, the measurements are used to perform a mobility assessment of the human computing various spatio-temporal parameters of human gait. However, this enhanced assessment is not within the focus of this paper.

Step 4 - Labeling Matrix Computation: Within the fourth step, the movement trajectory of the human is then mapped to fields within the environmental map.

All fields covered by the scan range of the robot are labeled (Fig. 4.d) and stored within a labeling matrix according to whether

- The field is free of obstacles and has not been crossed by the human.
- The field has been crossed by the human and should be therefore free of obstacles as well.
- The field is occupied by some kind of obstacle.

Step 5 - OOL Computation: Clusters of uncrossed free fields larger than the dimensions of the robot will additionally be marked as OOLs and are thus preferred navigation points of the robot. Utilizing the environmental map the robot can determine which fields can be measured from which OOL and thus which OOL provides the best vantage point to get optimal assessment results depending on the human's current and assumed position.

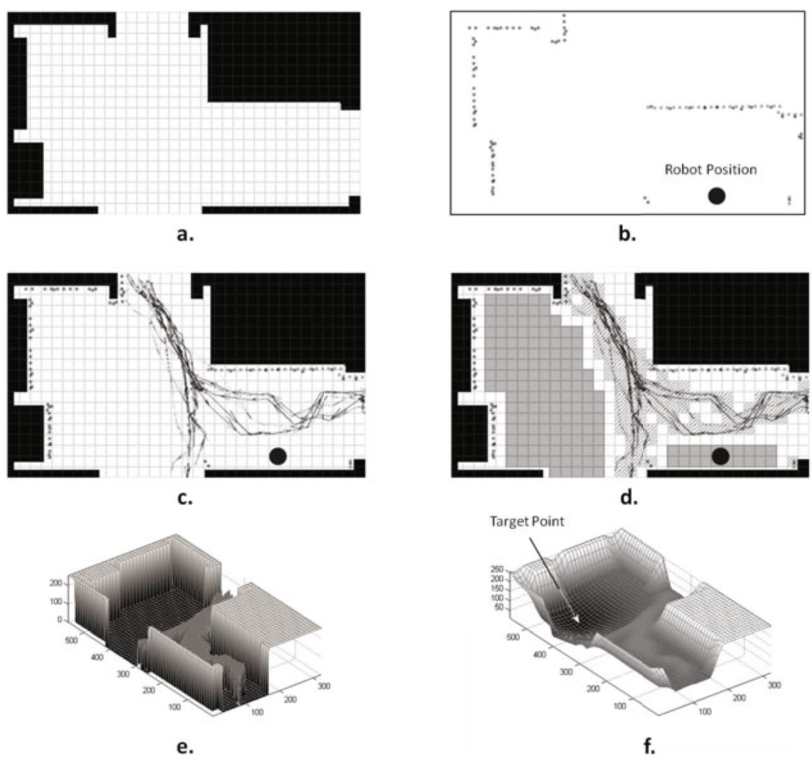

Fig. 4. Concept's Steps - a. Environmental Map with Field Allocation, b. Measurements during Environment Recognition, c. Mapping Segments during Self-Localization and Movement Trajectory Measurements, d. Visualization of Labeling Matrix within the Environmental Map, e. Visualization of Loading Matrix during Assessment Navigation, f. Visualization of Resulting Potentials after Application of the Loading Matrix; the Target Point is an Example to show the Gradient Characteristics if a Target is given.

Step 6 - Assessment Navigation: In certain situations the robot system will have to change its position. While the human is moving, better OOLs may become available or the human could get out of the sensors' sight, and therefore moving to the next OOL is necessary. After navigation to another position was initiated, the robot first uses the labeling matrix to compute a loading matrix (Fig. 4.e). The loading matrix weights fields within the environmental map according to their label within the labeling matrix. Fields crossed by the human are weighted lower than those free fields uncrossed. This loading matrix is then used to load the attracting potentials of the goal, e.g., by determining the Manhattan distance metric, when applying the potential field method so that free uncrossed fields are preferred for the robot over free crossed fields (Fig. 4.f). Additionally, the assessment results may be used while planning the execution of the computed path. In case the path overlaps with a movement trajectory of a human and the assessment has computed a self-selected gait velocity for this trajectory, the robot may get hints on how fast it should or could move on the corresponding fields.

6 Discussion

Our ultimate vision is to build a mobile robot which can be sent by postal package to a customer and works out-of-box starting from a safe place chosen initially by its owner. One of the greatest risks of such approach is that the robot hinders or endangers the resident, especially while it is nearly unaware of the environment at the beginning. Therefore, we introduced the concept of OOLs. Starting from its initial safe position the robot is meant to explore its environment navigating from one to another safe place while assessing the resident. However, in order to learn from the resident through assessments the robot has to keep up with the resident in order to being able to measure his or her movements. This makes it necessary to anticipate the resident's movements in order to initiate navigation to another OOL before the resident gets out of sight. A similar problem can be found in the automobile domain where pedestrians are tracked and their movements have to be anticipated for security reasons. Common approaches to this problem are the utilization of Kalman filters [40] or particle filters [41]. An approach taken by [42] relies on preliminary observed user paths and residence probabilities. The surrounding (home) is scanned by multiple laser scanners and the common paths of the users are generated. With this knowledge the robot can estimate the user's behavior (movement) and where the user most likely will stay for longer times. This information is used to adapt the navigation algorithms.

In contrast to this approach, we don't use prior knowledge about the environment and we include additional assessment knowledge and requirements. Besides navigating to another OOL when the robot anticipates that the resident will get out of sight, the robot should also navigate to a new OOL in case it provides better assessment results. For such benchmarking of OOLs quality criteria have to be defined. Such criteria may e.g., include the number of fields within the environmental map measurable from each OOL or the number of neighboring fields which have been crossed by the resident and thus indicate some kind of risk the user might step into this OOL. We are currently working on the definition of such criteria.

For now, the presented concept assumes that an environmental map is already available when the robot enters a new domestic area. This map is required for the self-localization step in which the robot matches recognized geometrical primitives from its current measurements with primitives within the map. However, the assumptions that the environmental map is already available, is only temporary in order to currently focus on our new concept of enhancing the robot's navigation. In the future, the robot is intended to build up such a map by its own using established techniques from the robotics domain summarized under the term SLAM [39]. Exploring a dynamically changing environment might also require employing more complex navigation strategies than only navigating from one to another OOL. At least the approach of navigating between OOLs only is not sufficient as long as not the whole flat will be measurable from OOLs.

Another common problem regarding assessments utilizing ambient sensors is the identification of residents monitored. Within our previous work we have explicitly assumed that the resident lives alone and has no pets and that in case of visitors the assessment is paused. However, this assumption is not realistic. Again, approaches from the automobile domain might provide a solution where different traffic participants like pedestrian, motor cycles, and cars have to be distinguished. One approach is to utilize the typical outlines of such participants [40]. However, instead of distinguishing different types of participants, we have to distinguish different instances of the type "resident" within the domestic environment. A possible approach is to utilize the assessed spatio-temporal parameters of gait like described by Orr and Abowed [43]. However, it is still a question of research if these parameters are sensitive enough to distinguish any two residents. Distinguishing between residents and pets may again be possible by utilizing their outline in the measured range data.

7 Conclusion

A new concept for enhancing a mobile robot's navigation through mobility assessments was presented. The concept is a first step towards realizing our approach to mobility assessment which utilizes a mobile robot as mobile software platform and its laser range scanner as measurement device. Our main aim is to enable the robot to avoid endangering or hindering the human during the assessments. Therefore we introduced the concept of Optimal Observation Lots (OOL) which refers to safe areas near to the human's typical movement trajectories which provide good assessment results.

The presented concept combines our previous work, i.e. the potential field method for determining movement patterns and the precise measurements of human movement trajectories by a laser range scanner. Currently, we assume the robot already has a map of the surrounding environments available. In the future, we plan to collect this information by utilizing SLAM. The overall flow of the concept has six steps: Environment recognition, self-localization, movement trajectory measurement, labeling matrix computation, OOL computation, and assessment navigation.

While we already implemented first parts of the algorithm, the next step will be a complete implementation on the mobile robot "Peekee II" and an evaluation of the system with probands in a living lab. Additionally, the ranking method for OOLs will be enhanced as well as the assessment itself which is also adapted to the special requirements on a mobile robot.

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Emergency Indoor and Outdoor User Localization

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Abstract. Within the context of the automatic detection of a medical emergency and the aim of providing medical care as fast as possible, it is of utmost importance to detect the current position of the patient. The more precisely the patient location can be determined and the more effectively the paramedics are guided towards the patients current location, the less time is wasted prior to the initial medical care provided to the patient after the emergency has occurred. This paper describes a first, prototypical realization of a combined indoor and outdoor user localization component developed within the Smart Senior project. Apart from a detailed description of the technical background of the realized component, an important aspect discussed in this paper is the distinction between the two different concepts of “locating a user” and “finding a user”.

1 Introduction

The research project Smart Senior[1] develops technological and comprehensive solutions for senior citizens to live an independent life. The aim is to support older people in day-to-day life, social interaction and in terms of health in such a way that they can remain living in their familiar environment. The project is aimed both at senior citizens living generally independent lives, as well as at acutely or chronically ill older people in need of assistance and care. Within the context of “mobility and security”, a subproject in Smart Senior is dedicated to the development of emergency assistance system. The goal is to develop a system capable of continuously monitoring the vital functions of a person and automatically detecting critical medical situations. Furthermore, the system shall not only detect such a situation but it should be capable of classifying the medical problem that has occurred. This classification may help health personal to take correct decisions when selecting appropriate countermeasures. As soon as a medical emergency is detected by the system, an electronic emergency call (eCall[2]) is initiated and the corresponding paramedics are being informed about the emergency automatically.

The main motivation behind the technology is to offer the potential users of the system a higher degree of security in their everyday lives. This holds especially for users with a particular medical indication (i.e. prior medical incidents which indicate a higher risk of recurring medical problems). These people are usually limited in their personal, everyday freedom simply by the fear that they might suffer another medical emergency in a situation where they may not be immediately supported by medical personal. Even worse, there is a strong fear that such an incident may occur when there is nobody around in the particular situation.

To offer the aforementioned security to our target group, the system has to be able to handle situations in which there is nobody around the user to offer assistance. This is especially true in situations where the user of the system is disoriented or maybe even unconscious. In these situations it is of utmost importance not only to detect the medical emergency automatically, but also to accurately determine the user's current location. As of today, there are numerous different technologies for locating either mobile devices or users [3,4,5,6] in different environments and application contexts.

Unfortunately, none of the existing approaches is capable of covering all application contexts and environments of our everyday lives. To allow for the desired security the system shall offer the user at any time and in any given environment, an approach that combines the different underlying technologies into a single concept. The resulting quality of the determined location in such a system may vary depending on the location technology coming to use in a particular situation. However, each technology must at least allow us to guide the paramedics towards the current location of the user. Since it is an important point in our concept that we rather aim at "quickly finding" a user as opposed to always precisely locating a user, we will discuss this particular aspect in more detail in the following section. Consequently, we will discuss the different application scenarios in which the system may operate and finally we will introduce the current prototype. We will sum up the paper by reviewing the currently achieved goals and by discussing current as well as future additions to the system.

2 To Locate Or to Find?

In this section we want to motivate the distinction between "knowing where a person is" and "finding a person". So, why is there a difference at all? Imagine that we ask somebody on the street to help us in finding a particular sight. In principle there are two different ways in which the person (assuming that he/she knows where the sight is) may help us in finding the sight. We may either use a map and the person may simply show us on the map the location of the sight. Or, in case we don't have a map, the person may sequentially describe to us, how we may get to the sight starting at our current location. In the first case, we now know exactly where the sight is and may easily reach the desired location. In the second case however, we do not know exactly where the sight is located. From the description we got, we may derive the direction in which it is located and maybe we can also make certain assumptions about the distance to the sight (we have built up a mental map [7]). Even though the two different approaches vary significantly, as a result of either solution we will be able to get to the sight using the given information.

The point we are trying to make with this short example is that it is not necessary to have a precise location when trying to get to a particular spot. In many cases it may be sufficient to get a route description starting at a given point, which may guide you towards the desired location (as discussed in more detail in [7]).

When transferred to our particular application scenario, what we would like to point out is that the final goal is to allow the paramedics to find the user (in the case of a medical emergency) as quickly as possible. This is substantially different from other application scenarios, like for example navigation systems, which may only work based on a correct location at any given time.

The prototype we have realized so far and which we will describe in the remainder of this paper mainly focuses on situations in which the current position of the user may be determined with the necessary quality to efficiently guide the paramedics to the spot. In the outlook of the paper we will describe the current extensions we are developing right now which will allow us to cover also situations where the system may not come up with a precise current position of the user but rather with a way-finding description starting at the last known position of the user. We will now continue with a description of the different application scenarios covered by our prototype.

3 Application Scenarios

To ensure that our location system reliably works in any of the potential application scenarios we may find in everyday use of the system, in a first step we divided the different scenarios into two main groups. We distinguish between indoor and outdoor locations. The underlying reasoning behind this decision is based on the fact that either of the two groups has completely different technological bases when it comes to locating a user or a device. In our setup, in any of the given application scenarios we are assuming the use of a mobile device (e.g. a Smartphone) by the user. Therefore our user location component actually locates the mobile device of the user which is supposed to be always carried around by the user.

A different group within the Smart Senior project is currently developing a system of vital sensors connected to the mobile device via a wireless protocol. The derived data from the vital sensors are collected on the mobile device of the user and continuously being analyzed in order to detect anomalies in the data and to infer potential medical risks/emergencies automatically. This will trigger both an eCall and the localization module.

We will now take a closer look at the different application scenarios supported by our system. In the following subsections we will introduce the scenarios and we will discuss the data acquisition on the mobile device required for the different location technologies. However, since the analysis of this raw data is realized on a server component, we will not discuss the different algorithms here, but in section 4.

3.1 Outdoor Locations

In outdoor scenarios, the location is usually detected (i.e. calculated) by measuring the signal strength or runtimes of wireless signals and consequently using triangulation to derive the current position. The typical approach is to collect the signal strengths of several wireless senders on the device which is to be located. If the device is aware of the location of each sender, an algorithm may derive the distance from the device to each of the currently detected senders. The algorithm may be either based on the signal strengths measured or on precise timestamps in the signal which may be used to determine the runtime of the signal from sender to receiver. In either way, starting with three or more simultaneously received signals of different senders, the device may use triangulation to determine its own position relative to the senders and consequently its own position in an absolute coordinate system if the concrete positions of the senders are known with respect to the absolute coordinate system. The most commonly known system of this kind is the Global Positioning System (GPS) which is the de-facto standard for outdoor localization.

3.1.1 In the Vehicle

Within the application scenario "Emergency Assistance" we integrated a car featuring a navigation system. Therefore, the car is capable of determining its current location. The location technology within the car is based on the aforementioned GPS and is further enhanced by sensors integrated in the car (e.g. sensors measuring the steering angle or current velocity). If the system on the mobile device detects the occurrence of a medical emergency of the driver, the car is being alarmed via a wireless communication network. As part of our subproject within Smart Senior a prototype of a car is being developed capable of autonomously and safely steering the car to the emergency lane and bringing the car to a full stop. As soon as this has been accomplished, an eCall is send automatically. The position information integrated in the eCall is determined by the car and handed over to the mobile device sending the eCall on request. The mobile device consequently sends the eCall. In the case of a non-functioning location system in the car (maybe due to a car accident), the current position is detected by the mobile device itself as described in the following subsection.

3.1.2 Outdoors

In case the user is located in an outdoor location but not in the car, the current location of the user is determined with the help of the mobile device as soon as a medical emergency occurs. As in the case of the vehicle-based scenario, the base technology is GPS which is aided by additionally incorporating GSM (mobile network) signal strength measurements. Using a combination of both signals, the most probable location of the user can be determined. However, the GPS position is not only detected ad-hoc when necessary, but instead the position is constantly detected and stored in chronological order (in the current implementation, data is recorded and stored every 30 seconds). After a pre-defined period of time (currently set to 30 Minutes in our prototype), the mobile device opens a connection to a location server (we will describe the server component in section 4) and uploads the collected positioning data in a compressed and encrypted format. To our understanding it is necessary to keep this positioning history since often enough at the precise moment when we need to detect the user's current position, a precise GPS location is not available. However, most of the time (talking about situations where the user is not entering buildings), these weaknesses in GPS quality are temporary. Therefore, often enough only a few seconds (or maybe minutes) before, the GPS position was good. Hence, we need to keep the history to be able to look back to maybe find a better clue in the positioning data going just a few steps backwards. We also use the GSM data to get a rough estimate of the user's location in case the GPS does not yield any position information at all.

3.2 Indoors

As opposed to the outdoor scenarios, there is no single solution to indoor localization. The main reason for this is quite obvious. While it is possible to establish something like a GPS for outdoor locations, there are quite a few reasons why this is not possible for indoor locations. First of all, the massive structure of buildings influences most wireless signal distributions significantly. Therefore, if we would try to establish something like the GPS for indoors, we would have to deal with the problem that the signal distribution within buildings varies to such a degree, that it is impossible to accurately calculate runtimes or to receive valuable signal strength measurements (the GPS actually proves this hypothesis since this is exactly why the GPS does not work indoors very well). Therefore, in indoor location scenarios, local location approaches are the preferred choice. There are quite a few available solutions on the market for indoor positioning. They range from highly precise technologies to others which only detect a certain area within a building where the device to be located probably is. Some approaches do rely on triangulation and therefore need to know the exact positions of all senders involved [8] or it is at least necessary to estimate those positions [9]. Others rely on a fingerprinting approach [10,11]. The idea is to separate the location service into two phases. In a first phase, fingerprints of wireless network signals (and sometimes also their strengths) are recorded at all locations of interest (i.e. those locations at which we would like the indoor location system to work) following a certain pattern. The pattern may for example demand that a recording is done in each room of the building. Or it may demand to do recordings on a real grid (for example separating the floor into 5x5 meter squares and taking a fingerprint in the center of each square).

The problem with both approaches is that the underlying wireless technologies used to detect the user position (usually WiFi and/or Bluetooth) are quite unstable with respect to their signal distribution. This is for example due to the fact that the frequency coming to use suffers from a high degree of signal absorbance when passing through water. Since human bodies are composed to a large degree of water, the number of persons around while taking wireless measurements has a strong influence on the signal strengths detected at any given position. Also, varying humidity may play a role. Furthermore, depending on the building structure, signal reflection on walls may also strongly influence the measured signal strengths and especially the calculated runtimes. It is therefore necessary to find an algorithm which yields position data precise enough to easily find the person in the building and which on the other hand is stable enough to constantly produce the same positioning results even under varying conditions. In our current, prototypical implementation, the mobile device collects raw data (e.g. fingerprints) of wireless networks. It stores them in a local cache and periodically uploads the data (together with the corresponding GPS and GSM data) to the server. The server based data analysis and derivation of the user position will be described in detail in the following section.

4 System Architecture

The decision to use a client-server architecture in our project for the localization module was based on quite a number of reasons. First of all, increased battery consumption due to constantly running complex algorithms on a mobile device is a serious issue. Secondly, since we do not only make use of global technologies like GPS and GSM for localization but also use local technologies like WiFi and Bluetooth localization, there would be a large demand for storage space if we were to put all the necessary additional data regarding building structures and WiFi/Bluetooth setups on each of the mobile devices. The mobile device would have to hold all the material for each building known to the system. This would include map material, metadata and to a large wireless fingerprint database. Furthermore, each additional building added later on to the system would have to be integrated in each of the mobile devices which perform the localization. Therefore, constant and costly updates would be necessary. Taking all this into account and keeping in mind that we do not need a constant user position but only a position when a medical emergency occurs, we opted for the infrastructure as depicted in figure 1.

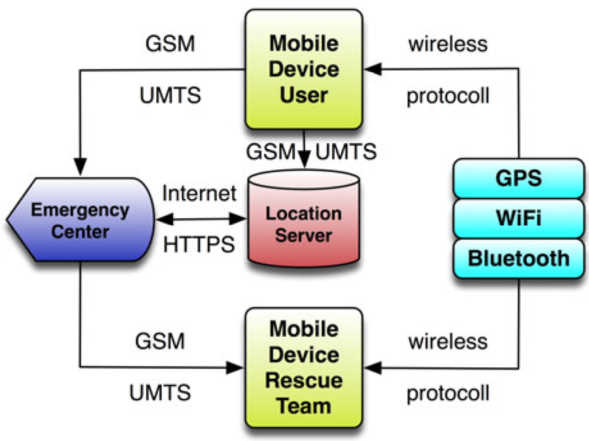

Fig. 1. Communication flow of the localization module

As mentioned in section 3, the client (mobile device of the user) periodically pushes the accumulated raw data necessary to locate the device to the server. Since the underlying protocol between server and client is basically an encrypted socket connection, the transport can be done with any available data network but typically will be realized via GSM oder UMTS (whatever is available). Figure 1 also shows a direct communication channel between the mobile device of the user and the emergency center. This is the route which allows for the transmission of the eCall.

Since the positional information in many cases is more complex than a simple latitude/longitude pair (as provided by the GPS), the information is only indirectly included in the eCall. Indirectly means, that the eCall contains a link to a website which is especially generated for this particular eCall. The website is being generated by the location server as soon as the mobile device of the user signals the server, that an emergency has occurred. Hence, there is an HTTP based connection between the emergency center and the location server. The moment the eCall arrives at the emergency center, the person in charge may request the positional information by clicking on the provided link. We will see in more detail how this works in section 4.2. Finally, figure 1 also includes a communication channel between the emergency center and the mobile device of the paramedics. In our scenario, this additional mobile device may be used to efficiently communicate positional and also medical data regarding a particular eCall to the paramedics. Furthermore, the device may be used in such cases, where the exact location of the user (i.e. the users mobile device) could not be detected and it will therefore be necessary to support the paramedics in finding the user. This particular situation will be discussed in the conclusions and outlook section. We will now continue by going into the details regarding both client and server implementation.

4.1 Smartphone Components

For our prototypical implementation, we have chosen the HTC HD2 Smartphone as our mobile device. The device features a large, capacitive touch-screen, a fast processor and integrates GPS, WiFi and Bluetooth devices. In addition, we find a G-Sensor (Accelerometer) and an electronic compass. The operating system is Windows 6.5 and the implementations have been realized using C# in conjunction with the .NET Compact Framework. Due to the large screen size the device is especially well suited for the development of user interfaces especially aimed at the target user group of seniors. Unfortunately, what the device lacks is a sufficiently large battery. Even though compared to other competitive Smartphones, the battery-life of the device is to be considered as "normal". This means that normal usage of the device will drain the battery down to somewhere between 40 and 0 percent within 24 hours. This already indicates that energy-efficiency is a real issue here. Since we aim at a 24/7 service, implementing a technology which will result in an empty battery after only a few hours is not what we want (we will discuss energy-efficiency in section 4.1.1). We have implemented three different modules running on the mobile device. The first module being the "Location Logger" (we will refer to this module as the "logger") is realized as a background process which runs continuously and which communicates with the location server. It also offers a local communication channel for other local modules (for example the module responsible for monitoring the vital data of the user will communicate an occurring emergency via this channel). Since the logger is a background process, we have realized a second module to control it. The "Location Control" (we will refer to this module as the "controller") is capable of starting/stopping the logger. It connects to the logger via the aforementioned communication channel. Over this channel it may also trigger an immediate data upload to the server and it may send an emergency signal to the logger for simulation purposes (this module is not intended for the end user but only for our development phase). Finally, we have implemented another module called the "Location Recorder" (we will refer to this module as the "recorder"). This tool is not used by the end user of the system but by the system operators. Its main purpose is to build up the database for our indoor positioning technology. This is done by combining wireless network fingerprints with metadata provided via the interface of the tool. In the following subsections we will introduce each of the modules in more detail.

4.1.1 The "Location Logger"

The logger is the module that runs in the background on the users mobile device to take fingerprints of wireless networks as well as of GPS data periodically. It has been realized in C# using the .NET Compact Framework. Using several, publicly available libraries, we have gained access to all the necessary devices (Bluetooth, WiFi, GPS, G-Sensor). When the tool is started, it shows a splash screen and then disappears in the background. The fact that it is running is not visible in the system controls and it can only be shut down by using the controller. In order for the tool to work also, while the device goes into standby mode, we had to ensure that the device will not shut down the necessary devices. To save energy, we actually allow the system to shut down all devices apart from the G-Sensor from which we read continuously (the G-Sensor is always active on the device and hence reading the data doesn't yield additional power consumption).. We make use of the G-Sensor data to determine, whether the device is being moved at all. If it has not been moved for a certain period of time, we assume that there is no need to update positional data. If however the device has been moved, we use a timer which wakes up all necessary devices for fingerprinting every 30 seconds. A fingerprint consists of the current GPS reading, current GSM reading, 5 second Bluetooth scan and 10 sequential scans for WiFi access points (the reason why we use several scans will be explained in section 4.2). The total duration for our fingerprinting mechanism is around 10 seconds. Using this setup with our integrated energy consumption optimization, we end up with a total runtime of around 8-10 hours. Fortunately, there is a battery pack available for the HTC HD2 which doubles the batteries capacity, which would bring us close to 24 hour runtime (actually it will be at least 24 hours, since usually at night the device won't be moved and hence the energy consumption will go down).

The fingerprint data is stored in a proprietary XML format on the device. After a pre-defined period of time (a good choice seems to be 30 Minutes), the tool will automatically compress and encode the data and send the resulting packet via a TCP socket connection to the server.

To allow other local processes running on the same device (like the controller or the health monitoring module) to communicate with the logger, it implements a local TCP socket server. Via this socket, it accepts certain commands which may for example trigger an immediate fingerprint recording or which may indicate an emergency. In the latter case, the logger will respond with a unique URL-String to be integrated in the eCall (this URL will later be provided by the location server, see section 4.2). Furthermore, it does a final fingerprint recording and then uploads all the remaining data to the server, including the information that an emergency has occurred.

4.1.2 The "Location Control"

The controller is used to start/stop the logger and to trigger certain actions in the logger. When started, the tool checks whether the logger is already running. In case it is not running, the only option the tool offers is to start the logger. Otherwise, if the logger is already running, the controller automatically connects to the local communication socket offered by the logger. Via this communication channel, the controller may request status data and it may send commands to the logger. The location control is a tool which will not come to use on the end users device, but it is rather a tool for testing and simulating. Therefore it includes an option to force the logger to do an immediate fingerprint. And additionally, it may send an emergency command to the logger, hence simulating what would happen if a real medical emergency would have been detected. The user interface of the controller is depicted in figure 2 on the left hand side.

Fig. 2. Location Module: Controller and Recorder Tool

4.1.3 The "Location Recorder"

The third tool we have realized on the mobile platform is the recorder. Its main purpose is to gather the necessary data for our WiFi and Bluetooth based indoor positioning technology. The tool is to be used by a system operator to do controlled recordings of wireless fingerprinting data and to combine this with the desired metadata. Since the metadata can be provided with the user interface of the tool, there is no need to prepare the recordings. Instead, the user of the system may simply move to a certain location in the building he is currently working on and type in the necessary metadata prior to taking the recordings. The data is stored in a hierarchical structure on the device's file system. This means, that all recordings of a single building will be organized in a folder containing folders for each floor of the building which again contain the recordings of each room/spot. Hence it is not necessary to edit all metadata fields in each recording. In addition, the user may choose the number of sequential WiFi recordings he would like to take and how long the delay between each recording should be. How this data is used will be explained in section 4.2. When a recording is done, the tool first scans for Bluetooth devices for 5 seconds. Consequently it will perform the desired number of WiFi recordings. All the data is then stored in a proprietary XML format at the correct location in the hierarchical file system folder structure.

The tool also integrates a switch (TD, standing for test data) which allows the user to determine, whether he wants to record a fingerprint for the location database on the server or whether he would like to record a fingerprint sequence which may be fed into the location algorithm on the server to calculate the current position. We use this mechanism to verify the positioning quality of the algorithm. Figure 2 (right hand side) shows the recorder while performing the third of 30 WiFi recordings. In the lower part of the user interface there is also a text field which shows the currently read WiFi and Bluetooth data.

4.2 Localization Server

As we have seen in section 4.1.1, the client (i.e. the logger module running on the mobile device of the user) is a rather simple recorder of raw data. It does not perform any analysis of the acquired data. Instead, it simply transfers the data periodically to the server. Hence, all the logic behind the location has to be integrated in the server. Since the server has to handle different client raw data (GPS, WiFi, Bluetooth, GSM) using completely different algorithms, we will subdivide this section according to the different analysis technologies realized in the server. However, we will start by describing the general setup and overall strategy behind the location server in the following sub section.

4.2.1 Server Setup and Overall Analysis Strategy

All modules of the location server have been realized in Java. The server itself has two main purposes: data aggregation of all connected clients and location detection using the aggregated data as soon as a client signals an emergency. The final result of this analysis is a website generated by the server which holds all necessary positional information to be read and interpreted by a human person in the emergency center.

The moment a client signals a medical emergency to the server, the server usually has a wealth of information at hand (i.e. the aggregated data of the particular client) to analyze in order to derive the current positional information. The strategy to choose the best available positional data is rather simple. We have implemented a ranking function estimating the "value" of each available position information. A position information may be derived either on the basis of a GPS data set or by analyzing wireless signal based fingerprint raw data. The server parses backwards through the data history. At each entry it extracts and evaluates both the GPS based position (if available) and the wireless signal based position (again, if available). The ranking function will always rank a GPS based position lower than a wireless signal based position. This is due to the fact, that GPS is less precise in general. However, the ranking function also takes into account the age of a position. Therefore, after analyzing a number of historic positions in the accumulated data (currently we make use of 50 data entries), a newer GPS position may be ranked higher than a slightly older wireless signal based position, due to the ranking function.

In the following subsections we will go into the details of both GPS and wireless fingerprint based positioning algorithms as they are currently realized in our prototype.

4.2.2 GPS Based Localization Analysis

GPS based location in principle is very easy. Just read the latitude and longitude data from the GPS signal and show the position on a map. Unfortunately, in real life it is not that simple at all. GPS signal quality varies to a high degree between a very good positioning signal (sometimes in the range of 10 meters accuracy) and a completely absent signal. Therefore, it is no use to simply take the GPS position and interpret this data as "the truth". Instead, we need to analyze the quality of the signal. One very simple counter measure against bad quality GPS positioning is to estimate the position accuracy by means of analyzing the quality of the GPS signal. If the accuracy falls below a certain threshold, we simply ignore the position and rather take a look at the next older GPS position in our history. Since the common reasons why the GPS signal quality goes down are well known (e.g. inside buildings the signal is obscured by the building structure), we have come up with another method to minimize GPS false positioning. We make use of the human intelligence available at the emergency center. For example, often when moving through a building, the corresponding GPS signal circulates around the building. In figure 3, all GPS positions are incorrect, since each of them was recorded while being inside the building in the middle of the picture. Algorithmically it is quite a lot of effort to find out, whether the signals in figure 3 are actually circulating around a building located somewhere in the centre of the GPS positions. However, for a human user of the system it is a simple look on the satellite image with overlaid GPS positions to answer the same question. Therefore we include in our results not a single, but a number of past GPS positions.

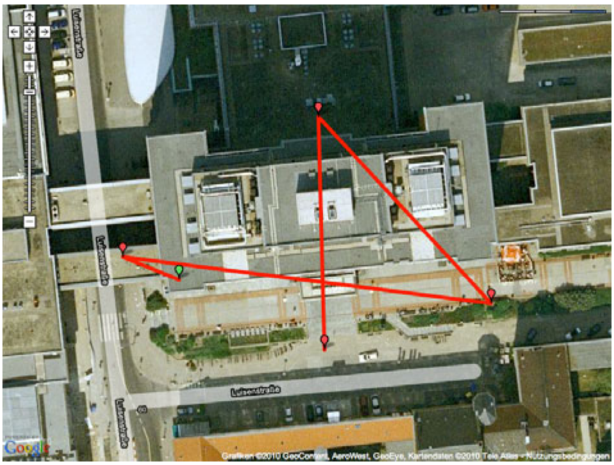

Fig. 3. Circulating GPS position while being indoors

4.2.3 Wireless Based Localization Analysis

Our indoor localization approach is based on fingerprints of WiFi and Bluetooth networks or more precisely on the detection of nearby wireless LAN access points and Blue-tooth devices. We opted for fingerprinting instead of other approaches which require knowledge regarding the concrete setup of the WiFi network (e.g. for runtime measurements we would have to know the exact location of each of the access points, so that we could use a triangulation approach to calculate the current position) since this will allow us to use the technology basically in any building (or area) that features a sufficient WiFi setup. Also, at the current setup we rely on metadata instead of actual map material. So instead of showing the users current position on a building plan, we may only present the metadata as it was annotated during the recording phase of this particular building. Later in the project we will add 2 ½ D building models to generate routing descriptions inside of buildings.

The basic idea is to take a single Bluetooth scan and a sequence of WiFi scans together. WiFi has a larger range but may sometimes yield ambiguous results. Bluetooth has a short range but hence a limited coverage. Together, Bluetooth data may help to disambiguate WiFi signals (this technique is usually referred to as “sensor fusion”, see also [12,13]). Since the WiFi signal strength may vary significantly (as mentioned before), we use sequences of WiFi scans. In section 4.2.3.1 we will explain, how these sequences are analyzed and accumulated. One important fact to point out is that while WiFi signal strength measurements are rather unstable over time, WiFi visibility counting in our experience is far more stable. In our approach we combine both technologies.

In order to map the current fingerprint recordings of the user's device onto previously recorded fingerprints and corresponding metadata, we have chosen a completely new and maybe somewhat surprising approach. Instead of implementing our own complex matching or similarity detection algorithm, we have adapted a well established technology from another application area. We are using the open source search engine Lucene[14] to build an inverse index of our metadata and the corresponding fingerprint data. This approach yields several key advantages. First of all, Lucene (using an inverse index) is highly scalable. This may not be an argument if you only have one or two buildings in your database with the corresponding few hundred WiFi and Bluetooth measurements. But it may be important if this number goes up to thousands or even hundreds of thousands of buildings. Using Lucene, there is no significant performance difference between an index holding a few or a few million entries. The second main advantage is the fact that Lucene features a very nice ranking algorithm. So, instead of just getting a single position candidate, using Lucene we get as a result a list of possible candidates all together with their corresponding confidence values. Why is this so important? Again, we may use the intelligence of the human person in the emergency center that is confronted with the positional information. Instead of giving a single indoor location, we present a list of possible candidates ranked by the confidence value. Therefore, if the algorithm is quite sure, the confidence value of the first candidate will be significantly higher than the one of the second candidate and so on. However, if the algorithm is not so sure, the confidence values will be very similar. Hence the human person in the emergency center may easily inform the paramedics, that there are two or three different current user locations that are almost equally probable. Fortunately, as we will show in the results section, those "insecurities" usually only occur between location that are very close to one another (usually it's just the room next door). In the following two subsections we will introduce the indexing technology as well as the corresponding query technology.

4.2.3.1 Indexing Metadata and Fingerprint Data

The data that is used to build the location index is directly taken from the XML data stored locally on the mobile device by the recorder (see section 4.1.3). The indexing module parses through the folder structure generated by the recorder. Each XML file found corresponds to a single recording with corresponding metadata. The fingerprint data consists of an XML Element holding the Bluetooth device IDs which were detected during the recording and of a list of XML Elements each holding the Device IDs of the access points that were "seen" during a single scan (a single recording usually includes a sequence of scans). In the case of the WiFi data, in addition there is also information on the signal strength of each access point seen during each scan. The following is a very simple example of a single WiFi scan:

```
<REC>02216A012DBD-93 020B6BB08063-86
000B6BB08063-86 0A0B6BB08063-86
060B6BB08063-86</REC>
```

This means that during this scan, 5 different access points were detected (one has a signal strength of -93 while the other four have a signal strength of -86). This raw data is accumulated before it is actually added to the index. Going through the list of Elements holding the WiFi recordings we count the number of occurrences for each of the access points. In addition, for each access point, we also calculate the average signal strength over all WiFi scans of a recording. Both numbers are then normalized to integral numbers ranging from 1 to 10. For a single access point that was “seen” during a recording, we add two data entries looking as follows:

```
02216A012DBD_7 02216A012DBD&9
```

This basically means that this particular access point at this particular location (where the recording was taken) was seen in 70% (indicated by 02216A012DBD_7) of the recordings with an average signal strength of -90 (indicated by 02216A012DBD&9). In section 4.2.3.2 we will explain, why we had to simplify those numbers to integral numbers of 1 to 10. This accumulated data is added to a single field of a new Lucene document to be added to the index. In addition, the Bluetooth Device IDs in the Bluetooth Element are also added to the data field. Consequently, each metadata element is added as a separate field of the document as well. Finally the document is added to the index.

4.2.3.2 Querying the Index with Current Data

In order to find the most probable location candidates in our database (the index), we have to perform a single query on the Lucene index. When the raw data of a single wireless network scan is to be analyzed, we perform very similar operations to the ones we perform when adding locations and corresponding fingerprint data to the index (see section 4.2.3.1). Again, we count the number of occurrences of a single access point ID and we also calculate the average signal strength over the sequence of wireless network readings. These numbers are then normalized in the same way, like we did when indexing the data. Once again, we come up with something like this for each access point ID we find in our sequence of fingerprints:

```
0A0B6BB08063_8 0A0B6BB08063&7
```

At this point it would be possible to build a single query string concatenating all the single strings generated for each access point. However, this would mean that the results would only show documents from the Lucene index, where exactly the same terms were found. So, an access point in the database that was seen in 80% of the fingerprints at a single location would only be found if the query would actually include exactly the right term for a 80% occurrence of the access point ID (e.g. 0A0B6BB08063_8).

The same holds for the average signal strength. Therefore, instead of querying the index only for the current number of occurrences and for the current average signal strength, we build a query searching for all possible numbers of occurrences and medium signal strength. Since this is hard to describe, here is an example:

```
0A0B6BB08063_1^0.3 0A0B6BB08063_2^0.4
0A0B6BB08063_3^0.5 0A0B6BB08063_4^0.6
0A0B6BB08063_5^0.7 0A0B6BB08063_6^0.8
0A0B6BB08063_7^0.9 0A0B6BB08063_8^1.0
0A0B6BB08063_9^0.9 0A0B6BB08063_10^0.8
```

In the above example, the number of occurrences in our current fingerprint sequence for the access point ID 0A0B6BB08063 was 80%. Since we also want to find all locations where the access point was visible (during our measurements taken for the index) but not in 80% of the cases but instead with any other number, we have to search for all possible terms describing those situations. The trick is that we assign a different "importance" to each of the query terms. The term representing the exact number of occurrences as in our current sample will get the highest number (in Lucene, this is called "term boosting" and is indicated by the symbol "^" followed by the value you want to assign to the number) of 1.0. The remaining 9 query terms we add to the query get "importance values" representing how much they differ from our current sample (i.e. they get lower importance, the further they are from the current sample). To summarize, the constructed query will find any document in the index where in the data field the access point ID appears, regardless of the number of occurrences. However, the closer the number of occurrences resembles our current sample, the higher the document will be ranked in the results.

The same mechanism is also applied to the average signal strength value. In total, coming from a single access point ID, we end up with 20 query terms added to the overall Lucene query. Finally, we add the Bluetooth device IDs from our current sample to the query. At this point the query is complete and we may resolve it by using it on the Lucene index. The result is a ranked list of possible location candidates (currently we have chosen to only ask for the 5 most promising results). These candidates (being Lucene documents) hold also the necessary metadata to describe the different locations. Hence, if our result list is not empty (i.e. there is at least one access point ID in our current sample that also exists in the index), we may use the result list immediately to present possible current locations of the user on the website generated by the location server.

Again, since the results are being interpreted by a human person, the confidence values for each result in the list give a clear indication about the "reliability" of each of the possible location candidates. Even if there is only one possible candidate found, the confidence value clearly indicates how likely it is, that the location is correct.

5 Results

Since the GPS used for outdoor location finding is not under our control, we have no influence on the quality of this particular positioning service. Therefore, we may only say that our outdoor location service performs just like any other service based on GPS.

We will give a little more detail on the analysis of the indoor location performance, since we have implemented a completely new algorithm combining different sources of information. To evaluate our indoor positioning approach, we have tested it in two different buildings. Both of them are office buildings however they feature quite a different wireless network setup. The first building (actually the project office of the DFKI in Berlin) features a completely symmetrical building structure. This means each floor of the building looks exactly the same and each wing of the building has a sibling. The WiFi setup within the building is identical on each floor, consisting of a single access point being always located at exactly the same position. This means, that we have a vertical setup of our reference signals (the access points) while we mainly wish to locate the user in the horizontal extends of each floor. Due to the homogenous setup, this building is a particularly hard candidate for wireless network based indoor positioning.

The second building (the floor of the Chair of Professor Wahlster at the Saarland University was measured) is a university building and neither the building structure nor the wireless network setup are symmetrical or homogenous. Actually, the wireless network setup is quite chaotic with sometimes up to 45 access points being visible at a single location. Perfect conditions for wireless network based positioning.

The initial prototypical setup we used for indoor positioning was solely based on counting occurrences of WiFi access point IDs in sequential WiFi scans. Our chosen testbed was the "problematic" offices of the DFKI in Berlin. Due to the homogeneity and symmetry of the building and WiFi setup, the first results were not as good as we would have hoped for. Hence, in order to improve the location quality, we added additional strategies and data. In sequential order we added Bluetooth support followed by wireless signal strength support. Finally, we integrated all data in a single approach. In figure 4 we present the results of all four different strategies.

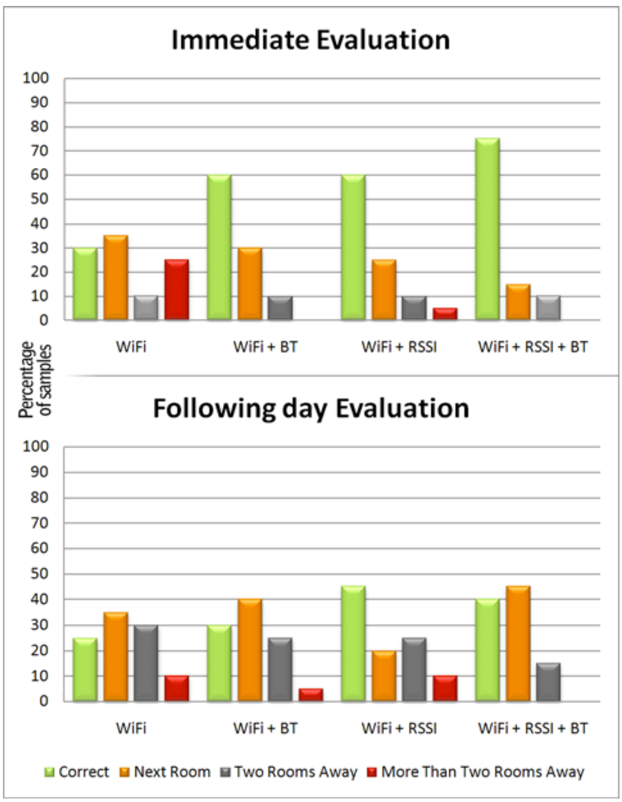

Fig. 4. Performance influence of different data sources

The results in figure 4 show that adding the Bluetooth readings (WiFi + BT) significantly improved the results and especially removed all cases where we had an error in positioning (meaning that the derived position ended up to be more than two rooms away from the real position). Adding signal strength readings but omitting Bluetooth data (Wifi + RSSI) yielded similar improvements to the previous condition.

Finally, combining all data sources into a single approach turned out to be the best solution (WiFi + RSSI + BT). As we have mentioned before, some of the data measurements we are using (especially signal strengths of WiFi networks) are not absolutely stable over time. Hence we compared all four conditions temporally as well by repeating all conditions on the following day. Generally speaking we see a decreasing positional quality in all of the four conditions. While the effect is very little in the "occurrences counting condition", it has a notable effect on all the remaining three conditions. However, the graph also clearly indicates that even under these circumstances, the approach combining all data sources still turns out to be the most precise of all the different setups. Therefore, for all further evaluations we have chosen to take into account all available data sources (WiFi + RSSI + Bluetooth).

In a second evaluation step we wanted to find out how the indoor location technology performs in the two different buildings we have discussed above. As mentioned before, wireless network measurements may vary significantly when taken with a certain temporal distance. Hence, we have taken measurements at both buildings for our location index. Immediately after each of these recordings we did an evaluation recording to check the immediate positioning quality. We took additional evaluation recordings after 24 hours and another one after a week. Figure 5 represents the analysis of the acquired data.

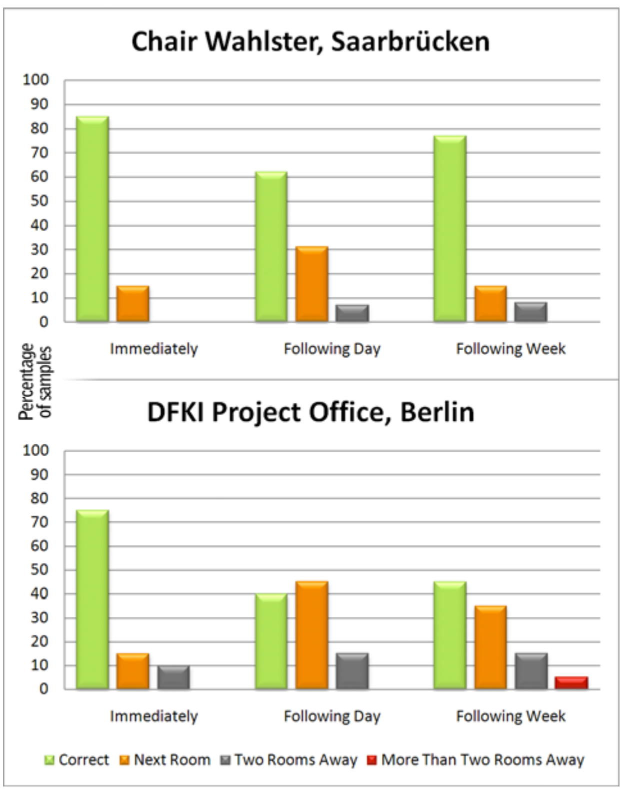

Fig. 5. Indoor positioning temporal performance

Figure 5 clearly confirms our assumption that the symmetrical setup of our project office in Berlin would have a significant influence on the overall performance of the indoor positioning approach based on wireless networks. Nevertheless, the graph also shows that the approach (while performing very successful at the Saarbrücken office with 85% correct positions and only 15% of the derived positions being one room away from the real position) still performs sufficiently well even under such circumstances as we find them in our office in Berlin. Sufficiently well in our application scenario means, that the paramedics may find the user with the help of the system without losing too much time. Both graphs show that in the majority of cases, the acquired position information points either to the correct room in the building or to a room adjacent to the correct room (Next Room). Only in very few cases we end up with a position being 2 rooms away from the real position and in only one case we had a total failure (meaning that the position was more than two rooms away but still on the right floor in the right building).

6 Conclusions and Outlook

In this paper we have presented our prototypical implementation of a 24/7 indoor and outdoor emergency localization system. The current implementation focuses on situations that allow for a localization of the user either because he/she is outdoors and hence we may use the GPS or he/she is indoors in a building that has been added to our indoor location database. In both cases, we may derive a user position based on different technologies presented in this paper.

However, we are well aware of the fact that there is quite a large quantity of locations where neither of these technologies will work. For example, being inside a building that is not known to the system, we may neither use GPS nor the presented indoor positioning approach. Equally problematic are outdoor locations where the GPS signal is obscured by some large object like a building or a tunnel. To also integrate a potential support for such situations, we are currently working on a supplemental approach. The idea is to guide the paramedics to the last known position of the user (this can be either based on a recent GPS coordinate reading or an indoor position derived from the user's data history).

The paramedics will be equipped with a mobile device as well. In conjunction with the last known position, the chronological wireless signal fingerprint data of the user's device will also be transferred to the mobile device of the paramedics. This data will then be fed into a tool that may assist the paramedics in finding the user by following the "invisible trail" of wireless network signals that has been recorded by the user's device while he was moving from the last known position to his current location. Starting at the last known position of the user, the tool on the paramedic's device will use the fingerprint data to estimate distances to the different signal sources as they were measured in the original recordings on the user's device. Based on these assumptions, the device will suggest a direction in which the paramedics should move. While moving, the tool will continuously scan for wireless network signals and compare those with the data from the user's device. This comparison will indicate, whether the paramedics are moving in the right direction. If the direction appears to be wrong (since the current readings considerably differ from the readings of the users device), the tool automatically update its calculations and ask the paramedics to move in another direction.

We hope that in this way the paramedics will still be much quicker in finding the user (even though it may not be as convenient as the approaches presented in this paper) as compared to a situation where they don't have any positional information at all. Supporting these situations as well will hopefully yield the desired confidence we wish to offer to the potential users of the system.

The Smart-Senior project consists of a consortium of 29 project partners of either industrial or research background and it is funded the German Ministry of Research and Education (BMBF).

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Unobtrusive In-Car Vital Parameter Acquisition and Processing

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Abstract. In this contribution, a system for unobtrusive acquisition and processing of vital parameters using body-worn and car-integrated sensors is presented. The system consists of a steering wheel attachment with sensors, sensor processing and wireless communication interface and a portable monitoring unit for wireless data reception, display and interface to the car information system. A great effort is done worldwide to develop technical solutions helping elderly people to keep mobile and thus autonomous, including monitoring vital signs for patients needing continuous medical care or preventive solutions allowing regular health checks. In-car vital signs monitoring is a good approach to solve this problem. This solution focuses on the effective integration of display solutions and selected sensors for an improved usability and lower-ing of the system-related driver's distraction.

Keywords: Vital parameter, car integration, mobility, elderly people, acquisition, processing, display, vital sign, mobile.

1 Introduction

In an aging society, it is very important to enable people to live an independent life for as long as possible. This goal can be achieved keeping people in good health through prevention, early diagnosis and short hospital stays in the first place and assuring that elderly people with cognitive or physical impairments keep self-sufficient. Personal assistant devices are devices designed to achieve both parts of this goal, allowing both motivation to live a healthy life, early detection of changes leading to illnesses and aids to keep independent when illnesses or age-related impairments are already there. Such systems can be embedded in an intelligent home or be portable systems, but they can also be embedded into vehicles. As many people spend a considerable amount of their time in the car, a system able to record vital parameters during the drive could have many benefits. The time spent driving or inside traffic jams could be used for regular health checks. In addition to this, such a system could help people being constricted in their mobility because of the need of continuous monitoring. The monitored data could also be used to detect characteristics about the driver's state and positively influence them, e.g. lowering the music volume or blocking incoming calls if a state of particularly high cognitive stress is detected. After the state of the art overview and task description, this paper will describe the developed system as well as its implementation and two experiments which have been done during and after its development. The first experiment was done to ascertain the basic possibility to embed sensors to acquire vital parameters efficiently during a driving task as well as to explore possible relations between vital parameters and cognitive stress. The second experiment was done to prove the correct functioning of the sensors embedded into the car. In addition to this, the planning of an evaluation on the street with the scope of testing the system in real road traffic will be presented.

1.1 State of the Art in In-Car Vital Parameter Monitoring

Especially if blood alcohol concentration and fatigue aren't considered as such, there aren't any car-embedded commercially available devices to measure vital parameters in a car. Thus, the discussion in this section is limited to contributions found among the research area.

The foundations of in-car vital parameter monitoring lie in non-invasive measuring methods which have to be easy to use and dependable. Such systems are common when measuring a person's physical or psychological state without the need of their cooperation, e.g. when they are involved in their normal tasks.

The first approaches in in-car monitoring of vital parameters were motivated in the assessment of the driver's emotional state to determine his driving capability. Against the background of rising traffic volume, driving speeds and related amount of car accidents the assessment of stress determined by the driving task was to shed light on its influencing factors in order to realize counteractive solutions.

The driver's ECG (electrocardiogram) is acquired in [1]. The pulse variability is associated to the activity of the parasympathetic nervous system and is used to ascertain the stress level. To be able to measure the ECG most of the time, electrodes were placed on the steering wheel, on the gear selector and on the left armrest. Reference [2] also presents a system measuring ECG in order to detect the stress level. Here, dry electrodes on the steering wheel are used and compared with electrodes placed on the chest. The signals were digitalized and sent to a PC via Bluetooth. While the ECG was recorded, GPS (global positioning system) was used to protocol the driving speed as a reference for stress. In [3], an expansion of system [1] measuring also body impedance (using electrodes on the steering wheel) and blood pressure (using a self developed optical system on the dashboard) was presented. All sensors are connected directly to a PC for evaluation using an analog to digital converter. The system described in [4] detects the stress level using sensor data from ECG, EMG (electromyography), skin resistance and respiratory rate. A reference stress metric was also determined using video cameras recording the driver's facial expression. On most of the observed drivers a strong correlation between stress level and both heart rate and skin resistance was found, and it was suggested to use this data to control non critical car systems. Reference [5] describes a system measuring blood pressure, blood volume and differential skin temperature (on cheeks, nose and finger tips). Reference [6] presents an approach to intervene into the car control based on acquired psychic-physical parameters. Sensors acquiring ECG, EEG (electroencephalogram), skin resistance and temperature directly on the driver's body were applied to be able to detect an inability of the person to drive and, e.g., activate the brakes as a consequence.

An overview of the presented systems and their main characteristics is given in Table 1. Summing up all the mentioned systems contain approaches to measure vital parameters inside a car and to determine the driver's current state. Only in [3] the chances lying into the recording of the state over a long period of time in order to eventually detect abnormal changes in early stages are identified. There is an overall strong focus in the integration of a wide range of sensors in order to detect a state as comprehensively as possible. This has the disadvantage of applying many sensors and electrodes on the user, which will most probably constrain him in his driving task. All systems also evaluate the recorded data on a PC. This solution can be used in experimental setups, but is not suitable for a device which has to be integrated in an automobile for everyday-life recordings.

Table 1. Sensors and devices used in the presented state of the art. CE = Electrodes in car; BE = Electrodes on body; BHS = Hall sensor on body; BA = Anemometer on body; BT = Thermistor on body; OS = Optical system; TPP = Transmissive photo plethysmograph; WL = Wireless; W = Wired; PC = Personal computer.

	[1]	[2]	[3]	[4]	[5]	[6]
HR Variability	CE		CE			TPP
HR (Heart Rate)	CE	CE	CE		TPP	TPP
ECG	CE	CE	CE	BE		
EEG						BE
EMG				BE		
Body impedance			CE			
Blood pressure			OS		OS	
Blood volume					OS	
Skin resistance				BE		BE
Resp. rate				BHS	BA	
Diff. skin temp.					BT	
Oxygen Saturation					TPP	
Communication	W	WL	W	W	W	W
Processing	PC	PC	PC	PC	PC	PC

1.2 Task Description

The goal of the presented project is to develop a system able to acquire vital parameters focusing on sensors commercially available and which can be integrated into a car without distracting the driver. In addition to this, the goal is to develop a platform able to process the data and display it for the user or transmit it to the car information system during the drive, without the need of integrating an additional embedded PC into the car. Thus, the system should be easy to install even retroactively and easy to use in everyday life. The only sensor considered to be possibly worn by the user is a chest harness for heart rate measurement, as this is an already popular and widespread system.

2 System Concept

2.1 Static System Concept Description

The system was first published in [7]. This paper presents an alternative version, which is less car-embedded and thus easier to install retroactively.

The system can be divided in three components:

Sensor unit: This is a unit attached to the steering wheel with integrated sensors which are able to acquire the driver's vital signs on contact. In addition to this, it contains electronics communicating with the sensors in order to acquire their data. The sensor unit also contains a wireless interface in order to transmit the data. This unit is powered by an exchangeable battery.

Receiver unit: This is a portable unit which receives all sensor data from the sensor unit and is able to further process it. In order to communicate with the sensor unit, it must contain a wireless interface. In addition to this, it must contain data processing, storage and display devices. This unit uses battery power and needs an interface in order to recharge the battery and export the data. This component and the sensor unit are mandatory and need to be installed into the car.

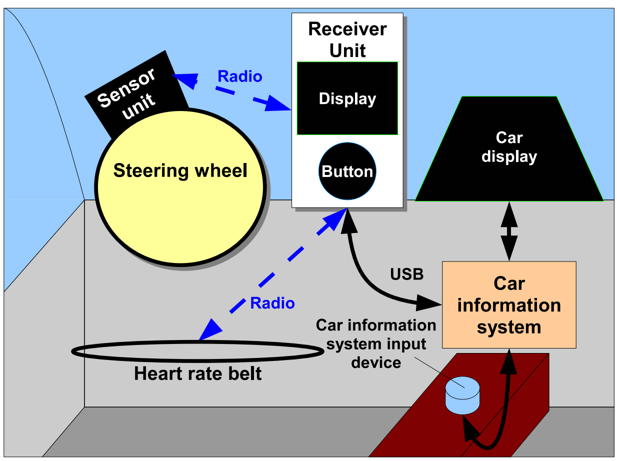

Fig. 1. Description of the system's parts and interfaces.

Car information system: A car manufacturer willing to give the user the option to display the measured data and setup the system more comfortably using the car information system has to integrate as a third component a USB (universal serial bus) interface to the car information system as well as a software extension of this system capable of communicating with the receiver unit.

A scheme showing the system's composition can be seen in Fig. 1.

2.2 Dynamic System Concept Description

In this section, the processes running on each system component and their interactions are described.

2.2.1 Sensor Unit

The process running on the sensor unit reads out the sensor data periodically and listens for requests from the receiver unit. When a request comes in, it sends the requested data to the receiver unit or it sends an error message, in case the sensor data is not available (e.g. because the sensor is not used at the moment).

2.2.2 Receiver Unit

The receiver unit periodically sends sensor data requests to the sensor unit through the wireless interface. In addition to this, it calculates periodically the heart rate given by the heart rate belt. When it receives a request from the car, it answers the request sending data or an error message. When the user pushes the button, the display is turned on for a given time. While it is on, the display controller actualizes periodically the shown data sending requests to the receiver unit. With every other push of the button while the display is on the user can cycle through the available sensor values. After a given time without button activation, the display enters a sleep mode. Also the whole receiver unit switches to sleep mode when it doesn't receive requests for a given time.

In order to be able to utilize the knowledge about the driver's vital parameters, the receiver unit doesn't just react to sensor data requests. It also calculates a stress level characteristic, which can be used e.g. to control the cabin environment by regulating the music volume or blocking incoming calls. This can be done sending "recommendations" to the car autonomously, whenever the car should be informed about a particular event, like a sudden vital signs change which may require attention. For example, even when the receiver unit is in sleep mode, it wakes up regularly and checks whether a specific sensor is being used by the driver. If this is the case after a given non-usage period, a recommendation to show the sensor's data is sent out both to the receiver unit's display controller and to the car information system. On reception of the recommendation, the receiver unit's display turns on, while the car information system switches to the menu showing the desired sensor data without the driver needing to use its input device to do this.

2.2.3 Car Information System

Apart from the usual processes running within a car information system, a new functionality is added: on activation of the menu item "Fitnessmonitor", the user can display the available sensor information. The car information system sends requests to the receiver unit in order to actualize the sensor data. In contrast to the receiver unit, on the car display it is not only possible to see the current data, but also the devolution of the values over time. As stated above, the car information system also receives recommendations from the receiver unit and reacts accordingly.

3 System Evaluation

For evaluation, the presented system was built in a way described in section 3.1 and two experiments were conducted. The first one, described in section 3.2, had the purpose of measuring the driver's distraction due to sensors attached to the steering wheel. The second one, described in section 3.3, was conducted to evaluate the sensor's reliability when integrated into the car. In section 3.4, a planned evaluation in real road traffic is described.

3.1 Materials and Methods

3.1.1 Sensor Unit

Two conductive electrodes are embedded on the sensor unit's rear side (Fig. 2, bottom right).

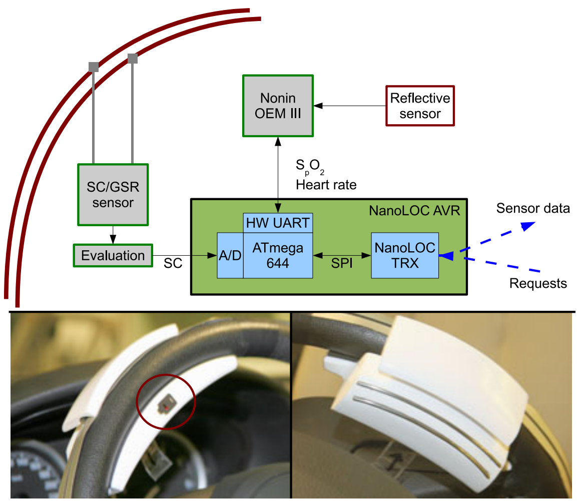

Fig. 2. Top: Description of the sensor unit's parts and interfaces. Bottom left: Detail of the pulse oximeter. Bottom right: Detail of the skin resistance electrodes.

Between these electrodes, the driver's skin conductivity can be measured whenever he touches them both. The electrodes are connected to an evaluation unit like the one described in [8].

The second sensor is inset on the sensor unit's front side, in a position where the driver can position his thumb easily during the drive (Fig. 2, bottom left). It is a reflective pulse oximetry sensor connected to an OEM III module (Nonin Medical Inc.) for evaluation.

Both sensors are connected to a nanoLOC AVR Module (Nanotron Technologies GmbH) via an A/D converter input and the serial interface, respectively. This module includes an AVR ATmega644 (Atmel Corp.) microcontroller and a nanoLOC TRX

Transceiver (Nanotron Technologies GmbH). For the system scheme, see also Fig. 2, top.

The whole system is powered by exchangeable, rechargeable batteries.

3.1.2 Receiver Unit

The receiver unit is designed as a portable unit which can be taken out of the car by the user and attached into the car like an external navigation system. It is thus powered by an internal battery which can be recharged inside the car or in any USB plug using the unit's interface (Fig. 3, bottom).

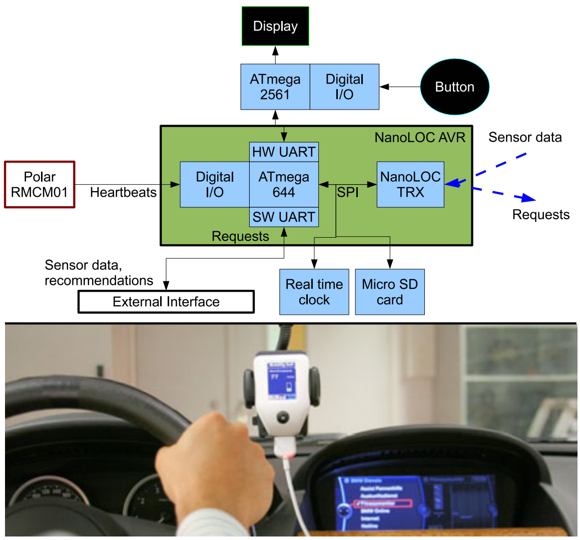

Fig. 3. Top: Description of the receiver unit's parts and interfaces. Bottom: Receiver unit in use inside the car. The unit's function is independent from the usage of the external interface.

The receiver unit also contains a nanoLOC AVR Module which is connected to a real time clock, a micro SD card, a RMCM01 OEM Module (Polar) and another AVR ATmega2561 (Atmel Corp.) microcontroller controlling a 2.1" 65536 color TFT display (D012, Speed IT up) (176x132 pixel). The ATmega2561 is connected to the button on the receiver unit. For the system scheme, see also Fig. 3, top.

The unit consumes approx. 100 mA when in use and 20 mA when not, operating with a battery voltage of 3.7V. Thus it must be recharged approx. every three days using it for one hour a day. The RMCM01 heart rate belt module indicates every heartbeat received by a Polar Wearlink belt with a trigger pulse on the output line, thus the heart rate must be calculated by the microcontroller. A plausibility check is also necessary, as the heart rate belt module usually sends several pulses for each heartbeat or phantom pulses when receiving noise. As a consequence, the heart rate given by the pulse oximetry sensor is always more reliable and is used exclusively when both heart rate readings are available. In summary, the receiver unit is able to wirelessly request and receive information from the sensor unit to find out whether it is within receiving range. If this is the case, for each sensor it can store a value or an error code indicating that the sensor is not in use. The micro SD card can be used together with the real time clock for long-term, time-stamped data storage and extraction.

3.1.3 Car Information System

To enable external communication with the receiver unit, the serial communication pins of its ATmega644 are connected to the interface. The same protocol to request information employed between the ATmega644 and the ATmega2561 is available to request information through the external interface. A 650i car (BMW Group) was used to demonstrate how this can be utilized by a car manufacturer to embed received data into the car information system (Fig. 4, bottom).

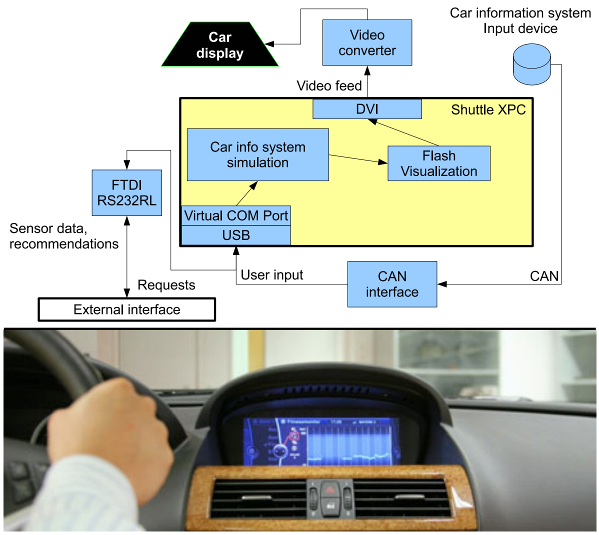

Fig. 4. Top: Description of the car information system's parts and interfaces. Bottom: Detail of vital parameters displayed on the car information system.

The car was modified in order to have a USB plug in the driver cabin, so the receiver unit can be connected to the car's information system. Cars will most probably have such an interface in near future. If not, the system can easily be adapted expanding the serial interface with a Bluetooth module, as most cars already support Bluetooth communication with e.g. mobile phones. To implement the new functionality into the car information system, a flash simulation of this system running on an XPC System (Shuttle Computer) was modified. The XPC System is connected to the car's display and CAN bus in order to visualize the simulation and to get user input from the information system input device. This is a common approach for prototyping new features of a car information system. For the system scheme, see also Fig. 4, top.

3.2 Preliminary Experiment

3.2.1 Motivation

In the run-up to the system development it was necessary to determine which sensors are capable to acquire vital parameters without distracting a driving user. Furthermore, possible realistic usage scenarios and correlations between cognitive stress and driving situations had to be explored.

3.2.2 Setup

The experiment took place inside a static driving simulator (Fig. 5, right) with 21 male and 3 female subjects, 36 year old in average. Every subject was asked to drive through 5 simulated scenarios:

- Scenario “sparse traffic”.
- Scenario “heavy traffic”.
- Scenario “dynamic heavy traffic”.
- Scenario “dynamic heavy traffic and secondary task”.
- Scenario “interurban and city drive”.

Fig. 5. Left: Frame of the four recorded views during the tests. Right: Experimental setup.

The secondary task in the fourth scenario consisted in counting down loudly in steps of seven. During the drive, the subject’s vital parameters were recorded with a sampling rate of 50 Hz using the following sensors:

- Skin temperature and skin resistance sensor attached on the back of the steering wheel’s left radius arm (iSense, Werfen Austria GmbH).
- Skin temperature and skin resistance sensor attached to the left hand’s forefinger (iSense, Werfen Austria GmbH).
- Transmissive pulse oximeter attached to the right hand’s forefinger, measuring heart rate and oxygen saturation (PEARL, medlab GmbH).

The test subjects were asked to use the sensor fixed to the steering wheel whenever it was possible without being distracted from the driving task. Before the first and after the last scenario, a baseline reading was taken. Between the scenarios the following questionnaires were filled out to acquire subjective data:

- Basler existential-orientation-scale (Befindlichkeitsskala) [9].
- NASA Task Load Index [10].
- Simulator sickness questionnaire [11].

In addition to the objective and subjective driver data, several internal simulator values were recorded with the same sampling rate. These values included speed, acceleration, attitude angle, yaw rate, driven distance, differential lane angle, lateral position, steering wheel angle, steering rate, throttle pedal setting, braking pedal setting, turn indicator state, overall vehicle position and orientation and motor rotation speed. Regarding the driving situation, the number of available lanes, the distance to the next car, the number of cars on the driver's lane before and behind the driver and the overall traffic density were recorded.

In the dynamic scenarios the simulator generated and recorded two critical driving situations:

- Situation "merger".
- Situation "braker".

The "merger" situation occurs when a vehicle suddenly changes to the driver's lane, while the "braker" situation occurs when a vehicle suddenly brakes sharply in front of the driver. However, those situations are recorded even if the situation doesn't influence the test subject (e.g. happens too far away).

The overall test duration averaged to 60 minutes and was recorded as video footage including a view of the driver cabin, a detail view of the steering wheel sensor, a view of the foot space and a 3rd person simulator view of the test subject's vehicle (Fig. 5, left).

3.2.3 Results

3.2.3.1 Sensor Availability

The average sensor availability (percentage of recordings with valid values) was minimal in the scenario with dynamic heavy traffic and secondary task. Here, it was 91% for the pulse oximeter, 99% for the finger-attached skin sensor and 73% for the steering wheel-attached skin sensor.

3.2.3.2 Significant Vital Parameter Variations

On average, the test subject's heart rate is significantly higher in the scenario with dynamic heavy traffic and secondary task, both as absolute value and as difference to the average value (Fig. 6). After a critical situation, in most cases a heart rate rise can be found. This effect does not happen consistently and features a high variance, nonetheless it must be taken into account that vital parameter changes can occur due to the driving situation and not due to pathological reasons.

The change of skin resistance in consequence of critical situations was less consistent. No significant effects could be found on the skin temperature or on the comparison of the baseline measurements before and after the test.

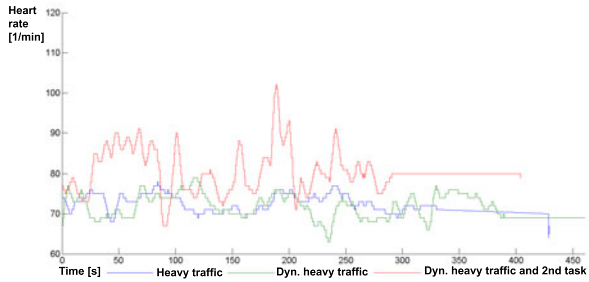

Fig. 6. Measurement of heart rate characteristics during different driving simulator scenarios.

3.2.3.3 Subjective Results

Evaluating the existential-orientation scale, a rise of the excitement from the first to the fourth scenario was found as intended. At the same time, concentration and balance dropped. The values in the last scenario were similar to the ones in the third. The evaluation of the task load index showed that the test subjects classified the progression of scenarios as increasingly demanding both mentally and physically. Concurrently, the estimated quality of task fulfillment and well-being dropped. In the course of the test single subjects reported increasing indisposition (3 subjects had to abort the last scenario) within the expectancy for static simulators.

3.3 Sensor Evaluation Experiment

3.3.1 Motivation

To verify the validity of the data delivered by the sensors embedded into the steering wheel and adapted to be evaluated by a microcontroller, a second experiment was done. Thus, the experiment can be divided into three parts:

- Skin resistance (3 test subjects, average age 26)
- Heart rate and oxygen saturation (2 test subjects, average age 25)
- Heart rate (Polar) (2 test subjects, average age 25.5).
  For every test subject, 20 different measurements were taken.

3.3.2 Setup

The experiment has been carried out with the sensor unit described in [7]. For every sensor, the sensor data was requested from the receiver unit through the external interface and stored on a PC. At the same time, the same value was measured on the test subject using a conventional sensor. The conventional sensors used as reference were:

- Skin resistance: Nexus-10 (Mind Media BV) connected to the output of the SC/GSR sensor together with the system's sensor unit.
- Heart rate and oxygen saturation: OnyxII (Nonin Medical Inc.) attached to the ring finger of the test subject, on the same hand activating the steering wheel sensor.

- Heart rate (Polar): OnyxII (Nonin Medical Inc.).

The sensors were evaluated based on the error value e:

$$e = \left|(V_S - V_R)/V_S\right| \cdot 100\% \,, \tag{1}$$

where V_S is the value provided by the developed system and V_R is the value provided by the reference sensor.

3.3.3 Results

3.3.3.1 Skin Resistance

The Nexus-10 system has a measuring range from 1kΩ to 10 MΩ, whereas the developed system has a range from 170kΩ to 1MΩ, as the developed system is bound to the restrictions of the ATmega644's built-in A/D converters. Thus, within the system's range the maximal error was 18%, while it reached a maximum of 76% in one of the test subjects having a skin resistance out of the system's measuring range.

3.3.3.2 Heart Rate and Oxygen Saturation

In the heart rate, the error reached a maximum of 15% in one single measurement. The average error was 3% for the first test subject and 7% for the second. The oxygen saturation could be measured with a maximal error of 5%, while the average error was 1% in both subjects.

3.3.3.3 Heart Rate (Polar)

In the first subject the heart rate was detected with a maximal error of 15% and average error of 3%. On the second the effects of noise were detected, thus the maximal error was 20%, with an average of 6%.

3.4 Real Road Traffic Experiment

3.4.1 Motivation

The real road traffic experiment will be carried out to prove the following points:

- The system is able to detect correct values inside a real vehicle in a real traffic situation.
- The system is able to get values during a real drive.
- The system is accepted and used by people within the target group.

3.4.2 Setup

At least n=20 people in an age above 50 will take part in the test. During the test, they will be asked to drive a route of 16 km length three times. During the drives, data will be collected about how often the sensor are being used (test drive 1) and the system's values will be compared to values recorded by a reference measuring system (test drive 2). Before and between the drives, the test subjects will be questioned about the system to get subjective statements about the system's evaluation. An overview about the test procedure is given in Fig. 7. The tests will be carried out at the beginning of November 2010.

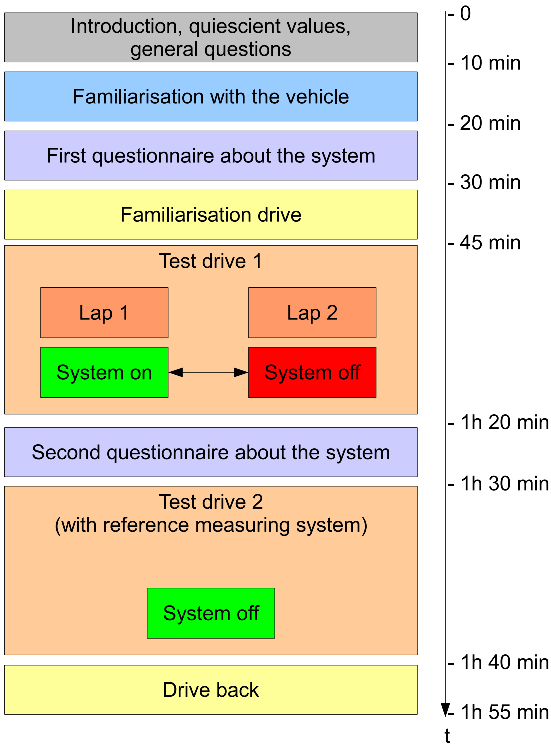

Fig. 7. Overview of the planned test procedure in real road traffic.

4 Conclusions

A prototype of a system for unobtrusive in-car vital parameter sensing is presented. For the first time, this prototype was presented in [10]. In an experiment exploring the usability of embedded sensor in the car and possible correlations between vital parameter changes and driving situation it was shown that sensors embedded in the steering wheel are easily usable without distracting the driver, and a correlation between heart rate and cognitive stress was detected. A second experiment ascertaining the accuracy of the system showed that the developed system has acceptable error values, as they lay within or below the error rates of conventional systems for the measurement of those parameters. The planning of a third experiment evaluating the system in real road traffic was presented.

The system has the advantages of being able to measure vital parameters without distracting the driver and of evaluating the sensor data on a microcontroller, thus allowing an easy integration as small handheld device. Additionally, it offers an external interface and a communication protocol allowing car manufacturers to expand their car information system in order to utilize the information. Thus, it provides a basis for several pervasive applications supporting the mobility of elderly people, from regular in-car health check-ups to the adaptation of the car to the driver's current state. As next step, the presented experiment in real road traffic will be carried out and evaluated.

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Within the research consortium of the Bavarian Research Foundation (BFS) "FitForAge" a team of scientists and engineers affiliated to 13 departments of the Bavarian universities Erlangen-Nürnberg, München, Regensburg and Würzburg works together with 25 industrial partners on the development of products and services for the aging society.

The scope of the research consortium is to develop technology based solutions which will help elderly people in their future living environment comprising home and workplace as well as in communication and transportation. Eventually not only elderly people but also all social groups should profit from these solutions.

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Overview of Indoor Positioning Technologies for Context Aware AAL Applications

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Abstract. Many AAL scenarios, such as those found in the public-funded German R&D project SmartSenior, are based on location information about a person, which makes the position key context information. Previous papers have dealt with the design of a SmartSenior positioning system for emergency scenarios, both indoors and outdoors. This paper focuses on non-critical non-emergency scenarios, e.g., activity recognition and indoor navigation. We present the state-of-the-art in indoor positioning and the current research trend towards including additional sensor information to achieve positioning enhancements and gather more context information. After introducing a few interesting scenarios, we present a guideline on how indoor positioning can be classified in technical ways and also in more abstract ways. We also define metrics (accuracy, costs, privacy, context information) which we then use to evaluate the current state-of-the-art research. Based on this evaluation, we discuss possible solutions for the previously presented scenarios.

Keywords: overview, indoor, positioning, ambient assisted living.

1 Introduction

The paradigm of ambient assisted living (AAL) has shifted from mere research to practical in use products as the western population grows older. But more feasible solutions must be developed to allow elderly people to live at home longer and remain independent. The main research fields are mobile healthcare or home care systems, which measure vital data to recognize or even prevent emergencies. At the same time, elderly people still in good health can be supported by systems and services which offer security at home and "lifestyle functionalities". These systems need ambient and vital context to react properly. Many time critical emergency scenarios, such as those found in the German public-funded R&D project SmartSenior, are based on location information about a person, which makes the position key context information. Previous papers have dealt with the design of a SmartSenior positioning system for emergency scenarios, both indoors and outdoors, which often need high accurate positions [1]. This paper doesn't focus on time critical emergency scenarios. The authors in [2] present a very elaborate and deep view into each positioning technique. We attempt to only provide an overview of the current state-of-the-art of the main positioning techniques (e.g., WLAN, RFID, BT and inertial sensors) and systems using multiple mediums so that we are able to discuss a few AAL scenarios. This paper provides an updated overview with new insights on the objectives covered by [3].

We point out three fields among the vast number of possible scenarios. For each field we present a scenario, which we use to discuss possible techniques in section 5. The focus in each scenario is the location of a person or the movement from one position to another.

Ambient assisted living (AAL)
The Ambient Surrounding field is primarily concerned with the research of sensor systems. Buildings are equipped with sensors, which enable detection of diverse situations. In the field of AAL, research is comprised of reasoning methods, machine learning, data mining and desire to detect automatically various situations. We on the other hand attempt to find out what role positioning techniques play in ambient assisted living. Take for example the scenario of persons with dementia. It is desirable to detect this disease as soon as possible before accidents happen, like a forgotten cooking pot on the stove or the cigarette in the ash tray. If the home has installed an object finder, which helps the person to find important and tagged items, like keys, a cell phone, a remote or a wallet, the first hint of an abnormality may be when the object finder is called more often. Additionally, warning systems in the house can react better if the position of the person is known. For example, the warning information that the stove is still running is useless if the person stands next to it but becomes more effective if it is known that the user has not been in the kitchen in over 10 minutes. However, dementia patients in hospitals present a different scenario. It might only be necessary to know whether they are inside the area they are allowed to be, or if they have left it.

Activity recognition
Activity recognition can be understood as part of AAL. It is used to monitor the behavior of mostly elderly people to deduce abnormalities. Our attempt is to find out what positioning techniques can provide to help support Activity recognition scenarios. Activities based on positions or position shifts can include information like walking, sitting, lying, falling, leaving a room, or no movement at all. An example within the healthcare sector is the disease Alzheimer where people affected suffer from a reduction of flexibility and mobility. These symptoms can be detected by examining a change in movement pattern or by a general reduction in movement activity. The goal is to detect anomalies as soon as possible so precautions can be installed in the person's home, a caretaker can be found or possibly even move the person into a nursing home. After Alzheimer is diagnosed, monitoring the movement behavior represents an ability to follow the disease's progress.

Location based services (LBS)/Indoor navigation
Navigating through a large, unknown building, especially for elderly people, can be very hard and most likely stressful. Maps on the wall are barely enough to

assist in finding the target. Personal navigation aids, which provide the current position and directions to the target, alleviate the problem of getting lost. Let's consider the scenario of a person who just completed an operation and is sent to a rehabilitation center for 3 weeks. Instead of receiving a folder full of papers about upcoming exercises, floor plans, diet information and timetables, the patient would receive a personal digital master, associated with the rehab center's system. Upon arriving at the center, the patient can start the navigation assistant which guides him to his room. While passing by the big swimming hall, the assistant instructs him that he should come to this location for his 2 pm appointment. The linking of the current position and information related to this position become very useful, when a personal calendar is involved. In other cases, where people are sent home to recover may not require the indoor navigation system described above, since they know their home. However, if for example they have sustained injuries to their eyes, they would greatly benefit from a guidance system which allows them to walk through their home without seeing their surroundings. The remainder of this paper is structured as follows: In section 2, we present a guideline on how indoor positioning can be classified in technical ways and also in more abstract ways. Section 3 comprises of metrics which we then use as much as possible to evaluate the current state-of-the-art research. Based on this evaluation, we discuss possible solutions for the previously presented scenarios in section 5. Finally, section 6, provides a summary of detected problems and future research opportunities.

2 Fundamentals and Classification

Wireless positioning systems rely on an air medium as a communication channel which suffers from multipath propagation and shadowing. These issues corrupt the metrics that positioning systems attempt to extract from the signals and can be quite severe in indoor environments. As a result, much of the research in positioning systems in the past has focused on attempting to enhance existing algorithms to try to lessen or overcome these corruptions and improve accuracy. However, without fully knowing the level of corruption, enhancements are not effective in increasing accuracy. Hence, current research also attempts to create hybrid positioning systems. Hybrid wireless positioning systems combine various wireless positioning techniques in a way to collectively reduce the impact of corruption on each of the individual techniques and thus, creating a technique more robust to corruption. As more research goes into the hybridization of wireless positioning systems, the integration of sensor technologies, such as light sensors and accelerometers, has become another point of interest. Consequently, the indoor positioning research field began to expand, and now perhaps even shift, to sensor fusion. Hybrid systems and sensor systems can be combined to system using multiple mediums. In section 2.1, we introduce different classification characteristics for positioning systems, and then, we present a discussion about the methods used in positioning systems in section 2.2.

2.1 Classification

The following list provides a classification guideline for positioning systems and also gives an overview of the main elements:

What are the position calculations based on?
The primary function of wireless and hybrid wireless positioning systems is to extract parameters from a signal. These parameters come in a variety of forms such as angles, ranges, or velocities. Typically, they are determined by the underlying physical layer via radio, infrared or ultrasound measurements. Sensor fusion methods add to the above by not only using the physical layer signals but also using the informational data the sensors offer, such as light intensity or sound levels.

Which component measures parameters and/or calculates the position?
According to [4] four possible topologies can be distinguished: In a network-based positioning approach, both, measuring and calculations are performed by the network, whereas in terminal-based, the roles are reversed. In terminal-assisted positioning, the measuring is done by the terminal and transferred to the network that subsequently calculates the position. In network-assisted, the roles are again reversed. Network-based approaches have the advantage to be independent from the terminals and no software has to be installed on all terminals. If network providers are not interested in positioning, terminal based approaches can be interesting. Terminal assisted approaches are common and especially in sensor fusion feasible. Terminals can measure locally different sensor information and the network can offer powerful server to process complex algorithms. Network assisted approaches are not frequently applied.

How are positions calculated?
Because transforming measured parameters into an actual position falls in the domain of research, calculation algorithms are discussed in section 2.2.

What is the reference system of calculated positions?
Positions can be computed as physical (e.g., coordinates in WGS-84) or descriptive positions (e.g., room numbers). Positions can also be absolute (e.g., an x/y coordinate in a shared reference system) or relative (distance to a certain element).

What level of accuracy is needed?
Different applications require different levels of accuracy. Possible levels include a certain area in a premise (e.g., south wing of building 1), a room, a floor, or if high accuracy is needed, an actual x-y-z coordinate in a three dimensional space. Hybrid wireless positioning systems usually focus on enhancing the accuracy of standard wireless positioning systems and limit the number of outliers. The innovation with sensor fusion systems is that additional information is available. The focus is on both enhancing the position accuracy and also detecting additional (context) information, e.g.:

a. Flow control. E.g., by detecting how many people leave/enter an area and how many people are currently in an area, without everyone holding a trackable mobile device.
b. Movement. E.g., Change of the location: by detecting movement accurately or quickly towards or away from a certain spot E.g., Movement activities: by recognizing running, walking, using an elevator or escalator or no movement at all.
c. Ambient information. E.g., by detecting a lack of light in a room or the rise of temperature in a room.

How much is the privacy of the user protected?
When it comes to calculating the position of a person not an asset, privacy is an important issue. Because position is sensitive information, only two levels of protection can exist. The first protects the information and doesn't reveal it to externals, e.g., network operator, and the second reveals it. Full protection can only be provided by network assisted system or systems that don't use an existing infrastructure (e.g., dead reckoning systems), since any level of communication with an infrastructure would allow the network operator to calculate the position. When the sensitive data is revealed, a user's privacy decreases with a rising level of accuracy of the position (e.g., a GSM cell based positioning system which locates a person in an area with a radius of 2 kilometers around the airport reveals less sensitive data than the information that the person is in the left wing of Terminal 2, which in turn is less sensitive than the information that a person sits on the desk in his office).

2.2 Positioning Methods and Principals

As previously mentioned, wireless positioning methods suffer from multipath propagation, which is caused by diffraction, refraction, fading and reflections. Moving people, electrical devices and certain materials (e.g., metal or gypsum plaster) amplify these effects, which makes it almost impossible to model real radio propagation behavior. In the following sections classical positioning methods are outlined and followed by an overview of principals of systems using multiple mediums.

Proximty
Proximity sensing leverages the limited range of radio signals. When the signal of a base station can be received by a terminal and vice versa, the terminal is in range of that base station. Since signals have a maximum range r_{max}, the position of the mobile terminal can be approximated in a circular area around the base station with radius r_{max} or simple just the position of the base station.

Lateration
To calculate the position, Lateration analyzes the distance between the base station and the terminal. The distance defines a circle around the base station, where the terminal finds itself on the circumference. With Lateration more than just one base station is taken into account and hence, more circles can be defined.

Since the terminal must be on all circumferences, the position can be calculated as the point of intersection of all. In a two dimensional space, three base station within reach is sufficient to calculate the position; in a three dimensional space, an additional base station is required. If the distance can't be determined directly from a range finder, measurements based on time or time difference can be used. To calculate the distance out of time measurements, the velocity of the signal must be known Methods based on measurements of time are called Time of Arrival (TOA) methods. In the case of measurements of the time difference, they are called Time Difference of Arrival (DTOA) methods. Both methods need synchronized components (terminals and base stations) and even small synchronization discrepancies will result in positioning errors.

Angulation
The method of Angulation calculates the position of a terminal by using angles. The components which receive the signals and calculate the position must be able to define the angles of the incoming signal. In the example of a terminal-based system, two or more signals must be received by the terminal to calculate the intersection and hence the position of the terminal. Due to measuring errors, the calculated position is very likely an approximate area but a precise coordinate.

Pattern Matching
Pattern matching (or Fingerprinting) is carried out in two phases. The Offline phase offers the possibility to collect sensor data (e.g., RSSI values of WLAN access points) according to known positions. In the second phase, the Online Phase, real-time data is captured by mobile terminals, and the results are compared to the data sensed in the Offline Phase. The position stored by the best match is the current position of the terminal. Examples which use this technique are deterministic methods, like k-nearest-neighbor and probabilistic methods. For more detailed information consider [5].

Systems using multiple mediums
As mentioned in section 2, we refer methods as hybrid methods, when they combine techniques based on calculating the position on the signal delay or other physical signal attributes. Conversely, we refer methods as sensor fusion methods, when the actual information (e.g., light or acceleration) carried by the signal is used to calculate the position or movement patterns etc. With both hybrid and sensor fusion methods, new algorithms are no longer only concerned with how to calculate the result in the most efficient and accurate manner, but they must also be able to intelligently combine the different data.

Some approaches combine the values manually using an algorithm designed only for the purpose to calculate the best results, while others try to be more general and define a middleware that can deal with a lot of heterogeneous sensor information as opposed those used for just one purpose. In the following we will not distinguish between these approaches or look deeper into middleware research.

By using a lot of sensors, and their associated data, the need for efficient filters arises. We will not go deeper into the topic of filters, but would like to mention two promising filters: the Kalman filter and particle filter.

3 Metrics

Aside from the accuracy and precision level achieved, the costs of a system are an important factor, especially for economical purposes. Additionally, we consider privacy and possible context information as relevant factors about a system.

Accuracy and precision
Accuracy describes the degree of how close the measured value matches the actual true value. Precision or reproducibility on the other hand, is the degree to which repeated measurements under unchanged conditions show the same results [6].

Costs
The costs of an IT system can be categorized as initial costs and ongoing IT management costs. Initial costs consist, among others, of hardware costs, software license fees, software configuration and customization work, installation, and infrastructure cost such as network cabling or an electricity supply. Ongoing costs can include software support contracts-fees for license renewals and upgrades, hardware upgrades, communications capacity, maintenance and replacements. We will focus mainly on hardware costs, but want to point out that particularly important for positioning systems are also energy costs, since mobile devices don't have an endless energy capacity.

Privacy
When new approaches are found or new systems built, the focus lies mainly on positioning the target more accurately and more efficiently, and little attention is paid to the privacy of location data. As long as objects or assets are tracked, privacy may not be a real issue, but as soon as the positions are those of people, they become sensitive data. As mentioned before, only network assisted approaches or independent systems without external help of an underlying network structure are able to protect the privacy. As long as the terminal doesn't establish a connection to a network, but only scans passively the network for data, terminal based approaches protect the privacy. In other systems, the data becomes more sensitive, the more accurate and detailed the information about the position is.

Possible context information
Since we point out the connection between pure positioning systems and sensor fusion, we will try to point out, what additional information can be gained with sensor fusion.

4 Overview of Systems and Solutions

In this section, we will present current developments in indoor positioning. It is not possible to introduce every technique and approach in detail. The aim of this paper is to give an overview of trends in each technology. In section 4.1 the focus is on single medium technologies and comprises of GSM, UWB, RFID WLAN, BT, RFID and the 802.15.4 standard. In section 4.2, we present multiple mediums approaches.

4.1 Single Medium

GPS has become the standard for outdoor positioning, but due to poor reception in buildings, it is not as successful indoors. For this reason we will focus on other technologies that research is done in this field and refer to GPS in section 4.2 only in the context of multi mediums systems.

Global System for Mobile Communications (GSM)
GSM is a widely used standard for mobile telephony. The signal ranges can extend over 30 kilometers outdoors but are highly depending on the surrounding terrain. Out of the multitude of positioning methods possible [4], the most common method is cell ID positioning. It can be performed by either the terminals or the network and neither will require further modifications, which makes this method cost efficient. The terminal's position is estimated to be that of the base station to which it is currently connected; typically, that will be the closest one. The accuracy is related to the size of a cell, which can range anywhere from 100 m to 35 km. As a result, this positioning technique can only provide very rough estimates. Cell based positioning carried out by the terminal can be classified as network assisted positioning and is implemented for example in Google maps or skyhook applications. Because the provider always knows which cell the user is located within, the privacy of this approach is only maintained by the fact that positions are not very accurate. The authors in [7] address the problem of privacy in GSM networks.

Ultra Wide Band(UWB)
UWB is designed for low-power and high bandwidth wireless personal area networks. Furthermore, it operates in the range from 3.1 GHz up to 10.6 GHz, which limits interferences with its high channel capacity at short range. UWB allows very accurate positioning within the range of centimeters (15cm) and is feasible for both 2 dimensional and 3 dimensional indoor positioning. A commercial system available is Ubisense [8]. The advantage compared to other systems is that Ubisense calculates the position with two different methods (TDOA and AOA) which makes it very robust and allows high performance and high precision positioning.

In [9], a UWB positioning system within the EU funded "EMERGE" project is presented that uses Time of Arrival (ToA) and Direction of Arrival (DoA) measurements. In comparison to Ubisense, both approaches yield similar median accuracy values. However, the presented LOSSLES technique has a significantly lower variance of the position estimates compared to the Ubisense solution.

Wireless Local Area Network (WLAN)
The term WLAN is used for IEEE 802.11 standard [10], which operates in the 2.4 GHz band and offers up to 600 Mbps with 802.11n. The range is between 20 to 70 meters, depending on the antennas and the materials of walls. WLAN became a common network structure for both homes and offices, and therefore, systems using this underlying network structure can save on costs of purchase.

Ekahau [11] is a commercial system, which can operate over any brand or generation of Wi-Fi network and offers sub room-, room-, floor- and building-level accuracy. The system uses a probabilistic method to calculate positions based on RSSI values and can easily scale to support tens of thousands of tags on a single server. A basic approach for WLAN positioning is explained in [12]. Based on RSS values of commercial WLAN routers the position is calculated by the network. To improve positioning various parameters must be adjusted. Hence, the authors in [13] examine what sources of position errors exist and how they can be avoided or their effects be diminished. A WLAN positioning system is implemented and led to the result that adding more access points doesn't necessarily cause an enhancement of local positions, but global positions do see an improvement. Furthermore, a symmetric set up of access points is recommended in order to achieve high mean signal strength values everywhere. Different approaches have been explored to see how influence of interference can be reduced effectively. For example in [14], the authors try to find relationships between measured signal strength values and the actual spatial distance between access pints. In addition to physically changing the locations of access points or modifying the operating systems of access points, much research is done in attempts to enhance algorithms in ways to be able to handle and reduce problems, e.g., multipath propagation, better. Chan *et al.* try to reduce signal strength jitters by applying a discrete Fourier transformation and a Kalman filter at the expense of higher computational complexity [15]. An improvement to the classical deterministic method KNN is achieved in [16] by preselecting the neighbors via clusters called cluster filtered KNN (CFK). CFK first gets the K neighbors as same as KNN does, but instead of taking all the nearest K neighbors into account, CFK uses clustering technique (according to the physical location of each neighbor) to partition these neighbors into several disjoint clusters. Then, only one cluster is chosen as the delegate while the others are filtered out. Finally, the estimate is calculated based on the elements of the delegate. The results for different cluster and selection algorithms show that in average the CFK is better than KNN especially with great K.

Bluetooth (BT)
The Bluetooth specification is designed for shortrange and low power wireless communication in the 2.4 GHz ISM band. Nowadays, most mobile devices have Bluetooth technology integrated into them by default which makes it an ideal technology to base a positioning system on. Although, most typical wireless based positioning methods can in theory be implemented using Bluetooth, TOA and TDOA require clocks much more accurate then the specification requires and AOA require special antenna not associated with Bluetooth. A 3-D positioning

system using the extended Kalman filter on distances estimated by received signal strength and a simple propagation model is presented in [17], which achieves 3.76m of accuracy. Room level accuracy is obtained by [18] with the use of the inquiry response rate parameter of Bluetooth devices.

Radio Frequency Identification(RFID)
RFID systems exist in various types and can be categorized depending on the frequency or the type of the tags (active/passive) used. A comprehensive overview of RFID is provided in [19]. RFID systems were originally used for only identification purposes and consist of an RFID reader and RFID tags. To process information of RFID tags, a middleware is implemented. RFID is a popular technique in the research field of positioning because of the low-cost of production for the tags. Jensen *et al.* introduce a graph model that allows the combination of various positioning technologies by a single data management system [20]. To test the model, an RFID based positioning system is being evaluated. RFID readers are used to position the mobile device via proximity sensing. In order to detect a change in room, two readers are used per door allowing room level accuracy can be achieved. By using the cheapest RFID technology, RFID systems can still remain cheap even with a high amount of mobile devices. The main factor in cost is the RFID reader that must be installed in buildings independent of the number of mobile devices. Since this system is infrastructure based and offers room level accuracy, full privacy is not provided. In [21], the authors present an approach where three RFID readers in reach of the mobile device are used to calculate the position. The system was designed to reduce errors caused by multipath propagation in NLOS situations but only provided good results in LOS situations.

The approach in [22] introduces a similar approach to LANDMARK [23]. The readers are allowed to be moved around and used to calculate the position with the aid of landmarks. Landmarks are defined by RFID tags, and their positions are known. With these landmarks and two RFID readers, the system is capable of calculating the position of the mobile device based on the distance between the mobile device and the landmarks. The goal of inventing the system with landmarks was to reduce influences of multipath propagation. By applying a Kalman filter and using RFID maps, the result was enhanced even further. The system in [24] implements a terminal-assisted approach. RFID readers are located on the mobile device. The reader scans for nearby RFID tags, which reply with their position. In addition to the position the reader learns the signal strength (RSS). The coordinates and RSS values are forwarded to a calculation server, which provides the current position of the mobile device. Since a terminal assisted approach is used, the user can decide whether he allows positioning or not. If positioning is performed, the information isn't necessarily only available to the user.

Inertial Systems (IMU)
Inertial systems calculate positions via dead reckoning. An inertial unit can consist of one or more inertial sensors, like an accelerometer, a compass or a

gyroscope. Based on the initial position, the subsequent positions, the orientation and the velocity can be calculated without outside references. Inertial systems are installed in ships and airplanes, but also some commercial GPS based navigation systems in cars come with inertial units that allow these systems to guide cars when the GPS connection is interrupted, e.g., in tunnels. Positions are calculated by integrating twice over time. As in [25] the approach works well in cases when the object moves only in a two dimensional plane, without spinning around its own axis. If three dimensional movements are needed, an additional gyroscope is required to calculate the rotation around the axes of the object. However, the way positions are calculated runs the risk of becoming imprecise over time if sensors deliver noisy data. Therefore, indoor positioning methods of humans calculate positions based on detecting steps in accelerometer data. Changes in directions can be determined using a magnetometer. To calculate absolute positions out of the relative positions gained from inertial systems, external help is needed for the first initial position, e.g., via WLAN [26]. The costs of a positioning system vary depending on the sensors used. High precision sensors allow direct calculation of the position via integrating the raw data over time, whereas current smart phones provide accelerometer, compass and gyroscope in a low accurate segment, suitable for the step counting method. Since this approach is terminal based in the sense that it doesn't need any underlying network structure (besides the original first position) this approach provides full privacy. Accuracy as well as precision varies not only depending on the sensors used but also on the method and algorithm implemented. Additional context information like the type of movement or a confident assessment of if the person moves or stands can easily be obtained.

Approaches using other mediums

A lot of different approaches were developed using various techniques. For lack of space, we would like to mention a few, beginning with [27]. The authors used Camera and Barcodes to calculate the position.

The standard 802.15.4 is a well established protocol in sensor networks, which the authors of [28], [29] and [30] use to position mobile targets. An approach based on CDMA is presented in [31]. The system ComPass is presented in [32], which uses lowpower radio and VHF radio band and offers low power consumption and functionality with cell batteries.

4.2 Multiple Mediums

We will introduce a few interesting systems, which use multiple mediums to calculate positions.

WLAN + RFID

A positioning system that combines the technologies of WLAN and RFID is introduced in [33]. The capabilities of RFID are leveraged to improve performance of a WLAN fingerprinting based technique by reducing false positives. WLAN fingerprinting inherently produces false positives due to the fact that signal propagation is not statically defined in environments suffering from reflections. As a result, within a large area, multiple distant positions can have similar RSSI signatures. This technique splits the positioning area into smaller zones with the use of RFID technology. By first taking RFID reads, the technique determines which zone the unknown entity is in and therefore performs the WLAN fingerprinting on positions only within that zone. Hence, false positives associated with distant position not within that zone are avoided. The technique was founded to provided accuracy improve compared to traditional WLAN fingerprinting when tested in both indoor and outdoor environments and with varied project parameter.

IMU + UWB, Inertial sensors + RFID + cameras
Coralles *et al.* try to detect body movements of a person in the industrial field with inertial sensors [34]. The 18 sensor units were included into a suit, which is worn. The system was enhanced and corrected by the UWB system Ubisense. Although due to costs and impractical handling, this approach is not feasible for non-critical AAL scenarios. It might be interesting for applying suits to patients with certain diseases in hospitals or mental homes, where movement of limbs is important for recreation. The authors in [35] present a dead reckoning system that uses ultrasound positioning in a sensor fusion manner. When the dead reckoning based position strays too far from the ultrasound based position, the user's position is set to the ultrasound position and the dead reckoning system is reset. This is a terminal-based system as it doesn't communicate with the infrastructure and just listens to ultrasound beacons. In [36], a system combining inertial sensors (accelerometer, gyroscope, magnetometer and barometer), RFID and data from surveillance cameras is presented. Due to the fact, that with step detection algorithms a lot of imprecise parameters are taken into account (like step length, small errors in heading directions etc), a position correction to the real position over time is necessary. The authors show how trajectories from persons wearing the inertial units can be matched with trajectories from room surveillance cameras and map. Therefore, they are able to detect the correct person out of many passing by the camera. Additional active RFID tags were installed to reduce the drift of the inertial data. This approach doesn't protect the privacy since the approach has to share data between different systems to enhance services. The authors claim costs are not high since only existing infrastructure is used. Experimental tests will have to be performed to prove the theoretical achievements.

WLAN + Altimeter + Image
A combination of WLAN, altimeter, and images is presented in [37]. Since WLAN fingerprinting produces multiple positions with similar likelihoods, this technique attempts to filter out incorrect positions and find better likelihoods for the possible estimates. There are three steps that the techniques out. First a WLAN fingerprinting procedure is performed to determine a set of possible positions and their associated likelihoods. Next based on altimeter readings, positions from this set that are on the incorrect floor are eliminated. Finally, a scene analysis is performed to adjust the associated likelihoods of the positions. Two indoor tests were performed and showed that the addition of the altimeter

greatly improves results. However, the benefits of a scene analysis stage were inconclusive. This system is terminal-based since all measurements and calculations are performed by the user's device. Being WLAN based, this system has relatively low costs since WLAN infrastructure is already widely in use and altimeters are relatively cheap.

BT + compass module
In [38], the authors combine BT positioning with a compass module. The compass module, consisting of a compass and an accelerometer, calculates positions based on the step counting method. These positions and BT positions based on RSSI values are fused with a particle filter. Even when BT cannot provide current positions during paging, this system bridges this time with the compass module positions. In comparison to other BT only methods, e.g., KNN, the authors show that the errors are reduced from 7m in KNN to 3m in their approach. Nowadays smart phones already provide compasses, accelerometers and BT and additional BT tags are already available in buildings. This approach is terminal based, since the data is collected on the mobile device and processed there. However, it seems that the device establishes a connection to the BT tag, and therefore, the BT infrastructure has the possibility to learn position information.

Ultrasonic + Magnetic
A sensor fusion positioning system that combines a Cricket-based system with magnetic detection is presented in [39]. The wellknown Cricket system uses ultrasonic sensing between fixed location beacons and mobile listener devices to determine location. Although this traditional method provides quite accuracy positioning data, the accuracy decreases as more distance is placed between beacon and listener. As a result, the sensor fusion method uses ultrasonic detection as its primary method and relies on magnetic detection for location correction. The system uses magnetic reference markers that the mobile device can detect and better determine its location. Indoor tests showed an improvement to 3cm of error with the sensor fusion method compared to 5cm of error with the traditional Cricket system. Being a Cricket-based system, this method is terminal-based and protects the privacy of the user. However, the costs of implementing the system are high since a Cricket beaconing network must be installed in the building.

GPS + IMU, GPS + WLAN
As mentioned before, GPS is well established outdoors. However, since it delivers poor signals indoors, indoor systems combine GPS with other techniques, e.g., with inertial sensors in [40]. The same sensors are used in [41] to detect movement patterns of persons, such as if the person stands or sits. This information in combination with the last GPS coordinate is used to determine in which shop the user currently is based on an existing database of available shops. Additional information like opening hours of shops is used to exclude shops which are closed. Guillemette *et al.* combine GPS with WLAN (Ekahau) to achieve an indoor positioning system [42]. The system is applied to track security personal in order to

protect them. Additionally, the authors discuss the effects of observation system like theirs in reference to how people feel uncomfortable or liberticidal.

Camera + microphone
In Surround Sense [43], the authors introduce a system which uses WLAN, sound, accelerometer, color and light to create a fingerprint. Since sound can vary over time at a specific place, it wasn't used as a matching scheme but as filter. The accelerometer delivered the state (stationary or in motion) and also acted as a filter. The camera captured light and thematic color schemes in a room which represent one matching scheme. WLAN was used as a matching scheme if light/color was not available; otherwise, it acted as a filter. The authors use GSM positioning to have rough position (e.g., the position of a person is calculated around a big mall) and tried to enhance this position (in the means of gaining the information e.g., in which store the person exactly is). A detailed experiment was performed and the average accuracy of 87% (in comparison WLAN achieved 70%) was promising.

5 AAL Use Cases

In the introduction we picked out a few scenarios from three AAL fields. We will recall the scenarios and discuss briefly possible feasible techniques.

5.1 Ambient Assisted Living

We stated that it was desirable to detect dementia disease as soon as possible before accidents happen, like a forgotten cooking pot. And if the home has installed an object finder, which helps the person to find important and tagged items, like keys, a cell phone, a remote or a wallet, the first hint of an abnormality may be when the object finder is called more often. An object finder can be implemented with RFID. Important items are equipped with small passive RFID tags whereas the object finder is the RFID reader. In the case of small electronic items, e.g., cell phones or PDA's, WLAN based positioning by the underlying network structure is feasible as well.

Other scenarios depicted in the introduction needed quite exact positions of people in their homes, to enable these smart homes to react properly, whereas sometimes the information if a person leaves a marked off area is enough. In order to find the location of a person to e.g., monitor the behavior, a mobile device or a tag (RFID/BT/etc) must be carried continuously. Considering no one likes admitting they are becoming older, it is unlikely that people would be willing to carry around devices manufactured specifically to monitor the position or behavior of elderly people. However, some watches provide BT or WLAN techniques which would be a feasible possibility to achieve positioning without compromising the carrier. An alternative to positioning methods with a tag carried on one's body is an equipped apartment with sensors. Anonymous data via e.g., motion detectors which achieve room accuracy can suffice for the scenario, where the presence of a human being next to the stove is enough to understand the situation.

5.2 Activity Recognition

As defined before activities based on positions or position shifts can include information like walking, sitting, lying, falling, leaving a room, or no movement at all. We depicted the example of a person with Alzheimer disease. In early stages, people affected suffer from a reduction of flexibility and mobility. These symptoms can be detected by examining a change in movement pattern or by a general reduction in movement activity. Movement patterns are determined easily with inertial sensors. But as stated above, the person must carry the sensor unit. Modern smart phones provide low cost inertial sensors (e.g., accelerometer, gyroscope and a magnetometer) and can therefore provide this information as long as the phone is carried by the person. Usually after arriving at home, cell phones are put on a shelf and can't monitor the person anymore. Intelligent carpets (pressure mats) are a possible equipment for homes, which can measure even a slight changes of a person's gait. General activity must not only be discovered by position changes but can also be supported by sound (e.g., TV or radio) detected by the microphone of the cell phone or by aromas (e.g., cooking) detected by an upgraded or modified smoke detector.

5.3 LBS and Indoot Navigation

Location based services and indoor navigation are the main and original use cases of indoor positioning. A lot of different location based services exist and each of them needs different kinds of position information and a general recommendation cannot be offered. With indoor navigation it is similar, depending on the way people are navigated to a target, the needed accuracy of the current position varies. If premises want to offer a basic aid, e.g., in the form of 'After you entered the building the room x is in the left wing' a rough position via WLAN suffices to detect whether a person is completely wrong or in the correct wing of a building. If, like in our example a high precise navigation is desired, WLAN might not be enough and must be enriched with other data. Inertial sensors provide a good support as long as the distances and time frames don't become too big. UWB systems can provide high accuracy but are expensive, due to the fact the infrastructure must be installed in the building. UWB combined with a barometer is preferable for situations such as fall detection recognition. The accuracy of 15 centimeter and the supported information of a change in the altitude can provide good results.

6 Conclusion and Future Trends

This paper provided an overview of the current indoor positioning techniques and pointed out the variety of systems that combine multiple media or fuse data to optimize positions and position changes. We attempted to evaluate the research approaches according to metrics like accuracy, costs, privacy and when possible additional context information. According to the discussed techniques and the examples introduced in the beginning, we showed that in general techniques can't be clearly deemed the best for particular scenarios, but we did discover that several approaches have advantages and disadvantages against each other. The difficulties detected during the research of the current state-of-the-art were the different experimental setups and evaluations of each system. Direct comparison of different approaches is hard, due to the fact that test bed parameters vary from approach to approach. Additionally, information about costs for each system is mentioned rarely and must be estimated by the reader. Remarkable is the lack of information about the computational and energy costs, since often calculations are computed on small terminals which don't come with large energy capacities or processing power. Various approaches, using more than just one medium to position people, are released; most of them use a filter to fuse the data collected from different sources. Aside from finding best combinations of different mediums, it is interesting to find out which filter combinations work best for a certain set of mediums. More research how people react on continuous positioning would be interesting in order to find out which compromises people are willing to accept. On the other hand new approaches should be considered, which allow for the user to obtain the own current position without revealing it to others. Network assisted approaches don't exist in a large quantity. Research could find out, how to easily implement a network assisted approach, which allow users to gather their position and afterwards decide self determined who is allowed to learn this position.

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Chapter 6: Telemonitoring

Ambulatory Treatment and Telemonitoring of Patients with Parkinson's Disease

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Abstract. Body sensor networks (BSN) promise to enhance quality of life in common human habitats. The very next and natural step towards the improvement of the already valuable applications based on BSN is the incorporation of body actuator devices which adapt its actuation dynamically based on the information provided by the body sensors, thus forming Body Sensor and Actuator Networks (BS&AN). This paper shows how BS&AN can be exploited to create an innovative system to support the treatment of patients affected by Parkinson's Disease (PD). The combination of clinical and technological knowledge in BS&AN allows to significantly improve the quality of life of patients suffering from PD.

Keywords: Parkinson's disease, body sensor and actuator networks, intraoral device, *HELP* project, mobile health, mHealth.

1 Introduction

Parkinson's disease (PD) is a pathology that is thought to affect more than four million people worldwide. It is the fourth most frequent disease of the nervous system after epilepsy, brain vascular disease and Alzheimer's. The average age at diagnosis is currently 60 years. Given the rapidly aging population, PD is becoming a major public health issue in Europe [1]. Without treatment, PD progresses over 5–10 years to a rigid, akinetic state in which patients are incapable of caring for themselves. Death frequently results from complications of immobility including aspiration pneumonia or pulmonary embolism. The availability of effective pharmacological treatments has altered radically the prognosis of PD. In most cases, good functional mobility can be maintained for many years and life expectancy is increased substantially [2]. Primarily, therapies are aimed at minimizing symptoms and maximizing function and quality of life. However, intensive supportive care is needed, demanding the allocation of enormous resources besides the strictly medical ones. This makes necessary an alternative way to face PD not only in managing patients at an individual level, but also in optimizing cost effectiveness of health care plans. The *HELP* system ("Home-based Empowered Living for Parkinson's disease patients" [3]), which is currently under development, proposes solutions to improve quality of life of PD patients based on:

- A Body Sensor and Actuator Network (BS&AN) made up of portable or wearable devices to monitor health parameters (e.g., blood pressure) and body activity (e.g., to detect gait, absence of movement) as well as to release controlled quantities of drugs.
- A remote Point-of-Care (PoC) unit to supervise the patients under control of clinical specialists.
- A telecommunication and service infrastructure to analyze and transfer information from the user to an automated system (most of the time) or the PoC (for the regular follow-up and emergencies) and vice versa.

The design of such a complex system deals not only with technological aspects, but involves medical and social issues as well. The EU-funded *HELP* project aims at filling the gap between the different knowledge domains by using a multidisciplinary integrated approach derived from the collaboration of partners whose expertise stems from various fields. Therefore, hospitals and pharmaceutical technologists, telecom operators as well as technology and clinical research centres belong to the project consortium. The remainder of the paper is organized as follows: Section 2 provides more insights into the clinical aspects of PD. Section 3 describes the technical *HELP* infrastructure. Section 4 highlights the relevant aspects related to the BS&AN architecture adopted. Finally, Section 5 draws the conclusions.

2 Context

PD is a slowly progressive disorder of the central nervous system. Characteristic neuropathologic features of the disease are dopaminergic neuron degeneration in the substantia nigra and the presence of eosinophilic intracytoplasmic inclusions (lewy bodies) in the residual dopaminergic neurons [4].

PD originates from a deficiency in the release of dopamine owing to cell destruction in part of the brain stem. PD comprises as cardinal features bradykinesia (slow movement), muscular rigidity, resting tremor and postural instability. In the more advanced phase of the disease, patients experience freezing episodes in which they actually "freeze" and are not able to perform any physical activity during up to one hour. Apart from motor symptoms patients can experience non-motor features including depression, sleep disturbances, dizziness and problems with speech, swallowing and sexual functioning. PD greatly impairs the patient's quality of life increasing also caregiver distress.

The drugs usually administered to PD patients are globally divided into those delivered constantly at similar doses ("basal" treatment) and others given on demand to"rescue" patients from freezing episodes (i.e., sudden episodes of bradykinesia and rigidity).

Levodopa (L-DOPA) is the most effective pharmacologic agent for PD and remains the primary treatment for symptomatic patients. However, its long-term use is limited by motor complications and drug-induced dyskinesia. Dopamine agonists are an option for initial treatment and have been shown to delay the onset of motor complications. However, similar to L-DOPA, various adverse events (e.g., dizziness, hallucinations and dyskinesia) are also reported with the use of dopamine agonists [5,6]. The main goal in the treatment of PD is the maintenance of constant dopamine stimulation, thus avoiding off periods. By achieving this goal, people suffering from the disease will be able to live longer independently in their own homes. If less direct care is needed, caring relatives and informal carers will also experience an indirect increase of their quality of life since the need to dedicate effort and time to take care is lowered. Unfortunately, the majority of drugs for treating PD, particularly L-DOPA, provides pulse stimulation of dopamine release rather than continuous stimulation.

Maintaining a constant level of drug avoids the dose-dependent side effects and co-morbidity. In turn, this will improve the quality of life of patients. Additionally, fewer complications will reduce required hospitalizations, thus decreasing medical and assistive costs. Since less medication needs to be delivered compared to currently available systems, the treatment expenses for PD patients are also reduced. Furthermore, patients can be provided the tranquillity that their doctor is always aware of their disease situation by making patient's medical data online accessible to medical staff and by bringing patients and staff in contact by means of videoconferences. All this enables a high degree of life comfort for the patient.

3 The System Components

A broad representation of the *HELP* architecture is depicted in Fig. 1 which represents the connection between the patient and the PoC through a mobile access offering the capability to monitor and control the BS&AN. Moreover, videoconferencing capabilities are provided through a broadband access. Whereas the use of networking systems in health-related applications is not new [7,8], the solutions adopted by *HELP* are particularly innovative due to the devices involved in the BS&AN. The system integrates the following components:

– A remote PoC unit to supervise the patients. Such a system is able to manage the therapy, to control the strategy to tackle disease progression and to mitigate PD symptoms. The PoC also stores all the data regarding patient information and therapies.
– A BS&AN to control the actual drug infusion into the patient's body by gathering environment information, detecting movement requirements and controlling drug delivery devices. Components and functionality of the BS&AN will be detailed later in Sect. 4.
– A mobile gateway as management element of the BS&AN connected to a remote assistance system through the telecommunication network. Therapeutic relevant information, such as compliance with the therapy plan and

medication, can be collected, analyzed and transmitted via mobile gateway to the PoC unit. If necessary, the doctor can early intervene and adjust the therapeutic regimen.
– A broadband fixed and mobile telecommunication and service infrastructure.
– An H.264 multilanguage videoconferencing system based on broadband connection that eases the interaction between professionals in the PoC unit and patients at home.

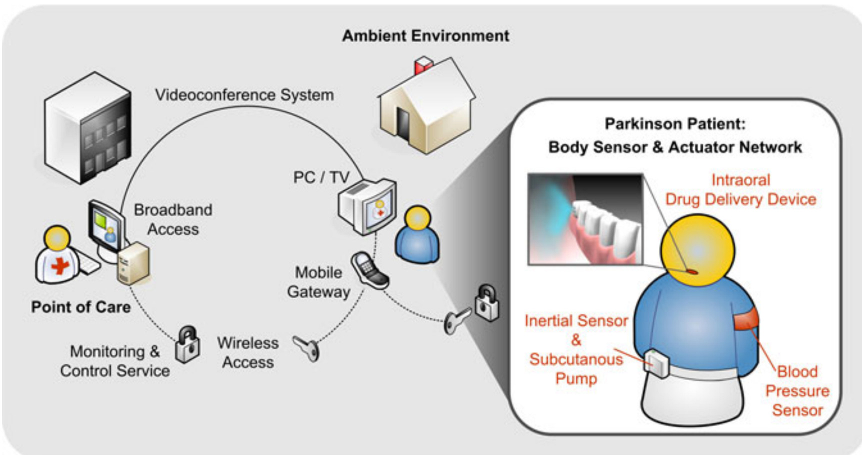

Fig. 1. Architecture of the *HELP* system.

The core of the system is represented by the BS&AN which guarantees the ubiquity of the proposed solution. In fact, the real advantage derives from having the constant medical control necessary for a PD patient without dramatically modifying his/her daily life. In the next section, the BS&AN will be analyzed in detail.

When dealing with technological setups that support clinical trials and involve patients, three important aspects must be taken into account: user acceptance, usability and accessibility. All of them have been specifically addressed when the *HELP* system architecture has been conceived. Acceptance is ensured as the delivery of medication is done automatically and in a transparent way to the user, either intraoral or subcutaneous. The drug delivery devices adopted are generally well accepted by patients [9,10]. Thus, usability by handicapped users (as are PD patients) is one of the strongest features of the project.

Gathering medical information of the patient doesn't require user intervention and is done continuously, either in an automatic way (e.g., by motion detection) or with simple patient intervention (e.g., using a domestic blood pressure meter which is widely used nowadays by aged citizens, most of them having a device at home or filling simple questionnaires). In both ways, sending and storing information as well as the communication among the different parts of the BS&AN is done by means of a mobile gateway, a well known consumer device with integrated wireless technology preventing any human intervention during operation.

A simple web-based system is used as a medical interface to access the medical data gathered from the patient including dose evolution charts, movement analysis, hypotension, videoconferencing and variations of the drug dosage patterns which is widely accepted in this professional sector [11]. At the patient's side, presenting drug dosage evolution as well as videoconferencing with the doctor is done at home by means of the most commonly used device in the domestic environment, i.e., the TV set. In outdoor situations, the mobile gateway can be used to access the same services using smart touchable phones. Such phones are the most simple, easy to use and adaptable devices which meet the needs of this population group.

Finally, automatic and transparent drug delivery as well as very high usability as described before makes our solution inherently accessible since the utilized interfaces are not dependent on the degree of disability of the person. Offering to the physician and social care professionals tools to interact with the patient and to handle their medical and social situation online as well as remotely makes the *HELP* system especially accessible for patients with cognitive impairment.

4 BS&AN Structure

The Body Sensor & Actuator Network is composed of:

- A control system
- A non-invasive intraoral drug delivery device[1] [12]
- A portable subcutaneous pump dynamically delivering medication to the patient
- An inertial sensor located on the belt of the patient extracting information about the patient's physical activity (movement) in order to infer drug needs
- A commerically available blood pressure monitor to supervise the patient's overall health condition
- A mobile gateway in charge of two fundamental tasks: (i) management of the BS&AN network (including its connection with the PoC) through wireless access, (ii) hosting of the control algorithm that computes the control actions.

4.1 Control System

The control system decides the amount of drug to be delivered to the patient by two different types of input signals. This includes information provided by the sensors (i.e., motion analysis, blood pressure, emergency buttons) and the assignments provided by the physicians via PoC. Combining these data, the algorithms compute the orders to be sent to the infusion pump and the intraoral device which act both as actuators of the BS&AN.

[1] As continuation of the successful FP6 funded project IntelliDrug.

4.2 Intraoral Drug Delivery Device

The intraoral system adopted in *HELP* represents a revolutionary method for delivering drugs according to the patient needs in periods lasting days, weeks or months in long-lasting therapy of PD. This controlled drug-delivery device is implanted or inserted onto a prosthetic tooth crown, a denture plate or a dental implant and refilled or replaced as needed. The drug delivery may be passive or iontophoretically controlled. The delivery is typically done in accordance to a pre-programmed regimen and at a controlled rate.

The intraoral device envisages variation of the patient's medication within boundaries specified by the medical supervision. Therefore, the patient can replace a drug delivery cartridge that is docked on a partial removable prothesis (Fig. 2). The fill level of the cartridge is identified with a separate base station before and after usage. Patient relevant data (compliance, medication, etc.) are collected analyzed and can be transmitted via gateway to the PoC unit. If necessary, the doctor can intervene and advise the patient to adjust the medication by replacing the drug load of the cartridge.

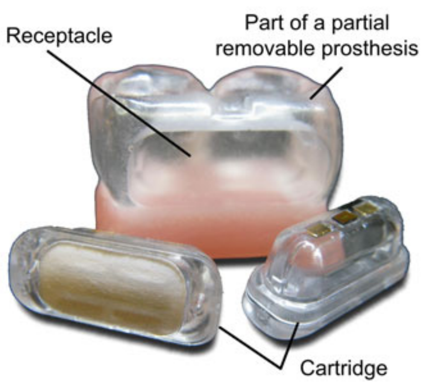

Fig. 2. Intraoral drug delivery cartridge which can be attached to a part of a partial removable prosthesis.

Docking and undocking of the cartridge to the partial removable prothesis and the base station, respectively, has to be easy. Therefore, usability criteria are followed by designing an attachment system that can be handled by PD patients affected by motility disorder.

The osmotically-powered intraoral device targets a continuous and highly precise medication with anti-Parkinson drugs. The osmotic power of saliva and salt is used to release the separately stored drug from the device. Thereby, the osmotic pumping principle has to encounter changing ambient conditions such as varying temperature, pH-value and saliva secretion.

4.3 Subcutaneous Pump

Small size (portable) subcutaneous pumps for the ambulatory infusion of apomorphine for PD treatment are already commercially available [13]. The challenge for the inclusion of these devices in the *HELP* project is its adaptation to the BS&AN.

A wireless communication module is required to connect the device with the gateway, allowing information exchange with the control system. Fig. 3 shows a commercially available subcutaneous pump adapted with the wireless module.

As asked by the physicians, two types of operational modes for the apomorphine infusion are addressed: flow rate and bolus dose. The desired values during both operational modes are determined by the algorithms at the PoC and validated by and transmitted from the gateway device. The pump has an internal control system that ensures the infusion of the requested doses.

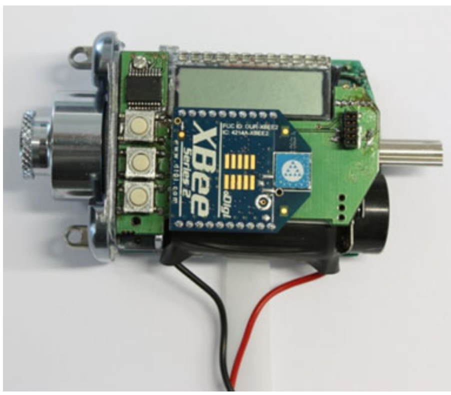

Fig. 3. Subcutaneous pump with wireless communication module.

4.4 Inertial Sensor

Accelerometers, gyroscopes and magnetometers capture physical signals produced by body motions. The sensor nodes process these signals in order to extract the spatiotemporal properties of the patient's motions, i.e., patient's postures, energy expenditure and daily living activities. These variables are permanently sent to the gateway as the controller input to ensure a treatment adapted to the motor needs of the patient. An internal communication module is further required to establish constant information exchange with the gateway/controller. Figure 4 shows the sensor internal components. The sensor is already able to detect when the patient is walking. It also counts the patient's steps and his/her energy expenditure during daily life.

Fig. 4. Inertial sensor with wireless communictaion module.

4.5 Mobile Gateway

The mobile gateway is an embedded system with higher processing and memory capabilities with respect to sensor nodes and can be used to (i) configure, monitor and control the sensor network, (ii) collect and send data to a remote service center, and (iii) locally process data, for example to manage alarms to be sent to the service centre or specific users.

For this reason, the gateway is directly connected to all other devices and can be logically considered as the sink of a classical star topology network. As different medical devices might support different radio interfaces, the gateway can manage two different sub-networks: a ZigBee network and a Bluetooth network. The use of different wireless protocols is beneficial for fulfilling the requirements of the project. The aim to use as many commercially available products (like the blood pressure monitors) leads finally to the Bluetooth standard which is more established in medical environments. On the other hand, ZigBee implementation provides an easier integration inside newly developed devices (like for example the base unit that allows the communication between the gateway and the intraoral device or the subcutaneous pump) and longer battery life of the sensor since the system must be able to run at least 8 hours without interruption. Concerning the implementation of the wireless interfaces on the gateway, it must be also noted that there is still no support for the ZigBee standard while the support of Bluetooth is a common feature for nearly all mobile terminals. To solve this problem, a special MicroSD card with an embedded ZigBee node is used.

The setup of the network must also ensure security features. Therefore, the communication between medical devices and mobile gateway is protected by means of the secured mode [14] that the ZigBee standard offers in order to protect the communication directly at network layer. Thanks to ZigBee security tools data transmission is encrypted by 128-bit AES and access control is performed: The mobile gateway is instructed to establish a communication only with its own system devices. Similarly, the devices are instructed to communicate only with the gateway. Moreover, each transmission includes the patient ID, the device ID and the time and date of transmission.

The BS&AN communication process is managed by the application running on the mobile terminal (Fig. 3). The medical devices are in sleep mode unless they need to transmit data to the gateway or send an alert message. This approach ensures efficient use of computational power minimizing battery consumption of the sensors. The mobile terminal will be also localized by GPS or by the GSM network in order to have more data available for the prediction algorithms and for providing the position of the patient to the PoC in case of alarms.

Fig. 5. *HELP* Widget on the mobile terminal.

Besides these aspects, the *HELP* project attempts to implement innovative solutions for the BS&AN. One of these goals is to be compatible with the most popular international standards for wireless medical devices. From this point of view, Bluetooth Health Device Profile [15] and the ZigBee Healthcare Profile [16] are both adopted by the Continua Health Alliance [17,18] as PAN and LAN reference technology, respectively. Unfortunately those profiles do not allow the use of new types of devices besides those standardized so far. In order to include the intraoral device base unit, it has become necessary to create a different private communication profile that could be published in the future as an extension of the Telecom Services Profile [19].

5 Conclusion

This paper has provided insights on the *HELP* system conceived for PD patients by detailing the system architecture and the BS&AN created around a mobile gateway and medical devices.

HELP is able to fulfil the yet unmet needs derived from the drawbacks of traditional PD treatments. Thus, it would improve the quality of life of aged people suffering from PD and reduce co-morbidity. By doing so, the users are enabled to conduct an independent life in their own homes.

The last phase of the project will include trials with PD patients. This will provide the necessary feedback to thoroughly and fully assess the consistency of the *HELP* solution and its compliance with the challenging objectives. The development of such a complex high-tech equipment as the intraoral device implies the confluence of very different competences and may give the desired precise control offering the most therapeutic outcome. This kind of innovative high-tech product could supply new commercial challenges for the Pharmaceutical Companies.

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Prototype Implementation of Standard-Based Interoperability Guidelines: Experiences and Results Regarding Telemonitoring Applications

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Abstract. The guidelines of the Continua Health Alliance (CHA) aim at establishing interoperability based on existing standards and inoperability profiles in order to guarantee plug & play for AAL and Telemonitoring systems. This paper presents the recommendations and the experiences resulting from a prototype implementation, covering the full path from a sensor system to an electronic health record. Since a guideline for the WAN-Interface is not yet available, an appropriate IHE profile has been used. Overall the interoperability could be demonstrated, even though for the practical usage some questions regarding the sensor-patient assignment and the manager application function remain unanswered.

Keywords: Interoperability, standards, Telemonitoring, Personal Health, Health Care Record, eHealth, AAL.

1 Introduction

The objective of the Continua Health Alliance (CHA) [1], an organisation representing more than 200 companies worldwide is to establish interoperability for telemonitoring (TM) products. Most of the TM products available today are proprietary and lead to a reduced flexibility for the different user groups (patients, medical doctors, TM service providers, hospitals…). Plug & play is rarely possible, neither for the integration of already available systems for vital sign monitoring, nor for storing the documentation by the TM service provider in the electronic health record. This judgement stays, even with the patient's consent. For solving this interoperability issue the CHA has developed extensive guidelines based on the existing standards. They serve for TM of vital signs and support the Ambient Assisted Living (AAL) arena, e.g., fall and movement sensors.

TM is characterized by multiple benefits: (i) personal safety and self determination for the patient, (ii) high-quality and immediate health care, (iii) reduction of in-patient

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stays and thereby costs and (iv) new ways of nursing and medical care schemas [2-5]. The limited use of TM in routine health care provision can be referred to the missing reimbursement schemes and to the technical and organisational complexity of a particular implementation.

The objective of this paper is to assess the level of interoperability achieved by a prototype implementation for TM according to the CHA guidelines and associated standards for personal health monitoring. In addition, open issues for a day-to-day usage are discussed.

2 Material and Methods

2.1 System Architecture and Responsibility

Fig. 1 shows the typical setup of a TM approach being compatible to the CHA guidelines. In addition, Fig. 1 identifies the responsibilities for the TM caring and coaching services and the operation of the TM infrastructure. For most of the offered services, the infrastructure represents a closed system with proprietary interfaces. As such, the benefit for the service providers is two-fold: (i) offering the TM components to the customers as a single-source vendor and (ii) continuously acting as a provider of TM services.

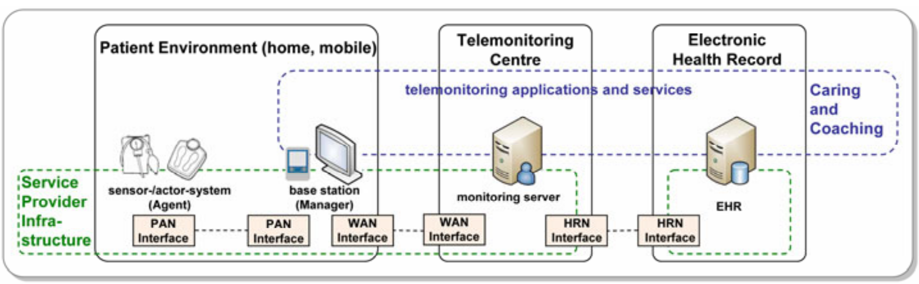

Fig. 1. Typical telemonitoring system architecture with responsibilities

2.2 PAN-Interface

At the patient's home sensor-/actor-systems communicate with a base-station using the so-called PAN (Personal Area Network). For maximum flexibility the PAN should use wireless transmission to allow for mobile communication both at home and outside. Permanent or on demand wire-based communication restricts the PAN access to the home situation.

Table 1 lists protocols available for the PAN. The CHA has selected the Bluetooth Health Device Profile (HDP) and the USB Personal Health Device Class (PHDC) profile. Zigbee has been chosen as a future candidate. Each of the protocols specifically supports health device communication by guaranteeing e.g., bandwidth through quality of service (QoS), mutual authentication and use of ciphering for data protection.

Table 1. PAN-Interface protocol candidates

protocol candidates	transport OSI 1-4	application OSI 5-7	Data protection	format/ protocol	CHA
proprietary	?	?	?	f/p	-
IrDA	x			p	-
USB	x			p	-
RFID, NFC	x			p	-
Bluetooth, Zigbee	x		opt.	p	-
WLAN, Wi-FI	x		opt.	p	-
ANT, ANT+	x			p	-
USB PHDC	x			p	x
Bluetooth HDP	x		x	p	x
ISO/IEEE 11073-20601	-	x	-	f, p	x

The standard ISO/IEEE 11073-20601 Personal Health Devices (named x73 PHD in the remainder of this paper) exclusively addresses the application domain. Its architecture guarantees structural, syntactic and semantic interoperability in combination with the device profiles of the ISO/IEEE 11073-1104xx which represent devices covering the range from vital signs to fitness and activity monitoring.

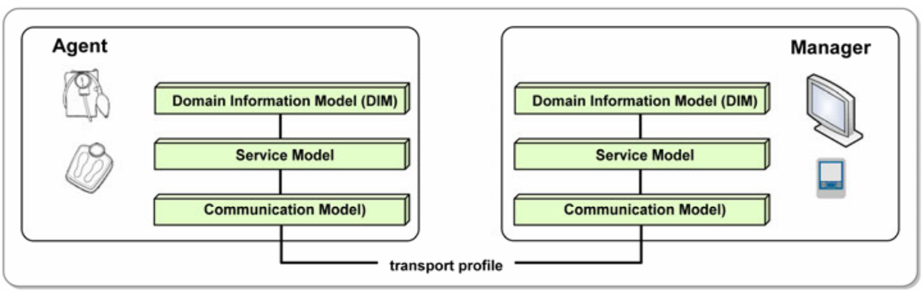

Fig. 2. Architecture of the ISO/IEEE x73-PHD

Interoperability is achieved by (i) a Domain Information Model (DIM) for each measurement type (e.g., blood pressure) which includes the context (e.g., measurement method, position like lying or sitting), (ii) a Service Model with standardized interaction methods between the so-called Agent (representing the sensor-/actor device) and the Manager (the base station), and (iii) a Communication Model with a transaction based protocol to transfer serialized objects in a point-to-point communication (Fig. 2). In addition, the Service Model fulfils the plug & play requirement for devices. Every Agent (sensor-/actor-system) is able to register itself with a Manager using its System-ID and Config-ID (Fig. 3). If the Agent is unknown to the Manager, it has to provide its configuration for storage at the Manager. This is needed, in order to establish the transaction-oriented association. If the Agent is already known to the Manager both can directly set up the association. The communication is bi-directional: EventReport() sends messages from the Agent (e.g., measurement data) and Action() allows the Manager to transmit commands to the Agent. As a result, the Manager can handle multiple Agents which make themselves known by the plug & play approach described above.

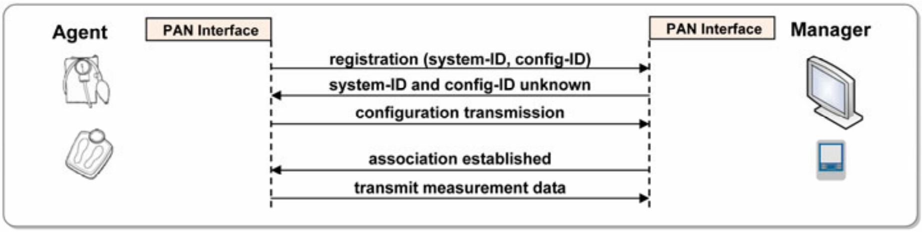

Fig. 3. Plug & play between the Agent and the Manager

2.3 WAN-Interface

The WAN-Interface is located between the Manager and the TM-Centre. The currently available version of CHA Guidelines does not include specifications for this interface. However, data transport does not pose a problem. A variety of communication protocols (e.g., POTS, ISDN, GSM, UMTS, EDGE, DSL) together with appropriate data security measures (e.g., SSL/TLS, VPN) can guarantee an efficient and data protection compliant transmission. On application level the usage of the IHE Profile PCD-01 (Patient Care Device – Communication of PCD Data) is likely [6] providing the following functions:

(i) unidirectional from the Manager to the TM-Centre
(ii) periodic or event driven transmission
(iii) usage of the HL7 unsolicited message ORU^R01 which as such in compliant to (ii)

Table 2. ORU^R01 message structure

segment	content	cardinalities
MSH	Message Header	mandatory
PID	Patient Identification	mandatory
PV1	Patient Visit	optional
OBR	Observation Request	mandatory
NTE	Notes and Comments	optional
TQ1	Timing / Quantity	optional
OBX	Observation Result	mandatory

The message ORU^R01 (Table 2) holds patient identifying data in the PID segment and uses the OBX segment for the personal health data. The specification of

PCD-01 requires the transfer of measurement data together with a representation of the DIM in order to convey device and context information. The mapping of the DIM to the fields of the OBX Segment takes place at run-time since the DIM gets only available after the transfer of the configuration from the sensor-/actor-system to the Manager during the initial plug & play procedure.

2.4 HRN-Interface

The Health Record Network (HRN) Interface connects the TM-centre with the patient's health record, thereby facilitating the connection to the carers and medical doctors (assuming the patient has granted appropriate access rights). In addition to the measurement data and its context the HRN interface transports caring and coaching information from the TM-centre to the health record as shown in Fig. 4.

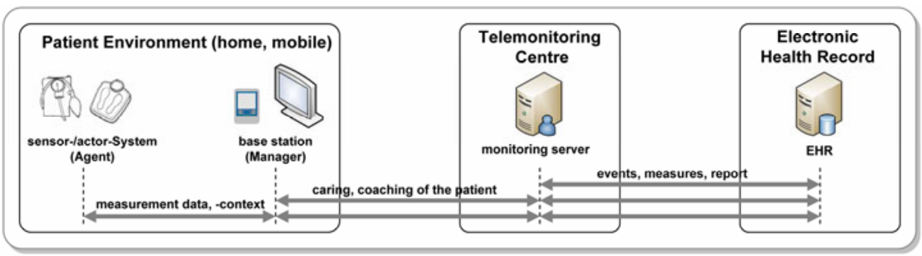

Fig. 4. Dataflow analysis of the full path between the sensor-system and the electronic record

The CHA has decided on two properties:

(i) Data representation has to be according the implementation guide for the Personal Health Monitoring Report (PHMR) [7] developed jointly by HL7 and CHA and based on the Clinical Document Architecture (CDA version 2) [8] of HL7. The PHMR allows for storing the measurement data as 'observations', additional information or diagrams as 'attachments' and textual information as 'narrative text'. As such, it conforms to the data flows depicted in Fig. 4.

(ii) By selecting on the Cross-Enterprise Document Reliable Interchange Profile (XDR) [9] from the family of IHE XDS profiles [10] the CHA decided on a container-based approach for documentation in the electronic health record which uses predefined meta-data as an overall description of the document. XDR implements a direct point-to-point communication with either HTTP for online or SMTP for offline transfer. The XDR message consists of a SOAP Envelope with a MIME attachment holding the PHMR (Fig 5). Information provided in the SOAP Body allows the assignment to a specific patient. The storage function of the XDR compliant record system is called via a web service whose calling parameters are provided by the SOAP header.

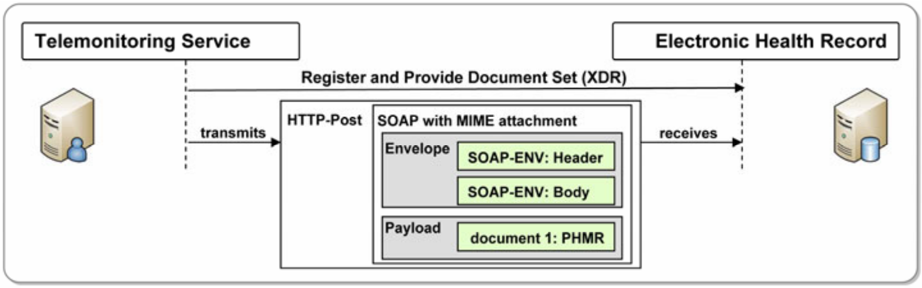

Fig. 5. Point-to-point communication using IHE XDR

2.5 Prototype Implementation

The application profile thermometer (11073-10408) has been selected for a prototype implementation. This scenario is comparable to typical AAL measurements of the Activity Living Hub (11073-10472), even though they are more targeted to record events. The scenario is shown in Fig. 6. The Agent has been implemented in C/C++ using a microcontroller (Atmel) and maps the objects of the DIM to appropriate data structures and types. For the protocol stack the two-level approach developed discriminates between static and dynamic contents. Since static contents has to be generated only once at start-up or reconfiguration time the effort at the sensor system site is minimized and mimics resource efficiency. Transport via the PAN interface has been established via Bluetooth.

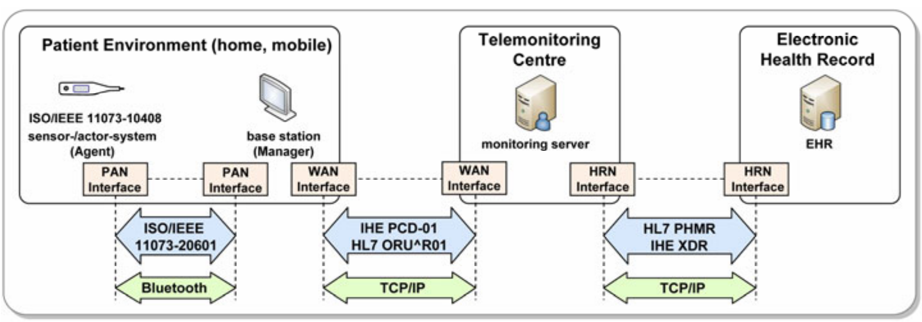

Fig. 6. Architecture of the prototype implementation

The Manager has been realized in an object-oriented development environment (C#, .NET) using a Windows platform. According to Fig. 2 the Manager has to dynamically implement the DIM. For facilitating the mapping from the serialized DIM contents as received via the PAN interface to an instance of the DIM using classes a generic parser had to be developed. The WAN interface of the Manager relies on a standard TCP/IP connection. A HL7 message ORU^R01 has been used for the measurement data and the context, however with some hard-coded segments, e.g., for the patient identifying information.

At the TM centre, the mapping of the HL7 message to the PHMR is the prerequisite for the representation in the HRN interface or as document for the electronic record. For the electronic record the Open-Source-Project ihe.codeplex.com [11] was used to implement IHE XDR as subset of XDS.b.

3 Results

The plug & play interoperability between an Agent and a Manager has been proven by the prototype implementation of the PAN interface. Automated registration of an Agent with the Manager forms the basis for plug & play. In addition, the measurement data and their context can be provided for the electronic health record. As expected, the overhead increases with each step of the process, starting from about 60 bytes per data item in the PAN interface. Taking continuously recorded data into account, the ratio will be improved.

The effort for implementation of the Agent was low due to limited requirements imposed by the DIM and by establishing the communication protocols.On the other hand, the effort for the Manager was high, since it had to comply with the requirements of the x73-PHD. In particular, for the implementation of the hardware oriented Service Model in an object-oriented environment (.NET) UML was used to represent the ASN.1 protocol definitions prior to implementation. The mapping to the HL7 ORU^R01 message was achieved without problems based on the required serialisation.

The static approach used for translating between the ORU^R01 to the PHMR simplified implementation at the site of the TM-centre.

Despite the fact, that some standards and profiles are still under development (ISO/IEEE 11073-20601 and HL7 PHMR) and that the CHA guidelines do not yet cover the full path from the sensor-/actor-system to the electronic health record, the prototype implementation demonstrated that a standard compliant and interoperable TM infrastructure can be established. First steps in that direction can be observed in the market of TM products. However, these are mainly related to x73-PHD compliant products which in some instances have achieved certification by the CHA [12].

In addition, the electronic health record HealthVault provided by Microsoft allows for storing data from x73-PHD products. However, due to the usage of specific converters for the proprietary data model of HealthVault, the intended plug & play is not sufficiently adhered to.

4 Discussion

The guidelines of the CHA lead to a standard compliant implementation of the full path between a sensor-/actor-system and an electronic health record. Looking at the practical usage and the selection of standards and interoperability profiles some open issues remain unsolved.

4.1 Practical Usage

The communication features a mainly unidirectional behaviour. Despite the fact that the Manager has methods for controlling the timing of measurements (Set-Service for

Scanner classes) or to initiate a data transfer (Action Service), it is not clear how these settings are to be made available to the Manager via the WAN interface from the TM-centre. The roadmap in the IHE whitepaper Medical Equipment Management [14] plans a configuration and software-patch management. As such, this implementation could result in some feedback for the x73-PHD. It might as well facilitate the interconnection of actor-system needed in an AAL context, which currently lacks support both in an “open loop” (non time critical) and a “closed loop” (time critical).

It is a positive feature of the x73-PHD that includes the usage of a sensor system (e.g., a body weight scale) by more than one person with a person-ID in the measurement data. However, the procedure on how to establish the assignment person to person-ID has not been described yet.

In the same context, the assignment of measurement data of a sensor-/actor-system to a customer of the TM-centre has to be assessed. Primarily, each measurement data is uniquely identified by a set consisting of sensor-ID, config-ID and person-ID. The procedure for assignment described by IHE in the document Patient Identity Binding Option for Device Enterprise Communication (DEC-PIB) [15] foresees the use of technical means (e.g., RFID or barcode) and/or a manual assignment by the carer or medical doctor based on a selection list. This list should be provided to the Manager by the TM-centre using Patient Demographics Query (IHE ITI-21). As a result, the Manager has to handle patient identifying information, which as well is required for the PID field in the PCD-01 message.

Taking a data protection viewpoint, the assignment of measurement data to a specific patient could be moved to the TM-centre because the set of sensor-ID, config-ID and person-ID is uniquely identifying.

Since this set is free of person identifying data communication the PAN interface requires ciphering only as it is accomplished by the profiles USB-PHDC and BT-HDP.

4.2 Selection of Standards and Profiles

The guidelines of the CHA primarily rely on model-based standards (x73 DIM, HL7 PHMR). However, the ORU^R01 message for the Agent to Manager communication is a HL7 V2.6 message and disregards a domain related and model-driven HL7 V3 development. A justification may be derived from the onset, using the DIM of the x73-PHD for the Agent and its mapping, including measurement data and context information to the OBX-segment of the ORU^R01.

The communication between the TM-centre and the Agent using the PCD-01 profile guarantees basic functionality. However, the profile PCD-02 ‘Subscribe to PCD Data’ would support an extended functionality based on a so-called filter which would support a selection of measurement items and the measurement frequency.

Specifying the PHMR and CDA respectively results in a completely structured and persistent document. Such a document can be stored as well in the electronic patient record of an institution as in the personal health record of patient. If the record system offers an IHE XDR compliant interface, a complete compatibility with the CHA guidelines is achieved. Otherwise, these self standing and semantically enriched documents are well suited for being stored in commercial electronic record systems, most of which provide a container based approach for documents.

The CHA did not decide on the alternative approach using the EN 13606 [16] even though it has the capability to fulfil the requirements. On the one hand, the EN 13606 features a model-driven approach and supports a fine granular representation of measurement data with context information using archetypes, on the other hand is allows for the structuring of a health record and a secured communication of so-called health record extracts. A potential reason to disregard the EN 13606 may have been the availability of the x73 DIM for various vital signs and the late availability of the EN 13606 from year 2008 onwards.

5 Summary

Telemonitoring (TM) serves for a providing care and coaching services to customers and patients. Currently, the establishment and operation of a TM-centre faces a variety of proprietary and heterogeneous products, which do not sufficiently support plug & play. In addition, a major effort is needed for integration of these products, however without guaranteeing syntactic, structural and semantic interoperability.

The prototype implementation along the guidelines of the Continua Health Alliance (CHA) demonstrated that the full path from sensor-/actor-system to the health record can be achieved purely based on standards and associated profile. The PAN and HRN interface have been defined by the CHA, the WAN interface required to assume, that IHE PCD-01 profile will be selected by CHA.

The prototype implementation results in the required interoperability at all levels. It is to be expected, that vendors will offer CHA compliant and certified products not only for the PAN interface but also for the WAN and HRN interface. As a result, this would foster openness of the market and extend application domains in order to facilitate the routine usage of TM and AAL approaches.

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Author Index