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Kecheng Liu
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(Eds.)

# Information and Knowledge Management in Complex Systems

16th IFIP WG 8.1 International Conference
on Informatics and Semiotics in Organisations, ICISO 2015
Toulouse, France, March 19–20, 2015
Proceedings

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# IFIP Advances in Information and Communication Technology 449

## IFIP – The International Federation for Information Processing

IFIP was founded in 1960 under the auspices of UNESCO, following the First World Computer Congress held in Paris the previous year. An umbrella organization for societies working in information processing, IFIP's aim is two-fold: to support information processing within its member countries and to encourage technology transfer to developing nations. As its mission statement clearly states,

> *IFIP's mission is to be the leading, truly international, apolitical organization which encourages and assists in the development, exploitation and application of information technology for the benefit of all people.*

IFIP is a non-profitmaking organization, run almost solely by 2500 volunteers. It operates through a number of technical committees, which organize events and publications. IFIP's events range from an international congress to local seminars, but the most important are:

- The IFIP World Computer Congress, held every second year;
- Open conferences;
- Working conferences.

The flagship event is the IFIP World Computer Congress, at which both invited and contributed papers are presented. Contributed papers are rigorously refereed and the rejection rate is high.

As with the Congress, participation in the open conferences is open to all and papers may be invited or submitted. Again, submitted papers are stringently refereed.

The working conferences are structured differently. They are usually run by a working group and attendance is small and by invitation only. Their purpose is to create an atmosphere conducive to innovation and development. Refereeing is also rigorous and papers are subjected to extensive group discussion.

Publications arising from IFIP events vary. The papers presented at the IFIP World Computer Congress and at open conferences are published as conference proceedings, while the results of the working conferences are often published as collections of selected and edited papers.

Any national society whose primary activity is about information processing may apply to become a full member of IFIP, although full membership is restricted to one society per country. Full members are entitled to vote at the annual General Assembly, National societies preferring a less committed involvement may apply for associate or corresponding membership. Associate members enjoy the same benefits as full members, but without voting rights. Corresponding members are not represented in IFIP bodies. Affiliated membership is open to non-national societies, and individual and honorary membership schemes are also offered.

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# Preface

The 16th International Conference on Informatics and Semiotics in Organisations (ICISO 2015), following the footsteps of earlier events in the conference series, was devoted to the latest research in informatics and organizational semiotics. The aim of this conference is to provide a focal forum for participants from various domains of information management and information systems, computational science, semiotics, finance and accounting, business and enterprise, service science, and business and engineering. One of the important emphases of this 16th conference was information and knowledge management of complex systems, such as large-scale projects, network of networks, and dynamic and evolving enterprises (see www.orgsem.org for earlier conferences since 1995).

Effective information and knowledge management through the entire lifetime of a complex system such as a space project or a network of networks is critical. Some systems such as space projects are transient and dynamic, with clearly defined stages and involving different players at these stages. Consistency, coherence, and continuity in information and knowledge management are the key to success. However, an adoption of information and knowledge management is often hindered right from the beginning by the challenges and sometimes resultant deficiencies in understanding the complex system itself, and by the related requirements for information and knowledge management.

Between stating the broad objectives and defining precisely the means of satisfying them with a clear plan of action, the project requires the contribution of a growing and changing community of players that must also develop trusting relationships and be able to share information and knowledge, even while working on designs and plans that often introduce creative but possibly conflicting ideas. Such a situation is not the prerogative of space projects; other projects and dynamic systems such as nuclear engineering and product innovation, for instance, also share these characteristics.

Information is an important resource for any organization, whether it is large or small, or in the service or production sector. To understand the nature of information and how it can be effectively managed and used in organizations is highly relevant. Following earlier events in the series, the key theme of this conference was on information, and management in complex organizations such as space industries and research institutions. Particular interest was placed in exploring and understanding from both theoretical and empirical perspectives how information enables an organization to sustain and, furthermore, to leverage innovation and competitiveness. In both cases, the organizations will rely heavily on effective management and use of information.

Informatics is the study of information as a resource, which helps a business organization, often through knowledge management, innovation, and service design, engineering, and management. Organizational semiotics, as a discipline of

study of sign, information, and human communication in organized contexts, will provide a holistic and comprehensive approach with which to examine the issues of information management and utilization from a scholarly and practical perspective.

The conference received 46 paper submissions from 17 countries, which demonstrates the success and global dimension of this conference. From these, 21 (45%) were accepted for presentation. These numbers show the intention of preserving a high level of quality for future editions of this conference. The papers are organized into five topics: organizational semiotics theory and concepts, organizational semiotics application, information systems and services, complex system modelling and simulation, innovation and organizational learning.

The high quality of the papers received imposed difficult choices in the review process. To evaluate each submission, two rounds of paper review were performed by the Program Committee and reviewing panels, whose members are highly qualified researchers in the conference topic areas. Moreover, ICISO also featured a number of keynote lectures delivered by internationally recognized experts, namely, Mr. Ruediger Suess and Mr. Uwe Knodt from DLR German Aerospace Centre, Cologne, Germany, and Dr. Vincent Minier and Dr. Vincent Bontems from CEA French Alternative Energies and Atomic Energy Commission, Saclay, France. Although not included in this volume, we also had great pleasure in having a special contribution from, Prof. Ronald Stamper. These special contributions were significant highlights and brought great added value to the conference.

Building an interesting and successful program for the conference required the dedicated effort of many people. We would like to express our thanks to all authors including those whose papers were not included in the program. We would also like to express our gratitude to all members of the Program Committee and auxiliary reviewers, who helped us with their expertise and valuable time. Furthermore, we thank the invited speakers for their invaluable contribution and for taking the time to prepare their talks.

Moreover, we thank the session chairs, whose contribution to the diversity of the programme was essential. Finally, we gratefully acknowledge the professional and organizational support from Centre National d'Etudes Spatiale (CNES), France, and Henley Business School, University of Reading, UK.

January 2015

Kecheng Liu
Keiichi Nakata
Weizi Li
Daniel Galarreta

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# Abstracts of Invited Talks

# Bottom-Up! - Social Knowledge Sharing in DLR

Ruediger Suess and Uwe Knodt

DLR German Aerospace Centre, Cologne, Germany

As a research organisation, the German Aerospace Centre (DLR) relies on creative and disruptive ideas to create new knowledge efficiently. But how can those new ideas be raised when you see that there is a lot of inefficiency in the knowledge flow? Three years ago Mr. Uwe Knodt started to investigate the knowledge management processes of DLR. For this purpose a new internal project "Establishing an integrated knowledge management system (EIWis)" was launched. By conducting surveys on employees' needs concerning knowledge, he found out that the knowledge processes were not primarily driven by technology but especially by the way people react and interchange information with each other. The information technology is not the key to a successful knowledge management, but the people are. Following that, the improvement of knowledge processes can be done by bringing the right people together - whether online or offline – in order to share their knowledge and develop new ideas. Whenever technology is used to enhance these knowledge processes, it has to be in a social way to improve the bottom-up knowledge flow.

Mr Ruediger Suess integrated EIWis into his strategic project portfolio. He connected other strategic projects with knowledge management and reported the results directly to the board. He will show how an organized project portfolio can help to reach the strategic goals.

Uwe and Ruediger will also show two examples. The first example is the DLR-Wiki, in which each employee can easily share his/her own knowledge with others inside DLR. The second example is the Knowledge Sharing Meeting, a format of collaboration workshops aiming at creating communities of experts by using a bottom-up approach with the acceptance of executive staff. An overview of the other knowledge management activities at DLR will also be given.

**Mr Ruediger Suess** is project portfolio manager at the Corporate Strategy and Alliances division at the headquarters of DLR – the German Aerospace Center, located in Cologne /Germany. In his current function. As project portfolio manager Ruediger Suess coordinates the update of the corporate strategy at DLR and manages the portfolio of strategic projects for the implementation of the corporate strategy.

**Mr Uwe Knodt** is Project Manager for Knowledge Management, DLR.

# Knowledge Management and Digital Diagrammatisation of Innovative Technical Systems

Vincent Minier and Vincent Bontems

CEA French Alternative Energies and Atomic Energy Commission, Saclay, France

A novel methodology is proposed for the analysis and knowledge management of the processes leading to innovative industrial. The methodology is derived from study cases in the field of "big science" instruments, such as space telescopes, for which the technical and natural environments are necessary conditions for their functioning. Big Science instruments are designed and realised over a long time, sometimes decades, and each generation represents a major technical progress compared to the precedent ones as they are always made to accomplish huge breakthroughs in science. They result from international planning, complex management, scientific coopetition, industrial research and production, and inventions born in the fundamental research laboratories. Similar properties characterise large programs in the space, energy or maritime industries. In this paper, we focus our study on the Herschel space observatory, an ESA space science mission launched in May 2009 and ending in April 2013. The study consists of various steps, including technological analysis, interviews with the designer team, analysis of transductions inside the instruments, historical analysis of technical lineages, and socio-technological analysis of the industrial design process. At the end of the study process, thanks to digitalisation, this information can then be displayed as digital database, diagrams and images allowing knowledge management, innovation forecast and even public outreach. Then, we introduce the concept of digital "Image-Objects" in the framework of the Gilbert Simondon's cycle of technology. "Image-objects" could be, for example, some interactive diagrams, e-book, MOOCs or even exhibits. The cultural role of these digital devices is not only to display technical information about the objects but also to valorise their cultural signification. They are not some scientific relics. They are Image-Objects, which convey explicit and latent meanings about the technical objects and, above all, about their invention. Image-Objects are meant to be a major booster for the culture of invention.

**Dr Vincent Minier**, is an astrophysicist at CEA (French Alternative Energies and Atomic Energy Commission) in Saclay, France. He leads the ExplorNova research project that explores the scientific, technological and cultural dimensions of space sciences, deduces innovating models for the future and share knowledges with all (http://explornova.cea.fr).

**Dr Vincent Bontems**, is a philosopher at CEA (French Alternative Energies and Atomic Energy Commission) in Saclay, France. His work concerns mainly the philosophy of sciences and technology, the sociology of sciences and the images. He is an expert of Gilbert Simondon, a french philosopher of technology and the author of Bachelard (Les Belles Lettres. Paris. 2010). He leads a seminar in Paris on Design and Innovation.

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# A Generative Grammar for Modal Syntagms

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**Abstract.** The contribution presents a generative grammar for Greimas' semiotic square, designed to represent modal syntax. In particular: (1) the grammar will generate both modal syntagms and their structural descriptions; (2) the articulation of the immanent narrative structure will be clarified; (3) structural features which are not manifested on the linear surface will become easier to examine. This model contributes to computational narratology theory, aiming at merging post-structuralist narratology with formal language theory.

**Keywords:** Computational Narratology, Generative Grammar, Modal Structures, Semiotic Square, Automaton.

## 1 State-of-the-Art

Greimas and Courtés [11] highlighted how formalization could be useful for proving logical coherence to the structural framing of semiotics, and for comparing different theories applied to the same cognitive object. Generative grammar and its success have a clear influence on Greimas' project. He developed his structural semantics by utilizing computational linguistics [9], formulating the semiotic square to describe the fundamental syntax of meaning [12], which should then generate the more complex structural levels. Following the same line of research, this paper aims to develop a generative grammar that formalizes fundamental syntax. In particular, we are interested in generating modal operators which feature narrative enunciates. In this manner we intend to study the immanent articulation of modality, and describe it in terms of standard algorithmic procedures which can be applied by researchers – cf. "automaton" and "algorithm" in [11].

Greimas' modal semiotic square[1] [10] is displayed in table 1:

The semiotic square summarizes the respective relations between four kinds of simple semiotic oppositions: antonymy (a versus b); presupposition (if a then not b and/or vice-versa); contradiction (a versus not -a); and neutralization (not a nor b). This abstract, fundamental syntax articulates the modalities. The table presents the relationships between the various possible modal syntagms, composed by a modal operator (M) and an enunciate (R), which can express an action (to do) or a state (to be). Modal syntagms are combination such as "Wanting to do"; "Not being able to be"; "Not having to do"

[1] Petitot tried to demonstrate the inconsistency of the semiotic square by using Boolean logic (cf. 3.3.3 in [18]), yet committed a trivial error. He wrote that 1+1 = 0 whereas, given the idempotent laws, in Boolean algebra 1 + 1 = 1. For an outline of the semiotic debate on the consistency of the semiotic square, see [4], [7].

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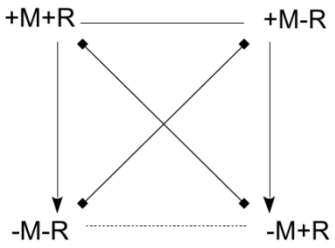
**Table 1.** The semiotic square

| Relations: | Square |
|---|---|
| +M+R – +M-R:= antinomy<br>+M+R – -M+R := contradiction<br>+M+R – -M-R := presupposition<br>+M-R – -M+R := presupposition<br>-M-R – -M+R := neutralization |  |



In the framework of a structural semantics, modalities are considered to be general values that are immanent to different semiotic manifestations, such as a literary text, a movie, as well as a technical object [5]. For example, the "Being able to do" modal syntagm can feature the hero of a movie or a real employee, when either of them find something that allows them to reach their goal (a magical potion; a new software).

Two distinct fields of research converge in Greimas' model: modal logics [2], [19], and structural linguistics. Greimas and Kalinowski worked together on the link between them [15], until the second scholar decided that the two disciplinary souls could not inhabit the same body [16]. Seen through deontic logic, for example, if "I have to do something" then "I can do it", "ought implies can" and therefore modal operators are inter-defined. In semiotics, on the contrary, the two modalities are largely independent, given the modal conflicts we find in texts. Kalinowski, instead, rejects this liberalization of the relationships between modalities, in spite of the fact that there are many logical systems in which the operators are not inter-defined[2].

A typology of different possible modalities is presented in table 2:

**Table 2.** Modal typology. Each symbol represents a generative grammar category (upper case) or a terminal modality (lower case).

| *Modalities (S)* | *Virtualising (V)* | *Actualising (A)* | *Realising (R)* |
|---|---|---|---|
| Exotactical *(X)* | Having to (h) | Being able to (a) | Doing (d) |
| Endotactical[3] *(N)* | Wanting to (w) | Knowing to (k) | Being (b) |

[2] For example, in the intuitionistic framework, modal operators are usually independent [6]. An example of intuitionistic deontic logical framework has been proposed in relation to the Talmud [1]. Furthermore, since each system in modal logics represents a specific textual domain that assigns a specific non-ambiguous meaning: for example, Kripke's structures for temporal logic have been converted into Moore's machines [21].

[3] A modality is exotactical when it links enunciates with different subjects, endotactical when it attains a single subject. cf. "Modality" in [11].

The kind of modal syntagms we would like to produce are composed of all of the possibilities generated by the semiotic square in table (1), when M corresponds to virtualising or actualising modalities, and R to realising ones. For example: (+a+d); (-w+b); (+h-d) are well-formed syntagms because they can be generated by selecting a corner of the semiotic square and by substituting the values seen in table 2 for the categories M and R. We would also like to generate a structural description of these syntagms. There are numerous possibilities. If we want to accurately represent the typology in table 2, we require an unrestricted grammar. Otherwise, by making minor changes to the categories used to classify the modalities, we can design simpler grammars. This second option finds support in Hjelmslev's empirical principle, which privileges coherent, adequate, and simple theoretical choices [13].

## 2 An Unrestricted Grammar

In order to represent Greimas' typology (table 2), we will first consider an unrestricted grammar $G_1$, that is able to generate a modal syntagm, and is represented by a combination of two lower case letters each of which is preceded by a positive or negative sign – see table 3. The grammar consists of two alphabets Z and T, variables (upper case letters) and terminals (lower case letters), and an initial variable $I \in Z$. It also contains a set of rules of substitution $\alpha \rightarrow \beta$ where $\alpha$ is a string of variables, and $\beta$ is a string of both variables and terminal symbols.

**Table 3.** The unrestricted grammar $G_1$. Each symbol in Z represents a category within the grammar structure– cf. Tables 1 and 2. We have added the category C to represent the endo/exotactical category, and the category G (+/-) to represent the affirmative/negative opposition. The subset I of Z includes the starting symbol S, whereas T is the set of terminal symbols.

| Symbolic repertoire | Rules | |
|---|---|---|
| Z:={S, M, R, C, G, V, A, X, N} | 1 – S → | GCMGCR |
| I:={S} | 2 – G → | + |
| T:= {h, w, a, k, d, b, +, -} | 3 – G → | - |
| | 4 – C → | X |
| | 5 – C → | N |
| | 6 – M → | V |
| | 7 – M → | A |
| | 8 – XV → | h |
| | 9 – NV → | w |
| | 10 – XA → | a |
| | 11 – NA → | k |
| | 12 – XR → | d |
| | 13 – NR → | b |

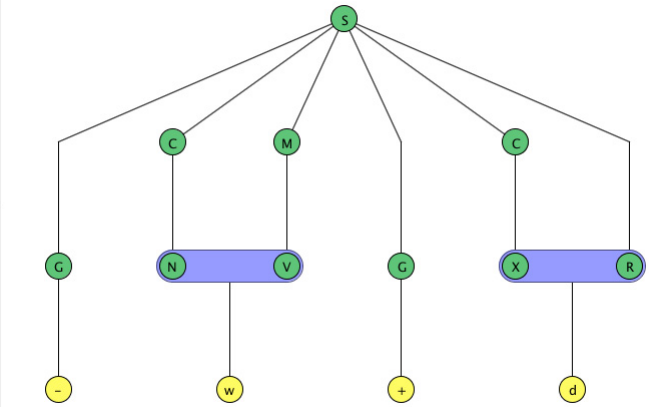
A derivation starts from the initial symbol S and applies one of the rules of substitution. The language generated by the grammar is a string consisting only of terminals that can be derived from I with a chain of substitutions.

In order to provide an example of the way in which the grammar works, we derive the modal syntagm:

(a): -w+d (“not wanting to do”)

We can also design the tree of substitutions, which reveals the hierarchical relationships between the terminals (see table 4). The tree shows how each symbol of the alphabet Z represents a category in the meta-language. For example, w is an endotactical virtualising modality, whereas d is an exotactical realising modality. This grammar is an unrestricted one, therefore some of the substitution rules are contextual. For example, according to rule 8, one can substitute h in V iff it is preceded by an X.

**Table 4.** The derivation of (a). This figure was generated with JFLAP (www.jflap.org)

| Rule | Steps of the Derivation | Tree |
|---|---|---|
| | S |  |
| 1 | GCMGCR | |
| 2 | -CMGCR | |
| 3 | -CM+CR | |
| 5 | -NM+CR | |
| 4 | -NM+XR | |
| 6 | -NV+XR | |
| 9 | -w+XR | |
| 12 | -w+d | |



## 3 A Context-Free Grammar

We can reduce the complexity of this grammar if we observe how the endo/exotactical category is implicitly represented by the two separate rules which allows to substitute each V/A/R modality with two and only two terminal symbols, without changes in the generated language. The result is the context-free grammar $G_2$, shown in table 5. Table 6 shows the derivation of (a).

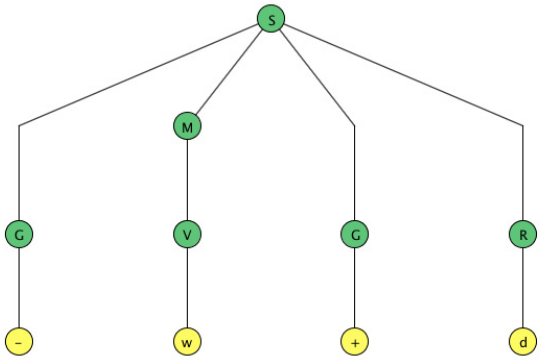
$G_2$, is remarkably simpler than $G_1$ not only because it requires less rules and symbols, but also because it is context-free, it does not use contextual rules.

**Table 5.** The context-free grammar $G_2$

| Symbolic repertoire | Rules | |
|---|---|---|
| Z:={S, M, R, G, V, A} | 1 – S → | GMGR |
| I:={S} | 2 – G → | + |
| T:= {h, w, a, k, d, b, +, -} | 3 – G → | - |
| | 4 – M → | V |
| | 5 – M → | A |
| | 6 – V → | h |
| | 7 – V → | w |
| | 8 – A → | a |
| | 9 – A → | k |
| | 10 – R → | d |
| | 11 – R → | b |

**Table 6.** The derivation of (a) in $G_2$

| Rule | Steps of the Tree Derivation |
|---|---|
| | S |
| 1 | GMGR |
| 2 | -MGR |
| 3 | -M+R |
| 4 | -V+R |
| 7 | -w+R |
| 10 | -w+d |




## 4 A Right Linear Regular Grammar

If we drastically change the philosophy applied to the representation we can further reduce the complexity of the grammar (see $G_3$ in table 7 and the corresponding derivation of (a) in table 8). This time we need only two categories (S, R) that respectively

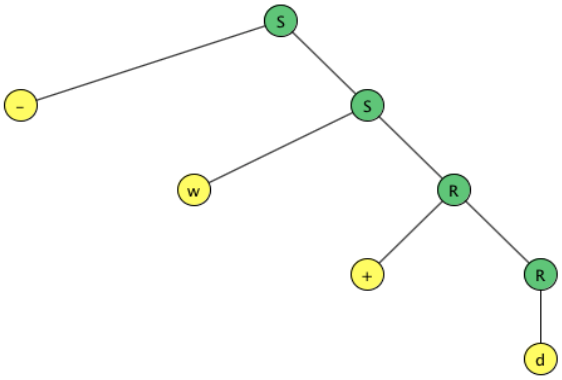
correspond to the modal enunciate and the doing/state enunciate. Both are preceded by a positive or negative symbol, and each category can be substituted with a terminal symbol.

**Table 7.** The right-linear regular grammar $G_3$

| Symbolic repertoire | Rules |
|---|---|
| Z:={S, R}<br>I:={S}<br>T:= {h, w, a, k, d, b, +, -} | 1 – S → +S<br>2 – S → -S<br>3 – S → wR<br>4 – S → hR<br>5 – S → aR<br>6 – S → kR<br>7 – R → +R<br>8 – R → -R<br>9 – R → b<br>10 – R →d |

**Table 8.** The derivation of (a) in $G_3$

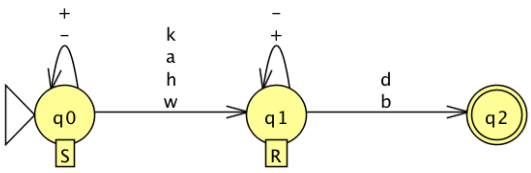
| Rule | Steps of the Tree Derivation |
|---|---|
| | S |
| 2 | -S |
| 3 | -wR |
| 7 | -w+R |
| 10 | -w+d |




Regular grammars generate regular languages: according to automata theory, a finite-state automaton can determine if a particular expression belongs to the grammar [14] – see table 9. The automaton is composed of three states. The initial one, q0, corresponds to the S category; the second one, q1, corresponds to the R category; and q2 is the final state. The symbols of the string (a) represent the transitions between states. As the reader can see: when the automaton reads the (+, -) symbols it remains in the same state; when it reads the (k, a, h, w) symbols it changes its internal states to q1; and finally, if it reads (d,b) it reaches the final state. Then, the automaton accepts the string as belonging

to the grammar. If this does not happen, the string is rejected. Following Chomsky, the grammar can be considered a model of modal competence, whereas the automaton is a model of modal performance [3].

**Table 9.** A finite-state automaton that can establish if a string of symbols belongs to $G_2$. The figure was generated with JFLAP (www.jflap.org).




## 5 Conclusions

What is the "true" grammar, among the three we proposed? There was a similar debate in the sixties concerning syntax grammar. Chomsky [22] proposed extra-linguistic criteria to facilitate the choice between different models, such as the "psychological plausibility". In my opinion, this only led to a circular reasoning basing cognitive linguistics on cognitive psychology and vice-versa [23]. A grammar is just one of the possible solutions to the problem of how to construct a formal demonstration in semiotic theory, showing an immanent structural articulation of meaning. As is shown by $G_2$, some semantic features are incorporated in the syntax. This means that the more complex grammars explicit simpler semantic features of each modality, h = +V+X, "Having to do" is "Virtualising and Exotactical". In Greimas' structuralist perspective, "Semantic" means simply relational and functional (a given tract such as the "virtualising" tract cannot exist positively, i.e. independently from the presence of "actualising" and "realising" tracts). In $G_3$, some semantic features of modality are lost: the automaton in table 9 is just a simple form of the semiotic square. As Marsciani wrote, even formal languages have categories that represent their semantics [17, pp. 22-24]. Thus, the identification of Hjelmslev's symbolic systems [13] with "asemantic" languages seems questionable.

A tree such as the one in table 8 at least reveals a structural feature which was unclear in the other grammars: the ipotactical relation between the (do/be) enunciate and the modal enunciate. Furthermore, given that modal syntagms are generated by a right-linear regular grammar, they can be considered regular languages, a well-known class of formal languages. This is not a trivial result due to the properties shared by regular languages: commutativity, associativity, distributivity, idempotency … [14]. Thanks to these properties it becomes possible to describe the complex chains of modal syntagms we find in semiotic processes as modal devices which "merge" smaller languages generated by simple grammars such as $G_3$ [20, p. 70]. We observe another interesting structural

property of regular languages, they are neither recursive nor self-embedded. Now this is puzzling because narrative programs are both recursive and self-embedded [8]. They share these properties with language syntax, as represented in classical generative linguistics [3]. Therefore, further important research questions concern the origins of recursiveness, given the fact that this property is not present in the simpler, deep fundamental structures of meaning described by Greimas, but appear only at a certain degree of structural complexity.

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# A Semiotic Approach to Critical Reasoning

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**Abstract.** Information can be interpreted as in-formation, which refers to the potential of the form for a mediation of meaning. In this paper we focus on reasoning information and consider the question how form involved in reasoning can be used for an analysis of accounting narratives in corporate disclosures. An evaluation of experimental results is included.

**Keywords:** Semiotic, reasoning, rhetoric, argument, accounting narratives.

## 1 Introduction

The Latin word 'informatio' equivalently designates information and bringing-into-form (cf. in-formation). The second refers to the potential of the form for the mediation of meaning (cf. interpreted information). In an extreme case, form and interpretation can be uniquely related. This is parodied by the classical joke of a psychiatric institute in which patients tell stories to each other. As the stories are told frequently they are assigned a number. One of the patients says ‘number 42', which gets a big laugh. Another patient cries out 'number 68'. Everybody finds it hilarious. A new patient watching this cannot stop himself and shouts ‘number 232'! The entire public bursts into a huge laugh. 'Why are you laughing so much?' the patient asks. His neighbor responds: ‘We haven't heard this joke before.'

In everyday language use, form and intended meaning are rarely so closely related. In most cases we are in need of auxiliary words and more refined (formal) expressions for the communication of our thoughts. How does form mediate meaning? Traditional semiotics, which is concerned with interpretation enabled by the sign, does not consider this question. In this paper we suggest that an answer can be given by considering the sign to be an object, and following this line of thought, through introducing a form related, and in this sense, formal model of sign interpretation.

Form involved in information can be used for a derivation of meaning. In the example above, saying a number can be satisfactory as long as the relation between numbers and stories is known by the receiver. If the receiver is not familiar with this relation, the sender may have to use additional information, e.g. syntactic information, and so, a more elaborate form of expression in order to enable the interpretation intended to arise. Besides syntactic information hence a syntactic perspective, many

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other types of perspectives are possible such as a semantical, mathematical, and logical one, that all involve rules of interpretation including those that are related to the form.

If complex thoughts are to be communicated, for instance, an entire text, a sequence of signs is needed. In this case, an important goal is to enable the reader to reveal the line of reasoning by the writer. Reasoning too can be associated with form. In this paper we ask: what are the types of reasoning information, what are the involved forms, and what are the effects of the form on the mediation of reasoning? The answer suggested by this paper is briefly discussed below.

Sign interpretation can be modeled as a process. An analysis from the perspective of reasoning reveals the potential of the events of this process for a representation of the three types of reasoning, deduction, induction, and abduction, as sign aspects. The involved form can be associated with Aristotle's three syllogistic figures as a structure. Through their type of reasoning, the events of the process can be assigned a degree of truthfulness: necessarily true (cf. deduction), expectedly true (cf. induction), and hypothetically true (cf. abduction). By linking the forms of reasoning with their associated claims to truth, the process model can be used for measuring the plausibility and understandability of a sign, e.g., an accounting narrative.

Sign aspects are representations that are in a process of becoming a sign. The development of meaning through sign aspects can be explained by the metaphor of apparent motion perception. In that phenomenon, a series of steady pictures are presented and, although each picture may be meaningful in itself, combined they are interpreted as parameters in the experience of the series of pictures as motion. Snapshots correspond to a sign aspect, the experience of motion to a meaningful interpretation of a sign.

An advantage of the semiotic approach is its potential for a uniform representation for sign interpretation.[1] This enables syntactic information (e.g. required by a reasoning analysis) and reasoning information to be combined easily. Because of the involvement of the relation between formal and meaningful interpretation, we assume that through analyzing the form, we may draw conclusions about a possible meaning, e.g. from the syllogistic structure of a text about a type of reasoning.

This paper proposes the use of the process-oriented semiotic approach, as an alternative text-focused approach, to interpret corporate disclosures. Corporate disclosures constitute an important channel for organizations to communicate with the public users since it contains rich content of information. Decision-making is built on efficient and effective processing of financial and non-financial (narrative) information [1]. The paper is based on the premise that goal of a critical corporate disclosure should be to reach conclusions by means of reasoned argument.

Research on understandability of accounting narratives in corporate disclosure has gained increasing importance over the years [2,3]. Prior studies can be categorized into two groups measured by content (thematic analysis) [4,5,6,13] and form (syntactical analysis) [7,8,9]. Thematic content analysis is to 'extract and analyze themes inherent within the message' [11] so as to find trends, correlations or attitudes from the text. Syntactical studies adopt readability formulas such as Flesch index,

[1] For a number of perspectives (cf. knowledge domains), including those mentioned earlier, this has been illustrated in [10].

Dale-Chall index, and Fog index to measure the probable readability of texts from the perspective of syntactical complexity. This study fills in a gap in the literature on corporate disclosures and communication research in relation to the meaning interpretation of accounting narratives. This approach shows advantages over other traditional ones, in a high degree of focus on the form and process of disclosures rather than on the text itself.

The structure of the paper is the following. First we briefly delve into Peircean semiotics (sect. 2). This is followed by an introduction of a process model of sign interpretation (sect. 3). Finally we offer an explorative study of our model to an analysis of accounting narratives i.e. chairman statements (sect. 4). We close the paper with a summary of the results (sect. 5).

## 2 Signs and Interpretation

Peircean semiotics is founded in Peirce's theory of categories [14]. Contrary to the Aristotelian view that phenomena can be classified in two types, attributes and substances (that are a carrier of attributes), Peirce distinguished phenomena in three categories, firstness, secondness, and thirdness, that have a relational character. An example of phenomena is a letter-V formed by a pair of fingers. The two fingers, their shape, incidence, etc., as a quality, are a firstness; ad-hoc relations between the qualities, such as the simultaneity involved in the incidence of the two fingers, are a secondness; meaningful interpretations of a relation, such as the interpretation of the incidence relation of the fingers as the symbol of victory, are a thirdness. The categories are ordered according to a relation of involvement, e.g. simultaneity (secondness) is involved in the interpretation of the letter-V as a symbol of victory.

Beyond the above dependency between the categories, we are interested in the process generating meaningful interpretations (thirdness) from qualities (firstness), through a mediation of relations (secondness). In order to develop a model for this process we need to introduce a few assumptions that are concerned with the questions how qualities may appear, how they may establish relations in an ad-hoc, and a meaningful sense.

In our model below we assume that qualities appear via interactions with the interpreting system (e.g. the human). In an interaction, the qualities of the stimulus (cf. effect) affect the interpreting system occurring in some state. This effect ($q_1$) and state ($q_2$), that both are collections of independent qualities, define the input for information processing (cf. firstness). The goal of interpretation is establishing a relation: why this effect is occurring to this state. To this end, the interpreting system has to sort out the two types of qualities in the input, abstract them from one another in order to determine their interpretation in the light of complementary or context information (cf. secondness), and finally, establish a relation between the input qualities in context, through predication (cf. thirdness). See Fig.1.

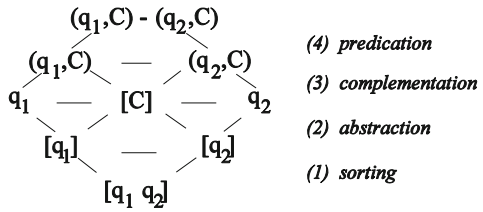


**Fig. 1.** The process model of cognitive activity. State (q1), effect (q2), context (C). Horizontal lines designate relations. The types of interpretation events are displayed on the right-hand side, in italics. Square brackets indicate that an entity is not yet interpreted, usual bracket symbols and a lack of brackets indicate that some interpretation is already available.

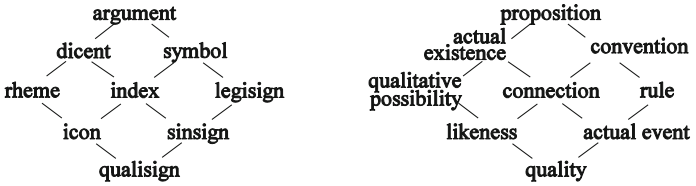


**Fig. 2.** Peircean sign aspects (left) and corresponding mundane terms (right)

Conforming to our goal, which is the definition of a process model of interpretation, our focus is restricted to interpretation as a sequence of events (hence in the paragraph above references to the Peircean categories are references to categorical aspects only). Following this line of thought we offer a semiotic analysis of our process model and assign sign aspects to its events [12]. See Fig.2. The goal of this slightly technical part in the next paragraph is to show that the events can be assigned to all Peircean sign aspects hence, in this sense, the process is semiotically complete.

State and effect appear as independent qualities ([q1 q2]; *qualisign*). Sorting of the input has the sign aspects of likeness or constituency ([q1]; *icon*), simultaneity ([q2]; *sinsign*), and connection[2] ([C]; *index*). As a state may occur in itself, but an effect always assumes the existence of a state, qualities of the state and effect can be used for a representation of a relation of constituency and simultaneity, respectively. Abstraction of the input qualities has the sign aspects of a possible state (q1; *rheme*), and effect (q2; *legisign*). By virtue of the involvement relation between state and effect, the abstract effect, which stands for the possible combinations known about the input state and effect, has the sign aspect of a habitual event. An expression of the abstract state and effect, in context ([C]), has the sign aspects of an existent or actual state ((q1,C); *dicent*), and a conventional event ((q2, C); *symbol*). Finally, predication, expressing a relation between the input state and effect in context has the sign aspect of a proposition which is a premise ((q1,C)-(q2,C) ; *argument*).

[2] We tacitly assume that C, representing complementary information corresponding to q1 and q2, appears together with q1 and q2 as a quality. In Fig.1 this is omitted.

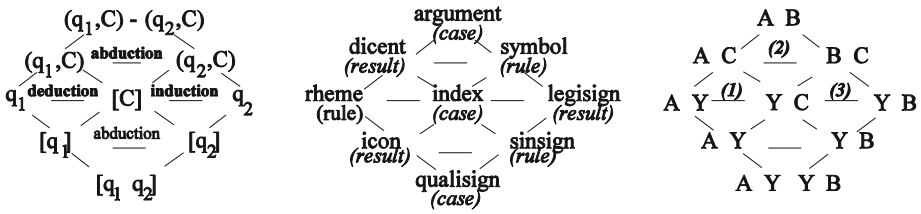


**Fig. 3.** A reasoning analysis of the process model. Types of reasoning aspects (left), syllogistic functions (middle), and formal expression (right). Aristotle's three figures are referred to by integers in parenthesis (see also Fig. 4). A Y and Y B designate q1 and q2 as premises

| *deduction* | *abduction* | *induction* | *figure−1* | *figure−2* | *figure−3* |
|---|---|---|---|---|---|
| rule | rule | result | Y C | B C | Y C |
| case | result | case | A Y | A C | Y B |
| result | case | rule | A C | A B | B C |

**Fig. 4.** A functional (left) and a formal representation of Aristotle's syllogistic figures. Deduction corresponds to figure-1, abduction to figure-2, induction to figure-3 [10].

The introduction of a semiotic analysis above was necessary in order to be able to offer a reasoning analysis of our process model. In this paper, our focus is on the relational events themselves. The reasoning aspects, syllogistic functions (following Peirce [14]), and formal expressions, associated to them are depicted in Fig. 3. In our analysis below we may refer to the events by their syllogistic terms in Fig. 4.

The generation of the final predication relation has the reasoning aspect of *abduction (2)*. Through combining the expressions of the state (A) and effect (B), in context (C), we raise a hypothesis concerning their relation, which is involved in a meaningful interpretation of the input interaction. The generation of a possible representation of the input state in context has the aspect of *deduction (1).* In this event, complementary information (Y), that the interpreting system is familiar with, is used to derive 'new' information (C) about the state (A). This is opposed to the event generating an expression of the effect in context, which has the aspect of *induction (3).* In this event, a habitual interpretation of the effect (B) is applied to hence tested for a new state (C), enabled by the context (Y). A presentation of the input qualities as co-occurring premises, by sorting, has the aspect of abduction, degenerately (in a reasoning sense).

Noting the completeness of the process model, the semiotic analysis (Fig. 2) shows the involvement of all nine Peircean sign aspects, the reasoning analysis (Fig. 3) reveals the potential of the process for a representation of all three types of reasoning as aspects of reasoning, syllogistic functions and formal expressions. By virtue of the dependency between the categories, we may assume that the above completeness (secondness) is involved in a meaningful interpretation of the input as a phenomenon as well (thirdness).

In the case of language phenomena, examples of an effect are words, sentences, paragraphs, or even entire texts, for instance, chairman statements. In this paper, we assume that in such statements, complex thoughts by the author are split into smaller fragments, in order to help the reader's comprehension. Each paragraph is meaningful

in itself and layout is used to draw the reader's attention as well. If a paragraph is an expression of a single thought, then by virtue of the completeness of meaningful interpretation, it must represent all three types of reasoning (aspects). From this we conclude that when the line of reasoning is complex, the author of the text may wish to add formal information thereby enhancing a reasoning interpretation by the reader. We conjecture that through analyzing the form of reasoning involved in a text, a measure of plausibility and understandability by the reader can be derived.

## 3 An Illustration of Corporate Disclosures

We apply our theory to a paragraph found in a chairman's statement[3] (See also Fig.5). We assume that a syntactic analysis of the input sentences is available. In our reasoning analysis below, sentences are interpreted as premises, the subject and predicate of a sentence as the minor and major terms of a premise. A common term can be found by matching. Information, such as syntactic and semantic-syntactic, necessary for this operation is assumed to be available (this may put a great burden on lexicon definition).

A sentence may function as a premise in different syllogisms. A syllogism can be interpreted from the perspective of itself, as well as from the stance of the paragraph as a whole. The import of a syllogism can be the expression of a reasoning aspect in the interpretation of the paragraph (cf. the positions in the upper 'triangle' marked by rheme, legisign and argument), but also it can be only a representation of a single sign aspect (cf. the positions in the lower 'triangle' marked by qualisign, rheme, and legisign). In the second case the involved reasoning aspect is represented degenerately, from a logical stance (see sect. 3.1 and 3.2).

**S1:** *Rebuilding the bank is a significant challenge but I believe we now have the tools to begin turning the business around.*

**S2:** *Niall Booker, a veteran of the banking world, joined the Bank at the same time as me, and he and his new Executive Team have worked closely with the Board over the second half of last year to understand the true state of the Bank.*

**S3:** *Devising a Recapitalisation Plan acceptable to all stakeholders in very difficult circumstances, we were able to complete the Liability Management Exercise (LME) in December without which we wouldn't be here today.*

**S4***: This could not have been accomplished without the support of the vast majority of our subordinated bondholders, customers and colleagues for which we are extremely grateful.*

**Fig. 5.** A sample paragraph from a chairman's statement

### 3.1 S1

The first sentence, S1, is setting the scene (the first clause in S1 is setting the context). This sentence is not part of a syllogism, except as a proposition which is a conclusion.

[3] The Co-operative Bank plc. Annual report and account, 2013

The subject *('we')* and predicate *('have the tools to begin turning the business around')* are brought into relation via predication. In the interpretation of the paragraph as a whole, the above two symbols are used for a definition of the icon and sinsign positions. The first clause of S1 is represented as complementary information in the index position ('*Rebuilding*', '*challenge*'). See Fig. 6. Note the relation of overlapping between the abduction involved in predication (cf. S1) and in sorting (cf. paragraph).

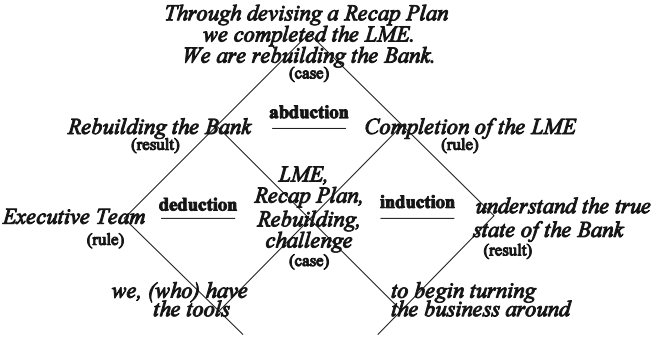


**Fig. 6.** A reasoning interpretation of the paragraph depicted in Fig. 5. A representation of the qualisign position is omitted. In the icon position, '*have the tools*' mediates between '*we*' (agent) and '*to begin turning the business around*' (theme). The term, '*Recap Plan*' is used as short for '*a Recapitalisation Plan acceptable to all stakeholders*'. Reasoning aspects that are represented degenerately (in a logical sense) are omitted.

### 3.2 S1 – S2

S1 and S2 can be interpreted as premises of a syllogism exhibiting the aspects of induction (cf. Fig. 4). The common term is defined by the expressions '*Rebuilding the Bank*', and by '*Niall Booker*' and '*Executive Team*', as theme and agent, respectively, of the predicates of S1 and S2 interpreted as major terms. The import of this syllogism in the paragraph as a whole is an expression of the legisign position:[4] '*understand the true state of the Bank*' (a full definition: '*(they) worked closely to understand the true state of the Bank* IS *(enabled by) having the tools to begin turning the business around*'). In addition, S1 and S2 can also be interpreted as premises of a syllogism exhibiting the aspects of deduction. This time the common term is defined by 'Rebuilding the Bank' (S1), and '*worked closely to understand the true state of the Bank'* (S2). The import of this syllogism is an expression of the rheme position[5]: '*Executive Team*'.

### 3.3 S2 – S3

S2 and S3 can be interpreted as premises of a syllogism exhibiting the aspects of induction. The common term is defined by the expressions '*He and his Executive Team*',

[4] It will be applied as result in a later syllogism exhibiting the aspects of induction.

[5] It will be applied as rule in a later syllogism exhibiting the aspects of deduction.

and '*we*'. The import of this syllogism in the analysis of the entire paragraph is a representation of the aspect of induction and an expression of the symbol position (rule): '*completion of the LME*' (a full definition: *'(we) were able to complete the LME* IS *(through) understand(ing) the true state of the Bank'*). Information about *'the Liability Management Exercise'*, involved in the expression of the symbol position, as well as information about '*devising a Recapitalisation Plan',* occurring in the first clause of S3 are represented as a context sign, in the index position ('*LME*', '*Recap Plan*').

### 3.4 S1 – S3

S1 (by its first clause) and S3 can be interpreted as premises of a syllogism exhibiting the aspects of deduction. The common term is defined by '*challenge*' (S1) and '*we*' (S3), as theme and agent, respectively. The import of this syllogism in the paragraph as a whole is a representation of the aspect of deduction and an expression of the dicent position (result): '*Rebuilding the Bank*' (a full definition: *'Rebuilding the Bank* IS *(was) enabled by the completion of the LME (through) devising a Recapitalisation Plan*').

### 3.5 S3 – S4

S3 and S4 can be interpreted as premises of a syllogism exhibiting the aspects of abduction. The common term is defined by the expressions '*complete*', and '*accomplish*'. The import of this syllogism in the paragraph as a whole is a representation of the aspect of abduction and an expression of the argument position (case): '*This (=the completion of the LME hence the Rebuilding of the Bank)* IS *(accomplished through) devising a Recapitalisation Plan*' (a full definition, following paraphrasing: '*Through devising a Recapitalisation Plan we completed the LME. (This way) we are rebuilding the Bank'*.

A reasoning interpretation of S1 and S4 is already involved in that of S3 and S4; a reasoning interpretation of S2 and S4 is not possible.

## 4 Experimental Results

We devised a test to measure understandability and plausibility, using two sample chairman's statements taken from 2009 and 2013 Annual Report of a UK company. Understandability was tested through questions concerning the meaning involved in the informationally *not* represented syllogistic aspects according to our analysis, while their meaning must be clear to the reader, by virtue of the assumed completeness of the paragraphs. Completeness offers the possibility to verify whether the syllogistic structure is a good approximation of reasoning involved in meaningful interpretation. For instance, a paragraph, which can be analyzed in inductive syllogism(s) must convey information about the reasoning aspects of an involved deduction and abduction as well that can be verified through questions. Scale questions (1=Not at all plausible, 4=Plausible) were employed to test plausibility thereby to determine the persuasiveness. The score can be used for verifying our hypothesis concerning the ordering of syllogistic schemes. We conjecture that a text mostly representing the reasoning aspects of deduction will be perceived to be more plausible than a text, which mostly representing the reasoning aspects of induction (testing) and abduction (hypotheses). A tacit goal of this

experiment is to show that an analysis of reasoning can be analogous to syntactic parsing.

The experiment was conducted with undergraduate accounting students in a UK university. It resulted in 27 responses, from which 21 were acceptable, from a group of 70 students. These students' first language was English and can be classed as knowledgeable users of financial reports. Each student was required to read five paragraphs extracted from two chairman's statements and fill out an on-line questionnaire via Kwiksurvey, consisting of 14 multiple-choice questions. The experiment required about 20-30 minutes to complete. SPSS was used to analyze the data as part of a descriptive statistics research, which measures the occurrence of the 'correct' answers for each question. When measuring understandability, one cannot expect a single correct answer since the interpretation process among individuals is different. Therefore the answers to the type of questions were distributed in levels of 'correctness' (1=worst answer, 4= best answer).

We found that in questions measuring understandability, once the text is complete from a reasoning stance, 76% students were able to select the best and second best answers, while 14% chose the worst answer. In the case of incompleteness, only 9% students managed to select the best and second best answers. This indicates that completeness leads to better understandability. The results from the plausibility questions showed that the use of aspects of deductive reasoning makes the paragraphs more plausible as deductive reasoning conforms to more logical reasoning and to less persuasive reasoning. In the experiment, all questions deriving from deductive reasoning type attracted only one "not at all plausible" answer. The answers to questions involved in inductive reasoning were more dispersed than others, ranging from "plausible" to "not at all plausible". A very interesting finding was that no students chose "not at all plausible" for abductive type of reasoning questions, which is deemed to the correct answer. Instead, nearly half of the students selected "plausible" in their answers, which means that students could still be persuaded by a "good reason". This supports Fisher's (1987) narrative assumption that human beings are fundamentally storytelling creatures, therefore, the most persuasive information is not that of a logical argument, but instead a narrative rationality.

## 5 Summary and Future Research

Accounting narratives in annual reports constitute a key part of corporate disclosures. Organizations utilize narratives to communicate corporate information to various publics. Effective communication depends on the accuracy in the construction and transmission of the message between senders and readers. In this paper, we presented a practical illustration of the application of our semiotically inspired process model to interpret a text (i.e. chairman's statement), through the analysis of syllogistic forms. Our experiment results suggest that the syllogistic form analysis measure aspects of the understandability and persuasiveness. This form-oriented study contributes to the narrative studies by capturing both syntactic and semantic interpretation. The limitation of the study is that we only investigate 2 chairman statements and the scale of the experiment is small. We leave an examination of the statistical correlation between syllogistic reasoning and understandability/plausibility for further research.

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# Information Systems and Sign Systems

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**Abstract.** The organisational world can be considered as a collective of social sign systems and formal sign systems (computer based information systems). In this paper the issue of the fundamental differences between the two kinds of sign systems will be discussed, and the implications of these fundamental differences for system development.

**Keywords:** Organisational Semiotics, Sign Systems, Business Processes.

## 1 Introduction

Semiotics is the study of sign processes. In organisational context it covers the study of the use and the production of signs in the execution of business processes. The information flows within an organisation are inextricably connected to the use of signs. Signs are the tangible or intangible carriers used for the transfer of information, and interpretation of signs generates meaning.

Within an organisation all kinds of different sign systems are used. In the development of information systems, we generally tend to be focused solely on one kind of sign system, namely the highly structured and formalised IT sign system. In analysis, modelling, requirements elicitation, specification, design and building we use partly formalised language in order to construct IT artefacts, rigid and formal computer based sign systems. Yet, in the daily routine of business processes, real people do not use only or even primarily formalised language. People interact through various kinds of social sign systems like natural language, specialised language (jargon), body language, pictorial information, and they use experience and background knowledge in their daily business routines. People interact on the basis of a combination of patterns, conventions, and norms. In the execution of their organisational tasks real people must deal with real world situations and with the expectations of other real people, using IT systems, natural language, sensory information, experience and background knowledge simultaneously in order to interpret the situation, take the correct actions, and inform people and automated processes in subsequent processes.

Much organisational work is routine and can be automated. At the same time, automation itself is a human activity. Both automation projects and working with the results of automated operational processes are human activities and must necessarily be covered by human responsibilities in the organisation. This implies that formal sign systems (computer systems) will always be embedded in social sign systems.

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In the study of the use of information systems in organizational context, we should focus on the role of information in the business processes. The primary question should be: what information is needed in what form to carry out the tasks and responsibilities in business processes, where the tasks and responsibilities must necessarily include the production of information for subsequent processes. A similar focus on information rather than on technology is expressed by Ron Weber when he states that the core of the information systems discipline will lie in theories that account for information systems-related phenomena, and not in theories that account for information technology-related phenomena [1]. However, in much of ISR literature, and also in the statement on the IFIP website of the scope of TC8, the emphasis seems to be on the application of information technology [2].

For the exchange of information between business processes different kinds of sign systems are involved, some formal, some informal. The different sign systems may complement each other, or they may overlap. One can distinguish between the mechanisms of the formal organisation (as specified in the official documents) and 'shadow' mechanisms (as evolved through the needs of the processes as perceived by the people involved). This leads to the following questions:

- Which different kinds of sign systems can be distinguished within an organisation, and what are their respective characteristics?
- What are the implications of the differences between sign systems for system development?

To find answers to these questions I will first discuss some basic insights from semiotics, and I will give tentative definitions of the concepts of sign system, formal sign system and social sign system. The paper will continue with a discussion of the economic criteria for the execution of business processes. The core of the paper is in the presentation and discussion of a typical business case and the role of formal and social sign systems in the case. To conclude, I will give provisional answers to the questions asked above, and I will indicate lines for further research.

## 2 Semiotics

Kecheng Liu writes in his work on organisational semiotics about the use of signs in organisations: "that all organised behaviour is effected through the communication and interpretation of signs by people, individually and in groups" [3]. According to a much used definition by Peirce "a sign, or representamen, is something which stands to somebody for something in some respect or capacity" (2.228) [4]. Any individual percept can (must) be interpreted and as such function as a sign. In semiosis, humans are aware of the difference between the sign itself and that which is represented by the sign. This awareness is fundamental for semiosis, as Van Heusden has analysed in his work. He defines: "Semiosis is the relating, by someone, of a form and an icon" [5]. In this definition, the form represents the general, the convention, the stability and the continuity. This allows us to communicate with each other. The icon represents the specific situation, the individual perception. The awareness of the difference between form and icon is the driving force in the development of meaning. New words and new meanings of words are implicitly learned by ostension (pointing out typical examples) by use, and by generalising

from individual instances of use to general conventional meaning [6]. A specific case of the development of general (and binding) meaning by conscious assessment of individual cases against general meaning is the administration of justice. One example from the Dutch High Court: when the maximum amount of nitrate on lettuce is explicitly bound by law, does the same law apply to crinkly lettuce? Is crinkly lettuce a different vegetable, or is it just another kind of lettuce? [7]

In the context of organisational semiotics, Van Heusden and Jorna have analysed how in organisations types of knowledge can be related to the use of signs. In sensory knowledge (the craftsman) the iconicity is predominant, in theoretically concrete knowledge standardised forms (codification) is predominant (classification schemes, conventional signs such as pictograms), and in theoretical knowledge (structures) the relation between abstract forms is predominant [8]. Their semiotic space, an adaptation of the information space of Boisot [9], has thus three axes: degree of sensory detail (global/detailed), degree of codification (weak/strong), and degree of theoretical abstraction (concrete/abstract). The semiotic space indicates the kind of knowledge that is predominant in a specific business process as the relative weight of the three dimensions. In each and every case, however, all three dimensions are present. Pure iconicity cannot be communicated (works of art come close), pure theory would be unconnected to concrete events (mathematics and logic come close).

In our social world we deal mostly with signs in the context of more or less comprehensive sign systems. Natural language is an example (utterances stand for meaning and intentions), it is the sign system in which our culture as a whole is embedded. Morse code is another example, and is a dedicated sign system designed for a specific purpose, both in a narrow sense (the coding of letters in dots and bars) and in a broad sense (the conventions that regulate the communication by means of Morse code). The nautical system of flag signals is another example of a sign system. To elaborate a little on the last examples (and in agreement with the general system theory that says that any coherent set of elements and relations can be considered a system): the system of flag signals, the system of colours and forms of buoys, the convention of nautical radio communication, the use of symbols on water charts can each be considered as separate sign systems, or the sum of all conventions regarding nautical communication together can be considered as a single sign system. Each part of the nautical sign system is governed by explicitly stated rules and conventions, the nautical sign system as a whole is both governed by the underlying rules and conventions, and will probably also show emerging social habits and patterns that are characteristic for certain places or for certain types of sea traffic.

In natural language a lot of different sign systems could be differentiated, and it would be difficult to find good demarcations between them. Lotman has coined the term “semiosphere” for the grand total of all the different and overlapping sign systems that make up the environment a human being lives in [10]. It is certainly not my ambition in this paper to develop a method for distinguishing all kinds of possible sign systems in human communication. For this paper it suffices to make the essential distinction between formal sign systems (especially as used in computer systems) and social sign systems (as used in human communication). I will start with some tentative definitions of sign system, formal sign system, and social sign system.

A **sign system** is a set of signs, used by a social group in a social context, together with for that group in that context settled practices regarding the application and interpretation of the signs and combinations of signs.

A **formal sign system** is a sign system where the set of signs and the set of rules governing well-formed formulas as valid combinations of signs are formally defined. A good example of a definition of such a system is the proposal for an International Algebraic Language (IAL, precursor of Algol-60) by Backus in his paper at the ACM-Conference in Zürich in 1959 [11]. Backus writes in this paper:

"(1) There must exist a precise description of those sequences of symbols which constitute legal IAL programs. Otherwise it will often be the case that a program which is legal and translatable for one translating program will not be so with respect to another.

(2) For every program there must be a precise description of its "meaning", the process or transformation which it describes. Otherwise the machine language programs obtained by two translating programs from a single IAL program may behave differently in one or more crucial respects."

What is stated here, is that given the formal and deterministic nature of translator programs (translating source code into machine code), the rules for the source code must be fully specified. If not, writers of translator programs may make different choices, resulting in different behaviour for the same source code.

A **social sign system** is a sign system where the set of signs and the set of habits governing the application and interpretation of signs are formed by social practices, varying from explicit stated rules via social conventions to evolving patterns). In law, we find explicitly stated rules. In the application of law (police, court) we recognise the normative force of social conventions and social patterns. For example, what counts as "self-defence" is dependent on the societal context and of the interpretation of the actual situation and the societal context. In the case of Oscar Pistorius in South Africa the judge had to decide whether to interpret Pistorius' killing of his girlfriend as an act of mistaken self-defence, as an act of manslaughter, or an act of murder.

## 2.1 Meaning and Sign Systems

Meaning can only be found in the use of social sign systems. A formal sign system by itself is devoid of meaning, although there is often the suggestion that it does have meaning. Backus writes "meaning" between quotation marks when discussing automatic processing or transforming, to indicate there is no real meaning involved here (my interpretation). I will give an example from daily practice of the meaninglessness of formal sign systems.

Some time ago I needed a new bank card because the old card was pretty damaged. It was still functioning, but it would be broken soon. In order to request a new card via the website of the bank I had to log in first. For this action I needed to use my damaged but functioning card. The request form for the new card asked for the reason (an obligatory choice) for requesting a new bank card: (A) my card is broken; (B) my

card was lost; (C) my card was stolen. My reason did not appear in the options. How to answer the question? My line of thought was: if I choose either “lost” or “stolen”, I will probably get a new PIN code. If I choose “broken”, I will retain my PIN code. Therefore, I chose “broken”. Then, I finished the other questions on the form and concluded my dialogue with the website by again using my damaged card and entering the security code connected to that card. The final message of the website was: “You requested a new bank card because your current card does not function any more. The new card will be available after three working days”. So, I had to use my damaged card twice to tell the system the self-same card did not function any more. I was quite happy this formal sign system did not have meaning!

This example shows three different domains of interpretation: (1) natural language as used and interpreted in human communication, here used for the description of the case; (2) the formal operations within the ICT system according to the formally declared variables, their values, and the conditions as specified in the program code; and (3) natural language in the presentation layer of the software. The last domain suggests the use of meaningful terms by the computer, but is nothing more than an alias for some formal variable or value on a variable.

## 3 Economic Norms

Information systems are resources for business processes, and just like any other kind of resource organisational and economic norms apply for their effective and efficient deployment. Information systems include all kinds of organised exchange of information, both computer based and based on numerous other forms of exchange of information by face to face meeting, email, reporting, and so on. Norms of effectiveness and efficiency are generic economic criteria and are always relevant. These norms apply for the use of sign systems in business processes like they apply for the use of every kind of resource.

Sign systems fulfil a role in the transfer of information within and between internal business processes, as well as in the interaction and transfer of information between the organisation and its customers, suppliers, and any other external stakeholder. Sign system A is better suited than sign system B for a certain task if A consumes less resources than B. Like many other economic issues the generic criterion is straightforward and clear. However, practice is more often than not complex and not straightforward: (1) the criteria for the successful execution of the task are multi-dimensional, (2) the term resources encloses a heterogeneous group of very different kinds of resources, (3) the determination of the price per unit consumed for a resource can be a highly complex and challenging issue, and (4) the attribution of the amount of resources to specific tasks is often difficult. All these consideration do not take away the fundamental insight that the issues of effectiveness and efficiency always apply in an organisational context. Sometimes effectivity will prevail, sometimes efficiency, but it is always an essential consideration in an organisational context.

Apart from the generic criteria mentioned above specific norms for the particular organisation will apply. Partly, these norms derive from the position of the organisation in its environment (for a company: primarily market relations, in combination with relations with other external stakeholders), and partly the norms derive from the internal

organisation (Mintzberg: the way of splitting up the tasks and the supplementary mechanisms for coordination of the tasks) [12].

In the context of this paper for the market relationship (both as seller and as buyer) the difference between classical contracts and relational contracts is very important [13]. Classical contracts are explicit and based on standard terms. These kind of contracts are therefore suited for elementary stand-alone economic transactions between anonymous trading partners, such as can be found on spot markets (buying a paper at the news stand or buying a shipload of crude oil). Relational contracts are not fully specified and are based on a longer lasting trusting relationship between the trading partners. In traditional economic theory, the model of the classical contract prevails with its notion of the individualistic and selfish behaviour of economic actors. In real economic relationships, elements of relational contracts are usually present. The relational aspect of economic relationships of the company with its customers and suppliers is the basis for some of the company's operational norms in business processes. In executing its processes the implicit rules of the economic relationship with the customer must be obeyed (and rules apply for the behaviour of the customer towards the company also). For those who are familiar with the Demo method: in Demo literature the examples are typically examples of transactions in classical contracts, and give therefore a distorted view of business practices [14].

## 4 Case Study

The following example shows what the considerations are in choosing the right sign system. Suppose a customer has a long standing relationship with his supplier / producer, and the customer asks: "Could you deliver about 3000 kg trimming in the second half of next week, not too fat". The supplier answers: "I will take care of it!". What kind agreement do we have here, as expressed in loose natural language? And how will this agreement be translated into the computer systems of the supplier / producer, from order entry, through production and shipping to delivery and invoicing?

**Producer / Supplier 1**

Suppose the supplier / producer has a simple and small-scale computer system for sales & invoicing. The internal processes are not supported by this system. In this situation the order will be put into the sales-system with customer-number, delivery date either Thursday or Friday (more or less arbitrarily), the quantity ordered is 3000kg, and the item-number for the product with the description "trimmings 80/20" (trimmings with 80% meat and 20% fat), price. If it is a regular order from a regular customer, this information will suffice. If this order is in some respect an exception to the regular habits and patterns, some notes will be made to remind the colleagues in production and shipment department what is to be known about this particular order. These notes might be made into the computer system (if some comment fields for free text are available), or in the sales-agenda of the sales-person, or on some paper.

When later on the order is prepared, and it is a regular order from a regular customer, then the information Customer C, Product P, Delivery D, Amount A will be sufficient for the production department to select or produce the trimmings that will satisfy this customer order. Just the variable parameters of the order are communicated to the shop floor. All further information to fulfil this order is known by the

employees on the shop floor, including the slack permitted in the product specifications, the delivery date and the amount to be delivered (routine is presupposed). In other words: to know the customer and the product ordered is sufficient for the execution of the order on the work floor, all to specifications and expectations.

Part of the established habits of this particular customer – supplier relationship might be that the supplier informs the customer on Tuesday or Wednesday what will probably be delivered, and when. Or the customer informs the supplier that due to unforeseen demand he has a shortage, so please deliver at the earliest possible moment.

**Producer / Supplier 2**

Suppose, by contrast, a supplier / producer who has a highly integrated ERP system. Here also the first step is order entry with the customer-number, product-number, delivery date, quantity, price. The differences are in the subsequent processes. The order data are processed in production planning, as a result production orders will be generated to have exactly the ordered quantity of the ordered product available at the shipping date. Next, production will execute the production orders. The shop floor control module of the ERP system will be monitoring the progress and results of the production processes. Deviations from the production planning are detected and result in corrective actions. If the output from production is less than planned, production will be replanned to produce the lacking quantity. If the output from production is more than planned, the extra output will be added to stock. Is demand for that product-number more than what is available, for example because of late orders from other customers, replanning (or buying) must provide the lacking quantity. All the actions indicated above can be executed automatically in the ERP system.

### 4.1 Analysis of the Sign Systems in the Business Case

In the examples above we see two different sign systems at work. The first supplier / producer uses a natural language sign system with apparently vague descriptive terms and very loosely formulated and imprecise specifications. The trade partners have a stable relationship and each of the trade partners in this economic relation understands the product, the market, and the partner. In this situation, the margins of the trade are sufficiently clear, the trade partners grant each other some latitude in the interpretation of the agreement, and as a result both the internal and external transaction costs are kept at a minimum level. It is a typical example of a relational contract.

For the financial aspects some very specific formal obligations apply. Financial transactions must be factual, consistent and transparent for external stakeholders (Inland Revenue, chartered accountants). Therefore, each invoice must have a unique number (with checks on completeness), and each invoice will show the VAT number of seller and buyer, and each invoice must declare the delivered goods (description and quantity). These formal requirements are met in the sales / invoicing system, partly automatically generated (unique successive invoice-number), partly configuration (VAT-rate, own VAT number), partly master data (VAT-number customer, address data of the customer, description of the product), and partly from order / delivery data (product-number, price, possibly discount, quantity delivered).

The second supplier / producer uses a formal sign system which operates by unique ID's for customers, address data, sales items and all other entities involved in the processing of information. The Bill of Material specifies precisely which resources in which quantities are required to produce one unit of a sales unit, sometimes in combination with a specification of setup times for production, sometime with a specification of setup times dependent on the preceding product on the production line. The ordering process (commerce), the production planning process (coordination), and the production and distribution processes (material handling) are (dis)connected by the ERP system

At the beginning of the trade process, at order entry, there is no difference between the two suppliers / producers. Basically, they record the same information in the same way. At the end of the trade process, after establishing the delivery data, the subsequent processes of preparing the delivery documents (either on paper or electronically), and invoicing are the same. The latter processes are bound by financial rules and commercial law. But in between, in all processes involved in order fulfilment, important differences can be found. In the case of the first supplier / producer, the order entry data are made available for the internal processes, and all interpretation is done by knowledgeable employees. In the case of the second supplier, the order entry data of this particular order is automatically processed together with a bunch of other customer orders. Formally derived information is made available for specific processes. The two essential differences between the cases are: (1) the kind of interpretation / processing of information, and (2) the kind of information that is available at different points in the order fulfilment processes. Both differences have a strong connection with the predominant sign system used for the internal processes in the organisation: a social sign system in the first case (common natural language, professional language, organisational terminology), formal sign systems in the second case (computer systems).

## 5 Sign Systems and Business Processes

From the example case it will be clear that formal and social sign systems differ in their characteristics to a considerable extent. A general problem in developing computer based information systems is a lack of awareness of these differences. Taken collectively, the user community tends to neglect the differences and ascribe meaning and a capacity of understanding to machines and automata, while the system developer community tends to neglect the differences and blame users for not making clear what they are doing and what they want. Under the hypothetical assumption that in a concrete project both user community and developer community (1) are well aware of the differences between formal sign systems and social sign systems, and (2) are well aware of the double embeddedness of formal sign systems in social sign systems (both in the development of formal sign systems and in the operational application of formal sign systems), the question is what the practical implications are of the differences in the development of an information system.

The same economic norms apply for information systems as for all other kind of resources; the information systems should be effective and efficient. Towards external stakeholders, effectiveness means satisfying their justified requirements and expectations

(the expectations being an essential component of relational contracts). For the internal business processes, the effectiveness of the information systems means satisfying the maxims of Grice for a conversation: give all relevant information for the task at hand, avoid all irrelevant information, be accurate, brief, clear and orderly [15]. To meet these Gricean maxims, some information is best provided by computer systems, and some by human communication. Situational factors like the kinds of relationship with the outside world and the internal company's culture are codetermining for what the best mix between formal and social sign systems would be.

John Kay writes: "The firm is defined by its contracts and relationships. Added value is created by its success in putting these contracts and relationships together, so it is the quality and distinctiveness of these contracts that promote added value" [16]. To sustain the distinctive capabilities of a company with relational contracts, social sign systems matter most.

Also important is the human accountability for actions in an organisational context. Tasks and decisions may be delegated to computer systems, but people are responsible for the execution of the automated tasks. Firstly, this implies that in the configuring of a computer system the responsible people in the organisation must determine the categorisations and the business rules, and must be able to observe and approve the behaviour of the system before operational application of the system. This makes high demands on the translation of the organisational practices into formalised models, and vice versa. Secondly, in operational use people must be able to translate their operational situation into meaningful categories in the computer system (N.B.: this means meaningful for the employee!). Thirdly, in operational use people must be able to translate output of the computer into meaningful information for their task at hand.

## 6 Conclusions

In the sections above the fundamental differences between social sign systems and formal sign systems were discussed and illustrated with some business examples. When practitioners in both the user community and the developer community are more aware of these differences, much would be gained already. Subsequent research is necessary to further conceptualise sign systems and its properties, and to analyse business processes in relation to the properties of sign systems.

Apart from the essential distinction between social sign systems and formal sign systems, many subtypes in both social and formal sign systems can be differentiated. However, there is the risk of uncontrolled proliferation in such differentiation when a clear goal is lacking. In Information Systems Research, the goal would be to gain a better understanding of the fit of computer based information systems to the business processes. In this perspective, both social sign systems, formal sign systems and business processes should be analysed and categorised in relation to each other. Several kinds of problems are to be solved: (1) the practical problem of the translation of information between formal sign systems and social sign systems; (2) the practical problem of the translation of information between different formal sign systems (in a heterogeneous landscape of different computer systems, also EDI issues); (3) the practical problem of translation between different social sign systems (a classical organisational issue); and last but not least (4) the fitness of a specific sign system for specific business processes.

To conclude, insight in the nature and characteristics of different kinds of sign systems is highly relevant for information system development, and will gain both economic results (effectiveness and efficiency, competitiveness) and organisational results (better definition of tasks, less erosion of responsibilities).

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# On the Relationships between Norms, Values and Culture: Preliminary Thoughts in HCI

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**Abstract.** Different studies and initiatives have indicated a new moment in the Human-Computer Interaction field that requires it to consider aspects that are difficult to be identified, such as values and culture. However, these aspects have been traditionally left on the margin of approaches for technology development, and still demand investigations on how to effectively deal with them in design activities. In this paper, we consider the concept of Norms as a promising concept to advance the understanding and knowledge on this topic, and draw on a socially aware perspective to the design of information systems, presenting preliminary discussions on the concepts of norms, values and culture, and their possible relationships, as a first step into a norm-oriented perspective for values and culture in HCI.

**Keywords:** Norms, Organizational Semiotics, Values in Design, Culture in Design, Information Systems.

## 1 Introduction

Every technology triggers (positive and/or negative) impacts on the environment in which it is inserted and on the people who live in this environment — even if they do not use it directly. Ubiquitous Computing, Wearable Computing and Social Software are some examples of how Information and Communication Technologies (ICTs) have permeated all aspects of personal and collective life. In this sense, the task of designing interactive systems has assumed new dimensions in terms of complexity and has required a wider and deeper understanding of the ethical and social responsibilities of those who create them [12].

Different studies and initiatives intended to identify, discuss and inspire the research in Human-Computer Interaction (HCI) have indicated a new paradigm, or wave, in the area [1][5][8]. This new moment requires HCI theories, methods and practices to be rethought in order to consider aspects that are difficult to be identified, such as values and culture.

Values are culturally built [13], varying in meaning, importance and priority according to the culture being analyzed and across time and space. Therefore, although there are some universal values, it is possible to say that values cannot be properly understood outside their cultural context: while a value indicates what is important for people, culture explains why [12].

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The (lack of) consideration and implication of values in technology are usually too subtle and only noticed when a social rule is violated, a behavioral pattern is broken, or a conflict of interest arises. The lack of attention to values and the complex cultural context of people have led to the creation of products that are not suitable to their needs and expectations, that do not make sense to them, and that often generates undesirable side-effects.

In the literature, there are relevant works on values and culture that discuss the design, adoption, use, and impact of technologies, the relationship between culture and usability, and that address the involvement/concern with values during design activities [6]. However, there is still a lack of studies that support the explicit and articulated involvement of both values and culture throughout the design process, helping designers to deal with them, reflecting them in their design decisions and products. From the perspective of the Semiotic Onion [16], there is a need for investigation on how to deal with values and cultural aspects not only in the informal layer, but also in the formal and technical ones.

In this paper, we start discussions about the potential of norms for supporting the understanding, involvement and formalization of aspects related to values and culture in the design of information systems from a HCI perspective. These discussions are grounded on different theories on norms, values and culture, as well as on practical examples. The paper is organized as follows: in Section 2, we present the background and a brief discussion on the concepts of values and culture, and in Section 3, we present different types of norms related to these concepts. In Section 4, we draw on the Value Pie artifact to exemplify different perspectives for the relationship between norms, values and culture, and in section 5, we present our conclusion and suggestions for future work.

## 2 Background

The ACM (Association for Computing Machinery) defines HCI as "*a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them*". This definition represents the complexity and comprehensiveness of the area, and attributes to HCI the responsibility to consider beyond technical issues, the formal and informal ones that coexist in society.

Aligned with ACM's definition for HCI, Winograd [21] asserts that the role of an interactive system designer goes beyond the construction of an interface to encompass all the interspace in which people live, and argues that it is necessary a shift from understanding the machinery to understand the lives of the people using it. This shift is key to the new moment in HCI that have been indicated by authors, such as [1][5][8][15], and results in a quite different perspective for the design of interactive systems, where technical issues play only part of the role, and not necessarily the most important one.

Such perspective have been proposed and explored by Baranauskas [3][4] for more than a decade through her social perspective to the design of interactive systems, often named as "Socially Aware Design". Baranauskas recognizes the existence of three levels in which humans operate and understand the world: the informal, formal and technical.

These levels were introduced by Hall [7] and structured by Stamper [16], through the Semiotic Onion (Fig. 1.), in order to explain how these levels exist in the context of organizations and information systems. The informal represents the culture, values, habits, beliefs, behavioral patterns of people and other aspects that are usually difficult to describe and even identify. The formal represents aspects that are well established and accepted, becoming social conventions, norms, or laws. Finally, the technical represents aspects that are so formalized that can be automated or approached in a technical way.

Grounded on Organizational Semiotics [9] and inspired by Participatory Design [14], Baranauskas [2][3][4] brings to HCI the understanding that any technical system exists in the context of a formal system that, in turn, exists in the context of an informal one. In this sense, a design process that is centered in technical aspects ends up giving little (or no) attention to the formal and informal aspects of organizations and the society, preventing designers from a wider sense-making of the problem being handled, the solution being designed, the stakeholders involved and the complex social world in which they live. Therefore, positive and negative effects on the formal and informal layers are completely undefined and unanticipated, leading to solutions that frequently do not make sense to users and trigger negative side effects on them and on the environment in which they are introduced.

Friedman [6] argues that, although the neglect of values (and here we include culture) in any organization is disturbing, it is particularly damaging in the design of computer technology where we can hardly disagree and negotiate about values and their meanings. In fact, as Hall [7] indicates, the technical system is where one can introduce changes with the greatest ease. However, as Baranauskas [2] indicates, the degree to which the system will respect or violate the *norms of the informal and formal systems* depends on how much these levels were understood.

In her socially aware design, Baranauskas [2][3][4] recognizes design processes as a movement that begins from outside to inside the Semiotic Onion (see the dashed arrows in Fig. 1.), crossing the informal and formal layers of signs towards the construction of the technical system. This movement favors the identification, articulation and formalization of relevant aspects of the social world, such as the ones related to stakeholders' values and culture. Therefore, when the movement returns, the technical system will impact on the formal and informal layers and on the society in an informed way, reflecting an understanding of the social world, potentially making sense to users, promoting its acceptance and adoption.

Adopting Baranauskas perspective, Pereira [10][12] proposed and experienced a set of artifacts to support the consideration and involvement of aspects related to culture and values in different design activities: from the identification of stakeholders, to the clarification of requirements and the evaluation of the resulting interactive system. Results obtained from different case studies recognized the need for further studies to support designers in the representation and formalization of such aspects, suggesting norms as a promising concept to be considered.

The three main words in this paper, "Values", "Culture" and "Norms" have been used in many senses, often with an unclear meaning. Each one has been the main concern of researchers from different disciplines, being approached and investigated for and from quite different perspectives. Therefore, we are not looking for an ultimate definition, and do not intend to unify the different interests and understandings around these words. Instead, we are presenting one possible view for them, which may support their consideration in the design of information systems from a HCI

perspective. In the next sections, we introduce the definitions we are adopting for each one, and develop a discussion about the relationships between them.

### 2.1 Values and Culture

In HCI, Friedman [6] have adopted a broad understanding for value, defining it as something that a person or a group of people consider important in life. This understanding goes beyond the notion of moral and ethical values, allowing additional notions (e.g., personal values, technical values). The key point we highlight in this understanding is that it opens space for considering (and inquiring) not only what theories and formal definitions determine as values, but mainly what people think about when they are thinking about values.

However, a more elaborated definition may be useful to support our discussions. According to Williams [20], the word "values" has been used to refer to interests, pleasures, preferences, moral obligations, desires, goals, needs, etc., reflecting a kind of selective orientation where the core phenomenon is the presence of criteria or standard of preference. The author defines values as core conceptions of the desirable within individuals and society that serve as standards or criteria to guide not only action, but also judgment, argument, evaluation, choice. This definition encompasses Friedman's aforementioned understanding and is the one we consider in this paper.
Stamper et al. [17] assert that people's systems of values are largely determined by their culture or subculture. Different authors, such as Hall [7] and Rokeach [13], recognize the cultural nature of values, arguing that their importance and roles vary strongly according to the culture being analyzed. In this paper, we adopt Hall's [7] understanding of culture, which refers to people's attitudes, material things, and learned behavioral patterns, representing the very different ways of organizing life, thinking, and understanding basic assumptions about the family, the economic system, and even the mankind. For Hall, culture controls the behavior of people in deep and persisting ways, many of which are out of their awareness, being the link between people and the means they have of interacting with others.

When talking about culture, Hall [7] believes it is more important to look at the way things are put together than at specific theories, suggesting that, although it is useful to question about specific situations, understanding the cultural context in which people live, the way they interact, and their behavioral patterns can offer more information than looking at pre-defined hypothesis. In this sense, the author proposed 10 Primary Messages Systems (PMS), or areas, he named the basic building blocks of culture (Interaction, Association, Learning, Play, Protection, Exploitation, Temporality, Territoriality, Classification, and Subsistence), arguing that any culture could be characterized, analyzed and compared through a combination between these areas (e.g., in a 10x10 matrix). Hall also suggests that values are developed according to these areas and their combination.

According to the exposed above, one may consider that: 1. if values are core conceptions of the desirable, and these conceptions are culturally determined, then, the desirable is not only influenced by what is taught, verbally communicated and explicitly identified in a society, but also by time and space (and their role in people's lives), socioeconomic conditions, and the environment characteristics (e.g., climate, natural resources). 2. If values serve as standards to guide action, judgment, argument,

evaluation, and choice, then, they may act as a specific kind of force that make "*the members of a community tend to behave or think in a certain way* [17]", i.e., a norm.

## 3 Types of Norms

The OS theory considers an organization and its information system as a social system in which human behaviors are organized by a system of norms [9]. Norms are a key concept in OS, being understood as collective constructions of agents at the social level, providing guidance for their actions. Among the methods offered by the OS there is the Norm Analysis Method, which supports the study of an organization from the perspective of the behavior of agents that are governed by norms, and that makes it possible to specify the studied organization by specifying norms.

Stamper et al. [17] argue that the shared norms are what define a culture, or a subculture, presenting and explaining different taxonomies for norms: 1. formality (informal, formal, technical); 2. Social psychological (perceptual, evaluative, cognitive, behavioral); 3. Kinds of tasks (substantive, communication, control). From these different kind of norms, the Evaluative Norms are considered the most basic ones, being directly related to people's system of values and influencing people's behavior (e.g., action, judgment, argument, choice). However, understanding evaluative norms, the way they interact with other kinds of norms, and representing them are still issues that demand further investigations.

In his book "Norm and Action", von Wright [19] developed a deep discussion on norms in general, exposing the complexity of giving a definition for the word norms, focusing on norms related to actions, and distinguishing between three major groups of norms: 1. rules, 2. prescriptions, and 3. directives. Briefly, 1) Rules are regulations or principles governing conduct within a particular activity, such as the rules of game, grammar, and even logic. 2) Prescriptions are commands, permissions and prohibitions, such as the laws of the state. 3) Directives are also understood as technical norms and are concerned with the means for reaching an ending, such as the instructions that will take the person who follows them to a specific result.

Additionally to the three major groups, three minor groups were introduced by von Wright [19]: i) customs, ii) moral principles, and iii) ideal rules. These groups may be related to one or more of the major groups, and can help us to discuss more about evaluative norms.

Customs determine certain patterns of conduct, exerting a normative pressure on the members of a community to follow them. They can be understood as social habits that are imposed on the members of a community rather than acquired by them individually. For instance, if a person is late for a meeting, it may be a custom he or she to apologize to the other participants for being late. Whether the apology happens, its intention (inform, explain, justify), in what moment (when the person arrives, at the end of the meeting) and in what way (gestures, voice tone, vocabulary) it happens, etc., reveal additional cultural norms.

Moral principles enter in the realm of ethics and, therefore, require a deeper and critical discussion that is out of the scope of this paper. The key point suggested by von Wright [19] is that moral norms are "conceptually autonomous", standing by themselves, and having complicated relationships to the other kind of norms and to

the (value) notions of good and evil. For instance, introduced in 2010, full body scanners at airports produced livid naked pictures of people. In several countries, the concern with the possible ethical problems triggered by these scanners resulted in different movements and actions: in United Kingdom, these scanners conflicted with child protection laws that ban the creation of indecent images of children [18]. While no one could argue against the possible evil consequences of producing and storing images of naked people, prioritizing people's security and well-being for the common good (e.g., against terrorism) was often used as a justification.

Ideal rules, in turn, are not directly related to actions, i.e. something to be done, but to the nature of being (or not being). Ideal norms are usually related to the idea of goodness, and unlike moral rules that are related to moral action, they set a pattern of what is good (the characteristic of being good). Ideal rules apply to people, organizations, as well as classes and objects, allowing us to say they apply to both agents and affordances. In the example of full body scanners, ideal norms would not define the properties or behavior of every scanner, but the ones that would characterize an ideal body scanner.

One may develop extensive discussion about these three minor groups of norms, bringing innumerous examples and exceptions. However, we can highlight two common points shared by these minor groups: 1) the existence of relationships with the major groups and between them; and 2) the idea of the desirable and, therefore, the link to the notion of values – what allow us to talk in terms of evaluative norms.

In von Wright's theory [19], the author argues that to understand the nature of moral norms is not to discover some unique features in them, but to survey their complex relationships to a number of other things. This may suggest that understanding evaluative norms is not to specify and represent their unique characteristics, but to recognize and understand their possible relationships to the other kind of norms. In the next section, we draw on the Value Pie artifact to expose practical discussions on values, culture and norms.

## 4 The Links between Values, Culture and Norms

The Value Pie (VP) is a culturally informed conceptual scheme for guiding discussions on values and culture in design [11] [12]. The VP was built on the grounds of Organizational Semiotics [9] and the Building Blocks of Culture [7], presenting three layers and ten slices that organize and support the discussion about values according to their dominant level of formality (informal, formal and technical) and cultural nature (Hall's 10 areas of culture) — see Fig. 2. Formality means that values are manifested on one of the three levels, but have aspects to be considered in all the three simultaneously. Cultural nature means that values are developed according to an area of culture, and with possible intersections between different areas. In [12, 10], the interested reader can find additional discussions and examples of values according to the VP and its dimensions.

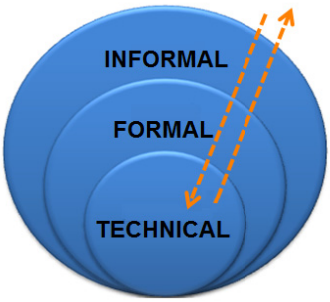


**Fig. 1.** The Semiotic Onion

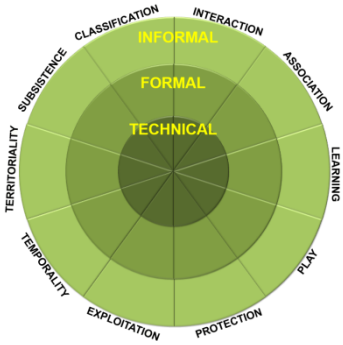


**Fig. 2.** The Value Pie

According to the notion of "privacy" given by Encyclopedia Britannica: "*the quality or state of being apart from company or observation; freedom from unauthorized intrusion (one's right to); a private matter*", one may see it was a value developed in the VP's "Protection" area, reflecting the importance of protecting personal information, things, ideas etc. — see Fig. 2. Because the areas of culture interact with each other, it is natural their values to present aspects developed from the intersection among them. For instance, when privacy refers to the protection of space (personal, social, physical), then it has a clear relationship to the "Territoriality" area.

Furthermore, what is necessary or expected to protect and why, what are the means to protect it, the extension and limits of privacy, and the importance given to it are examples of aspects that differ strongly according to the culture being analyzed. People from different cultures have their own informal understanding of what privacy is, as well as its meaning and importance. There are social protocols, conventions, rules and laws that are formally established to define the limits and guarantees of an individual's privacy. There are also some facets of privacy that are so formally accepted that can be technically supported, such as a curtain to cover a window, the wall for restricting the visibility of a house, and the privacy of medical examinations, just to name a few.

Considering Baranauskas' perspective to the design of information systems [2][3], the VP's structure suggests at least two core ideas on norms and values. The first idea is that each value has formal issues to be understood and considered, and that may be represented by norms. Therefore, norms may act as the bridge between the informal and the technical levels, specifying the way technical features should work. The second idea is that cultural areas, their values and, consequently, the norms related to them, are not isolated, but interact with each other in a complex interplay. Thus, if values are not understood in their cultural context, the norms related to them tend not to reflect their role and importance, being supported by technical features that do not make sense to users, do not afford the behaviors they are used to in their social world, and may trigger undesired side-effects on them and on their environment. Following, we present brief examples that illustrate the different norms we discussed in the previous section, and the way they are related to values and cultures of stakeholders.

### 4.1 **Designing the TNR** (Portuguese acronym for "All of Us Networked") **System**

In Brazil, public policies for inclusive education created the Specialized Educational Services (SES), in which teachers conduct activities with students in rooms equipped with specialized resources at traditional schools. In order to qualify professionals, teachers from all over the country started specialization courses within e-learning environments, but with a limited period (18 months). After that, teachers must be able to work with students regardless their disability, and have no additional support for a continuing learning. In this context, researchers from Education and Computer Science have been working in a research project, which one of the main goals is to design a social network system for these teachers. This system is intended to support teachers in their day-by-day work in a continuing education process.

The TNR system is being designed with representatives from the target audience in an iterative and incremental style according to Baranauskas' design model [2][3][4]. During all the design activities, artifacts created on the grounds of the VP were used to support the explicit consideration of stakeholders' values and culture. Therefore, the TNR system is a viable context to investigate and analyze the different norms related to values and culture. Following we present some examples.

***Customs:*** participatory activities with representatives from the teachers revealed the concept of "authorship" (property, ownership) as a value for them. Using a teacher's words: "*I understand that a contribution must be edited only by its authors. I think it is interesting a space for discussion, but respecting and keeping the contribution of each member. The interventions/editions in texts created by other people may not be well-accepted*".

In fact, teachers are used to work in groups, exchanging ideas and sharing materials; they believe it is possible to develop better solutions when they work together. However, the identification and the recognition of the individual contribution and participation must always be explicit and preserved. In an information system, they would not conceive the idea of someone but the author modifying an existing contribution (content). Therefore, a collaborative editor would trigger conflicts between the participants: e.g., a user could modify the text typed by other user when adding his or her own contribution. In this sense, a cooperative feature that allows users to contribute to each other but that identifies and keeps the individual contribution would be more adequate.

Norms may be derived from the explanation about this custom and may be represented according to the format proposed by the OS theory [9]. For instance: i) "WHENEVER new data is created in the system, IF it was created by a user, THEN the user must be defined as the data author". ii) "WHENEVER an existing data is selected, IF the user is the data author, THEN the user may update the data."

***Moral Principles***: because teachers are used to discuss their problems and ideas at their schools, they first did not express concern with privacy: they think it is good to share their opinions and information, and do not see risks in making them available to others. However, they are very concerned about security issues, and start to worry about privacy when they became aware of the possible impact on their life, or on the file of students and their families. This indicates that teachers believe privacy is important and must be considered, but they usually become aware of that only when a

problem or conflict arises. Therefore, the system should be designed not only to protect the stakeholders' privacy, but also to instruct users to be aware of it.

Example of norms: i) "WHENEVER new data is created in the system, IF it contains personal information of others, THEN its author must have the authorization to use the information". ii) "WHENEVER a new content is shared to other users, IF it is publicly available, THEN the user must indicate that the content does not offer risks to his/her privacy and the privacy of others".

***Ideal rules***: the system's terms of usage were also defined in a participatory way. As a by-product, teachers and researchers identified values that were not being considered in the terms, but that were important to guide the users' ethical behavior in the system (the ideal behavior). Thus, it was created a "Letter of Principles" to make these values explicit at the system home page. Examples of values are: i) Accessibility: the network must be able to attend to the different needs of a heterogeneous group of participants. ii) Autonomy: people may be capable of making decisions, planning, and acting in order to achieve their goals; of controlling the technology and using it. iii) Collaboration: possibility to cooperate, working together for a common goal. iv) Groups (team spirit): participants may work together, with common interests, needs and goals, supporting each other.

Mapping the values listed in the Letter into the VP supports a deep discussion about each one, and provides useful information for their effective consideration and promotion in the TNR system (due to the limited space we will not develop such discussion here). Example of norms: (accessibility) "WHENEVER a new content is shared, IF it is a picture or a video, THEN the author may inform a textual description for it."

The examples presented in this section demonstrate the existence of values related to different types of norms. For each type (customs, moral principles, ideal rules), behavioral norms where identified, indicating a relationship between them. These examples support our previous discussions about the importance of considering the different types of norms and their possible relationships. However, understanding how evaluative norms influence behavioral norms, and how they can be represented is still an issue that requires further research.

## 5 Conclusion

Considering values and culture in the design of information systems is still a challenge for the Human-Computer Interaction field. Although literature presents relevant works on these issues, how to support designers to deal with them and to reflect them in their design decisions and products are still open issues that require further investigations.

In this paper, we presented preliminary discussions about the relationships between norms, culture and values, offering a perspective to understand these concepts and articulate them. We consider norms as a concept able to support designers to move from informal understandings about values and culture of different stakeholders to their effective involvement and consideration in the resulting technical artifact. We also suggest that different types of norms interact with each other, and are required to represent different facets of values and culture.

For further investigations, it is necessary both deepen theoretical discussions and to analyze more practical examples. A conceptual scheme to represent norms and their interplay may contribute to clarify the relationship between norms and values, as well as to support the creation of artifacts and methods to carry design activities.

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# A Semiotic Approach to Investigate Quality Issues of Open Big Data Ecosystems

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**Abstract.** The quality of data models has been investigated since the mid-nineties. In another strand of research, data and information quality has been investigated even longer. Data can also be looked upon as a type of model (on the instance level), as illustrated e.g. in the product models in CAD-systems. We have earlier presented a specialization of the general SEQUAL-framework to be able to evaluate the combined quality of data models and data. In this paper we look in particular on the identified issues of 'Big Data'. We find on the one hand that the characteristics of quality of big data can be looked upon in the light of the quality levels of the SEQUAL-framework as it is specialized for data quality, and that there are aspects in this framework that are not covered by the existing work on big data. On the other hand, the exercise has resulted in a useful deepening of the generic framework for data quality, and has in this way improved the practical applicability of the SEQUAL-framework when applied to discussing and assessing quality of big data.

**Keywords:** Big data, data quality, Semiotic levels**.**

## 1 Introduction

The term 'big data' and the accompanying area have received increasing interest over the last years. The area is often defined through describing a number of V-s (Volume, Variety … etc). In a way, with an area where a major conference already in the seventies took the name VLDB - Very Large Data Bases one might wonder what is particularly different, and how the notion of data quality in connection to big data is different than data quality in general.

Data quality has for a long time been an established area of research [4] and work on quality assessment in data integration has also appeared as an area recently [24]. A related area that was established in the nineties is quality of models (in particular quality of conceptual data models) [25]. Data can be looked upon as a type of model (on the instance level), as illustrated e.g., in the product models in a CAD-system. Traditionally, one has looked at model quality for models on the M1 (type) level (to use the model-levels found in e.g., MOF). On the other hand, it is clear especially in product and enterprise modelling that there are models on the instance level (M0), an area described as containing data (or objects in MOF-terminology). Also if we look upon administrative data, e.g. data on persons, it is clear that this is an abstraction,

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focusing on certain properties (e.g. name, age) of persons based on the purpose of having the data, not being a mirror of reality capturing all perceivable properties of persons. Thus, our outset is that also data quality can be looked upon relative to more generic frameworks for quality of models.

In this paper we look on characteristics of big data in the light of data quality as conceptualized using the SEQUAL-framework for quality of models. We will in section 2 describe some different work describing big data characteristics. In section 3 we described SEQUAL and its specialization for data quality based on earlier work. The main contribution of this work is section 4, where we position the big data characteristics within this semiotic framework. Section 5 concludes the paper.

## 2 Background on Big Data

Big Data has by many been 'conceptualized' by letter-magic centred on the letter V. Big Data first related to Volume, but later 3 V, 4 V and 5 V frameworks have been presented. As a start, Beyer and Laney [6] describe 3 areas:

- Volume, referring to the size of the data.
- Variety, referring to the heterogeneity of data representations, data acquisition, and semantic interpretation.
- Velocity, referring to the rate at which new data arrive and the time in which it must be acted upon.

IBM presents four areas[1]. In addition to the three above, they mention veracity, relating to the uncertainty of the data quality. Another source[2] also add a fourth area, namely viability pointing to that it is necessary to filter through all the data and carefully select the attributes and factors that most likely to predict outcomes and matter most to the business.

Finally Advanced Performance Institute [23] summarizes the area with 5 V-s, giving a bit more detailed information on the characteristics. We further exemplify with the current situation in the media industry.

- Volume refers to the large amounts of data generated going from are Terabytes to Zettabytes and more. This makes many datasets too large to store and analyse using traditional database technology. New big data tools use distributed systems so that we can store and analyse data across databases that are potentially spread around the world. In the news area, it means that larger volumes of data are available to be analysed relative to understanding what is happening.
- Velocity refers to the speed at which new data is generated and distributed. One example is a social media messages going viral in minutes. Technology allows us now to analyse the data while it is being generated, without ever putting it into databases. E.g. the SAP HANA architecture is providing an in-memory database solution that can integrate transactional data and analytical queries.

[1] http://www.ibmbigdatahub.com/infographic/four-vs-big-data
[2] http://www.pros.com/big-vs-big-data/

- Variety refers to the different types of data that one might want to look at in concert. In the past one mainly focused on structured data that fitted into tables or relational databases. A large amount of the world's data is unstructured (text, images, video, voice, etc.), kind of data that is particularly relevant in the media industry. With big data technology one can now analyse and bring together data of different types such as messages, social media conversations, photos, sensor data, video and voice recordings. Note that the variety aspect is not particular to Big Data, the issues is also found within large organizations in their attempt to address data integration [19, 24] internally or in collaboration with business partners.
- Veracity refers to the messiness or trustworthiness of the data. With many forms of big data, quality including accuracy are less controllable (just think of Twitter posts with hash tags, abbreviations, typos and colloquial speech as well as the reliability and accuracy of the content). In the media industry the veracity issue has become increasingly acute with the mix of journalistic and public sources of news.
- Value. Having access to big data is no good unless one can turn it into some value. This can be said to relate to Viability as described above. To have value in the news area, it is important to be able to report quickly based on what is happening. In newspapers we find for instance special systems such as Quake-Bot used by LA Times for more or less auto-generating news-articles based on available data. It can also be an issue as for the rights of reusing existing data to create value from the data.

On our own account, we add the need for visualization. To be able to get value from the data, it must be abstracted and visualized in an appropriate way to make the data useful, applying and extending techniques in the area of information visualization [35].

## 3 SEQUAL Data Quality Framework

SEQUAL [17] is a framework for assessing and understanding the quality of models and modelling languages. It builds on early work on quality of model [22, 26], but has been extended based on theoretical results [27, 28, 31] and practical experiences [17, 21] with the original framework. It has earlier been used for evaluation of modelling and modelling languages of a large number of perspectives, including data quality [18, 19], data modeling [16], ontologies [11], process modeling [1, 15], enterprise modeling [20], topological modeling (maps) [29] and goal-oriented modelling [13, 14]. Quality has been defined referring to the correspondence between statements belonging to the following sets:

- **G,** the set of goals of the modelling task.
- **L,** the language extension.
- **D**, the domain, i.e., the set of all statements that can be stated about the situation.
- Domains can be divided into two parts, exemplified by looking at a software requirements specification:

  - Everything the computerized information system (CIS) is supposed to do. This is termed the primary domain.
  - Constraints on the model because of earlier baselined models such as system level requirements specifications, enterprise architecture models, statements of work, and earlier versions of the requirement specification. This is termed the modelling context. In relation to data quality, the underlying data model is part of the modelling context when it is defined.

- **M**, the externalized model itself.
- **K**, the explicit knowledge relevant to the domain of the audience.
- **I**, the social actor interpretation of the model
- **T**, the technical actor interpretation of the model
- The main quality types following the steps of the so-called semiotic ladder [9] are:
- Physical quality: The basic quality goal is that the externalized model **M** is available to the relevant social and technical actors (and not to others).
- Empirical quality deals with comprehension and predictable error frequencies when a model **M** is read by different social actors
- Syntactic quality is the correspondence between the model **M** and the language extension **L**.
- Semantic quality is the correspondence between the model **M** and the domain **D**.
- Perceived semantic quality is the similar correspondence between the social actor interpretation **I** of a model **M** and his or hers current knowledge **K** of domain **D**.
- Pragmatic quality is the correspondence between the model **M** and the actor interpretation **(I** and **T)** and application of it.
- The goal defined for social quality is agreement among actor's interpretations.
- The deontic quality of the model relates to that all statements in the model **M** contribute to fulfilling the goals of modelling **G**, and that all the goals of modelling **G** are addressed through the model **M**.

### 3.1 Data Quality Relative to the SEQUAL Quality Types

We here discuss means within each quality level, positioning the areas that are specified by Batini et al. [4] and Price et al. [10, 11]. These are emphasised using italic. This overview is largely taken from [18].

**Physical Data Quality:** Aspects of persistence, data being accessible (Price) for all (accessibility (Batini)), currency (Batini) and security (Price) cover aspects on the physical level. This area can be looked upon relative to measures of persistence, currency and availability that apply also to all other types of models.

**Empirical Data Quality:** This is addressed by understandable (Price). Since data can be presented in many different ways, this relates to how the data is presented and visualized. How to best present different data depends on the underlying data-type. There are a number of generic guidelines within data visualization and related areas that can be applied, and we will only mention a few of these here. For computer-output specifically, many of the principles and tools used for improving human computer interfaces are relevant at the empirical level [33]. For visual presentation of data, one can also base the guidelines on

work in cognitive psychology and cartography with the basis that data is meant to be useful in connection to communication between people.

**Syntactic Data Quality:** From the generic SEQUAL framework we have one main syntactic quality characteristics, syntactical correctness. This means that all statements in the model are according to the syntax and vocabulary of the language

Syntax errors are of two kinds:

- Syntactic invalidity, in which graphemes not part of the language are used.
- Syntactic incompleteness, in which one lack constructs or information to obey the language's grammar

Conforming to metadata (Price) including that the data conform to the expected data type of the data (as described in the data model) are part of syntactic data quality. This will typically be related to syntactic invalidity when e.g. the data is of the wrong data-type.

**Semantic Data Quality:** When looking upon semantic quality relative to the primary domain of modelling, we have the following properties:

- Completeness in SEQUAL is covered by completeness (Batini), mapped completely (Price)**,** and mapped unambiguously (Price)**.**
- Validity in SEQUAL is covered by accuracy (Batini), both syntactic and semantic accuracy as they have defined it, the difference between these is rather to decide on how incorrect the data is, phenomena mapped correctly (Price), properties mapped correctly (Price) and properties mapped meaningfully (Price). Since the rules of representation are formally given, consistency (Batini)/mapped consistently (Price) is also related to validity. The use of metadata such as the source of the data is an important mean to support validity evaluation of the data.

Properties related to the model context are related to the adherence of the data to the data model. One would expect for instance that

- All tables of the data model should include tuples
- Data is according to the constraints defined in the data-model

The possibility of ensuring high semantic quality of the data is closely related to the semantic quality of the underlying data model. When looking upon semantic quality of the data model relative to the primary domain of modelling, we have the following properties: Completeness (Moody and Batini) (number of missing requirements) and integrity (Moody) (number of missing business rules) relates to completeness.

Completeness (Moody) (number of superfluous requirements) and integrity (Moody) (number of incorrect business rules) relates to validity. The same applies to Batini's points on correctness with respect to model and correctness with respect to requirements**.**

**Pragmatic Data Quality:** Pragmatic quality relates to the comprehension of the model by participants. Two aspects can be distinguished:

- That the interpretation by human stakeholders of the data is correct relative to what is meant to be expressed. In addition to the data it will often be useful to have different meta-data represented (making it easier to understand the intent behind the data).
- That the tool interpretation is correct relative to what is meant to be expressed.

Starting with the human comprehension part, pragmatic quality on this level is the correspondence between the data and the audience's interpretation of it. Moreover, it is not only important that the data has been understood, but also who has understood (the relevant parts of) the data.

The main aspect at this level is interpretability (Batini), that data is suitably presented (Price) and data being flexibly presented (Price). Allowing access to relevant metadata (Price) is an important mean to achieve comprehension.

**Social Data Quality:** The goal defined for social quality is agreement. Relative agreement means that the various sets to be compared are consistent -- hence, there may be many statements in the data representation of one actor that are not present in that of another, as long as they do not contradict each other. The area quality of information source (Batini) touches important means for the social quality of the data, since a high quality source will increase the probability of agreement. Another term found in data quality literature on this aspect is provenance.

In some cases one need to combine different data sources. This consists of combing the data-models, and then transferring the data from the two sources into the new schema. Schema integration techniques [10] are specifically relevant for this area.

**Deontic Data Quality:** A number of aspects are on this level relating to the goals of having the data in the first place. Aspects do decide volatility (Batini) and timeliness (Batini)/ timely (Price) needs to relate to the goal of having and distributing the data. The same is the case for type-sufficient (Price), the inclusion of all the types of information important for its use. For anything but extremely simple and highly inter-subjectively agreed domains, total validity, completeness, comprehension, and agreement as described above under semantic, pragmatic and social quality cannot be achieved. Hence, for the goals on these levels to be realistic, they have to be relaxed, by introducing the idea of feasibility. The time to terminate a modelling activity is thus not when the model is ``perfect'' (which will never happen), but when it has reached a state where further modelling is regarded to be less beneficial than applying the model in its current state. Accordingly, a relaxed kind of these goals being dependent on human judgement can be defined, which we term feasible validity, feasible completeness, feasible comprehension, and feasible agreement. Feasibility thus introduces a trade-off between the value and drawbacks for achieving a given model quality. When we structure different aspects according to these levels, one will find that there might be conflicts between the levels (e.g., what is good for semantic quality might be bad for pragmatic quality and vice versa).

## 4 Applying SEQUAL on Big Data Characteristics

On a high level, we can position the big data characteristics described in section 2 in relation to SEQUAL data quality framework in the following way:

**Physical Quality:** Volume is particularly relevant on this level, since it can be hard to have access to all relevant data at the same time. That it is the right (most current) data that is accessible is influenced by the velocity of data change. Supporting provenance, it might also be necessary to store the full chain of the data revisions, and not only the last version. In general, provenance meta-data should be represented independent on the technologies used for data storage, e.g. by using PROV3. An area that is not so much discussed in the big data literature is aspects of security, although in particular the use of Big Data-oriented techniques on personal data is rife with privacy-challenges. If people are more aware of this, potentially more people will make it more difficult for those working with Big Data techniques to get access to all the data that is of interest, indicating a need to also be open on how Big Data (e.g. location data) is meant to be used in a preferably anonymous manner in doing analysis [7].

**Empirical Quality:** Visualization of data is typically done on the basis of guidelines from cognitive psychology, and applying these is a good approach for achieving pragmatic quality (i.e. that people understand what the accumulated data mean). Note that guidelines for aesthetics are partly incompatible, and one has to make choices based on the usage and interpreters of the representation. In connection to maps [32] states that "different combinations, amounts of application, and different orderings of these techniques can produce different yet aesthetically acceptable solutions". Since the data visualization often must be auto-generated (to address issues of velocity), aspects described under this level is even more important for pragmatic quality than for traditional models developed mostly manually by human modelers.

**Syntactic Quality:** Variety comes into play here, since not all data sources have a strictly defined meta-model with a pre-defined syntax. This means that to match the different data-sources, certain presumptions have to be made on the structure and contents of data, i.e. one need to instil structure if it is not there, and in some cases meaning (see semantic quality) to data based on at best qualified guesses.

**Semantic Quality:** Whereas traditional data quality aspects such as completeness, accuracy and consistency are not covered specifically in Big Data - literature, the area veracity points to data quality more generally. A reason for the wanted variety is to ensure completeness since not all relevant data is to be found in one data source. Variety on the other hand brings traditional challenges in data integration quality [24] matching data on different level of abstraction and preciseness. When data is retained from sensor networks, one might experience issues of redundancy (e.g. reporting location every second from an object that is not moving). Such redundancies should be filtered out as should erroneous readings due to noise, e.g. indicating than an object suddenly moved a large distance in a short time, and this filtering should be done in the right order. To avoid issues of poor physical quality, one might often abstract the data, in which case it is important that the resulting dataset keep the important characteristics of the original dataset [34]. This points to an interesting side of big data not experienced in traditional modeling and data representations, namely that the modeling is partly done by algorithms, and not only be humans.

**Pragmatic Quality:** Relates both to machine understanding of data sources, and of human understanding of the results. As for machine understanding, the issues here is

[3] http://www.w3.org/TR/prov-dm/

very different for different types of data (e.g. between structured and unstructured data such as text, video etc.). When it comes to human understanding of the results, this is primarily supported by taking empirical quality into account when devising visualizations of the data. Another approach that can be used is to provide personalized output, in which case it might be important to make the user-model used in the personalization controllable for the user [3]

**Social Quality:** Provenance relating to the trustworthiness of the source as part of veracity is central at this level. Also in combination with variety (including data coming from a variety of sources that is evolving in an uncoordinated fashion by autonomous agents constituting parts of a digital ecosystem), we get apparently new issues, since some sources might be more trustworthy than other. Also internally in organizations this might be an issue, e.g. matching personal data in spreadsheets, with data from enterprise systems such as a PLM-system [19]. Since these sources are in the same organization though, the possibility to enforce compliance is larger than in a Big Data setting. Due to velocity aspects, one might need to quickly and automatically deduce a trust-level using a trust model [2] based on existing meta-data on the data-source.

**Deontic quality** is closely related to what is meant under the point value, are we able to utilize the data for our purpose? Viability is a sub-point of this relating to the discussion of feasible quality in SEQUAL. Based on the goal of data-use, and also partly dependent on data sources to be matched, different weight might be put on different quality levels. A framework for personalization of big data quality deliberations is found in [8], using scientific data as a case.

## 5 Conclusions and Further Work

We observe on a high level that the V-characteristics of big data can be mapped and understood relative to the levels of model and data quality described in the SEQUAL framework, although the mapping is not 1-to-1. The focus areas of big data do not describe to the same detail though many of the aspects found relevant in work of information and data quality. Issues with variety in Big Data can often be related to issues found in data integration quality in general, but we have also identified new issues from Big Data research when combining the effect of several V-s.

We notice that the treatment of quality in the Big Data area is so far relatively shallow. A first step is to a larger extent describe quality of Big Data relative to traditional data quality. Future work on our general approach on data quality will be to device more concrete guidelines and metrics and evaluate the adaptation and use of these empirically in case studies, also studies dealing with big data - issue e.g. within the media domain. An important aspects is how to perform trade-offs between the different data quality types Some generic guidelines for this exist in SEQUAL [17], which might be specialised for data quality. We will also look at newer work [5, 12] in the area in addition to the ones we have mapped so far. Due to the rapid changes to big data compared to conceptual models indicates that guidelines for achieving and keeping model quality might need to be further adapted to be useful when achieving and keeping quality of big data ecosystems, especially since a lot of what is normally modelled by humans in a big data scenario are modelled through the use of complex algorithms.

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# Virtual Process Control Modelling in Organisational Semiotics: A Case of Higher Education Admission

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**Abstract.** This study explores Web-based virtual process control modelling based on organisational semiotics, Web modelling language (WebML), and higher education admission process. Despite some discussions on control activities in the organisational semiotics literature, less attention has been paid to process control modelling in general and Web-based virtual processes in particular. Process controls help to implement required organisational constraints as regulatory norms that enforce established rules, procedures, and standards for meeting intended organisational goals. This study contributes to organisational semiotics research by extending the discourse on control norms to the realm of Web-based virtual process modelling in a real life situation.

**Keywords:** organisational semiotics, business processes, process control, process modeling, virtual processes, WebML.

## 1 Introduction

This study draws from the theory of organisational semiotics and Web modelling language (WebML) to model virtual process controls based on a case study of a university's admission process. Business processes consist of related activities performed to achieve organisational goals. Processes can be physical or virtual. Whereas physical processes get performed through direct, co-located interaction between agents, virtual processes remove such direct, physical contacts and replace them with mediated remote interactions [1, 2]. For Web-based virtual processes, activities occur via the Internet [3].

Within the organisational semiotics literature, three forms of activities are discussed, namely substantive, communication and control [4]. While much attention has been paid to substantive norms in business process modelling [3], relatively less research has focused on control norms, especially in virtual environments. Process controls are embedded constraints that serve as conditions for performing related activities [5]. However, the increasing migration of physical activities to virtual environments calls for urgent research attention to virtual process control modelling. Therefore, this study employs organisational semiotics [4] and WebML [5-7] to explore virtual process control modelling in a Web-based higher education admission environment.

The rest of the paper is organised as follows. Section 2 reviews related works on virtual processes, process controls and business process modelling. Section 3 discusses

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the relevant organisational semiotics models used for the study. Section 4 uses a university's postgraduate admission process as a case study to illustrate a Web-based virtual process model embedded with controls. Section 5 concludes the paper with a discussion on its contribution and recommendations for future research.

## 2 Related Works

### 2.1 Virtual Processes

Organisational processes consist of related activities performed to achieve intended goals. Processes can be physical or virtual [2]. Whereas physical processes require direct contact between agents, virtual processes involve remote interaction [2] through a mediating technology such as the Internet. The mediating technology can be manual such the traditional postal system or Web-based. The focus of the current study is on Web-based virtual process.

Process virtualization has begun to receive attention in information systems research. However, the focus has been on theorizing and testing for which activities can or cannot be virtualized. Less attention has been paid to process modelling in general and controls in particular. [1] and [3] are exceptions that focused mainly on substantive activities, hence the focus of this study on process controls.

### 2.2 Process Control

Organisations institute process controls to ensure that activities are performed in accordance with prescribed norms [8]. For physical processes, controls are recorded in documents and are expected to be enforced by human agents. However, process virtualization offers an opportunity for their automation and delegation of enforcement to machine agents such as the Internet and Web applications. For Web-based information systems, a natural means for enforcing user control is through hyperlink navigation [5]. However, Web-based agents offer opportunities for process control enforcement beyond navigation. The WebML *if condition* notation shown in Fig. 1 offers an opportunity for specifying control activities beyond navigation.

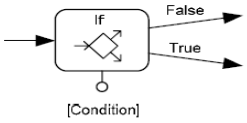



**Fig. 1.** If Condition Notation [5]

The *if condition* notation determines what can or cannot be done following a true/false conditional result [5]. Control norm has been extensively discussed in the organisational semiotics literature but less attention has been paid to its modelling. Therefore the *if condition* notation offers an opportunity for control modelling as discussed in Section 4.

### 2.3 Business Process Modelling

Business process modelling involves the use of symbolic notations to represent organisational activities and their relationships, often in a graphical format [9]. A typical business process model graphically displays related activities and related controls [10]. Process models therefore graphically display activities and their dependencies to define order of relationships [1].

By using symbolic notations and graphical display, business process models help to communicate and provide knowledge on existing or planned organisational activities and their relationships [9]. Business process modelling is therefore expected to be a significant precursor to any business improvement initiative. In line with this expectation, this study employs organisational semiotics and WebML symbolic notations for process control modelling to support process improvement in a higher education admission system.

## 3 Organisational Semiotics

Semiotics refers to the doctrine of signs and their interpretations [11]. Based on this perspective, organisational semiotics views organisations as information systems where agents create and use signs to perform purposeful activities [4] that are controlled by norms [11]. Business processes are conceived as behavioural activities controlled by norms as rules and regulations that determine which activities are permitted, mandated or prohibited [4, 12] and which agents can or cannot perform such activities [13]. This study draws from three organisational semiotics models: organisational onion, organisational morphology, and norm analysis method.

### 3.1 Organisational Onion

Organisational onion considers activities as a taxonomy of norms classified into three layers of informal, formal and technical [4] as shown in Fig.2.

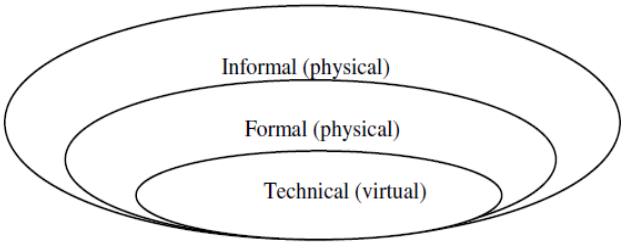



**Fig. 2.** The organisational onion [4]

Informal norms such as cultural values are implicit and thus not expressly documented. However, formal norms constitute documented bureaucratic procedures and guidelines. Finally, technical norms are formal norms that have been digitalized as part of computer-based systems. The three layers are however not distinct. The technical is part

of the formal, which together with the informal form part of the total organisation [4]. Norms can also be transformed from one layer to another. Thus, informal norms can be documented to become formal, while formal norms can be computerized or virtualized to become technical. In this study, the technical layer constitutes the virtual environment. Therefore, process virtualization refers to transforming physical processes from the formal and informal layers into virtual processes in the technical layer.

### 3.2 Organisational Morphology

Organisational morphology adopts a functional view of norms and classifies them into substantive, communication and control [11, 12, 14]. First, substantive norms govern the core activities performed to achieve the basic organisational goals. Second, communication norms concern the passing of messages between agents, such as reminders, inquiries, announcements and orders concerning facts, procedures and instructions. Finally, control procedures are meant to monitor and regulate substantive and communication activities based on expected standards, values or conventions. Control activities may also sanction, reward or punish agents. As shown in Fig. 3, each of the three activities can be further extended into sub-activities following a nested tree structure.

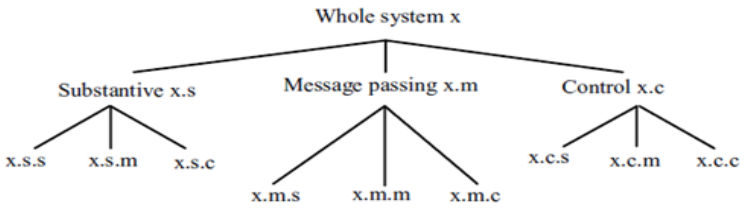



**Fig. 3.** Organisational Morphology [11]

The level of detail however depends on the context of the organisation or process [11]. Traditionally, all the three types of activities were performed through direct, physical interactions. However, in the modern digital economic environment, some of these activities are being migrated online as virtual activities. As noted above, [3] focused on modelling the virtualization of substantive activities but paid less attention to control norms. The current study therefore focuses on virtualizing control activities as demonstrated below.

### 3.3 Norm Analysis Method

Norm analysis method [12] helps to capture details of essential norms for specifying information needs [11]. The basic format for behavioural norm specification is as follows:

> **whenever** *<context>* **if** *<condition>* **then** *<agent>* **is** *<deontic operator>* **to** *<action>*

In order to accommodate process specification and their dependencies, [3] extended the basic format to include predecessor and successor activities as follows:

*<predecessor> <basic norm format> <successor>*

However, their extended model focused mainly on substantive activities and not on communication and control activities. While the basic norm structure is considered sufficient for communication activity, the current study further extends it for control activities with an **else** clause as follows.

***whenever*** *<condition>* ***if*** *<state>* ***then*** *<agent>* ***is*** *<deontic operator>* ***to*** *<substantive/communication norm>* ***else*** *<control norm>*

This extended norm structure was used to define the specification for control norms of the virtual admission process in Table 1 below.

## 4 Case Study: Virtual Admission Control Modelling

The study is based on the postgraduate admission process of the University of Ghana. University of Ghana was established in 1948 and remains one of the oldest and leading universities in Africa. In 2011, the first author initiated an action case study to virtualize the existing postgraduate admission process. In 2013, the system was extended to include process control. The current study is an extension [3], which focused mainly on process modelling without controls. This study extends the virtual process modelling to include control norms. System and user specifications were elicited by the author through participant observation, interviews, meetings, and focus group discussions with stakeholders.

### 4.1 Norm Specification

The admission process involves applicants completing online forms, uploading supporting documents and submitting them online. The web application then invites referees for reference reports. Once the references have been received, relevant departments assess each application and select recommend successful ones for admission subject to general requirements and vacancy. The admission office then vets all selected applicants based on the university requirements and notify them of the outcome. Informing the applicants ends the admission process. Decision to enrol forms part of the registration process.

With control norm specification architecture introduced in Section 3.3, Table 1 presents specifications for the substantive, communication and control norms identified from the case study.

### 4.2 WebML Notations

WebML [7, 15] is a visual modelling language that supports data and process driven web application design and development [5]. It supports both data and hypertext modelling. This study however focuses on the hypertext model to illustrate the implementation of virtual process control based on substantive, communication and control norms. Table 2 shows relevant WebML notations for this study categorised into content, operation and navigation units.

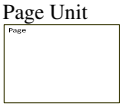
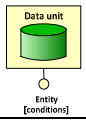
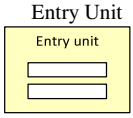
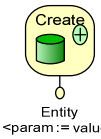
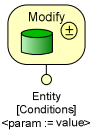
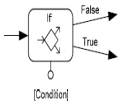
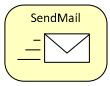
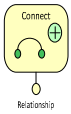
**Table 1.** Norm Specification for Virtual Admission Process with Controls

| Activity | Predecessor | Specification | Norm Type | Successor |
|---|---|---|---|---|
| Application | <open admission> | **WHENEVER** <Admission is open><br>**IF** <applicant likes a programme on offer><br>**THEN** <applicant><br>**IS** <may><br>**To** <select the programme> and < complete the online form>and <submit the online form> | Substantive | Reference request |
| Reference request | Application | ***WHENEVER*** *<applicant submits a form>*<br>***THEN*** *<Web-based admission system>*<br>***IS*** *<should>*<br>***TO*** *<request for references>* | Communication | Reference submission |
| Reference submission | Reference request | ***WHENEVER*** *<a reference report is received>*<br>***IF*** <All required references are received><br>***THEN*** *< Web-based admission system>*<br>***IS*** *<should>*<br>***TO*** *<link references to relevant application>*<br>***ELSE*** *<keep application on hold>* | Substantive .control | Selection |
| Selection | Reference submission | ***WHENEVER*** *<department accesses an application>*<br>***IF*** *<if applicant qualifies>*<br>***THEN*** *<Department Head>*<br>***IS*** *<should>*<br>***TO*** *<select applicant>*<br>***ELSE*** *<reject applicant> AND <inform rejected application>* | Substantive .control | Vetting |
| Vetting | Selection | ***WHENEVER*** *<applicant is selected by department>*<br>***THEN*** *<Admission office>*<br>***IS*** *<should>*<br>***TO*** *<vet selected application>* | Substantive | Admission |
| Admission | Vetting | ***WHENEVER*** *<application is vetted>*<br>***IF****<if applicant meets all department and university requirements>*<br>***THEN*** *<admission officer>*<br>***IS*** *<should>*<br>***TO*** *<admit applicant>and<submit admission letter>*<br>***ELSE****<reject application>AND<inform applicant and relevant department>* | Substantive .control .communication | <enrolment> |

Content units publish or accept data and therefore appear on web page. However, operation units manipulate or send data/information as backend activities. Such units do not therefore appear on web pages. Arrows are used to indicate links. While

content units publish or accept data and are therefore displayed on webpages to be manipulated by human agents, operation units are hidden activities that are performed by machine agents.

**Table 2.** Relevant WebML Notations

| Content Units | | | | |
|---|---|---|---|---|
| Page Unit | Data Unit | Entry Unit | List Unit | Navigation link |
|   |   |   |   |  |
| **Control Units** | | | | |
| Create Unit | Modify Unit | If Unit | Communication | Link Unit |
|   |   |   |   |   |

For detailed explanation and other notations see [7, 15]. In the next section, the *create* and *modify units* are used to implement substantive activities; the *If unit* and the *communication unit* are used to implement control and communication activities respectively. The content units are useful for accepting/publishing data on web pages. The *navigation unit* can be used to show direction as well as message passing.

### 4.3 Hypertext Model

WebML notations were used for the hypertext modelling of the virtual admission process control system. Fig. 4 presents the model and illustrates an instance of the application life cycle through the virtual environment based on the norm specifications for process controls shown in Table 1 and the hypertext notations in Table 2.

As shown in Fig. 4, the admission process begins when an applicant visits the application page to view the lists of available programmes presented by the selection programmes *index unit.* Once a programme is selected, the applicant proceeds to complete the online application form and upload all supporting documents through the submit application *data entry unit* on the application page.

An instance of the application is then created as represented by the *create unit.* The system also invites referees to present reports on the application. After which the system informs the relevant department to assess the application. Once the application is created, the system sends e-mail to referees requesting them to submit their reports. Referees then access the reference forms to complete the reports which are then linked to the application.

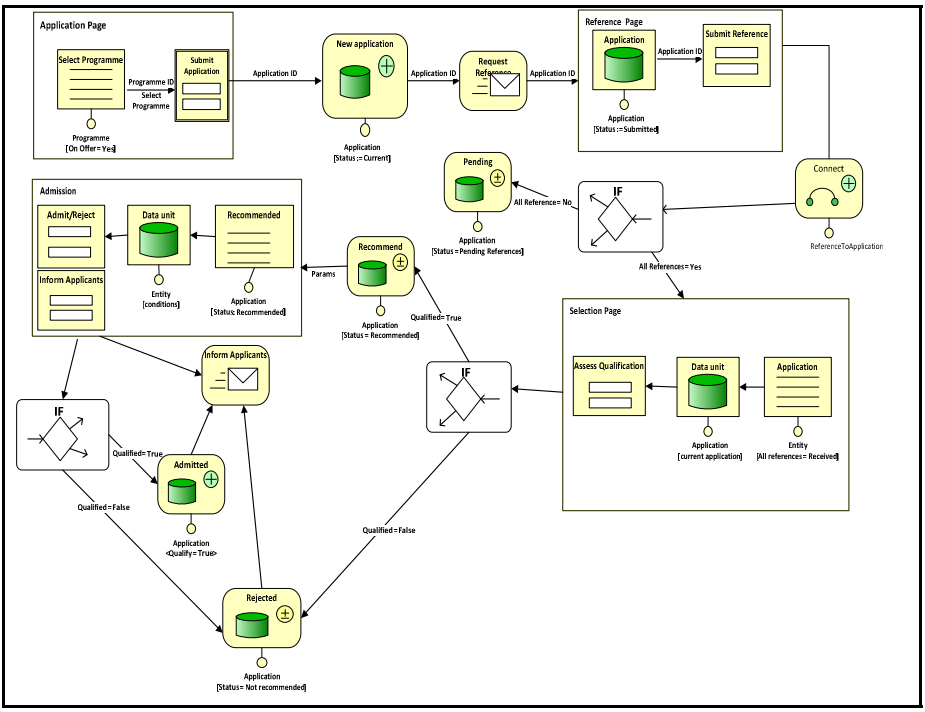



**Fig. 4.** Hypertext Model for Virtual Process Control

Following the implementation of the virtual admission process with embedded controls, the university's post-graduate admission process has become more efficient and responsive. Before the virtualization of the process controls, the enforcement of the controls were executed manually by human agents. However, by embedding them in the Web-based admission system, the responsibility has been transferred from human to machine agents, which are more efficient at ensuring compliance and enforcing conditions in the virtual process. Previous situations that relied on human memory often resulted in errors and failures to check the controls. However, the machine agent compliance is generally assured once the system has been tried and tested.

## 5 Conclusion

This study employed organisational semiotics and WebML for virtual process control modelling. The study contributes to organisational semiotics research, which has so far focused more on substantive norm modelling and less control norm modelling. Following [3], who employed organisational semiotics and WebML notations to propose a semiotic-based process specification architecture for substantive norms in virtual environments, the current paper extends the architecture to include an *if…then…else* clause that caters for control norm specification.

This study demonstrates the applicability of organisational semiotics and WebML notations to virtual process with control modelling. The resultant model demonstrates

how control norms can be implemented in organisational semiotics to enforce norm-based conditions in Web information systems. In terms of contribution to practice, the proposed approach can be applied to organisational domains where process controls are critical such as in hospitals, logistics and inventory management.

A key limitation of the study is the idiosyncratic nature of virtual process control across institutions and contexts. The proposed model is therefore expected to be adapted to rather than adopted for specific contexts. Future research can extend the model beyond the higher education admission context to other process control-based domains such as banking, accounting and health systems.

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# Assessing Pragmatic Interoperability for Process Alignment in Collaborative Working Environment

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**Abstract.** This paper is an extension of our previous study on pragmatic interoperability assessment for process alignment. In this study, we conduct four case studies in industrial companies and hospitals in order to gather their viewpoints regarding the concerns when condensing process alignment in a collaborative working environment. Used techniques include interview, observation, and documentation. The collected results firstly are summarised into three layers based on our previous developed pragmatic assessment model, and then are transformed into the elements which constitutes the purposed method, and finally based on the summarised results we purpose a method for assessing pragmatic interoperability for process alignment in collaborative working environment. The method contains two parts: one gives all the elements of pragmatic interoperability that should be concerned when considering process alignment in collaborative working environment, and the other one is a supplementary method for dealing with technical concerns.

**Keywords:** Pragmatic Interoperability, Process Alignment, Collaborative Working Environment, Interoperability Assessment.

## 1 Introduction

Process alignment in collaborative working environment is a complex domain due to human and technical factors and multi-stakeholder involved, and multidisciplinary nature of the problems. Organisation is such a complex area where business processes and functions require multi-systems collaborations, and highly relies on effective information communications among departments, and therefore faces many challenges regarding pragmatic interoperability such as information collision, policy obstacles, and procedure mismanagement. Our previous study has developed the semiotic interoperability framework [1][2] and several methods for measuring interoperability at different organisational levels [3][4]. This paper is an extension of our previous study on pragmatic interoperability assessment for process alignment. In this study, we conduct four case studies in industrial companies and hospitals in order to gather their viewpoints regarding the concerns when condensing process alignment in a collaborative working environment. Used

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techniques include interview, observation, and documentation. The collected results firstly are summarised into three layers based on our previous developed pragmatic assessment model, and then are transformed into the elements which constitutes the purposed method, and finally based on the summarised results we purpose a method for assessing pragmatic interoperability for process alignment in collaborative working environment. The method contains two parts: one gives all the elements of pragmatic interoperability that should be concerned when considering process alignment in collaborative working environment, and the other one is a supplementary method for dealing with technical concerns.

## 2 Background

In the study of the interoperability, most of the work focuses on discussion at a technical level. Although some of them have extended to deal with semantics, a very limited number of publications elaborate the interoperability at the pragmatic level [2]. Undoubtedly the research on technical and semantic interoperability can help establish a better understanding of data exchange and data interpretation, as well as leading to the development of supporting technologies and standards. However, the collaboration of different working processes require an assessment of pragmatic interoperability that ensures supported process can act upon the semantic information in order to deal with the complexity. Before defining pragmatic interoperability, our previous work has purposed the concept of semiotic interoperability [1], and has applied the concept in healthcare domain for analysing interoperability of collaboration at radiology department [4]. The concept of semiotic interoperability is based on the semiotic framework [5]–[7] that explains all aspects of how signs can be used and communicated for successful communication. Using the concept allows different parties/processes/organisations to work together through communication with insight into six levels: physical, empirical, syntactical, semantic, pragmatic, and social. At the pragmatic level, the interoperability is concerned with the relationship between signs and the potential behaviour and intention of responsible processes. Thus we defined the pragmatic interoperability as a level concerning the aggregation and optimisation of various business processes for achieving intended purposes of different information systems. In addition to our definition of pragmatic interoperability, other researchers have also contributed. Benson [8] defines it as coordination of work processes across different people to enabling work collaboration. Sadeghi et al. [9] state the pragmatic interoperability in healthcare is the ability among healthcare processes and various actors (i.e. healthcare providers and patients) that interact with information systems. Successful communication at this level is achieved if the hearer understands the speaker's intentions, which goes beyond the semantic interpretation of the communicative act. Interoperability is achieved at this level when processes serving different purposes under different contexts by different information systems can be composed to jointly support a common intention.

## 3 Methods

The study is mainly conducted through interviews and surveys in two industrial companies and two hospitals in China. One of the companies is an automobile manufacturer, and the other one is a software company that provides integration solutions for various building control systems. The background of the automobile manufacturer is that they have enabled automated information sharing among three parties: dealership repair facility, automobile rental companies, and themselves. The background of the software company is that they are currently running several integration projects which manly aim to enable information sharing among systems such as Building Management System (BMS), Energy Monitoring System (EMS), Invasion Surveillance System (ISS), etc. The background of the hospitals is that they tend to achieve information sharing among Radiology Information Systems (RIS), Electronic Health Record (EHR), and Picture Archiving and Communication Systems (PACS). The Radiology department provides diagnostic and interventional radiology for inpatients, outpatients and general practitioner referrals. Various healthcare services such as Computed Radiography (CR), Computed Tomography (CT), X-ray, and Interventional Radiology produce a huge amount of information regarding patient's healthcare delivery and clinical process.

This study adopts a qualitative research approach including various techniques [10]. During the data collection process, we reviewed the most up-to-date working documents published by the companies and hospitals, conducted an observation, and interviewed 31 experts in order to gather their viewpoints as inputs for developing the assessment method. Details of each technique are presented in following:

**Documentation & Literature:** The documentation included literature review covering research publications, official reports, and working papers from the companies and hospitals. The research publications were sourced from several electronic databases in terms of information systems, process integration/alignment, and health informatics. The working papers were provided by the companies and hospital IT services department.

**Observations:** We conducted one participant observation in working on several projects for the software company; and other three non-participant observations in the automobile manufacturer and hospitals focusing on their work processes, staff routine, individual activities, and technologies/techniques used for information sharing.

**Interviews:** 31 semi-structured interviews (summarised in table 1) were conducted with relevant stakeholders. The interviews lasted around 40 minutes and were on a one-to-one basis. The interviews were tape-recorded and later transcribed and rendered anonymously. The results of the interviews are summarised into categories which are used as key inputs afterwards for developing the pragmatics assessment framework.

After summarising all the key elements from interviews, this study also conducted surveys to all the interviewees asking them to scale how much each element would affect the process alignment based on their experiences. However, the results of the survey will be presented in future work.

**Table 1.** Summary of interviews

| Sectors | Sample | Years of experience | | | | |
|---|---|---|---|---|---|---|
| | | 0-5 | 6-10 | 11-15 | 16-20 | 20+ |
| Industry | 22 | 7 | 11 | 2 | 1 | 1 |
| Hospitals | 9 | 3 | 2 | 1 | 1 | 2 |
| **Total** | **31** | **10** | **13** | **3** | **2** | **3** |

# 4 Findings

As mentioned previously, this section presents the results from interviews, observations as well as literature reviews. The key concerns and barriers when considering working collaboratively in organisations are identified, and then each of the identified concerns are pinpointed into the Pragmatic Interoperability Measurement Model developed previously [4] as the key elements for assessment. This section firstly recaps the three layers of organisation (Informal, Formal, and Technical) which is used for setting the outline of all identified key concerns, and secondly these concerns are categorised more specifically into each element for developing assessment method based on the process of achieving intended purposes, at last some of the key elements are selected for discussion.

Our previous work purposed the pragmatic interoperability assessment model [2] based on Organisational Onion [6] defining three layers for understanding and capturing key concerns when considering process alignment and working collaboration. As depicted in Figure 1, informal layer contains aspects such as community, social norm, policy, and culture. Those aspects can be expanded to be different behaviour patterns of both organisations and individuals. The pragmatic interoperability is to align the different aspects in order to solve conflicts of cohesiveness. In formal layer, business functions and procedures play dominant role that specifies on how functions should be carried out and how tasks should be performed. The pragmatic interoperability is to align procedures and rules in order to achieve higher efficiency. It defines business goals, model business processes and brings the collaboration of administrations that aims to exchange information and have different internal structures and processes. Besides, this layer also supports the upper layer by addressing the requirements of the user community such as making services available, accessible, identifiable and user-oriented. The technical layer mostly refers to the technical computer systems and their technical functions. The systems and functions can be programmed according to norms and procedures. The pragmatic interoperability does not directly refer to this layer but undoubtedly requires continuous support from it which is to align technical functions and business processes in order to achieve higher system productivity. It supports seamless sharing of data, which is automated sharing of data between information systems based on a common exchange model. It also covers the technical issues of linking computer systems and services. A few key aspects are included such as interconnection services, data integration, open interface, data presentation and exchange, and accessibility will be dealt within this level.

Based on the results from interviews, the following summaries a list of key concerns of pragmatic interoperability when considering processes alignment and working collaboration. They are split into three levels as discussed previously.

| | |
|---|---|
| *Informal* | Community, social norm, policy, culture |
| *Formal* | Organisational strategy/vision, business governance, domain analysis, organisational roles, functional profile, rules, procedures, |
| *Technical* | Data semantics, information infrastructure, information model, schema, script, interface, platform, deployment model, |

**Fig. 1.** Pragmatic Assessment Model [3]

- **Informal**

To enable collaboration between different processes/systems/organisations, a shared intended purpose plays a key role that supports perceiving of personal beliefs and organisational ground rules, whereas an un-shared purpose may be considerable conflicts between the organisational level and personal level. Issues like restriction to staff behaviour, information collaboration (information channels alignment), varieties of purchased information systems (different venders and services providers), and privacy and security concerns should be solved in this level. Taking one example from one of the interviewed hospital, the informal level is to concern with the understanding of the healthcare, regulatory, legislative and healthcare environment in which information systems need to be deployed to support healthcare delivery. It requires agreement on key organisational concepts such as policies, processes and roles; it also captures relevant patterns such as compliance, governance, legislative and change management. There are other concerns summarised in table 2.

**Table 2.** Other concerns at informal level summarised from interview results

| Concern | Explanation |
|---|---|
| Culture issue | Tacit knowledge has not been explicitly stated and shared |
| Ethical issue | Appropriateness of taking actions on healthcare service delivery |
| Behavioural factor | Willingness to be open and to share |
| Management style | Leadership style influencing the degree of willingness of collaboration |
| Policy and procedure | Internal control process, work flow, staff relationships, communication patterns, cut-across political boundaries, etc. |
| Restriction to staff behaviour | Staff's fear on integrated working process as restriction that might control their behaviour |
| Privacy and security | Sensitive information of patient to be protected by law |

Policy is one the most important and most widely mentioned key concerns in discussion of interoperability at informal level. From its perspective, collaboration always faces obstacles, because it cuts across political boundaries, and causes amount of changes (e.g. internal control process, work flow, staff relationships, communication patterns) in organisations [11]. For instance, in the healthcare, before the integration of RIS, the political issues between clinicians and radiologists have been raised for long due to the autonomous role of clinician. Comparing with the radiologists, clinicians have the right to choose and take responsibility for their treatments made, and they have direct access to

the policy making. The integration of RIS will enable the information sharing between the clinicians and the radiologists, so that patient's information and treatments made by clinicians will be transparent for the radiologists. However, it is challenged as clinicians have concerns that the information they collect and the treatments they made are proprietary and thus unavailable for inclusion in the process of information sharing. The integration of RIS also solves a political issue that clinicians who are geographically separated from the hospital were having conflicts for decision making. A quote from one clinician is: *"… All decisions have to be made with support of our staff… the integration has a chance to work here only if the staff can see the benefits… "*

In line with the policy concern, another one comes from the medical staff is that they are seeing the collaboration of working processes as restriction that would control their behaviour. They are more interested in research than administration, and they await more benefits to patient care delivery from the information systems integration, rather than the improvements of communication with the staff. This is the decisive factor that will let them accept the collaboration. Besides there are also concerns regarding culture, privacy, and security, but there are not as highlighted as the previous concerns, thus we will elaborate them in this paper.

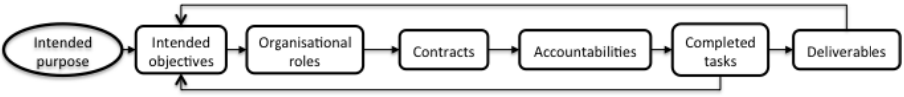


**Fig. 2.** Summarised procedure for meeting intended purpose from interview

- **Formal**

As discussed previously, to meeting shared purposes at formal level, organisations have a more specific procedure to follow. The procedure begins with setting up several intended objectives for the shared intended purpose, then allocates these objectives to relevant organisation roles, and signs contracts which define explicit tasks. The tasks relate to accountabilities for the completeness, quality, integrity and security of information that originates in one party and is transmitted to and used by another. Finally, the completed tasks with their deliverables are evaluated by matching the original defined intended objectives.

Besides the elements of this procedure, there are other concerns captured from the result of interviews (table 3).

**Table 3.** Other concerns at formal level summarised from interview results

| Concern | Explanation |
|---|---|
| Organisation structure | Centralised, decentralised, hierarchical, matrix, networked, etc. |
| Harmonized strategy | Aligned operations to be applicable on the strategic level |
| Performance constraints | Fewer investment but more effective collaboration |
| Cost constraints | Unexpected budget |
| Data source interoperability | Multiple data sources used for supporting process |
| Context awareness | Knowledge of context of both collaborative parties/processes |
| Varieties of purchased systems | Purchased systems from various venders with low capability |

To assess pragmatic interoperability, we should not only concern the information exchanged between technical systems, but also the knowledge of the context that the information exists within for each system or process. As quoted from one IT project managers, "*…It is important to articulate the requirement for context awareness that process representation begins. The context of the target system should also be made available to the origin system. Key questions such as what process will first operate on the information at the target system once it receives it, and what state of preceded processes are should be concerned…*" By understanding this context, the system engineer and integration designer can ensure pragmatic interoperability is addressed for the needs of process integration. To define the context, one manager of the logistics department said that *"Assume that the context is about internal workings of the process, in other words, the initialization state, the end state, the nature of data transformations, and details about the timing of the process are all considered, so that the receiving process can make better use of information it receives. This information is in context, but it also shows the dynamic nature of that context to the receiving system, because it now has specific information about the dynamic context within the originating system."* For example, context is seen as a demand for more information between the Model Manufacturing Demand Service and the Rental Fulfillment Service, so that a specific understanding of the models requested has a deeper meaning. This could be a specific based on the timing of the data, the initialization state of the Rental Fulfillment Service, and the data transformations. This gives a more dynamic picture of the context for the information being produced by one process for another, and allows for a deeper understanding of the meaning of that context.

Another example in the healthcare environment explains the concern of different data sources. The patient-centred care delivery is tailored to patient and requires collaboration of several information systems, and other involved team members also require the data of patient such as status and treatment. To deliver care for an individual patient, various activities need to be collaborative and to keep updating the database in real time. However, this collaboration is challenged duo to the complexity, it requires multiple data sources integrated to support the different requirements. *"… Originally, our IT environment operated with costly point-to-point interfaces, and we also lacked control of troubleshooting while the messages transmission failed… we operated within a manual environment where we needed to manually enter orders with their images received from outside reading facilities into our system, and had to fax copies back to the outside facilities…"* quoted from one clinician in radiology department. Information communication is also challenged due to the varieties of purchased systems for hospital. Those systems were provided by several small venders, who remained their competitiveness by selling only one type of systems or focusing on one specific function. This results in that the stakeholders get frustrated more often because the communication of patient's data/information failed among various systems. As one clinician stated: *"We became accustomed to telling our patients that we cannot provide the information for them immediately because their information cannot be accessed, although we have those information in the database… I normally have to download the hard copy and then manually re-input the data for my patient."* Furthermore, information communication is also challenged because the clinicians

and the radiologist were located in different rooms, and therefore the collaboration takes place asynchronously at most of the time, which can be solved via management channel.

- **Technical**

The purpose of technical level is to make exchanged data available for supporting the processes at upper level. For example, in healthcare environment, it is concerned with the understanding of technical functionality for supporting information systems. It requires agreement on a core set of technical concepts, such as technical components and devices, the interactions between components, interface and technical services; it also captures relevant patterns such as technical architecture styles and styles of component interactions. However, the study at this level is not the focus of the assessment of pragmatic interoperability, although it is vital to support the understanding the concerns of pragmatic interoperability at upper levels. Therefore, during the interview, only few concerns regarding technical level are summarised below, but we still purpose a method for dealing with those concerns in the next chapter.

**Table 4.** Summarised concerns at technical level from interview results

| Concern | Explanation |
|---|---|
| Semantic heterogeneity | Refers to the variation of semantic meaning in information resources which will lead to the semantic conflicts and complication for data integration |
| Ontology structure | Approaches that employ ontologies for information systems |
| Operation/system language | The language using in both systems |
| Ambiguous terminology | Differences in the use of terms across departments |

Next chapter will purpose a method for assessing pragmatic interoperability based on the results collected from this chapter. The method contains two parts: one gives all the elements of pragmatic interoperability that should be concerned when considering process alignment and working collaboration, and the other one is a supplementary method for dealing with technical concerns.

## 5 A Method for Assessing Pragmatic Interoperability

The nature of information communication relies on successful signs communication [1], which must start with understanding and modelling the organisation where information communication exists [6]. The organisation onion [7] stresses the distinctions as well as the interdependent links between the business process and IT systems. The organisation morphology provides a useful modelling method for understandings the norm structure of organisation. Each organisation can be characterised as a structure of norms that allow functions to be coordinated for certain purposes [6], and pragmatic interoperability, is to enable the purposes of each process can be understood and perceived during collaboration. Based on the results collected from the interviews and observations presented in previous chapter, we purpose a method for assessing pragmatic interoperability which contains two parts: one gives all the elements of

pragmatic interoperability that should be concerned when considering process alignment and working collaboration, and the other one is a supplementary method for dealing with technical concerns.

Figure 3 depicts the method purposed for assessing pragmatic interoperability. In the informal level, two key elements are defined: community participation refers to what parties in what roles are eligible to participate and what are the prerequisites for their participation, and policies refer to those policies within each party's jurisdiction that influence the interoperability of the organisation. Organisation may encode business rules that are not explicitly specified but cause incompatibilities in exchanged information. Aligning policies across jurisdictional boundaries is one of the most difficult tasks of collaboration.

In formal level, meeting shared intended purposes is the goal of achieving pragmatic interoperability when two process/organisations working collaboratively. The procedure has been identified based on the interview results. It begins with setting up several intended objectives for the shared intended purpose, then allocates these objectives to relevant organisation roles, and signs contracts which define explicit tasks. The tasks relate to accountabilities for the completeness, quality, integrity and security of information that originates in one party and is transmitted to and used by another. Finally, the completed tasks with their deliverables are evaluated by matching the original defined intended objectives.

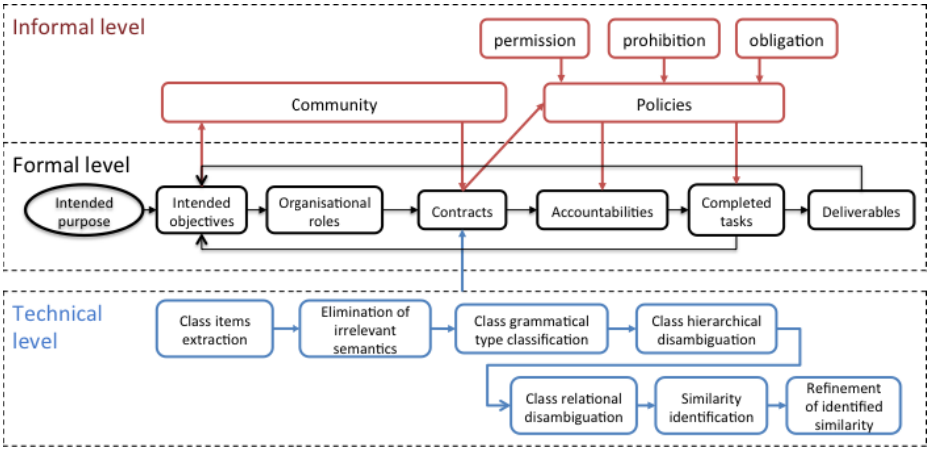


**Fig. 3.** Method for Assessing Pragmatic Interoperability

In technical level, we purpose a matching process that deal with the concerns summarised from the interview results such as semantic heterogeneity, ontology structure, and ambiguous terminology. The process contains seven steps (class items extraction, elimination of irrelevant semantics, class grammatical type classification, class hierarchical disambiguation, class relational disambiguation, similarity identification, and the refinement). In the class items extraction phase, the goal is to represent all the classes of the ontology in the same form. It is to represent each class like a set of terms. The characters are executed without meaning as so punctuation marks or spe-

cial characters. When dealing with issues like too many corresponding senses for each class term, the steps of grammatical type classification, hierarchical disambiguation, and relational disambiguation are used for articulating semantics of the information. After semantic disambiguation, different ontologies are compared by using defined metrics in order to identify and refine the similarities. As the matching process using at this level is not the focus of this paper, thus the elaboration of the process itself as well as its application and validation will be presented in future work.

## 6 Conclusion and Future Work

This paper is the extension of our previous research. It proposed a method for assessing pragmatic interoperability for process alignment in collaborative working environment. The study is conducted qualitatively by using techniques of interview, documentation, and observation. The results collected firstly summarised into three layers based on our previous developed pragmatic assessment model, and then categorised them into elements which constitutes the purposed method. The method contains two parts: one gives all the elements of pragmatic interoperability that should be concerned when considering process alignment in collaborative working environment, and the other one is a supplementary method for dealing with technical concerns. Validation and application for the purposed method will be presented in future work.

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# Clarifying the Situational Context of a TV Company towards the Design of iDTV Applications

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**Abstract.** Television has experienced transformations that directly impact the TV companies' production chain. In this sense, digital technology and *Interactive* Digital Television (iDTV) represent business opportunities in terms of investment spent by broadcasters. In this paper, we investigate the impact an iDTV application might have within a TV company by analyzing a situated context. To clarify the problem, we use the knowledge produced from workshops that were based on the Socially Aware Computing approach and that involved various stakeholders to design an iDTV application in a real context. The analysis is illustrated with the graphical representation of Ontology Charts and Norms projected for the observed organization. The findings indicate organizational changes that both suffer from and cause impact on the design of this kind of application.

**Keywords:** Organizational Semiotics, Semantic and Norm Analysis, Design Process, Interactive Digital TV, iDTV applications.

## 1 Introduction

Terrestrial TV has undergone transformations since its establishment. The first images were in black and white, with poor image and audio quality at the receiving end. Sometime after, analog TV won a new attraction: colors. Color TV was a dream of consumption for most viewers and boosted the reach of TV on society. The last major milestone has occurred with the arrival of Digital TV (DTV). DTV includes transmission and compression of digital signals, receiver processing capability and interactivity, thereby enabling Interactive Digital TV (iDTV) [10]. During this migration process, broadcasters have to adapt constantly in order to both meet the technical needs and please an ever more demanding audience. Hence, the TV companies need to improve their production chain with new methods to produce their programming. Such investments require new business models that justify these changes and bring benefits to broadcasters as well as to the audience. In this sense, the investments on DTV and iDTV should be understood as an opportunity to explore the development of new applications, reorganization of television production chains, generating business and social transformations [9].In fact, TV is a highly social and pervasive technology — characteristics that make it a challenging and interesting field for investments.

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With the arrival of DTV, a new business model emerged, and later iDTV opened up a variety of possibilities for new services for TV [15]. Cesar et al. [7] also draw attention to TV's potential social impact, and suggest research on iDTV that incorporates characteristics of viewers and everyday lives. For Kunert [11], beyond better quality in audio and video, viewers can actually interact with the TV, creating a close communication channel between the viewer and the TV companies. Moreover, in order to bring viewers to TV, Pedrosa et al. [14] consider the use of smartphones and tablets in the interaction with TV.

However, the design of interactive applications could be considered a new component into TV companies' production chains. While on the one hand, TV companies still do not have a culture of developing software systems, on the other hand, the software industry has no experience in producing TV programs. Thus, there is a need for creating a specific process for developing iDTV applications that considers both the particularities of television production and the foundations of software development processes [19]. When the need to design a new technology for a company arises, it seems necessary to understand the context into which the system will be inserted, and the main forces that act on it directly and indirectly. Understanding the forces that govern organizational contexts and identifying ontological relations and norms is necessary for the system to make sense to the company and its various sectors [12].

In this paper, we draw on the knowledge produced through workshops conducted in the practical context of a Brazilian TV company that is about to create its first iDTV application. The workshops were conducted in order to clarify forces that emerge within the practical context of this TV company towards the design of iDTV applications. The workshops were organized and conducted on the grounds of the Socially Aware Computing [2] approach to design, Organizational Semiotics [12, 17] and Participatory Design [16]. We discuss the main findings revealed from the study of Ontological Charts that were created from these situated workshops, and are grounded on Semantic Analysis Method (SAM) and the Norm Analysis Method (NAM). Our goal is to explorer how these methods can help us to understand the organizational context and also to anticipate organizational changes that might have an impact on future investments into the production chain and on the TV company's way of doing business.

The paper is organized as follows: Section 2 introduces the theories and methods that ground our work; Section 3 describes the practices conducted to support a situated and participatory design of iDTV applications; Section 4 presents the Semantic and Norm Analysis to clarify the situational context before and after the introduction of iDTV applications in the TV company production chain, and presents and discusses the main findings. Section 5 presents our final considerations and directions for future research.

## 2 Background of the Work

Organizational Semiotics (OS) understands organizations of people as complex systems of sign processing, and recognizes that a technical system is only part of a wider complex system in which people behave according to an organized system of norms. For this, OS proposes a comprehensive study of organizations on different levels (informal, formal

and technical), and their interdependencies. According to Liu [12], organizations themselves are information systems, and the organizational functions in these different levels are essential for designing a technical information system for this organization. In the informal level, an organization is composed of social norms that drive people's behavior, perceptions, beliefs, values, customs, habits, culture, etc. In the formal level, an organization has their own rules and bureaucratic procedures to do mechanistic and repetitive tasks. The technical system is a part of the formal level which can be automated.

In order to facilitate a better understanding, development, management and use of information systems, a set of methods known as MEASUR (Methods for Eliciting, Analyzing and Specifying User's Requirements) was developed in OS [17]. In this paper, two of these methods inspired our analysis: Semantic Analysis Method and Norm Analysis Method. The understanding of the design problem in the situated context was supported by practices of Socially Aware Computing [2].

Semantic Analysis Method (SAM) is a method to understand the nature and role of affordances (invariant patterns of behavior) and agents (affordances that can take responsibility both for their own and other affordances) in business systems. A business system could be considered a real information system, which is infinitely complex, and only a part of it can be modeled: just a realization (or an instance) of patterns agents' behavior. In practice, SAM focuses on the responsible agents and their repertoires of behavior. For this, the ontology chart maps the temporal relationships between the agent and affordances [12].

Norm Analysis Method (NAM) is a means to specify the temporal patterns of behavior (the social, cultural and organizational norms) governing the agents' actions in the business domain. Norms are linked to each part of the semantic model as the conditions and restrictions for the accomplishment of affordances. A norm can define responsibility for an agent occupying a certain role inside an organizational context and can specify conditions in which some agent can perform some action inside it. Norms have valid periods of existence and can be further specified in a structured way for being translated into a computable language [12].

Socially Aware Computing (SAC) [2] is a socially responsible, participatory and universal approach to the design of systems. SAC draws on OS [12, 17] to understand the context in which the technical system will be inserted and the main forces that directly or indirectly act on it; and on Participatory Design (PD) [16] to involve heterogeneous groups of people, who may influence and/or may be influenced by the problem being discussed, and to understand the situated context.

SAC understands the design of a system as incremental cycles that start from society and cross the informal and formal layers to produce a technical solution for an organization. The movement returns crossing the formal and informal layers alike, and impacting on the society; new incremental cycles may be necessary for the technical system to fit the needs of the organization.

## 3 The Situated Study

The study scenario is EPTV: a Brazilian broadcasting company whose program reaches a region in Brazil that includes 300 cities and more than 10 million citizens [8]. Four participatory workshops were conducted in the situated context of EPTV

aiming at the design of an iDTV application for the TV program "Terra da Gente" (TdG; "Our Land" in English; [18]). Ten participants directly and indirectly involved in the problem domain (e.g., designer, engineers, researchers, TV program director and interns) participated in these workshops.

The workshops were grounded on the SAC approach [2], which was instantiated for the situated context of EPTV (cf. Fig. 1). In this context, we used artifacts from and inspired by OS, such as the Stakeholders Identification Diagram [13], the Evaluation Frame [1], and the Semiotic Ladder [17], and created new practices for supporting participatory and situated design activities. The activities encompassed (see Fig. 1): A) the problem understanding, the proposal of solutions, and the analysis and organization of requirements for the application to be designed; B) Prototyping activities through an adapted version of the Brain Draw participatory technique; C) The materialization of the final prototype; D) Evaluations by representatives from the target audience, by Human-Computer Interaction specialists, and also in a participatory practice with the workshop participants. These activities contributed to the problem clarification, as well as to the design and evaluation of a prototype for an iDTV application. The interested reader may consult [4], [5] and [6] for detailed results and discussions related to these activities.

In this paper, we use information raised from the discussions during these workshops with the EPTV team in order to illustrate the company's organizational structure behind the TdG TV program. The intention is to show how the company is currently organized and uses efforts of several teams that influence and suffer influences from the TdG program to create a first iDTV application. Moreover, we wanted to prospect, according to the participants' perspectives, which organizational changes in the company might arise from the introduction of an iDTV application in the TdG production chain.

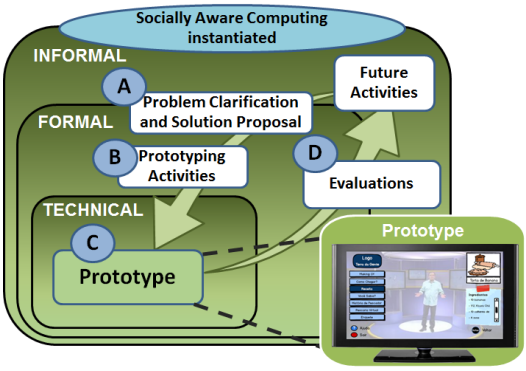


**Fig. 1.** Situated instance of SAC's meta-model for design

## 4 Towards Semantic and Norm Analyses

The following text is a description of the EPTV company based on the shared knowledge constructed during the workshops with the EPTV team.

EPTV is an affiliate of a large Brazilian broadcasting company. Currently, EPTV has several teams who work in different sectors that cover the management, production, marketing and transmission of the TV company. EPTV consists of a group with four main stations, and with the support of several rebroadcasting stations, it can cover all its audience with digital and analog programming. EPTV, as well as other affiliates, produces several regional programs (journalism and documentaries) that complement the national programming provided by the parent company, and reaching the local audience and providing marketing opportunities to advertisers and sponsors in the region. EPTV competes with other TV companies in order to attract the audience.

TdG is one of several programs produced by EPTV. TdG's production team works with a cohesive team of editors, writers, producers, designers, technicians and journalists, among other staff members. In addition to the television program, the TdG team also produces a printed magazine and maintains a web portal. Both the magazine and the web portal serve as complementary sources of material for the TdG audience and support TV programs from the parent company. Each member has well-defined rules inside the TdG team. For instance, the Chief Editor is the person who coordinates the production team (e.g., editors, journalists, designers, etc.) of the television program, web portal and magazine. The graphic designer is responsible for the graphic art of the television program and the web portal, and will be responsible for the graphic art of the iDTV application. TdG's team might also be engaged with financial issues such as making feasible the TV show's production costs and minimizing risks raising funding for the program as advertisers and sponsors.

After the program is produced, TdG has the support from the engineering team to transmit the program to its audience. The engineering team is responsible for technical aspects of transmission of several TV programs produced by EPTV, and also for the retransmission of television content that comes from the parent company. Engineering is also responsible for providing technical support (e.g., links between TV companies, TV programs produced for other affiliates) to distribute content among regional branches of EPTV, the parent company and other affiliates. Finally, engineering is responsible for entering data related to the local program, such as electronic programming guide (EPG), software updates and closed caption that complements the TV's schedule and are broadcasted together. The engineering team must also follow the DTV standards because the TV signal must run on several television receivers from different manufacturers. Any improper use might result in the TV signal not running properly or even blocking the receiver.

EPTV works with other relevant teams, e.g., for managing the organization and for hiring staff, but those are out of the scope of this paper. Figure 2 shows the ontology chart created for the EPTV company representing the TdG TV show as the focal problem.

When an iDTV application is introduced into a TV production chain, a development team is required in the TV company to develop the application in accordance with the programming languages defined by the Brazilian DTV standard (ISDB-Tb). For the application to use the interactive channel from connectivity companies, it is also necessary that this new team offers technical support for connectivity problems and management of data received from viewers. This team could be introduced inside EPTV as a separate department, as part of the production team or as part of engineering team. Moreover, it might be an external software company developing services

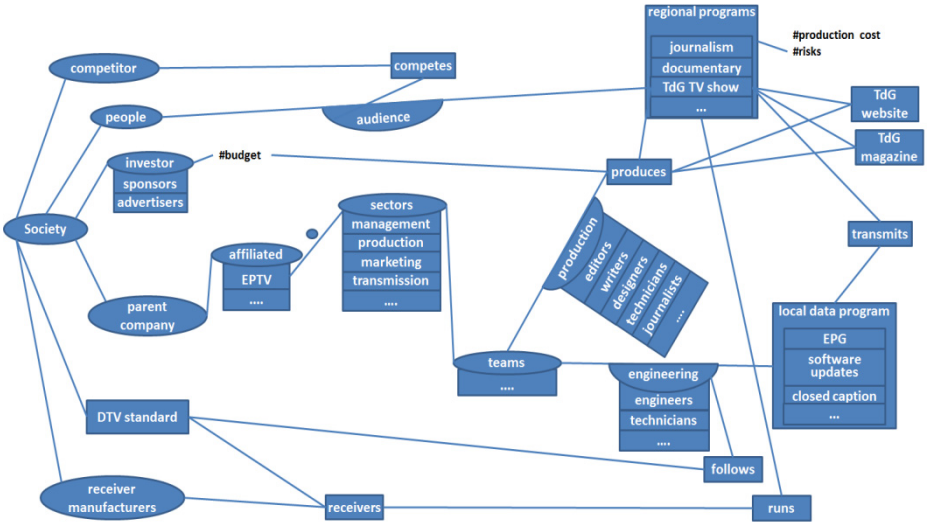


**Fig. 2.** Ontology Chart of EPTV representing the TdG TV show as the focal problem

for the TV company. Workshop participants suggested that the iDTV design team could be included into the production team but receiving support from engineering.

The engineering team also should propose novel technologies that can be incorporated into the TV company's production and transmission chain generating a relative market advantage. For instance, in the case of an iDTV application, engineering should evaluate solutions (e.g., programing language to be used, how to design the application, how to broadcast it) suitable to the organization's necessities. For engineering, the development of an iDTV application should require resources for purchasing multiplexing and broadcasting equipment to transmit the application with the TV show content. Furthermore, engineering should allocate human resources to operate such transmission equipment and adjust transmission according to the norms from the parent company, e.g., technical norms. The engineering team must also adjust bandwidth for the application transmission, making sure it will not overload the total bandwidth available for the transmission of television content, which includes video, audio and other data types. The period in which the application should be transmitted should also be adjusted according to the duration of the TV show. Thus, the application and its transmission should be of easy operation. Once implanted, these activities may be automated to require less effort from the engineering team.

The production team should consider that the insertion of an iDTV application might increase the TV show audience by people who like new technologies and innovations. Thus, the production team should conduct a careful analysis of the existing and potential future audience. If the iDTV application does not gain public acceptance, then it must be reformulated and not be transmitted together with the TV show. The production team must also produce the informational content of the iDTV application since it complements the current TV show. Similarly, a designer from the TV show should produce the visual iDTV application layout so that the application has the same visual identity as the TV show. The rationale to guarantee consistency between the TV

show and the application is to promote integration, i.e. by stimulating viewers to access additional information about the show or answering quizzes about the show's content.

The design of iDTV applications involves the allocation of additional resources (e.g., people and money), and this kind of application can introduce risks for the TV company since it is not yet fully consolidated in the market and does not have the full acceptance from viewers yet. Thus, the production team should analyze the viability to produce iDTV applications according to resources from the TV company.

On the one hand, EPTV understands that producing iDTV applications is a necessity from the market because other affiliates and competitors provide this type of application in their schedules. On the other hand, some sponsors and advertisers might not want this type of application because it can distract viewers, reducing their attention to their ads. Finally, as the television content is dynamic, the application development process and the produced application should be easily customizable.

Figure 3 shows the diagram with the partial Ontology Chart after inserting the design of an iDTV application within the chain of production for the TdG TV show at EPTV. The Ontology Chart is instantiated in the focal problem related to the production of the TdG TV show and the design of an iDTV application for it.

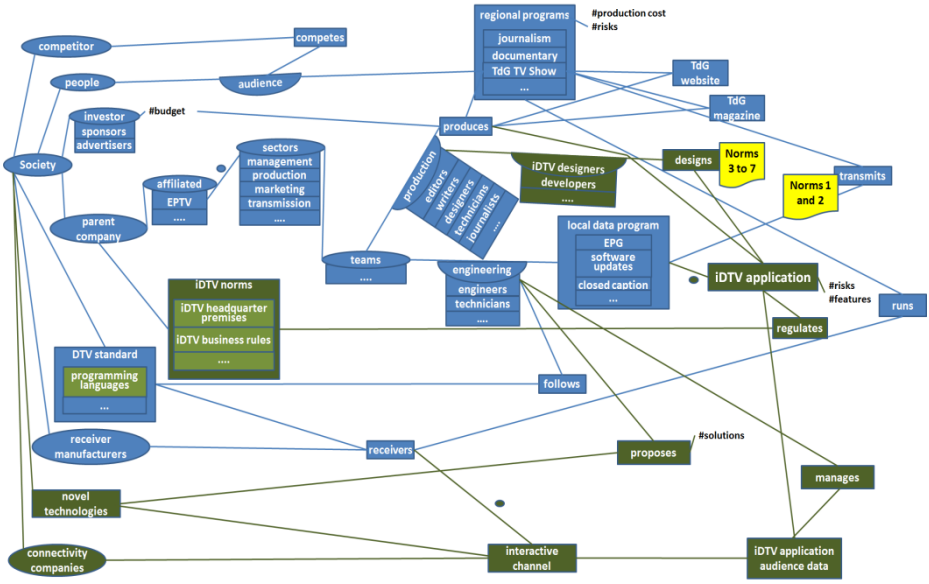


**Fig. 3.** Ontology Chart of EPTV after insertion of the design of an application iDTV

New norms (previously cited, and shown in Table 1) that impact on these ontological relations emerged (see Fig. 3). These norms should be analyzed by teams to identify the feasibility to produce the iDTV application. To make the dynamic part of the informational system explicit, the rules of behavior used in this paper are structured according to the behavioral norms format [12] "WHENEVER <condition> IF <state> THEN <agent> IS <deontic operator> TO <action>". Table 1 shows some of these norms: the first column contains an identification number to reference the norms in Figure 3.

**Table 1.** Some norms for EPTV after insertion of the design of an iDTV application

| Concern | Explanation |
|---|---|
| **1** | **Whenever** "an iDTV application needs to be transmitted" **if** "it is associated with a TV Show" **then** "the engineering team" **is** "obliged" **to** "adjust bandwidth and transmission time according to the duration of the TV Show" |
| **2** | **Whenever** "an iDTV application needs to be transmitted" **if** "it cannot spend a lot of resources" **then** "the engineering department" **is** "permitted" **to** "facilitate or automate the transmission operation" |
| **3** | **Whenever** "an iDTV application is designed" **if** "it addresses a diverse target audience" **then** "the production team" **is** "obliged" **to** "carefully analyze the audience" |
| **4** | **Whenever** "an iDTV application is designed" **if** "it doesn't have public acceptance" **then** "the production team" **is** "permitted" **to** "reformulate it or do not broadcast it together with the TV show" |
| **5** | **Whenever** "an iDTV application is designed" **if** "there are high risks for the TV company" **then** "the production team" **is** "obliged" **to** "analyze the risks to design iDTV applications" |
| **6** | **Whenever** "an iDTV application is designed" **if** "distract the audience in viewing ads" **then** "EPTV" **is** "permitted" **to** " customize the iDTV application to prevent that this happens" |
| **7** | **Whenever** "an iDTV application is designed for TdG" **if** "it must be updated weekly according to the current TV show content" **then** "the production team" **is** "permitted" **to** "develop easy to use mechanisms for customizing the iDTV application" |

### 4.1 Synthesis of the Discussion

EPTV workshops helped to understand in practice that to produce iDTV applications, the production chain requires efforts of several teams from the current broadcaster's production chain. Actually, an iDTV application in a TV show changes the model of developing TV content, and teams are not fully prepared to deal with the changes adequately. In addition, the passive viewer becomes an active user with the arrival of iDTV and should be examined more cautiously. Leaving this responsibility to software companies may not be suitable because of the difference between the TV show and the application domains. Finally, market uncertainties and the viewer's acceptance make it even more difficult to invest in resources for producing iDTV applications. Knowing the TV Company's situated context was a first step to understand these challenges and to propose a design process for iDTV applications that make sense for its different stakeholders, including the final audience.

The ontology and norms analysis performed to map out the organizational structure before and after the insertion of an iDTV application showed substantial changes in the organizational structure of the TV company. New organizational affordances, agents, norms and ontological relations emerged. It also was possible to point out what and where these changes occurred, giving an indication of how they should be taken into account in the adaptation process for inserting the iDTV applications in the TV production chain.

The ontology relations and norms were used in this paper to understand the situated context from a TV company, and some terms (e.g., EPTV and TdG) appear as realizations or instances of "universals" (a kind of a concept) and "particulars" (a concept). Although different from the proposed in the formal literature [12], these representations were useful to highlight organizational changes from a focal problem within the situated context of a company.

Even though the norms and ontology analysis came from knowledge of the situated workshops, many of the findings pointed out by the analysis may inform other organizations with different organizational structures.

## 5 Conclusions

The development of a TV show can be seen as efforts of skilled individuals working in teams. Each element has an important role in the development phases of the program [3].

In this paper, we analyzed in a situated context what impacts the insertion of an iDTV application might trigger in a TV company production chain. The findings indicate challenges that a TV company must face to restructure its internal production chain in order to support iDTV applications. In this sense, this study might be helpful to anticipate the impact that an innovation (e.g., a new model of the production process) can cause within the organizational system of the TV company. Furthermore, show the knowledge that emerges from an organizational analysis in situated context opens opportunities for future studies in the iDTV field, whether they either theoretical or fundamentally practical.

As future work, we intend to develop a design process for iDTV applications that considers the needs of different teams that compose the TV company in order to propose a process that fits the reality of the TV company, and which also takes into account the needs of a diverse target audience.

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# Applying Organizational Semiotics for Developing Knowledge-Based Cost Estimation of Construction Project

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**Abstract.** Cost estimation is a dynamic and knowledge intensive process. Current practice of construction cost estimation is a process with fragmented knowledge. In order to have an integrated process, semantic should be modelled in respect to pragmatic. The investigation of BIM-based cost estimation confirmed that IFC can provide construction project semantics but incapable of relating domain semantics and pragmatics. In order to overcome this gap, we adopt organizational semiotics to fully reveal semantic units of cost estimation from a process perspective. Pilot study confirms feasibility of this approach. Future research will be a case study to collect all the instances for semantic units. Then semantic consistency and pragmatic implementation should be realized by the applications. This research highlights the importance of alignment between semantic (domain ontology) and pragmatic (meaning in use), it contributes also to identify a new approach of knowledge engineering for construction professional services under BIM environment.

**Keywords:** analytical cost estimation, knowledge representation, information system development, industry foundation classes, quantity surveying.

## 1 Introduction

An exploration and analysis of various BIM-5D applications confirmed observations in the literature that model-based construction cost estimation need a new method that could meet the need to core cost estimating workflows [1–3]. Because in addition to material quantities, product features, such as openings and repetition, also affect construction costs [4]. Previously such factors are being considered by expert into the adjustment of estimation [5]. This approach is often difficult to integrate into current computing practices because it is a 'black box' and difficult for computer to understand [6]. Therefore, existing software tools do not explicitly capture quantity surveyors' rationale for how the component properties and product features affect the cost information and cost estimation requires contextual information and current support is in-

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sufficient for this requirement [4]. Meanwhile, conventional programming language is insufficient to deal with certain estimating activities for example comply with standard, which is an essential requirement for costing practitioner.

Existing knowledge engineering process produces ontology, in the form of classification systems and product data models, lacks effective modelling of concept semantics and related pragmatics: a fundamental requirement for human-based exchange of knowledge [7]. Being investigated into human reasoning processing, more specific, the cost estimating process consists of locating objective information, recognizing it in the immediate situation or in the past, evaluating the objective information, combining the information together, and then implementing it as a certain value of estimation. With the development of information technology, locating objective information is helped by using a search engine, recognizing objective information in the immediate situation or in the past is facilitated by cost database (cost index). However, by lacking a knowledge model of cost estimation which integrates domain semantic and pragmatics, the issues remain the same, firstly time is insufficient for doing cost estimation [8], secondly we are hardly able to find the valuable information [5], thirdly, cost estimation requires contextual information [4].

Furthermore the general idea is that data and services are semantically described with respect to knowledge representation language, which are formal specifications of a domain of interest, and can thus be shared and reused in a way such that the shared meaning specified remains formally the same across different parties and applications. Then a business process is being modelled with norms in order to capture the application logic. Finally a special purpose reasoning engine could be employed, based on logic programming that operates on the above two structures in an integrated way. The paper has been structured as follows: we firstly study the advantage of applying the framework, in which corresponding to the knowledge capturing problem in quantity surveying organization. Then the results of pilot study have been demonstrated to show feasibility of introduced approach. Finally conclusion and future research is presented.

## 2 Semiotics in Construction Domain

While the development of information technology, many software applications, for instance Sage Timberline [16], Innovaya Visual Estimating [17], CostX [18], and Nomitech [19], have been developed and applied in the construction cost estimation. However, based on case studies of the software using in cost estimation process, for instance BIM cases [1–3,20], and quantity surveyor cases [21–27], estimators still have to read and extract useful information from the model or manully rebuild a three dimentional model specific for cost estimation then conduct measuring by strictly complying with specifications such as SMM [28] or Professional Practice Guides [29] then applying unit price intuitively. Because of working complexity and comprehending deviation during the process, analytical cost estimation is both time-consuming and error-prone [30].

To improve the communication efficiency of BIM, Hartmann (2012) introduces semiotics to analyse BIM systems. This semiotic framework is focusing on technical perspective [10], according to Liu (2000)'s semiotics ladder, it focuses on IT-platform, however, to author's best of knowledge, the communication problem is an

inherent issue due to the nature of construction industry [12]. The analysis solo focuses on the technology part cannot solve the inherent problem of construction industry. High level requirements are not technical, but mainly social and organizational. Therefore, the success of information systems implementation depends more on how well an organization is prepared and organizational aspects are integrated rather than the pure technical systems itself [13].

Eastman [14] reveals that there are two major perspectives that influence the form of information technologies in the building information modelling: the organizational perspective, the technical perspectives, which includes software technology, the system architecture perspective, and the modelling technology perspective.

Organizational perspective depicts the structure of organization will influence information exchange and integration requirements. For example, traditional construction team, which is a virtual team with dispersed members working for a single project will have different requirements in contrast to an international building company that have various divisions, such as design, costing, and construction divisions [15]. Organizational requirements will guide the information techniques of the construction industry. Technical perspectives describe contribution from software technology, for instance new programming languages, function libraries, and exchange standard; the system architecture perspective, for instance different implementation methods, service oriented architecture (SOA) and P2P networks etc.; and the modelling technology perspective depict different modelling languages which focus on interoperability issues.

### 2.1 Current Ontology Application in BIM-Based Cost Estimation

Based on our literature reviews, current BIM-based cost estimation is a fragmented process with knowledge. Along the cost estimation process, IFC model provides the information of a building, IDM verifies the information exchanged between IFC model and the cost estimation, says quantity take off [31]. And the IFD supply the detailed components information contained in the general IFC model, however supports to cost estimation is not facilitated. Thus we need further improvement to BIM-based cost estimation.

In table 1 these researches highlight that highlight the gap of BIM-based cost estimation which it doesn't satisfy the needs of domain users. The different ontology languages used concerns us, we argue that without a process for integrating knowledge of cost estimation, such kind of knowledge is still lost by the system and mainly maintained by individual cost expertise. Furthermore we also believe that the general process can be further breakdown to support professional activities in detail, for example describe, identify, select, and adjust etc. can be employed to describe professional cost estimation process. We believe that without a new stance to review cost estimation as a human intervention process and without a comprehensive framework to provide a foundation of interaction between IT platform and human function, professional works cannot be further improved.

The greatest challenge however is that of engaging in the development of knowledge representation in BIM-based model which is a knowledge representation language as well. This requires a fully “a cost estimator mind” with high software modelling knowledge that can model the processes of developing a cost estimation. Thus it represents two major problems that the complexity of knowledge language

**Table 1.** Comparison between estimation methods

| **Estimation method** | **General Cost Estimation Process** | |
|---|---|---|
| | Cost Item Quantification | Unit Price Determine |
| **Conventional Cost Estimation** | Manual | Manual |
| **BIM based Cost Estimation** | Automatic* | Automatic* |
| **Ontology Improved BIM and language used** | 1: Describe cost item comply with standard; IFC-based ontology.<br>2: Identify working condition to select cost item; OWL | 3: Identify project location to select labour cost; UML+OWL.<br>4: Identify construction condition to adjust unit price; ontology language not specified |

Note: BIM based QTO and price identification doesn't comply with standard
1: [32]; 2: [33]; 3: [34]; 4: [35]

(industry foundation classes and ontology language) can hardly be understood by the domain user meanwhile knowledge engineer doesn't understand cost estimation in a good picture which could break cost estimation process into piece. Thus it is essential to have a knowledge capturing process could facilitate an integrated estimation process for estimating domain or at least could capture semantics and pragmatics.

### 2.2 Advantage of Applying Semiotics Framework to Cost Estimation

The adaption of the new approach needs a strong justification as it is essential for us to question about why stand from an organizational perspective for cost estimation. Capturing the rationale and identifying the knowledge intensive processes is not a trivial task. It is difficult for experts to explain what it is that they know. To data, the only thing we know is that the expert in the quantity surveying organization needs to make assumptions about future cost resulting from: different locations, fluctuation of labour productivity and changes in the market conditions [36,37]. Corresponding to our two problems of cost estimation, which are quantification and pricing. In software, the main stream is quantification which start with building drawings. Firstly expertise will extracting a set of building elements from drawings, then decomposing them into cost items. Once these cost items are complied with standard, they often make comparisons and references to historical projects respectively in order to predict the cost of the new project [38].

Together with the concerning of the development of information system, we adopt organizational semiotics which trying to understand cost estimation from an estimating process perspective. By capturing knowledge, the reasoning and inference steps can be delivered to the development of information system. We incorporate a suite of semiotics tools: semantic analysis and norm analysis [11]. Firstly, it identifies concepts of interest and the ontological dependency between semantic units, having established the ontology chart; it will then ascertain the semantic relations. Hence,

formalising these relationships to model the behaviour of organisational systems design [39]. In our research, the main focus addressed in engineering aspect has been put onto knowledge representation and information analysis to provide pragmatic and semantic support to quantification and pricing for cost estimation. This engineering perspective is related to information system engineering, which studies information system design and development. There are two major reasons why the engineering aspect is important to the automatic cost estimation:

- Adopting a proper information system engineering perspective helps grasping quickly the importance of information analysis and knowledge representation for cost estimation. The knowledge and information have to semantically represented, and reasoning engine can be supplied to enable estimator to leave tedious works as much as possible to system, in other words, to enable the system to automatic or semi-automatic perform cost estimation;
- On the other hand, with the rapid development and heavy use of IT, cost estimation needs a technology-led updated estimating approach. This approach should incorporating human inference, and we argue that the analyst should use compatible and systematic analytical methods as used in information system engineering or the related disciplines. Gaining a clear understanding of the state-of-the-art approach to information system could nourish the ideas for up-to-date studies of cost estimation and receives the payoff from information system for cost estimation;
- The semiotic approach takes one a step further. It will stress the distinctions as well as the interdependent links between the organization, the business process and the IT system. The notion of human responsibility and possibility of delegation of functions to an IT system is clarified.

Therefore, the authors' approach to 'expertise-based' cost estimating, is first to examine the current practice via a well-established framework, which links the physical world and social world through the information mechanisms expertise use in the organization. Secondly we employ semantic analysis in order to understand and capture the procedure knowledge used by experts when perform surveying, moreover standard investigation and observation have been conducted. By understanding these issues, it becomes possible to model the expert behaviour and further developing model in the sense of computability. Furthermore integrating such knowledge in a BIM system which enabling a knowledge-based approach to professional services. It is interesting to notice that some researchers are tagging IFC model as a semantic rich model [40–42], but others are claiming that IFC has insufficient semantic contained in the entity and relationships [43–45]. This conflict has been addressed by our framework.

## 3 Pilot Study and Results Discussion

An investigation of BIM-based cost estimation through organizational semiotics ladders has been conducted, from the physical token to social norms, six aspects of signs in the semiotics ladder of IFC-based cost estimation summarized the findings in the

analysis, due to page constraints, and detailed results are not presented in this paper. At technical perspective, in the physical level, STEP file and API usage is sufficient for establishing software integration and database exchange, however there is no implementation in knowledge base. In the empirical level, the emphasize is focused on IDM, which provides a mechanism to reduce the information uncertainty, however it is still highly in the initial phase and did not address the semantic, pragmatic and social problem derived from organizations. In the syntactic level, IFC provides a powerful schema that transmit construction information for all stakeholders but the redundancy and complexity of schema is barrier for the implementation. Moreover, regarding the domain practice, in other words the professional service provided by the participants, is requiring new entities that should be defined in the schema, especially the standards and professional activities.

IFC lacks the formal specifications to relate the entities and relationships to reasoning mechanisms from the human reasoning process perspective. As we discussed previously without an integrated process of cost estimation and a systematic framework, in the semantic and pragmatic level, the pattern of behaviour is not fully recognized and defined. For instance, in the current detailed cost estimation process, Comply with standard is a description of this behaviour, but the activities are not recognized nor computer supported. Other examples like forming behaviour which should before adjust behaviour has not been recognized either. These unrecognized behaviour patterns on the one hand are providing the flexibilities to do cost estimation but also is a time consuming process for cost estimation as expertise are mostly dealing with various software packages and attempting to link all these behaviours together to deliver cost estimation via quantity surveying approach.

After producing ontology chart of QS organization, the above three ladders, which are semantic, pragmatic and social, can be covered from an organizational perspective. Semantic analysis reveals professional activities that expertise are acting to accomplish their tasks. Norm analysis shows the pattern of expert problem solving and the logic behind the process. Briefly, professional activities and norms can be defined in the semantic. The affordances revealed in the semantic analysis can be formed as information requirements in empirical level. In figure 2, due to page limitation, we represent the stage of preparation (it can also be called classifcation stage), there are four actions we need to focus. They are dissemble, decompose, selects and synthesis. Figure 2 represents the semantic units translated into semantic web ontology (OWL), which is a knowledge representation language. The language has been widely accepted and used in the construction domain. All the categories can be related with professional activities, e.g. quantity surveying in the object property. It is important to notice that the most important aspect of OWL is their emphasis on tractability of inference. Furthermore a problem instance is solved by describing it and then asking if it is subsumed by one of several possible solution categories. By revealing professional activities and showing the dependency between semantic units as well as employ a special purpose reasoning engine, for example rule-based reasoning in logic programming, we could get a step further to implement the knowledge-based system, see figure 3.

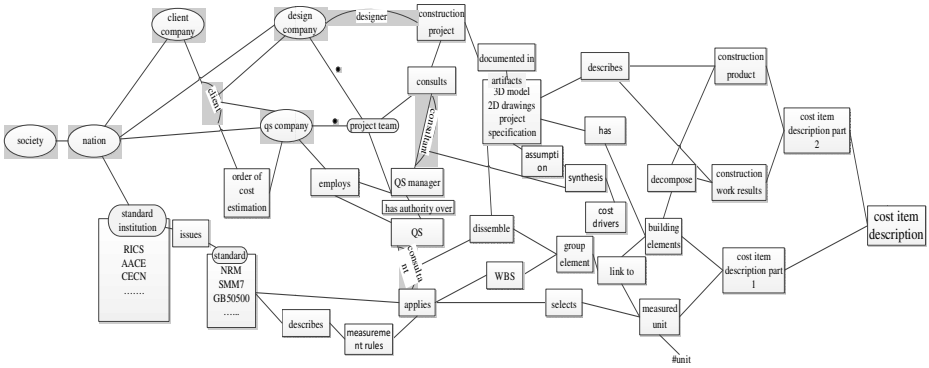


**Fig. 1.** Ontology Chart: Preparation of cost item

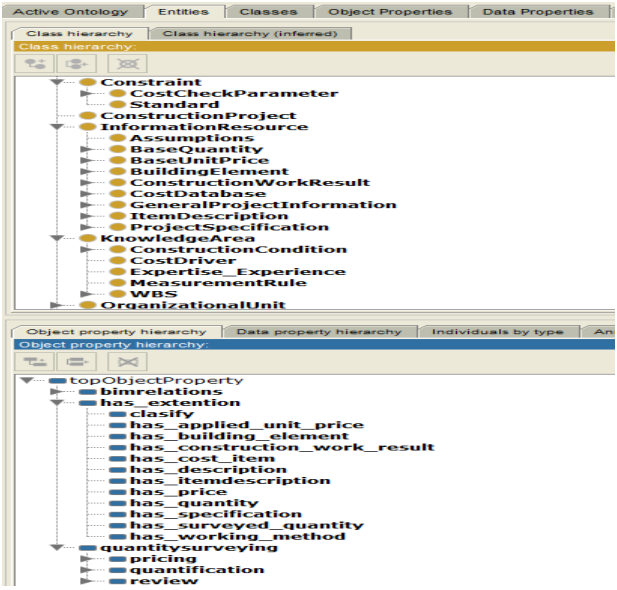


**Fig. 2.** Knowledge Representation of Analytical Cost Estimation in BIM

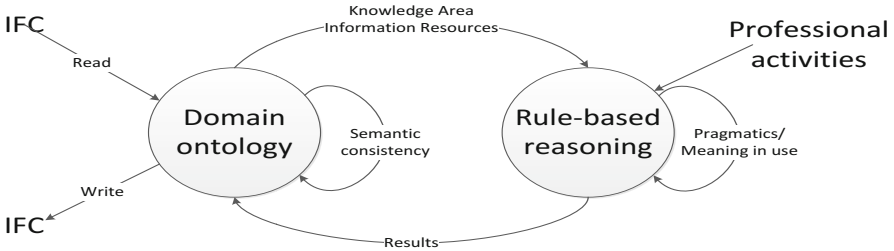


**Fig. 3.** Semantic and Pragmatic Implementation Map

Prepare stage: According to [46], the estimators first receive the order of cost estimation request from client. And the estimators will receive information about the new project in various forms. They *receive* a request to do the work, and data such as 3D models, drawings and project documents. From this information, the estimator deepens their understanding of what it is that needs to be estimated by *synthesising* all the data and information. The estimator needs to analyse the requirements, *decompose* the project and classify the type of product. A Work Breakdown Structure (WBS) is employed and used as the framework to cost the new product [28]. During the decomposing of project, the expert may need to obtain more data to clarify the product of the project. They also need to understand the constraints in terms of time and resources. Once they understand what is required, they establish and document any ground rules and assumptions and identify the main cost drivers of the project.

**Table 2.** Semantic Unit Analysis: select

| Semantic Unit: selects | | |
|---|---|---|
| Input: | Action description: | Output: |
| Conditions;<br>Potential measured units | Expertise strict applies measurement rules, the process can be depicted like that whenever certain condition meets, a particular measured unit will be selected, and the same as construction product, and construction work results. | 1. measured unit |
| Example:<br>1. Masonry, width of damp-proof is 500mm<br>2. Potential measured units: length in meter, area in square meter. | Together with the building section 14: Masonry, if the width of damp-proof is larger than 300mm, then it should be measured in square meter | Measured unit: square meter |
| Knowledge: Memory of the conditions for example 500mm width. | | |

```
select(Buildingcomponents) :-
        write('Measured Unit:'),
        has_covering(Buildingcomponents,X),
        X \== 0,
        has_property(Buildingcomponents,width,Z),
        C is Z*1000,
        C >500,
        units(area,A),
        write(A),
        fail.

select(Buildingcomponents) :-
        has_covering(Buildingcomponents,X),
        X \== 0,
        has_property(Buildingcomponents,width,Z),
        C is Z*1000,
        C =<500,
        units(length,meter),
        write(meter),
        fail.
select(_).
```

```
uses
1 ?- select(wall1).
Measured Unit:square_meter
true.

2 ?- select(wall2).
Measured Unit:meter
true.

3 ?-
```

**Fig. 4.** Results from a Logical Programming Environment

Table 2 discusses select in detail for an illustration. Norm analysis specify the rules used during the process, which has been illustrated in the logic programming language, see figure 4, when expert perform professional activity of select units in order to measure wall1 and wall2, the condition has been specified according to the standard and successfully differentiate two units for two walls. It presents feasibility of realizing quantity surveying in a logic programming environment.

## 4 Conclusion and Future Research

In a summary, IFC is a powerful modelling language and is viewed as a semantic rich data model. More specific, it presents the project components and it's constructing processes, and how they related to each other, especially for its geometry representation. However semantic contained in the IFC is mainly focused on the components and constructing process information. Regarding the new framework introduced to BIM-based cost estimation, IFC lacks of semantic, pragmatic and social from a human reasoning perspective in which there are two aspects of knowledge, they are 'know-what' (could be mostly stored in the IFC) and 'know-how'. As we can see the domain knowledge which in terms of norms is generally manipulating the components' information derived from IFC models. Thus the professional activities are of most interesting in this research.

Organizational semiotics has the capacity to reveal full semantic units for expert reasoning process and provide the alignment between semantic and pragmatic. The semantic units are modelled by organizational semiotics ontological chart, the ontological dependency fully describes the organization structures, inputs (semantic), professional activities (pragmatics), and results (intended semantics). By a simple mapping between OS semantic model and OWL semantic model, the revealed semantic units can be converted to OWL ontology in order to establish a common vocabulary of quantity surveying under a BIM environment.

This research highlights the importance of alignment between semantic (domain ontology) and pragmatic (meaning in use), it contributes also to identify a new approach of knowledge engineering for construction professional services under BIM environment. The roadmap and government report of BIM development confirm that BIM is toward a centre database of construction project. We believe that an integrated approach of semantic and pragmatic could promote BIM into a knowledge-based system, which currently hasn't been realized. Therefore the benefits can be identified from several perspectives, which are industry, domain user and research. From an industry perspective, a knowledge-based system which not only store descriptive knowledge but also procedure knowledge is essential for industry development. From a domain user perspective, implementing new techniques should truly benefits to the domain in terms of efficiency and effectiveness that aligned with human reasoning process. From a research perspective, semantic information exchange is the main stream of researches however the leverage of ontology implementation is still at the first stage which is the classification reasoning. Introduced new approach of knowledge engineering could facilitate discussions on the suitableness of general knowledge engineer process in the BIM environment and implementing the ontology in an innovative approach.

However the limitations are that revealed semantic units of organizational units and agents have not been used and there is no explicit contribution to pragmatic and semantic consistency although they are extreme important to the structure of BIM environment. On the other hand, virtualisation of this representation for domain user is quite difficult as there are many concepts and relations integrated and result in a human unreadable diagram. Future research will be focusing on find all the instances for the semantic units based on a case study, virtualisation of ontology need also being investigated that could be easily understood by domain user and redundancy of semantic units could be reduced in order to provide a precise semantic model of BIM-based cost estimation.

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# Designing Natural User Interfaces Scenarios for All and for Some: An Analysis Informed by Organizational Semiotics Artifacts

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**Abstract.** The design of Natural User Interface (NUI) technologies is still in its early stages; therefore, it does not have well-established guidelines, especially ones that consider the context of Accessibility. This increases the challenges for designers of these technologies to achieve products fulfilling their purpose. . In this paper we present a research project that aims at exploring NUI devices within the Accessibility context, with the goal of proposing ways to promote a better design for NUI technologies. We present this project from an Organizational Semiotics perspective, so that the context we aim to focus on shows itself clearly during the entire design process. Our ultimate goal is to promote better NUI designs, especially for people with disabilities, supporting their autonomy and inclusion in society.

**Keywords:** Human-Computer Interaction, HCI, NUIs, Accessibility.

## 1 Introduction

Known as Natural User Interfaces (NUIs), this interface paradigm in Human-Computer Interaction (HCI) encompasses devices and technologies that, as the term "natural" implies, only require users to do what comes naturally to them, instead of having to develop technical skills to be able to interact with the interface. This, as [1] argue, can both attract users who do not feel comfortable with the traditional mouse and keyboard interfaces, and elicit new design and engineering challenges that will inspire research in several different knowledge areas. However, to become actual usable products, these ideas need to consider, from the very beginning, the context in which the new technology will be used and who its potential stakeholders are. Organizational Semiotics (OS) provides tools with the potential for this analysis of organization and context, but given the novelty of NUIs there is the additional challenge derived from considerations of Accessibility and users with disabilities. Although there are some initiatives in this direction, be it in the form of general NUI guidelines [2] or in the form of design and evaluation heuristics for NUIs [3], creating new technologies with NUI that are both useful and usable by a vast diversity of users' capacities is still a challenge.

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The work described and discussed in this paper is part of a research project that aims at exploring existing NUI devices and testing both their own Accessibility (i.e., its interactability by people with disabilities) and their usage in the context of facilitating everyday actions of people with disabilities. The latter implies in either employing these devices as they are or by altering them or combining them with other devices. This project has two main goals. The first is to propose a conceptual framework for the design of NUI devices that consider the context of Accessibility. The second objective is to design and engineer new devices that not only help people with disabilities, but also that meet the requirements of Universal Design (UD). Once we achieve these goals, products may help in the design of new NUIs that encompass as many users as possible. Therefore, we aim at designing NUI-based technologies with potential of being more inclusive for people with disabilities and more interesting and useful for people without disabilities.

We believe that Organizational Semiotics (OS) can help to achieve these goals by providing a contextualized view of the problem we are dealing with. In this work we use the OS artifacts to clarify and represent our research project, showing how they allow pointing either in the direction of UD or of Assistive Technologies (AT). On one hand, UD means creating products that are usable by anyone, regardless of features such as age, culture, language or disability [4]. In Computing, there is a related term, "Universal Access", which refers to ensuring that all people have access to technology and information, and that these computing services are usable by anyone [5]. Although UD might seem very hard or even impossible to achieve, it should at least inspire designers to create better solutions [6]. Therefore, we believe UD is a design goal that should guide the design process from the very beginning of a computing project. On the other hand, AT refers to devices or computing systems created to compensate, relieve or neutralize body impairments [7]. This encompasses assisting people with disabilities in the execution of tasks and, in turn, improving their social participation and autonomy. Despite their potential benefits, ATs commonly suffer from abandonment by their users, usually because of difficulties related to adapting to the AT or in learning how to use it. To overcome these problems, it is important to involve the stakeholders in the design process, especially those closest to the users, such as family, friends, caretakers, doctors and nurses [7].

Looking at the two concepts of UD and AT it is possible to see they contrast in how they treat their target users: while UD tries to tend to as many users as possible, ATs focus on helping specific users perform specific tasks. However, they have in common the fact that they both need a deeper consideration of context and both can benefit from SO artifacts. In this paper, we will show how different uses of the artifacts can best promote either AT or UD.

The paper is organized as follows: In Section 2 we give an overview of the theory behind the OS methodology we employed. Then, in Section 3 we present the OS artifacts and the practical scenarios instantiated from them. Section 4 discusses how the different problem-solving approaches taken in each scenario reflect on the SO artifacts and, ultimately, in the final solution. Finally, Section 5 presents our concluding remarks and overview of future work.

## 2 Theoretical Basis

The Organizational Semiotics (OS) proposes a comprehensive study of organizations in different levels of abstraction (informal, formal and technical), and their interdependencies. For OS, organizations can themselves be information systems with norms and patterns of well-defined behaviors that regulate the internal processes within the organization. In this sense, an organization is composed of three layers [8]: informal (outer layer), formal (middle layer), and technical (inner layer). The premise behind the use of OS in information systems is understanding the situated context of the organization that the system will be inserted in, and clarifying the main forces that act on it, to propose a technical information system that makes sense for these organizations. Understanding organizational functions from the social level is essential for achieving this goal [8]. To enable a better understanding, development, management and use of information systems, a set of methods known as MEASUR (Methods for Eliciting, Analyzing and Specifying User's Requirements) was developed in the OS [9]. In this paper, we make use of some of these methods aiming at clarifying the problem and proposing solutions, which can have an impact on the design of both Universal Design and Assistive Technologies. For this, we use three artefacts, two of which are from the OS: the Stakeholders Identification Diagram (SID) and the Semiotic Framework (SF). The third one is the Evaluation Frame (EF), used to discuss problems the stakeholders may find and anticipate solutions to them [10]. We briefly describe them as follows, and in the next sections, we discuss their instantiations in our research project.

The SID [11] facilitates the identification of those involved in a particular design process. SID pays attention to different levels of involvement, interests, and expectations, allowing the visualization of stakeholders and their organizations inside five different categories: Operation, Contribution, Source, Market, and Community. In turn, the EF is intended to support reasoning about problems and solutions related to each stakeholder identified through the SID. Therefore, it favors the clarification and identification of requirements as well as the anticipation of issues that may impact/influence the solution to be designed. EF is represented in a table format where the columns contain problems and solutions, and each line references one of the five SID categories. The idea is to raise, in each of these layers, the identified problems and solutions for each group of stakeholders.

Finally, the SF [9] favors the identification and organization of requirements according to six different levels that represent different aspects of signs. The first three levels can be related to technological issues (the Physical, Empirical, and Syntactic), and the other three levels can be related to aspects of human information functions (Semantic, Pragmatic and Social World). The Physical World indicates the features and signs that can be measured by physical analysis and engineering. Empiric studies the properties of the signs. Syntactic analyzes the relationship between signs (whether formal or structural). Semantic describes the relationship between a sign and their meanings. Pragmatics studies the relationship between a sign and the behavior of the involved agents. Finally, the Social World evokes the need to understand how the rules of interactions between the groups work. The SID and EF were used to clarify

the scenarios in which we experienced NUI technologies, while the SF supported the organization and specification of requirements and design decisions to be made. Therefore, these three artifacts contributed with a perception of the problem domain and its possible solutions.

## 3 The Instantiated Artifacts and Case Studies

Although the term Natural User Interface (NUI) has gained power after the advent of innovative devices [1] such as the Microsoft® Kinect [12], NUI-based devices can be created using any kind of input modality, as long as the experience feels natural and the technology best reflects the abilities of its users [2]. This means that it is possible to create a Natural User Interface with a combination of older technologies (like mouse and keyboard) with newer ones (like gestural or touch), because the potential for naturalness is in those technologies, but not the guarantee of it. This trade-off between potential and guarantee creates excellent design and research opportunities, since the possible combinations of input and output devices for the creation of new NUIs are countless. However, it also elevates the challenges behind the task, since employing a technology that is recognizably in the NUI paradigm does not give certainty that the resulting device will actually provide a natural experience for the user. Part of the challenge also lies in understanding the NUI-based devices' potential for users and their context of use. This means taking into account different user needs, based on the characteristics of the users themselves and on where they would utilize the technology. In our research project, we look at this problem from the perspective of people with disabilities. We want to investigate how NUIs can help these users in several ways, such as in accomplishing daily tasks, gaining autonomy, being included in society and interacting with other people.

The first step to understand the problem is to look at the stakeholders of the NUI technologies and devices we aim to explore and design. This is where the SID comes in. In the inner layer, Operation, we have the users of the NUI devices, and, as we move to the outer layers, we define other stakeholders such as researchers and developers (Contribution) the users' families and friends (Source and Community), technology companies (Source and Market), Government and society (Community). In the EF, this brings out questions like "How does the device affect user's interactions and relationships with friends and family?" or "How does Government regulation adapt to the new devices?". Furthermore, although we guide our project with the principles of Universal Design [4], we are also trying to understand how to better design NUI-based devices for people with disabilities. Therefore, some of our stakeholders are specific to this audience, such as the industry of accessibility materials and associations for people with disabilities. In our EF, this leads to questions like "How do the associations for people with disabilities benefit from the devices and technologies created?", which we answer as "they have early access to prototypes and, later, can use the finished final products". Therefore, the SID and the EF give us a contextualized view of our research problem, helping us anticipate problems and solutions related to each stakeholder. To explore the artifacts even further, we have created from them three different case studies. The following subsections describe these case studies and explain how they contribute to our research problem.

### 3.1 Microsoft® Kinect and the Visually Impaired

In the first case study, we started from two stakeholders in our SID: "people with disabilities" from the Operation layer, and "technology companies" from the Source layer. We instantiated each as "people with visual impairments" and "Microsoft", or more specifically, its NUI device, the Kinect [12]. From there, we focused on the challenge of using the Kinect to help visually impaired people (i.e., the blind or people with low vision) in their daily tasks, such as navigation and recognizing objects, informative signs and people. The Kinect is a device composed of 3D depth sensors, an RGB camera and a microphone. Therefore, the main goal of this study case is to figure out how to translate the visual information input given by the Kinect into an output the target users can easily understand. For this, we chose 3D audio because of its capability of carrying information, such as the location of an object in relation to the user, in an indirect way. To test the applicability of this solution, we built a prototype, uniting the Kinect, bone conduction headphones and algorithms of Computer Vision (to interpret the visual input) and 3D Audio (to generate the auditory output). This prototype allowed us to conduct laboratory experiments with users and figure out technical, ergonomic and usability issues. Since until now we only have conducted experiments in controlled environments, so far we have tried to answer questions from the Operation and Contribution layers of the EF, such as "How efficient is the operation?", "How comfortable does the user feel using the device?" and "How does the user benefit from the device?". Once the experiments reach real-world tests, we will also be able to get feedback on the questions and problems presented in the other layers, like "How can friends and family help the user to configure or learn how to use the device?", taken from the Source layer. Therefore, the main contributions of this case study to our research problem are the insights into the building process of a NUI-based device, especially when the starting point is an already existing NUI technology that needs to be adapted. Additionally, we will also continue to see how the analysis we made with the SID and the EF applies in this instantiation of our research problem.

### 3.2 Samsung® Galaxy Gear and the Visually Impaired

In the second case study, we again started from two stakeholders in our SID: "people with disabilities" from the Operation layer, and "technology companies" from the Source layer. We instantiated each as "people with visual impairments" and "Samsung", or more specifically, one of its NUI devices, the first generation Galaxy Gear [13]. From there, we focused on the challenge of using this device to help visually impaired people with the task of recognizing people in their surroundings. The Galaxy Gear is a smart wristwatch (or *smartwatch*) that has an 800 MHz processor, 512MB RAM, 4GB of internal memory, 2 microphones, a speaker, Bluetooth capabilities and a 1.9 Megapixel camera on the wristband. It can also communicate with the user's smartphone to execute tasks such as answering calls and reading messages. Therefore, the main goal of this case study is to figure out whether and how a wearable device such as the smartwatch can help the visually impaired with the task of recognizing people around them. This involves not only developing Computer Vision algorithms

that are able to run on a device with limited hardware capabilities, but also figuring out the best ways to provide feedback to users in ways they can easily understand. Additionally, the feedback cannot overwhelm or embarrass the user. We have conducted experiments with users within laboratory conditions and found issues related to software, ergonomics and feedback. Therefore, similar to the first case study we have so far tried to answer questions from the Operation and Contribution layers of our EF. Once we carry on to real-world tests, we will be able to answer questions from the other layers, such as "How does the device affect interactions or relationships between the users and their families or friends?" (taken from the Source layer), or "How does the new device impact on NUI devices companies?" (taken from the Market layer). Additionally, in this case study we are again exploring a NUI technology (*smartwatch*) within the context of a specific group of users (the visually impaired); however, in this scenario we are not adapting the device on the hardware level so far, but on the software level. Therefore, the main contributions of this case study to our research problem are the insights into adapting, on the software level, a NUI wearable device to perform tasks it did not originally fulfill (recognizing people with the camera). Furthermore, we are also able to see how the analysis made with our SID and EF will continue to apply in a concrete instantiation of our research.

### 3.3 Web of Things in the Supermarket

In the third and last case study, we started from several stakeholders in our SID: "people with disabilities" and "other users" (Operation and Contribution), "technology companies" (Source), "NUI devices companies" (Market), "interested society" (Community) and "Academia" (Community). Their instantiations would be, on one hand, any person interested in receiving help with the task of selecting and finding items in a supermarket ("people with disabilities", "other users" and "interested society"); on the other hand, we have those involved in the area of the Web of Things [14] ("technology companies", "NUI devices companies" and "Academia"). Then, we focused on the challenge of using the Web of Things concepts to help any kind of customer to find and select items in a supermarket.

The Web of Things (WoT) is a research field derived from another field called Internet of Things (IoT). On one hand, the IoT is concerned with the transition of the Internet from a network of computers to a network of trillions of smart "things", such as mobile devices, home appliances and sensors. On the other hand, the WoT revolves around reusing and adapting technologies and protocols that exist in the current Web to build applications that will run in the IoT. Hence, this case study has the goal of using the network of sensors, smartphones and other "things" that may exist into the supermarket to help people in the tasks of finding and choosing products in the establishment. Additionally, the case study also encompasses providing ways to use the WoT to, direct or indirectly, make users help each other. This means providing functionalities that will allow, for instance, people without disabilities to give information that may help people with disabilities, such as product reviews and translation or transcription of information presented on the packing. Notice that this can also be useful to other types of users, such as foreigners, elderly and people who are uncertain about the quality of a product.

After coming up with the general idea of the case study, we looked at the possible technologies that could be used to create the device we are aiming at. We decided an RFID (Radio-Frequency IDentification) reader, some RFID tags and a text-to-speech software were enough for a first experiment. Despite the controlled conditions of our simulated supermarket, we discovered important issues related to the sound feedback, especially regarding the semantics and the syntactic structure of the information given to the user. More specifically, several users could not comprehend the directions to find the sections of the supermarket, and others had trouble understanding reviews of products left by other users. These issues are direct reflections of questions from our EF, such as "How efficient is the operation?" (Operation layer) and "How do users report problems?" (Contribution). Once we move on our experiments to non-controlled environments, we will be able to answer questions from other layers, like "How do supermarkets benefit from the device?" (Market layer) and "How can academia benefit from the device?" (Community layer). Therefore, the main contributions of this case study to our research problem are the insights into creating a device that, from the start, is aimed at any user and that helps people with disabilities. Additionally, also gain perspective on how our analysis made with the SID and the EF work on this instantiation of our research problem.

## 4 Results and Discussion

Each of the case studies described in the previous section was informed by analysis on the same SID and EF. However, while the first two scenarios adopted the approach of starting the design from an existing NUI technology, the third one started from the problem and looked for technological solutions to it. These two different approaches (and their consequences) can be evidenced in the Semiotic Framework (Fig. 1)

If we think about the organizational onion [8], the first two case studies have taken the direction that goes from the technical layer to the informal layer, while the third case study started in the informal layer and went to the technical layer. Looking at this in the SF, the first two case studies started in the most bottom step, the Physical World, by defining the technologies they would use in their designs (Kinect or smartwatch) and moved to the top step, the Social World. In turn, the third case study went the opposite way, by defining the problem and the concern for Universal Design in the top step, and then moving down to reach the Physical World. Hence, from now on in this text we will refer to the first approach as "bottom-up" and to the second as "top-down".

If we make a more detailed analysis, we can see the impact each approach has in each level of the SF (Fig. 1). The bottom-up approach starts in the Physical World by choosing a NUI device and combining it with the necessary auxiliary technologies, such as white cane for the blind user, headphones to receive audio output and, lastly, the multichannel communication needs to be considered. In the case of the Kinect, hardware and software modifications were made to implement one of the channels: the audio. In the case of the smartwatch, only software adaptations were necessary since the device's hardware already has multichannel capabilities. Moving on to the

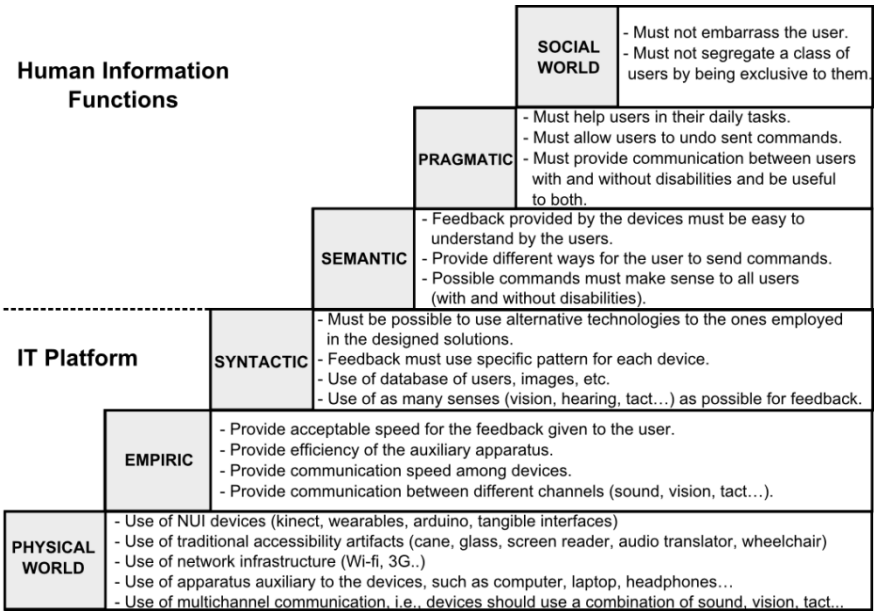


**Fig. 1.** Requirements represented in the Semiotic Framework (SF)

Empiric layer, the efficiency of the audio feedback is tested and adjusted, usually by software. Then, in the Syntactic layer, the pattern and format of the feedback are defined and possibly require more adjustments. In the Semantic step, we consider how much the audio cues are understandable to the users, and possibly make more adjustments. In the Pragmatic layer, we see how much the device as a whole is actually helping the user in the execution of a task. Finally, in the Social World step we consider issues related to embarrassment and segregation.

In contrast, the top-down approach starts by defining the problem (finding and selecting products on a supermarket) and committing to Universal Design, i.e., helping as many types of users as possible in the accomplishment of the chosen tasks. Moving to the Pragmatic layer, we think about how to provide communications between users, and how to make these communications useful for them and compatible with the proposed problem. Then, in the Semantic step, we design the input (commands) and output (feedback) messages so that they are understandable by as many users as possible. In the Syntactic layer this reflects upon the format we will choose for the messages, the types of senses (vision, tact, hearing…) we will choose to reach and which databases we will use. This also carries on to the Empiric layer, where we consider which communication channels to use and how efficient each one is. Finally, in the Physical World we actually select the devices that will be used and combine them to achieve a prototype of the solution.

Therefore, it is possible to note that, on one hand, the bottom-up approach requires software and hardware implementation from the very start, and for each step we move up on the SF, adjustments are required, which can be very costly both for designers (time and labor) and users (time). Additionally, the bottom-up approach also offers

less flexibility in terms of the technologies employed, since they are chosen very early. This also implicates that once we reach the Social World it may be very difficult to adapt the current physical apparatus to fit all. On the other hand, the top-down approach only commits to specific physical devices in the very last step, allowing designers to consider UD-related issues much earlier. This gives them freedom to select the NUI devices and technologies that best fit the requirements they came up with during the descent from the Social World to the Empiric layer. This can save both time and money, since it will be possible to compare, in the Physical World, the different options that satisfy the requirements and then select the one that costs the least. We believe that these crucial differences in the two approaches point to the contrast between designing an Assistive Technology (AT) and designing a solution that follows Universal Design (UD). While AT usually refers to a device or computing system that assists people with disabilities [7], UD defends the creation of products that are usable by the greatest possible extend of categories of users [4]. Hence, the SF indicates that, in the context of designing new NUI-based devices with a special attention to users with disabilities, the bottom-up approach may lead to an Assistive Technology that will most likely to address a specific category of user. In contrast, the top-down approach seems to promote Universal Design solutions. It is important to note, however, that within an iterative design process, it is possible to adapt the designs so they can address a wider variety of users, but this adaptation seems to be much more difficult if we are adopting the bottom-up approach.

## 5 Conclusions and Future Work

In this paper, we used the lens of Organizational Semiotics on a research project that aims at exploring the existing NUI-based devices in the context of Accessibility, either by testing their potential as assistive technology or by investigating how they can allow everyday actions of people with disabilities and others as well. The ultimate goals of this project are creating new NUI-based devices and proposing guidelines or conceptual frameworks for designing these devices in the future. The results of this study showed the usefulness of the Stakeholders Diagram and the Evaluation Frame to guide the creation of three different case studies scenarios and, in return, how the discoveries made in each case study reflected differently in the artifacts. In addition, we observed that the different directions of designing the scenarios reflected in the organization of requirements in the Semiotic Ladder. Finally, we observed evidence that starting a design from the top or from the bottom steps of the Semiotic Framework can have a huge impact on the way the resulting technology will address the user, either leading to an assistive technology or a solution for all, aligned to the principles of Universal Design.

We believe this evidence illustrates the contribution of Organizational Semiotics artifacts towards a design for all, especially in the context of using NUI state of the art devices. Hence, our future work includes proceeding with further iterations of each case study scenario to understand other semiotic aspects of those technologies in their real world usage.

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# An Evolution Method of Service View Products Supported Dynamic Integration of Information Resources

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**Abstract.** The original information system architecture Framework provides an integration mechanism of information system resources to support a specific operational mission, but it is difficult to describe and analyze the dynamic integration process of the information system resources to support the dynamic adjustment of operational mission in the future complex, changeable environment. This paper presents the modeling approach of the service view product, and focus on the evolution method of service view products to support the dynamic integration process of the information system resources.

**Keywords:** Architecture, Operational activity·Service View, System Resource, Evolution, Dynamic Integration.

## 1 Introduction

Information system architecture is defined as the structure of components consisting of its system, relationships, and the disciplines and guidelines governing their design and evolution over time [1-3]. It has great importance on the information system design, development, operation and evolution. Architecture is one of the key technologies to guide the information system integration. At present, much research on information system architecture is generally conducted based on the research of DoDAF. The original information system architecture Framework (C4ISRAF, DoDAF, i.e.) is based on many views, such as "Operational View, System View, Technical View," etc. through the mapping between operational activities and system functions, provides an integration mechanism of information system resources to support a specific operational mission, while it is difficult to describe and analyze the dynamic integration process of information system resources to support the dynamic adjustment of operational mission in the future complex, changeable environment. Although DoDAF2.0, NATOAFv3.0, MoDAF1.2 and other latest architecture frameworks including the description of service view[4-6], they just only describe the definition, role and content of the service view products without analyzing the internal logical relationship between operational view, system view and service view, so that it is difficult to guide modeling and analyzing application of the service view products. Therefore, using the SOA and service-oriented thinking[7-8], this paper extends the

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original information system architecture framework with increasing the service view products description in order to achieve the separation between the operational activities and the system resources. Then under the service view framework, this paper presents the modeling method of the service view products, and focus on the evolution method of service view products to support the dynamic integration process of the information system resources.

This paper is organized as follows. In section 2, we present a service view description framework of information system architecture. Section 3 discusses modeling methods of the service view products within information system architecture. In section 4, we propose an evolution method of service view products within information system architecture. Section 5 concludes the paper by noting the future works.

## 2 Service View Description Framework of Information System Architecture

### 2.1 The Original Information System Architecture Framework and Data Elements Relationship

The original information system architecture framework mainly described the system from three perspectives: the operational requirement and application, system design and technical constraints, namely Operational View, System View and Technical View[1-3]. In particular, operational view describes the operational mission decomposition, operational activity model, operational process model, the rules of operational activities execution and information exchange etc. which is contributed to complete the operational mission. Through the traceability relationship between operational activities and system functions, it can determine the relationships of systems, system functions, system communication and data transmission to support to complete operational activities, and provides an integration mechanism of information system resources. The structure and data elements of the original information system framework are shown in figure 1.

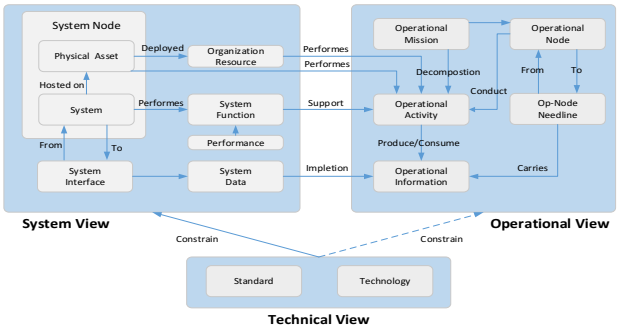


**Fig. 1.** The structure and data elements of the original information system architecture

## 2.2 The Reason of Introducing Service View

Under the guidance of the original information system architecture, to complete the system mission and realize the dynamic integration of system resources, the data elements of operational view and system view has following relation: the operational mission can be described by operational nodes which decomposed from operational task, operational activities and the relation between operational activities. The operational activities execution process need to produce and consume operational information, and operational nodes use system resources, operational activities are automated by system functions, system data exchange is fulfilled by operational information exchange between operational activities. Specifically, it is shown in the figure 2.

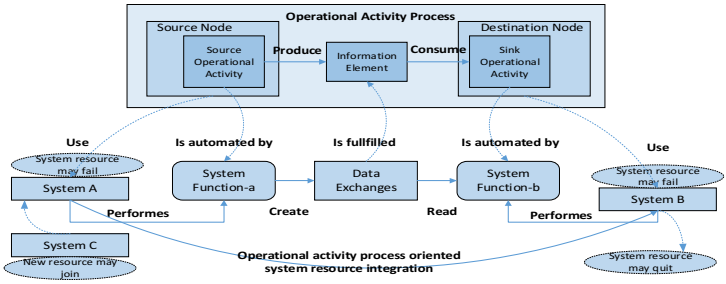


**Fig. 2.** Operational activity process oriented system resource integration

However there are many problems located in this system resource integration mechanism to complete operational activities process: firstly, system resources integration is difficult, such as the system A and B located in figure 2, may be developed by different developers using different platforms, different language and different technical implementation. Although the design of architecture describes the interface and data exchange standard of two systems in order to support the operational activities process, the workload of system integration is still relatively large. Secondly, under the condition of operational requirement change, the operational activities process may also change, system resources maybe quit or fail, and a new system resource need to be added the operational activities execution process. These changes need system resources described in system view adjust their structural connection according to the change of operational requirement and the state of system resources, in order to adapt to the change of the operational activities process and system resources. However the heterogeneity among system resources makes it is difficult to support the system resources structural connection rapidly change.

Cope with the above demand, using the SOA and service-oriented thinking, this paper brings forward a service view, between operation view and system view, to describe services, manage services and the interaction process between services from the perspective of service-oriented. The services can support the exchange of information between operational activities through XML data of standard SOAP protocol.

### 2.3 A Service View Description Framework of Information System Architecture

Service view acted as the intermediate layer between operation view and system view. On the one hand, it can abstract and package the distributed, heterogeneous and interconnection system resources of system view, on the other hand, it also need to support and adapt to the change of operational activities process in operational view. Therefore, the data elements described in service view include the description of service itself, such as service structure, service interface, service behavior, service property, etc. and the relationship between services, such as service connection structure, service interaction rules, service level, etc. Therefore the service view description framework can be divided into: the description of service itself, the description of relationship between services and the description of the relationship between services and the relation between services and other architectural elements, as shown in the figure 3.

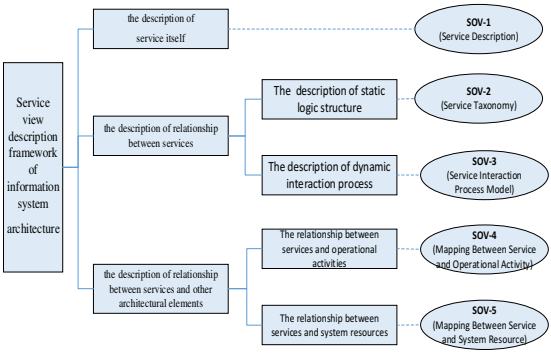


**Fig. 3.** The service view description framework of information system architecture

In order to avoid confused with the product name of systems View (SV), the name of Service View taken from the Service Oriented View, referred to as SOV.

## 3 The Modeling and Description Method of Service View Products within Information System Architecture

### 3.1 The Modeling and Description Method of Each Service View Product

(1) *Service Description (SOV-1)*

This product is the foundation of the description of other service view products. This product mainly realizes the package and description of a single system resources, namely the description of member service. Member Services(MS) can be represented by the following nine-tuple:

$$MS = (ID, Name, Description, Operation, \Pr ovider, Input, Output, Capability, QoS)$$

Among them, $ID$ represent service identification, $Name$ represent service name, $Description$ represent the description of service function or the supported operational

activity, *Operation* represent the operation provided by service, *Provider* represent the service provider's information, *Input* and *Output* respectively represent the input and output parameters of the service, *Capability* represent the service ability, *QoS* represent the service quality attributes.

(2) *Service Taxonomy (SOV-2)*

This product is mainly responsible for the classification and management of numerous member services involved in the information system, including hierarchical relationships, combination relations, derived relations and classification relations of member services. For this product, we can use the concept of the Service Group, to distinguish services from the similarity of service function. Service Group (SG) can be represented by the following seven-tuple:

$$SG = (ID, Name, Description, Operation, Input, Output, Capability)$$

The meaning of each element in this tuple is similar to the element in $MS$. Each service in the $SG$ is corresponding to one member service. Any service in the same $SG$ has the same function and interface, but the service provider's information and QoS are different.

(3) *Service interaction process model (SOV-3)*

This product is mainly used to describe the dynamic interaction between services, to support to complete operational activities process. We can use object-oriented Petri net to model this product[11]. Using the advantage of expression ability based on object-oriented Petri net, we can solve the defects of enough semantic expression based on ordinary Petri net. We can use the object of object-oriented Petri net to describe the sub-processes, and use the object Petri net hierarchical description mechanism reduces the complexity of modeling service interaction process, and can establish a mapping between service node and service group through elements of object-oriented Petri net, such as token, action function and predicate transfer function, etc. in order to solve the path selection of uncertainty activity and system resources dynamic change problem in the execution process of service interaction, to meet the needs of service interaction process model description.

(4) *Mapping between service and operational activity (SOV-4)*

This product is mainly used to describe the traceability relationships between operational view and service view in system architecture design, to ensure the accessibility between operational activities and services supported operational activities. It is a many-to-many relationship between services and operational activities. The traceability matrix can be used to describe this product. Traceability matrix can be represented by the following six tuple:

$$SerToAct = (ID, \mathrm{Re}lDescription, SerID, SerName, ActID, ActName)$$

Among them, $ID$ represent mapping relation identification, $\mathrm{Re}lDescription$ represent mapping relationship description content, $SerID$ and $SerName$ respectively represent service identification and service name, $ActID$ and $ActName$ represent activity identification and activity name.

(5) *Mapping between service and system resource (SOV-5)*

This product describes the traceability relationships between services and system resources, to ensure services can be implemented and deployed by the specific system

resources. It is a many-to-many relationship between services and system resources. The traceability matrix can also be used to describe this product. Traceability matrix can be represented by the following six tuple:

$$SerToSys = (ID, \mathrm{Re}lDescription, SerID, SerName, SysID, SysName)$$

The meaning of each element in this tuple is similar to the element in $SerToAct$ .

### 3.2 The Relationship between Service View Products

According to the above analysis of description and modeling method of service view products, the logical relationship between service view products is shown as figure 4.

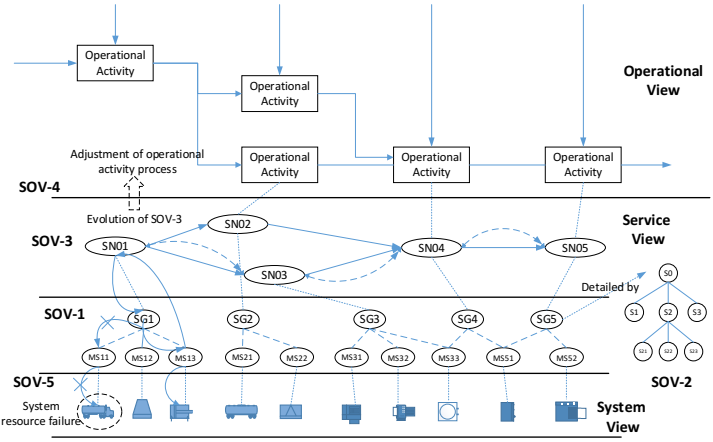


**Fig. 4.** The relationship between service view products

Among them, SOV-1 implement system resources packaged modeling and description, and set the detailed description of member service. With using the concept of service group, SOV-2 can realize classification management of member services described in SOV-1. Mapping relationship between services and operational activities (SOV-4) and mapping relationship between services and system resources (SOV-5) determine the traceability mapping relationship among service view, operational view and system view, and with other products of service view can realize the separation between system resources and operational activities.

## 4 Evolution Process of Service View Products within Information System Architecture

In current complex, changeable environment, operational mission and state of system resources are easy to change, which requires decision makers adjust operational activities process and system resources timely according to the actual situation[10]. Because the heterogeneity of information system resources, it is difficult to adjust system resources to

adapt to the adjustment of operational activities process. Therefore, in the information system architecture design level, describing and analyzing the possible evolution requirements of system execution process is convenient to guide information system executing to adapt to the change of information system construction demand in the future.

### 4.1 Evolution Demand of Information System Architecture

(1) *system resource failure*

As in figure 5, through the analysis of the operational mission requirements, operational activities process model is established, including operational activity A, B, C and the information exchange among them. According to the mapping relationship between operational activities and system resources, operational activity A, B, C respectively supported by system resource 1, 2, 3, the demand of information exchange among operational activities determines connection relationship among system 1, 2, 3.

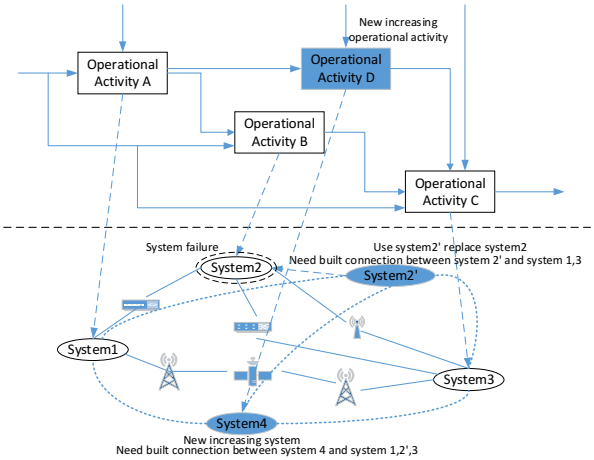


**Fig. 5.** Evolution demand of information system architecture

Assumes that system 2 suddenly becomes invalid, it is difficult to support to complete operational activity B. Then you need to use a system 2' which has the same function as system 2 to replace system 2, to enable the operational activities process to continue. Owing to the heterogeneity between the system resources, system 2 and system 2' may be developed by different manufacturers, used different techniques to realize, which cause their interfaces are different and difficult to establish communication connection between system 2' and system 1(system 3), thus leading to the failure of the operational activity execution process, affecting the completion of operational mission.

(2) *Operational activities process adjustment*

Using the above example shown in figure 5, assume it is need to increase new operational activity D, at the same time the logic relations between activity D and original activity A, B, C, such as exchange of information and sequential process, are set up.

In order to satisfy the adjustment of operational activities process, it need to increase system 4 in system resources, and need to increase information exchange relations between system 4 and original system 1, 2', 3 according to information exchange relations of operational activity D. Also, owing to the heterogeneity between the system resources, it is difficult to establish communication connection between system 4 and original systems in order to support or adapt to the adjustment of operational activities process quickly.

### 4.2 The Analysis of Service View Products Evolution Process

Service view acted as the intermediate layer between operational view and system view can effectively realize the separation between operational activities and system resources, and do not need specify a specific service in the service interaction process model, in order to effectively adapt to the evolution requirement of system resources failure and adjustment of operational activities process.

(1) *The evolution process of service view products under system resource failure*
In service view, the execution resource in service interaction process model(SOV-3) choose service group, not specify the specific member service instance. Therefore we can use service group to deal with the failure situation of system resources. Service view products evolution process is shown in figure 6, assume that the failure system resource is the specific member service instance chosen in service interaction process model.

*Step 1*: Collect and manage member services information using service group, and learn member service status and function change through perception context and environment monitoring.

*Step 2*: When the service group learn the member service served as execution resource in the service interaction process model is difficult to meet the needs of the service interaction process execution, Service group reselect another member service served as the new execution resource in the service interaction process model, which does not affect the execution of service interaction process and does not need to adjust operational activity process.

*Step 3*: When all member services in service group are difficult to meet the functional requirements of service interaction process execution, we can choose other backup service group registered in SOV-2, and choose the suitable member service instance meeting the requirement of service interaction process execution through backup service group. If not find alternative service group, then turn to the fourth step.

*Step 4*: Reselect redundant service interaction process model registered in SOV-3, and need to pay attention to ensure the mapping effectiveness between service node and service group.

*Step 5*: If there still exist service group failure mapped by service node in redundant service interaction process model, it need to perform evolution operation on service interaction process model by architecture designers.

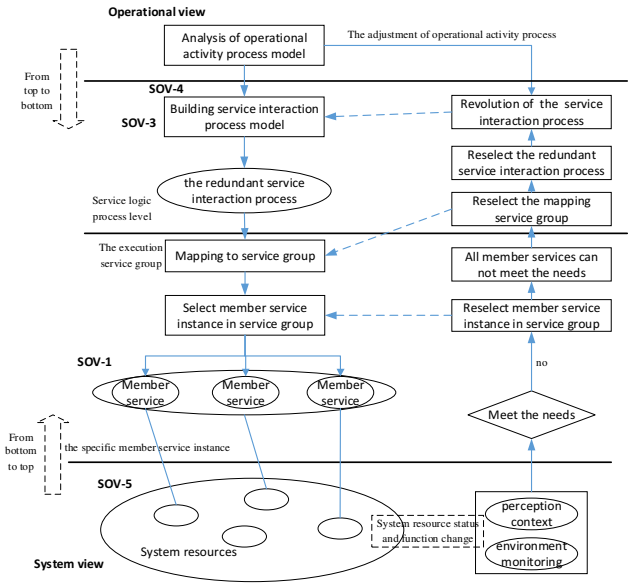


**Fig. 6.** The evolution process of service view products

(2) *The evolution process of service view products under operational activities process adjustment*

As operational activities execution process is supported by the service interaction process, it is need to analyze and adjust the service evolution process to deal with operational activities process adjustment.

*Step 1*: In the view of future uncertain operational activities process, we design the redundant service interaction process in SOV-3. If the redundant service interaction process model can satisfy the operational activities adjustment, the evolution process is over, otherwise turn to the second step.

*Step 2*:, According to the adjustment of operational activity process, architecture designers perform evolution operation on original service interaction process model to ensure the new model can support and adapt to the adjustment of operational activities process.

Note that, the above two evolution processes are likely to be involved in the evolution of service interaction process model. The evolution refers to adjust the service interaction process according to the adjustment of operational activity process, to support or adapt to operational activities after the adjustment process. From 3.1, we know service interaction process model is described by object-orient Petri net model, therefore the evolution of the service interaction process model can be converted into the operation of increase, delete, replace in object-orient Petri net model, at the same time also need to ensure the structure correctness and service resource effectiveness of service interaction process model after revolution. Due to the limitation of space, the specific algorithm is not introduced, and it can be found in [11].

## 5 Conclusions

This paper presents the modeling and analyzing of the service view within the information system architecture using service-oriented thinking and research on SOA, in order to describe and analysis the system resources dynamic integration and evolution demand of information system in the future complex, changeable environment. Our contributions make a base ground for the future research of information system architecture designing and analyzing. Future work will be perfect service view description framework of information system architecture and develop modeling tool based on this theory.

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# The Adoption of Smartphones Among Older Adults in China

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**Abstract.** This research aims to investigate the adoption of smartphones with older adults in China. Based on the literature review from previous research, a research model with eight research hypotheses is developed by extending UTAUT with a consideration of observability and compatibility from IDT, and perceived enjoyment and price value. This research model is empirically examined using survey data from a sample of 121 older adults in China. Five research hypotheses were positively significant supported, while three research hypotheses were rejected in this study. The results suggest that social influence, observability, compatibility, performance expectancy and perceived enjoyment, are important determinants for the use and adoption of smartphones with older adults in China.

**Keywords:** Adoption of smartphones, UTAUT, older adults.

## 1 Introduction

Today, smartphones become increasingly important in people's daily life. A smart phone is a mobile phone with more advanced computing capability and connectivity than basic feature phones. It allows users to make video calls, download and transfer files, and use internet-based applications. Smartphones have the potential to enhance the quality of people's life [5, 6]. For instance, people can get immediate access to information on a variety of topics through their smartphones. People get opportunities for entertainment in the form of games, movies, books through their smartphones. Moreover, smartphones can facilitate communication among family, friends and colleagues via social networking tools, emails, etc.

Most countries in the world are experiencing an increase in the average age of their population. The ageing of the population is one of the major challenges most countries have to face over the next few decades [12]. Older adults face challenges when they are using smartphones. A gap seems to exist in the adoption and use of smartphones by older adults. Some typical issues that impact their use of smartphones are as follows, lack of skills, too expensive phones, security and privacy concerns.

Given all the potential benefits smartphones can bring to the daily life of older adults, there is still an urgent need to examine the means to enable older adults to use

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smartphones. This research intends to bridge the research gap in the adoption of smartphones among older adults in China. The objective of this research is to examine the adoption and usage of smartphones with older adults in China. We attempt to investigate how various factors impact older adults' intention to use smartphones in China by a research model based on previous technology diffusion theories. The term older adult has been defined in a variety of ways in different articles, which ranges from over 40 to over 75. The distinction of "older" depends upon the specific context under consideration. Most people over 60 lack the essential skills to perform user survey and computer literacy to use smartphones because their education was interrupted during the Cultural Revolution in China. If we defined the older adult as people over 60, it would be extremely difficult to collect survey data for this research. Therefore, we defined older adult as people over the age of 45 in this study.

The rest of this paper is organized as follows: Section 2 discusses the theoretical background of this study. The research model and hypotheses are presented in Section 3. The research method and results are described in Section 4. This is followed by a discussion of the findings in Section 5. Section 6 concludes this research.

## 2 Background

### 2.1 Benefits of Use of Smartphones for Older Adults

Older adults can benefit from the use of smartphones in a number of ways. Mobile services available on smartphones may help older adults enhance communication with their families and friends, enrich their personal interests, and check various healthcare related information. Further, to address the problems raised by ageing population, many countries started Smart Cities project to fulfill older adults' needs across areas such as housing, social participations health care, and community support services, leisure, to make the city environment more elderly friendly. Smartphones can provide personalized health care, social services for older adults. Although there are many mobile services available on smartphones, many older adults are less aware of those services. This could be a potential reason why older adults do not use smartphones.

### 2.2 Digital Divide

Scholarly research on the digital divide has a long history back to the 1990s. Most researchers in Information Systems in the last two decades focus on Internet penetration through the lens of technology diffusion theory (e.g., TAM [4], IDT [14] , UTAUT [18]). The digital divide refers to the gap between those who do and those who do not have access to new forms of information technology [16]. Research on digital divide often starts by looking at users' access to new technologies. The types of access can be defined as 'physical access' and 'beyond access'. An increasing number of researchers suggested to study 'beyond access' with additional attention to social, psychological and cultural background. For example, Van Dijk [16] found a shifted research attention on digital divide from physical access to skills and usage.

Along with the popularity of computers and digital technologies, the digital divide in terms of physical access seems to be reduced in most developed countries.

The uneven spread of the mobile applications on smartphones has contributed to the popularity of the concept of the 'digital divide' associated with smartphones. It highlights the emerging social gap between those individuals who use mobile applications on smartphones and those who do not. It is believed that the major gap is based on socio-demographic dimensions (e.g., age, region, income, educational background). To reduce digital inequalities, we must understand the reasons for non-users' resistance to the use of smartphones. Investigating this digital inequality is of help to understand the diffusion of smartphones with different ageing populations.

### 2.3 The Adoption of Smartphones with Older Adults

Research work has been carried out by researchers in studying various aspects related to the adoption of smartphones [7]. In [3], Chen, et al. combined TAM and innovation diffusion theory (IDT) to study and explain the adoption of smartphones in logistics. Self-efficacy was a strong predictor of behavioral intention through attitude. Based on a study on the performance of mobile applications, Huang et al. [8] indicated that smartphones could become a suitable substitute of traditional computer. But, the performance of the applications on smartphones is poorly understood.

Although significant effort has been done to explore the adoption of smartphones, the research on the adoption of smartphones with older adults is still in its infancy. The samples used in previous research on the adoption of smartphones are relatively young. Concerning the research on the adoption of new technologies by older adults, most previous research [20] tends to focus on the use intention and adoption of computers and Internet by older adults. Lee et al. [10] examined older computer users' constraints at various age stages. An examination of the current literature reveals that few studies have addressed the use and adoption of smartphones by older adults. Pheeraphuttharangkoon [13] investigated the adoption and use of smartphones with older adults in the UK. However, the sample size with people over 50 years old is quite small in their study.

To our best knowledge, we have not found any studies addressing the adoption of smartphones with older adults in China. The digital divide along the age dimension has become a major concern in China. In developed countries, Internet penetration is saturated and average education level is high, it is easier for users to use smartphones. However, the average education level is lower, especially for older adults in China. According to the annual report 2013 from China Internet Network Information Center, the percentage of smartphone users aged above 45 is significantly lower than the younger generation. Therefore, it is worth to carry out this research to better understand older adults' behavior intention to use smartphones in China.

## 3 Research Model and Hypotheses

A research model that identifies important factors that impact older adults' intention to use smartphones was developed in this research. The proposed research model (see Figure 1) is an extension of UTAUT [18], with a consideration of observability and

compatibility from IDT [14], and perceived enjoyment [15] [17] and price value [19] from other technology diffusion theories. We have developed eight research hypotheses based on the research model. Each hypothesis as labeled in Figure 1 is elaborated below.

**Hypotheses developed from UTAUT**

Four key factors from UTAUT, Social Influence, Facilitating Conditions, Performance Expectancy and Effort Expectancy, were included in our research model. *Social Influence* is the extent to which consumers perceive that important others (e.g., family and friends) believe they should use a particular technology. Previous research also indicated that social influence is important for the adoption of smartphones [21]. *Facilitating Conditions* refer to consumers' perceptions of the resources and support available to perform a behavior. Users need to have digital skills to use smartphones. *Performance Expectancy* is defined as the degree to which using a technology will provide benefits to consumers in performing certain activities. Smartphones are able to provide potential benefits (e.g., always connected, healthcare information) for users. Once users have recognized these benefits, they are likely to use and adopt smartphones. *Effort Expectancy* is the degree of ease associated with consumers' use of technology. Learning a new technology often takes time and effort, particularly with older adults. If using smartphones is considered as an easy and straightforward process, users are likely to adopt smartphones. Thus, we proposed the following four hypotheses.

H1: Social Influence (SI) has a positive influence on older adults' intention to use smartphones.

H2: Facilitating Conditions (FC) has a positive influence on older adults' intention to use smartphones.

H3: Performance Expectancy (PE) has a positive influence on older adults' intention to use smartphones.

H4: Effort Expectancy (EE) has a positive influence on older adults' intention to use smartphones.

**Hypotheses developed from IDT**

Rogers [14] indicated that innovation that are perceived by individuals as having greater relative advantage, compatibility, trialability, and observability, and less complexity will be adopted more rapidly than other innovation. To further understand older adults' intention to use smartphones, two factors from IDT were included into our research model. As for the case of smartphones, *Observability* can be defined as the degree to which smartphones are visible to potential users. *Compatibility* can be seen as users' belief in the consistency of using smartphones with the way they live and work. Previous research also demonstrated that the importance of Observability and Compatibility to the adoption of new technologies (e.g., e-banking [9]). Therefore, the following two hypotheses were proposed.

H5: Observability (OBS) has a positive influence on older adults' intention to use smartphones.

H6: Compatibility (COM) has a positive influence on older adults' intention to use smartphones.

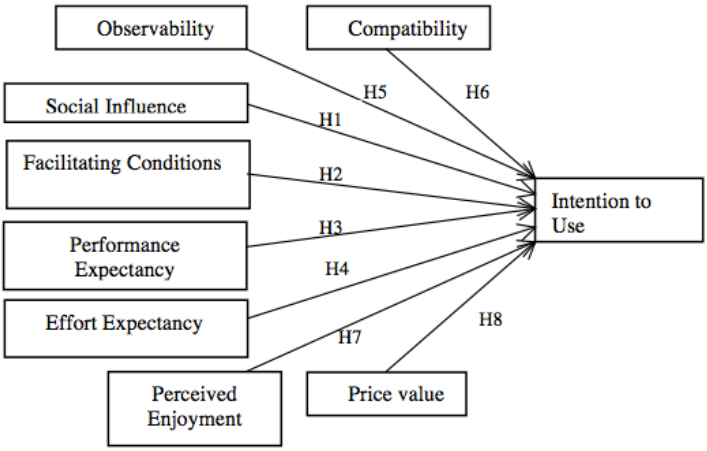


**Fig. 1.** Research Model

**Perceived Enjoyment and Price Value**

*Perceived Enjoyment* is defined as the extent to which the activity of using a specific system is perceived to be enjoyable in its own right, aside from any performance consequences resulting from system use [15] [17]. Users can have fun when they are playing games, and playing music on smartphones.

*Price value* is another significant factor affects users' adoption of a new technology. *Price value* can be defined as consumers' cognitive tradeoff between the perceived benefit of the applications and the monetary cost for using them [19]. It is believed that users are likely to adopt smartphones when the benefits of using smartphones are perceived to be greater than the monetary cost of smartphones. Hence, we proposed the following hypotheses.

H7: Perceived Enjoyment (PEJ) has a positive influence on older adults' intention to use smartphones.

H8: Price Value (PV) has a positive influence on older adults' intention to use smartphones.

## 4 An Empirical Study with the Research Model

To understand older adults' use and adoption of smartphones in China, the proposed research model and hypotheses were empirically tested using the structural equation modeling approach.

### 4.1 Instrument Development

The validated instrument measures from previous research were used as the foundation to create the instrument for this study. In order to ensure that the instrument better fit this empirical study, some minor words changes were made to ensure easy interpretation and comprehension of the questions. For instance, wording was

modified to fit the context of use of smartphones in China. A questionnaire was developed first in English and then translated into Chinese. Back-translation was conducted by bilingual third party to improve the translation accuracy. As a result, the measurement questionnaire consisted of 25 items[1]. A seven point Likert scale was used to examine participants' responses to all items in this part.

### 4.2 Samples

The data for this study were collected through self-administered questionnaires in the central part of China. The survey was distributed in terms of paper-based questionnaires individually from Aug 20th 2014 to Sep 30th, 2014. 132 completed questionnaires were collected, among which 121 of them were valid questionnaires (i.e., valid respondent rate 91.7%). Among the participants, 72 of the participants were male, and 49 were female. Moreover, 79.3% of participants had full-time jobs, 10.8% of participates had part-time jobs, 9.8% of participants had retired. Further, the top three most used featured on smartphones for the participants were: making phone calls, text messaging, and instant messaging feature (e.g., QQ, Wechat).

**Table 1.** Factor loadings, composite reliability, and AVE for each construct

| Construct | Item | Factor Loading | Composite Reliability | AVE | Cronbach's Alpha |
|---|---|---|---|---|---|
| SI | SI1 | 0.835 | 0.91 | 0.77 | 0.85 |
| | SI2 | 0.947 | | | |
| | SI3 | 0.840 | | | |
| FC | FC1 | 0.864 | 0.91 | 0.71 | 0.87 |
| | FC2 | 0.790 | | | |
| | FC4 | 0.887 | | | |
| | FC4 | 0.835 | | | |
| PE | PE1 | 0.860 | 0.90 | 0.75 | 0.83 |
| | PE2 | 0.929 | | | |
| | PE3 | 0.804 | | | |
| EE | EE1 | 0.941 | 0.95 | 0.87 | 0.93 |
| | EE2 | 0.941 | | | |
| | EE3 | 0.917 | | | |
| OBS | OBS1 | 0.939 | 0.94 | 0.89 | 0.87 |
| | OBS2 | 0.946 | | | |
| COM | COM1 | 0.941 | 0.95 | 0.87 | 0.92 |
| | COM2 | 0.948 | | | |
| | COM3 | 0.905 | | | |
| PEJ | PEJ1 | 0.937 | 0.94 | 0.89 | 0.87 |
| | PEJ2 | 0.947 | | | |
| PV | PV1 | 0.827 | 0.93 | 0.82 | 0.89 |
| | PV2 | 0.945 | | | |
| | PV3 | 0.936 | | | |
| IU | IU1 | 0.952 | 0.95 | 0.91 | 0.91 |
| | IU2 | 0.960 | | | |

[1] The survey items are available at this link:
http://www.idi.ntnu.no/~shanggao/oldadults.html

### 4.3 Measurement Model

The quality of the measurement model is determined by (1). Content validity, (2). Construct reliability and (3). Discriminant validity [1]. To ensure the content validity of our constructs, a pre-test of the questionnaire with a small group of respondents was conducted before the survey was distributed. To further test the reliability and validity of each construct in the research model, the Internal Consistency of Reliability (ICR) of each construct was tested with Cronbach's Alpha coefficient. As a result, the Cronbach's Alpha values range from 0.83 to 0.93. A score of 0.7 is marked as an acceptable reliability coefficient for Cronbach's Alpha. All the constructs were above 0.70.

Convergent validity was assessed through composite reliability (CR) and the average variance extracted (AVE). Bagozzi and Yi [2] proposed the following three measurement criteria: factor loadings for all items should exceed 0.5, the CR should exceed 0.7, and the AVE of each construct should exceed 0.5. As shown in Table 1, all constructs were in acceptable ranges.

The measurements of discriminant validity were presented in Table 2. According to the results, the variances extracted by the constructs were more than the squared correlations among variables. The fact revealed that constructs were empirically distinct. As good results for convergent validity and discriminant validity were achieved, the test result of the measurement model was good.

**Table 2.** Discriminant Validity

| Variables | SI | FC | PE | EE | Obs | Com | PEJ | PV | IU |
|---|---|---|---|---|---|---|---|---|---|
| SI | **0.88** | | | | | | | | |
| FC | 0.66 | **0.84** | | | | | | | |
| PE | 0.51 | 0.47 | **0.87** | | | | | | |
| EE | 0.43 | 0.43 | 0.38 | **0.93** | | | | | |
| Obs | 0.19 | 0.29 | 0.15 | 0.28 | **0.94** | | | | |
| Com | 0.73 | 0.52 | 0.59 | 0.50 | 0.15 | **0.93** | | | |
| PEJ | 0.60 | 0.47 | 0.49 | 0.46 | 0.37 | 0.63 | **0.94** | | |
| PV | 0.57 | 0.37 | 0.34 | 0.33 | 0.17 | 0.44 | 0.47 | **0.90** | |
| IU | 0.64 | 0.52 | 0.60 | 0.41 | 0.42 | 0.69 | 0.82 | 0.42 | **0.96** |

Note: Diagonals represent the average variance extracted, while the other matrix entries represent the squared correlations.

### 4.4 Structural Model and Hypotheses Testing

The structural model was tested using Amos 20.0. The results of the structural model are shown in Figure 2. The $R^2$ (R square) in Figure 2 denotes to coefficient of determination. It provides a measure of how well future outcomes are likely to be predicted by the model, the amount of variability of a given construct. In our analysis, the $R^2$ coefficient of determination is a statistical measure of how well the regression coefficients approximate the real data point. According to the result, 77% of the variance of behavior intention can be explained by the research model.

The standardized path coefficients between constructs are presented, while the dotted lines stand for the non-significant paths. Table 3 presents the path coefficients, which

are standardized regression coefficients. As a result, five (H1, H3, H5, H6, H7) of the proposed eight hypotheses were supported. The positive effects of perceived enjoyment on intention to use was quite strong, as indicated by the path coefficient of 0.85 ($p<0.05$). The other path coefficients of compatibility, observability, social influence, and performance expectation, to intention to use were statistically positively significant at $p<0.05$. But, there was no significant positive impact of facilitating conditions, effort expectancy, and price value on the intention to use smartphones with older adults. Therefore, H2, H4, and H8 were rejected.

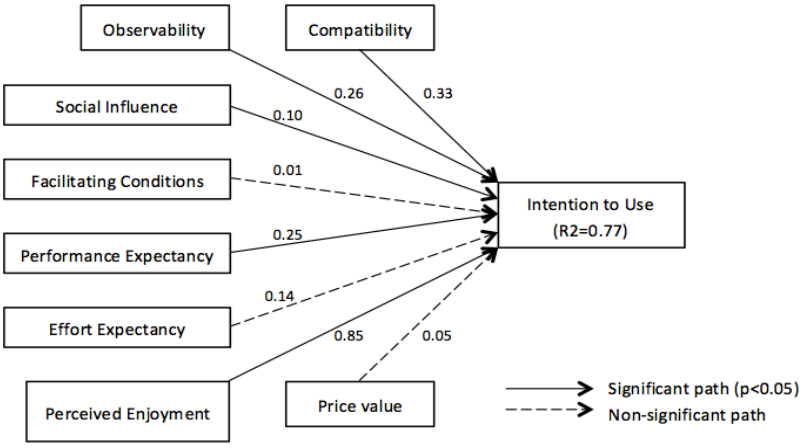


**Fig. 1.** Results of structural modeling analysis

**Table 3.** Test of hypotheses based on path coefficient

| Hypothesis | Path Coefficient | Hypothesis Result |
|---|---|---|
| H1 | 0.10* | Supported |
| H2 | 0.01 | Rejected |
| H3 | 0.25*** | Supported |
| H4 | -0.14 | Rejected |
| H5 | 0.26*** | Supported |
| H6 | 0.33*** | Supported |
| H7 | 0.85*** | Supported |
| H8 | -0.05 | Rejected |

*p<0.05; **p <0.01; *** p <0.001

## 5 Discussion

In this research, we studied the adoption of smartphones with older adults in China. The most important determinant for users' intention to use smartphones was perceived enjoyment. If using smartphones is fun, older adults are more likely to accept smartphones. Further, social influence was proved to be important for the use and

adoption of smartphones with older adults. It means that the opinions of friends and family have a positive impact on older adults' intention to use smartphones.

Performance expectancy had a significant positive impact on older adults' intention to use smartphones, while effort expectancy did not have a strong positive influence on older adults' intention to use smartphones. It seemed that older adults did not use smartphones just because it was easy to use, but rather because they found it useful for their work and life. Therefore, smartphones providers need to develop better solutions to make smartphones more useful. This also implied that content providers of apps on smartphones have to pay more attention to the usefulness of the content available on smartphones for older adults.

There was no significant positive impact of facilitating conditions on the intention to use smartphones with older adults. One possible reason was that facilitating conditions might be considered as a limiting factor when the needed facilitating conditions are not perceived by older adults. Therefore, the presence of the facilitating conditions did not motivate older adults to use smartphones. Another interesting finding was that price value had no significant positive impact on the intention to use smartphones with older adults. Since smartphones become inexpensive (e.g., the cheapest model from MI costs 100 USD) in China, most participants in this study can afford smartphones. It seems that they tend to focus on the factor (e.g., perceived enjoyments, performance expectancy) when using smartphones. Therefore, price value of smartphones becomes unimportant when it comes to the adoption of smartphones with older adults in China.

However, we were also aware of some limitations. Firstly, we only tested the research model and research hypotheses with older adults from five provinces in the central part of China. This sample might not be fully representative of the entire older adults in China. Secondly, all the data were collected using self-reported scales in the research. This may lead to some caution because common method variance may account for some of the results that has been cited as one of the stronger criticisms of tests of theories with TAM and TAM-extended research [11]. However, our data analysis with convergent and discriminant validity does not support the presence of a strong common methods factor. Last but not least, the findings of this study may be limited due to the relatively small sample size.

## 6 Conclusion and Future Research

This research was designed to study the adoption of smartphones with older adults in China. To the best of our knowledge, we have not found any studies concerned with older adults' intention to use smartphones in China. This study investigated older adults' adoption of smartphones by extending UTAUT with a consideration of observability and compatibility from IDT, and perceived enjoyment and price value. A research model with eight research hypotheses was proposed in the study. Five research hypotheses were positively significantly supported, while three research hypotheses were rejected in this study.

Continuing with this stream of research, we plan to further examine the applicability of the research model with other group of users in China (e.g., people below 45

years old). Future research is also needed to empirically verify the research model with larger samples across the world. We also plan to carry out a comparative study with older adults in the developed countries.

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# Towards Automatic Generation of Project-Based Solutions

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**Abstract.** Modern business models and processes usually demand an integrated utilisation of business frameworks and methodologies, such as PRINCE2® and PMBOK®, to produce meaningful business documentation and solutions. Often, the use of such frameworks is a prerequisite to engage with public or private sector large-scale projects. However, models contained in such frameworks usually lack formal semantics which may lead to inconsistencies between modeling solutions. The maintainability and reusability of such models tends to require manual intervention which is susceptible to human error. Software engineers used to experience similar issues and partially solved these by introducing a model-driven approach called Model Driven Architecture. In an attempt to adapt to industry needs, over the past five years Domain Specific Modeling has experienced increased popularity. The authors propose a transfer of concepts and logic from MDA and DSM to a project-based model-driven approach; facilitating the automated production of supportive documents for business decision making.

## 1 Introduction

Rapidly changing business environments require frequent re-calculation of business strategies. Such changes are frequent and unpredictable. Human responses to these changes can be prone to human error and not within the required timeframe. The current industrial landscape predisposes business solutions (business decisions and supporting documentation) with a number of defects in terms of lack of understanding and implementation of frameworks, methodologies and best practices. As a consequence, informal models or even non-modelled business solutions offer limited value to the business.

Such informalities, may lead to a number of limitations such as: the requirement for model specific training, difficulty in capturing changing business requirements and the use of inconsistent models which are often out dated. Effectively, changes that will not be included in all corresponding models will create inconsistencies since the models will no more reflect the actual business requirements. Subsequently, models will be discarded. "Often, the modellers themselves have disappeared, and any

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knowledge that wasn't captured in the specialised models is inaccessible, forgotten, or written off" [1]. In addition, informal models are limited to use by individuals, small teams or within single organisations due to the lack of information clarity and understanding of non-standard models among different teams or members. This leads to the inability to address key business environment factors.

In the last decade, software engineering solved most of the system modelling problems with the introduction of the Model Driven Architecture framework (MDA). MDA divides models into four abstraction layers; Computational Independent Model (CIM), Platform Independent Model (PIM), Platform Specific Model (PSM) and generated code. The key idea behind MDA is the production of formal models through consistent model transformation. Models of the PIM layer are transformed to models of the PSM layer and then to code. At each layer, the user can add details or tune the models as needed. Any model can participate in an MDA transformation as long as it has a corresponding meta-model. A meta-model is a model that explains the semantics of its corresponding model. In other words, a meta-model is data about data.

Our research extends the applicability of MDA and uses it to solve business modelling problems in the project management domain. In effect, a *domain* can be characterised as a business discipline, customer, company, contact, location. Domain Engineering such as Product Line Engineering, is the entire process of reusing domain knowledge in the production of new software systems. An essential idea in systematic software reuse is the application domain, a software area that contains systems sharing commonalities [18].

The reason the author's attempt to shed light on project-based modeling and automation regards noteworthy references from the MDA community on benefits realised in software development project management. As a result, this paper proposes a project-based approach to inherit the MDA concepts of Modelling and Meta-modelling, separate modelling layers and model transformations. This could potentially inherit a number of MDA established benefits realised over the past decade as follows ([2],[3],[4], [5], [6], [7], [8], [9]):

- Increase productivity and reliability through automated generation of business related documentation;
- Reduce time-to-market solution;
- Richer model semantics;
- Models with higher formality.

The proposed framework will be capable of supporting corporate decision making through business solutions provided that their corresponding meta-models are present. This project-based approach can be utilised as a solution generation tool to offer artefacts given the appropriate meta-model or pool of metamodels, model transformations and/or reusable project-based artefacts (meta-model or transformation).

Further to the introduction, this paper is organised as follows; in section (2) the definition of a model is illustrated and current modelling issues in software development are presented. Section (3) discusses in brief the various aspects of Model Driven Architecture. Section (4) presents a thorough account of the proposed project-based approach. Research conclusions and future work are discussed in section (5).

## 2 Project-Based Modelling Issues in Software Development

A model is a representation of a concept from the real world. An interpretation of a model gives a model meaning [10]. Models are widely used and are essential in other disciplines. For instance, prior to the construction of a bridge civil engineers produce a design that will be utilised as a blueprint for the construction of the bridge. It is not possible to start the construction of a bridge without any designs. However, it is not uncommon to start a business project without any planning and sometimes without concise and well-defined requirements or specifications or even clear business goals and objectives.

The paradox is that, software engineering can benefit more from models than other disciplines [11]. The current problem with models [12] is that most of the models are described in an abstract layer which is not very useful, indicating, what needs to be done at a given moment in time.

Nevertheless, business requirements change so rapidly that it is possible that the requirements might change while the project is still under development. Most of the cases the business solution will not reflect the design due to the high abstraction level of the design, time and/or cost constraints as well as incorrect or incomplete design. Provided there is a change request it is very likely that it will only change in the business solution and there is a possibility that nobody will update the design. These reasons will create an inconsistency between solution and design that will lead to the infrequent use or ultimately the disposal of the design.

Therefore, there is an explicit industry need to address platform complexity and the inability of third generation languages to alleviate this complexity and express domain concepts effectively. There exist MDA tools which can be employed to address these issues such as Eclipse Modeling Framework (EMF), Graphical Editing Framework (GEF), Graphical Modeling Framework (GMF) to which IBM contributes, Microsoft MS/DSL Tools, and Model Integrated Computing (MIC) utilised by Generic Modeling Environment (GME) developed by Vanderbilt University.

## 3 Model Driven Architecture

Prior to proposing a solution it is worth investigating how software engineering solved modelling issues presented in section (2). Model Driven Architecture (MDA) is a software development approach launched by OMG, [13]. The key idea behind the MDA framework is the separation of the development into three layers and the automatic transformation of models between the four layers by software tools. The business processes and requirements of the CIM layer are mapped to PIMs. These are then transformed to PSMs which are then transformed to code.

Human experts can execute manual tuning to each model and these changes will be carried over to the next model. MDA software tools allow changes made at a higher layer of the MDA to be reflected at the lower layers of the framework.“MDA is potentially advantageous because it shifts complexity away from developers and into the tool chain and, hence, the PIM-to-PSM transformation” [14]. MDA uses the Unified Modelling Language (UML), OMG’s main modelling standards which are

ISO standards and ITU-T recommendations. There are several model transformation languages; UML-RSDS [20], Epsilon [21], QVT-R, ATL, Kermeta, GrGen.NET. A comparison on the characteristics of some of these languages can be found in [22].

## 4 A Project-Based Approach

A project management oriented approach attempts to address Model Business Engineering (MBE) issues with an aim to assist project managers and other project stakeholders generate day-to-day business documents and/or perform decision making activities in an increasingly automated manner.

Research in the area of transformations of UML Activity Diagrams to BPMN 2.0 has indeed been stated in e-Government systems [15], [16]. There is also evidence for the BPMN 2.0 to UML Activity Diagram transformation [17]. However, such empirical research has not been considered in the industrial domains of project management for frameworks such as PRINCE2® and PMBOK® as well as service management such as ITIL®.

The project-based approach can be characterised as *'a structured approach to automated generation of modelled artefacts in the context of business disciplines, that can form the basis of decisions, business documents and/or business activities.'*

This approach can reach its end result i.e. business solution generation, through two abstraction layers; Project Specific Layer (PSL) and Business Solution Layer (BSL). The end result e.g. documentation, can lead to management decisions and/or a set of actions. A mechanism to support reuse of best practices when creating families of business solutions would be appropriate to consider at this stage.

To visualize a software model transformation consider Java or C++ code as the implementation solution i.e. PSM, see section 3. The model describing the code functions and variables is one abstraction layer higher than the implementation layer i.e. PIM, see section 3. In a similar way, project management documents or decision making artifacts can be characterised as part of the implementation layer or BSL. The model describing the BSL is the PSL.

The project-specific layer ensures a modelled business and leads to business solution. The business solution layer would effectively depict the real data relating to information fed in the previous layer.

In certain instances, capturing project stakeholder related information can be of substantial value in formulating an accurate business solution such as business policies that do not allow employees to work beyond the eight-hour shift since these set their rules in the environment in which the project is executed. Hence, capturing environment information can be vital for the success of projects.

Information pertinent to a specific project framework should be utilised in the project specific layer. Any pertinent information to e.g. PRINCE2® or PMBOK® should be utilised. Finally, PRINCE2® or PMBOK® produced documentation, roles, processes and functions signify a modelled business solution.

The project-based approach can help architects commit changes at the project-specifc layer which can then propagate to the business solution layer instead of having a monolithic transformation. The next sections describe thoroughly the project-specific layer.

### 4.1 Project Specific Layer

The project-specific layer can be defined as *'the depiction of project-based elements e.g. tasks, activities, resources, that can facilitate real world business solutions.'*

In this layer, it is recommended to select models from well established frameworks or industry standards with worldwide recognition. The accuracy of the result will heavily depend on the selected framework.

Taking into consideration the information available such as a meta-model that clearly states that the more certified PMs in structured PM frameworks the more successful that PM framework could prove to be in an organisation, it is clear that a structured PM framework would be selected for use within the enterprise. The business solution would relate to real data such as strategic corporate decision of whether to use a structured or agile PM framework. The business solution can be anything from a simple decision to complex models supported by vast documentation. In the scenario considered the business solution can either be a 'Yes' or a 'No'. In order to reach this stage, the data from PSM has to be extracted.

### 4.2 Business Solution

The business solution layer can be defined as *'the resulting business document(s), charts and descriptive information for a specfic project.'*

The business solution layer, contains the produced business documents such as business plans, progress reports, status reports, risk analysis documents, time tables, schedules and more artifacts that can be used for both day to day operation or strategic level information. Before this static documents are generated their corresponding meta-models are required.

There can be actions defined as activities to be performed by a human or software agent. Such actions can include, sending emails, perform transactions, make payments and more. To support the generation of such dynamic artifacts their corresponding meta-models should also include triggers with pre and post conditions. These can be defined in OCL or any other constraint language and must also be supported by the software tool producing the project-based model.

The project-based layers have been presented and thoroughly discussed. However, a closer examination of the approach with an example can form a concrete definition.

## 5 BPMN to UML-RSDS Transformation

Project change is inevitable whether it comes from within the project or from external factors influencing project scope. For these reasons, whenever change occurs, an agreed logical change management process has to be initiated that allows the project to identify, assess and control any potential and approved changes to the original baselines that where originally agreed for the project.

In addition, the use of a standardised change management approach can serve as a control agent to any Request-for-Change (RfC). Once the project scope and other key key associated documents have been approved, these become the project "baselines" and can only be changed after approval by the appropriate authority; normally the

Change Advisory Board. Change control and hence change management is not there to prevent changes, but to ensure that every change is agreed by the relevant authority before implementation. This section presents the transformation of a BPMN project-specific model from PRINCE2®, see Fig 1, to its UML-RSDS derivative model.

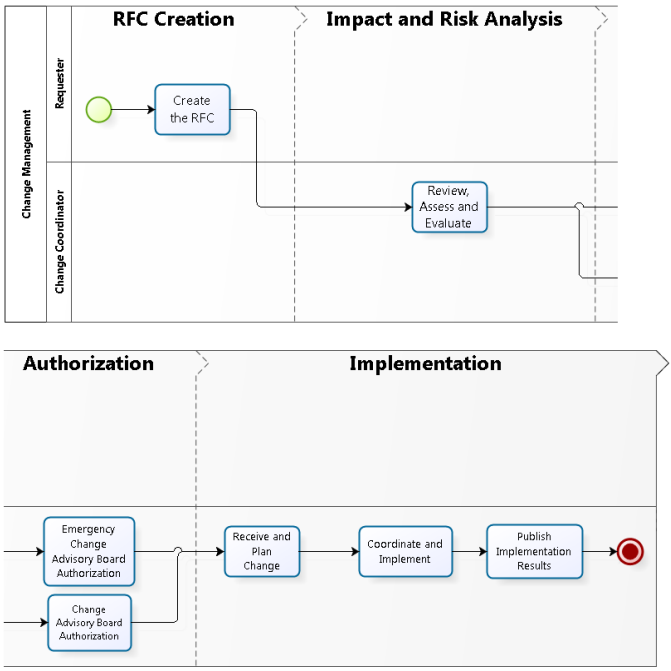


**Fig. 1.** Change Management Procedure of a Project

The next step is to produce the corresponding model using the UML-RSDS transformation engine based on a set of rules that apply for BPMN models. The transformations supported by UML-RSDS regard BPMN 2.0 elements set i.e. flow objects, connecting objects, artifacts. Swim lanes are not included in the below example nor can they be currently supported.

## 5.1 Rules

The mapping is described by one rule, and the execution semantics by several update-in-place rules defining how a process instance may evolve, and how its tokens may move around the process. The rules are described in textual representations derived from UML-RSDS models.

**Process Instantiation.** This is formalised by the following use case *initialise* post-condition on Process:

```
sn : flowElements & sn : StartEvent &
sn.eventDefinitions->forAll( ed I ed : TimerEventDefinition ) =>
ProcessInstance->exists( pi I pi.state = RUNNING & self :
pi.process &
  Token->exists( t I t : pi.tokens & sn : t.element ) )
```

"If the process has a StartEvent sn which has only TimerEventDefinition, create a process instance pi for the process, with one token at sn".

**Normal termination.** These are postcondition use cases of Process Instantiation:

```
state@pre = RUNNING &
process.flowElements->exists( e I e : EndEvent ) & tokens@pre->forAll(
t I t.element <: EndEvent ) => state = FINISHED &
  tokens@pre->isDeleted()

state@pre = RUNNING &
process.flowElements->forAll( e I e /: EndEvent ) &
tokens@pre.element->forAll( n I n : FlowNode & n.outgoing->size() =
0 ) =>
  state = FINISHED &
  tokens@pre->isDeleted()
```

Either (i) the process has an EndEvent, and all its tokens occupy EndEvent nodes, or (ii) the process has no EndEvent, and all its tokens occupy nodes with no outgoing flow. In either case the process is set to FINISHED and all its tokens deleted.

**Starting a process instance.** A process instance can start if it has a token t on a start event with at least one outgoing flow:

```
  state = RUNNING & t : tokens &
  fe : t.element@pre & fe : StartEvent &
  fe.outgoing->size() > 0 =>
  fe.outgoing->exists( sf I t.element = Set{ sf } )
```

The token on the start event is then moved to one of the outgoing flows of the start event.

**Ending a process.** If a process instance has a token on a SequenceFlow with target node an EndEvent, then the token can be moved to the EndEvent:

```
  state = RUNNING & t : tokens &
  fe : t.element@pre &
  fe : SequenceFlow &
  fe.targetRef : EndEvent =>
  t.element = Set{ fe.targetRef }
```

**Entering a task**

The same step applies if the target is a Task:

```
state = RUNNING & t : tokens &
fe : t.element@pre &
fe : SequenceFlow &
fe.targetRef : Task =>
    t.element = Set{ fe.targetRef }
```

**Leaving Tasks**

A process instance which has a token t on a Task fe can leave fe if fe has at least one outgoing flow:

```
state = RUNNING & t : tokens@pre &
fe : t.element@pre &
fe : Task & fe.outgoing->size() > 0 =>
    t->isDeleted() &
    fe.outgoing->forAll( sf I
        Token->exists( t1 I sf : t1.element & t1 : tokens ) )
```

t is deleted, and new tokens are created for the process instance on each outgoing flow.

**Entering parallel gateway**

Here we assume that there is at most one token for a given process instance on each flow element.

The process instance can enter parallel gateway pg if it has a token on every incoming flow of pg, and there is at least one such flow:

```
state = RUNNING &
pg : Para11e1Gateway &
ν = tokens->select( t I pg.incoming->exists( sf I sf : t.element )
) &
v.size > 0 &
v.size = pg.incoming->size() =>
    Token->exists( t1 I pg : t1.element & t1 : tokens ) &
    v->isDeleted()
```

A single token ti for the process instance on pg is then created, and the set v of the instance tokens on the incoming flows of pg is deleted.

In this case the constraint requires fixed-point iteration, as it writes the same data (Token: :element) that it reads. The let variable v is used to store the pre-value of the expression it is assigned.

**Leaving parallel gateway**
This is formalised by the following postcondition use case on Process Instantiation*:*

```
state = RUNNING & t : tokens@pre &
fe : t.element@pre &
fe : Para11e1Gateway &
fe.outgoing->size() > 0 =>
    t->isDeleted() &
    fe.outgoing->forAll( sf I
         Token->exists( t1 I sf : t1.element & t1 : tokens ) )
```

"If the process instance is running, and has a token t in a parallel gateway fe, with an outgoing flow, then delete t, and create a token for the process instance in each outgoing flow of fe."

### 5.2 Modeled Solution

The corresponding modelled solution of Fig. 1 is described with seven (7) tasks, two parallel gateways and a start and end node as follows below.

```
p1 : Process
p1.name = "BPMN2UMLRSDS"
pg1 : Para11e1Gateway
pg1.name = "pg1"
pg1 : pl.flowElements
pg2 : Para11e1Gateway
pg2.name = "pg2"
pg2 : p2.flowElements
se : StartEvent
se.name = "start event"
se : pl.flowElements
ee : EndEvent
ee.name = "end event"
ee : pl.flowElements
tl : Task
t1.name = "Create the RFC"
tl : pl.flowElements
t2 : Task
t2.name = "Review, Assess
and Evaluate"
t2 : pl.flowElements
t3 : Task
t3.name = "Change
Advisory Board
Authorization"
t3 : pl.flowElements
t4 : Task
t4.name = "Emergency Change
Advisory Board
Authorization"
t4 : pl.flowElements
t5 : Task
t5.name = "Receive and Plan
Change"
t5 : pl.flowElements
t6 : Task
t6.name = "Coordinate and
Implement"
t6 : pl.flowElements
t7 : Task
t7.name = "Publish
Implementation Results"
t7 : pl.flowElements
sf1 : SequenceFlow
sf1.name = "startTotask1"
sf1 : pl.flowElements
sfl.sourceRef = se
sfl.targetRef = t1
sf2 : SequenceFlow
sf2.name = "task1Totask2"
sf2 : pl.flowElements
sf2.sourceRef = t1
sf2.targetRef = t2
sf3 : SequenceFlow
sf3.name = "task2Topg1"
```

```
sf3 : pl.flowElements
sf3.sourceRef = t2
sf3.targetRef = pg1
sf4 : SequenceFlow
sf4.name = "pg1Totask3"
sf4 : pl.flowElements
sf4.sourceRef = pg1
sf4.targetRef = t3
sf5 : SequenceFlow
sf5.name = "pg1Totask4"
sf5 : pl.flowElements
sf5.sourceRef = pg1
sf5.targetRef = t4
sf6 : SequenceFlow
sf6 .name = "task3Topg2"
sf6 : pl.flowElements
sf6.sourceRef = t3
sf6.targetRef = pg2
sf7 : SequenceFlow
sf7 .name = "task4Topg2"
sf7 : pl.flowElements
sf7.sourceRef = t4
sf7.targetRef = pg2
sf8 : SequenceFlow
sf8 .name = "pg2Totask5"
sf8 : pl.flowElements
sf8.sourceRef = pg2
sf8.targetRef = t5
sf9 : SequenceFlow
sf9 .name = "task5Totask6"
sf9 : pl.flowElements
sf9.sourceRef = t5
sf9.targetRef = t6
sf10 : SequenceFlow
sf10.name = " task6Totask7"
sf10 : pl.flowElements
sf10.sourceRef = t6
sf10.targetRef = t7
sf11 : SequenceFlow
sf11.name = "task7Toend"
sf11 : pl.flowElements
sf11.sourceRef = t7
sf11.targetRef = ee
```

The following shows a trace of the execution of the transformation on this model:

```
Model loaded
Entering startTotask1
Left startTotask1
Entered Create the RFC
Left task Create the RFC
Entered flow task1Totask2
Left task1Totask2
Entered Review, Assess and
Evaluate
Left task Review, Assess and
Evaluate
Entered flow task2Topg1
Entered parallel pg1
Left pg1
Entering pg1Totask3
Left pg1
Entering pg1Totask4
Left pg1Totask3
Entered Change Advisory
Board Authorization
Left pg1Totask4
Entered Emergency Change
Advisory Board Authorization
Left task Change Advisory
Board Authorization
Entered flow task3Topg2
Left task Emergency Change
Advisory Board Authorization
Entered flow task4Topg2
Entered parallel pg2
Left pg2
Entering pg2Totask5
Left pg2Totask5
Entered Receive and Plan
Change
Left task Receive and Plan
Change
Entering task5Totask6
Left task5Totask6
Entered Coordinate and
Implement
Left task Coordinate and
Implement
Entering task6Totask7
Left task6Totask7
Entered Publish
Implementation Results
Left task Publish
Implementation Results
Entered flow task7Toend
```

The aforementioned textual workflow indicates consistency with explanations provide in section 5.1 whereby each step is thoroughly described. The benefits such an approach can realise in project management regard formalised models which respect project management processes modelled in BPMN. The textual representation of these models can potentially lead to advantages described in section 1.

## 6 Conclusions and Future Work

This paper attempts to highlight the potential research areas that can extend MDA aspects on DSM to business-specific model and more specifically project management. There are suggestions [19], that corporate decision analysis and decision making leading to changes, can be linked to business needs and improved decision making techniques by adopting approaches in model driven environments for software development.

Developing an integrated methodology on the marriage of MDA and business models is a multi-faceted issue. The paper proposes the utilisation of a renewed project-based approach that will form part of a structured treatment to business models and contribute to increased clarity and formality.

The proposal includes two layers; that can signify business oriented solutions and result to modelled decisions and management guidance documentation.

Extended research in the area of project-based automation could include transformations that support the full BPMN 2.0 elements set i.e. flow objects, connecting objects, swim lanes, artifacts. Future work should also focus on other practices outside MDD such as business analysis and service management. The MDA and BPM communities have taken steps towards attaining a more business-oriented approach to identified parts of projects which can be standardised. However, it is the authors' belief that building on the already available knowledge of both research communities, there are valuable lessons to learn and apply to other standardised business frameworks such as PRINCE2® for project management, BABOK® for business analysis and even ITIL® for service management.

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# Translation of Requirements Engineering Models

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**Abstract.** The globalization and the rapid development of information and communication technologies encourage organizations to work together. In software development, many works have emerged to support this cooperation using different tools and methodologies. Most of them focus on the design-stage concerns. However, very little works have dealt with cooperation during the early stage of software projects, namely Requirements Engineering (RE), despite the importance of this stage for the failure or the success of software projects. There exist different kinds of approaches to support the RE process in different contexts, based on models such as goal, viewpoint and scenario oriented. Each of these models relies on concepts which differ from one model to another. One of the difficulties for organizations that intend to work together in the upstream phases of software projects is summarized by the following question: What is the most appropriate approach every partner has to adopt? In this paper, we propose a translation process between RE models in order to ensure that organizations with different types of RE backgrounds and methodologies can work together to achieve their objectives while still using their own approach. The translation is performed using a unified meta-model issued from a semantic process of computing similarities between concepts of RE models.

**Keywords:** Requirements Engineering, Meta-modelling, models translation, similarities.

## 1 Introduction

In software engineering, many factors can be responsible for the success or the failure of projects. One of the reasons affecting the failure of these projects is the poor definition and management of requirements [1]. Hence, predicting and writing good requirements [2] is a key factor for the success or the failure of software projects. Requirements Engineering (RE) [3] is the discipline which aims at defining, managing and documenting software requirements in upstream phases of software lifecycle.

However, due to present-day globalization [4] of the business world, many organizations should cooperate in order to achieve their objectives. Cooperation is the manner of coordination that is necessary for agreeing on common objectives and for the coordinated achievement of common work among participants [5]. Unfortunately, most of the work that discusses cooperation in software engineering such as [6] and [7] focuses only on the

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design stage of software development lifecycle and do not address the RE upstream phase. Very little works have focused on the cooperation in RE. The fact that RE is important should have led to more interest in cooperation in this phase.

Different kinds of solutions have been proposed to support the RE process: goal oriented approaches such as i* [8] deal with actor dependencies, goals and intentions, viewpoint oriented approaches such as PREview [9] deal with the perception of actors, and scenario oriented approaches such as CREWS [10] describe functional behaviors by means of scenarios. This variety of solutions makes cooperation among organizations stakeholders in this phase a difficult activity due to the heterogeneity between these models.

Bendjenna et al. [11] proposed a solution which aims to integrate the three concepts of goal, viewpoint and scenario into one model in a cooperative environment. The work is embodied in the proposal of MAMIE as a new approach that should be used by all organizations stakeholders in order to allow cooperation between them. On the contrary, our work stems from the idea that preserving as far as possible the working environment of the stakeholders involved in organizations which aim to cooperate is more realistic. This leads us to propose a translator between different kinds of existing RE models that follows, in a broader way, the principle of Cares and Franch [12]. These ones have defined a "super meta-model" hosting identified variations of i* and implementing a semantic preservation oriented translation algorithm between these different variations.

Our translator allows organizations that use different kinds of RE models to cooperate continuing to use their usual approaches, without forcing them to spend time, human and financial resources in order to migrate to a unique RE model. The RE translator lies on our so called UREM unified meta-model which is issued from a semantic process of computing similarities between concepts of RE models ([8], [9] and [10]).

In this paper, we present a 3 phases process to translate RE models (Fig. 1). The following section 2 presents the two first phases of the translation process: the unified requirements engineering meta-model UREM, and how correspondences between concepts are built. In section 3, we discuss the third phase of building the RE translator which involves 'how' the translation between heterogeneous RE models is performed. Section 4 presents a case study to evaluate our work. In section 5, we conclude and draw perspectives.

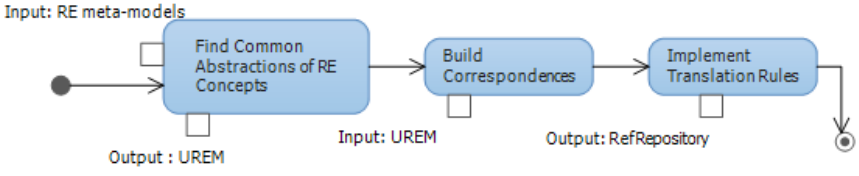


**Fig. 1.** RE Translator Building Process

## 2 UREM: Unified Requirements Engineering Meta-model

In this section, we use a unified RE meta-model to create correspondences between meta-models of 3 representative RE approaches: i*, PREview and CREWS. This meta-model represents the common abstraction of those RE meta-models. These correspondences represent the core component of the translator between RE models. The translation between models using these correspondences can be achieved by finding for each concept in a source model the most suitable correspondent concept or collection of concepts in a target model. The resulting so called UREM meta-model is illustrated in Figure 2.

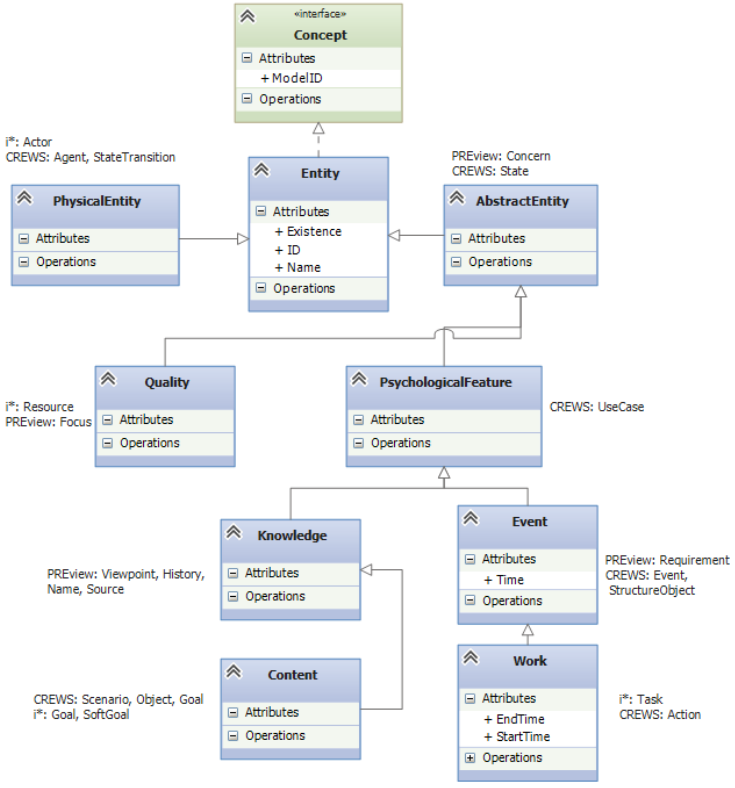


**Fig. 2.** UREM Meta-model

Each class (abstract concept) in UREM (Fig. 2) represents an abstraction of a set of similar RE concepts. These concepts are labeled beside each abstract concept in Fig 2. Similar concepts are concepts that share some common ground (attributes). In a previous work, we adopted a rigorous semantic process [13] based on the semantics of words which represent RE concepts. This process is performed using WordNet [14] and is composed of several steps starting with the classification of RE concepts into two categories: concepts that can be retrieved directly from WordNet (category 1) and

concepts that cannot (category 2). This categorization leads us to develop an incremental process by applying several algorithms on concepts of category 1 using WordNet: (1) Word Sense Disambiguation (WSD), (2) treat concepts as a tree in WordNet and compute distances by finding the least common parent (hypernym). Afterwards, we compare concepts of the category 2 to the tree that represents concepts of the category 1 and their parents in order to find similarities.

UREM is represented as a tree where abstract concepts are parent nodes (hypernyms) of different RE concepts (nodes). For each concept, we can find the most suitable correspondent (the most similar concept) in a target model by browsing the tree as follows:

- If several paths lead from a given concept to one concept in another model, we use least common hypernyms as described in [13] to find the shortest path between concepts. If the shortest path leads to several concepts in a same target model, we consider all these concepts as a correspondent. For example: Goal concept of i* has the same distance to several concepts in PREview: Viewpoint, History, Name and Source. If a concept has child and parent nodes, we always browse the tree according to the shortest path. Finding paths is a key factor to build correspondences.
- We build sets of correspondences between the three RE models from the results of the previous steps. For example: Goal and SoftGoal concepts in i* have Scenario, Object and Goal target concepts in CREWS, and Viewpoint, History, Name, Source target concepts in PREview. In the same time, Scenario, Object and Goal concepts in CREWS have Viewpoint, History, Name,Source target concepts in PREview. UseCase has also a short path to these concepts. We build the overall correspondence: {Scenario, Object, UseCase, Goal (CREWS), Goal, SoftGoal (i*), Viewpoint, History, Name, Source (PREview)} that is stored and used as a reference to translate these concepts from a model to another.

The resulting sets of correspondences are:

- C1 = {Scenario, Object, UseCase, Goal (CREWS), Goal, SoftGoal (i*), Viewpoint, History, Name, Source (PREview)}
- C2 = {Action, Event, StructureObject (CREWS), Task (i*), Reqirements (PREview)}
- C3 = {Agent, StateTransition, State (CREWS), Actor, Resource (i*), Concern, Focus (PREview)}.

In this section, we have built correspondences relationships among RE concepts. In the next section, we discuss the last phase illustrated in Fig. 1 to build the RE translator related to; how to perform translation between those concepts using the defined correspondences.

## 3 Translation between Requirements Engineering Models

In this section we describe how to translate RE concepts using correspondences created in the previous section. Figure 3 illustrates the design of the translation process between concepts.

The design illustrated in Fig. 3 is based on the factory design pattern [15] which allows users to translate and create, for a source concept, one or more target concepts without bothering them with the entire specification of these target concepts that they do not need to know, or they do not have the abilities to handle. The translation should be performed through a common interface called IConcept. The user asks ConceptsFactory for translation that needs the use of a referential repository: RefRepository.

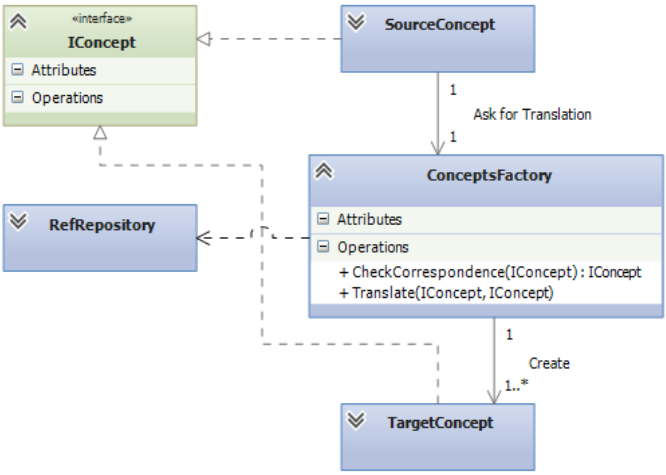


**Fig. 3.** Design of Translation Process

RefRepository stores all possible correspondences generated in the previous section between concepts of i*, PREview and CREWS models. For each correspondence, there exist translation rules which describe how to translate a source concept to a target model. RefRepository defines two types of translation:

- Automatic translation is used with the first and the second type of translation. This rule operates when the Concepts Factory creates automatically a new instance of a target concept from the source one by checking the most suitable correspondence in RefRepository. Afterward, the factory translates source attributes to target attributes in the new target concept by moving the value of source attributes to a target attributes. The factory uses simple naming conventions to name the new target concepts.
- Semi-Automatic translation is performed after the automatic translation if a part of source concepts cannot be translated correctly to the target model. We perform a translation aided by questions {Which, How or What}. Two lists of elements (concepts and attributes) are created, one for source elements that are not translated correctly to the target model and the other is composed of empty instances which represent target elements in the target model that are not created in the automatic translation. Fig. 4 illustrates these lists. Each list is divided in three sets according to the correspondences that are previously defined. Users can help the RE translator

using their experience by answering several questions on the source elements. Answers to these questions are a guide to find a matching (translation) between source and target elements that are not translated automatically.

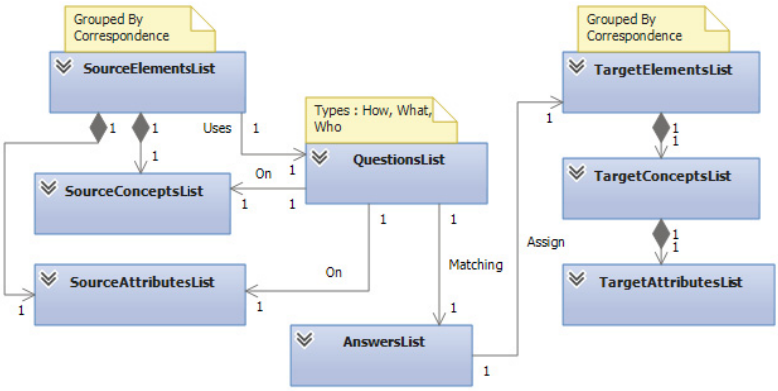


**Fig. 4.** Structure of Semi-Automatic Translation using Questions

RefRepository (Fig. 5) contains a set of elements. Each element is either a concept or an attribute and it belongs to a model. Each element is included in a correspondence where each one has a set of Naming Conventions and a set of questions that will be used in the semi-automatic translation.

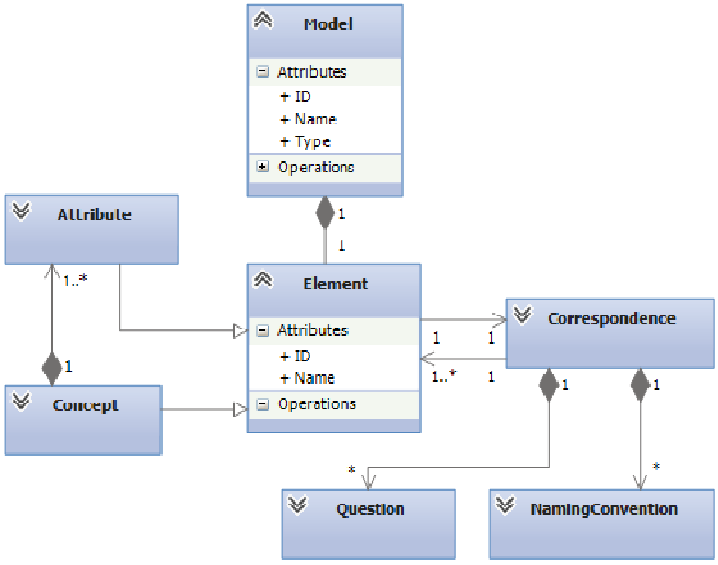


**Fig. 5.** Class diagram of the referential repository (RefRepository)

# 4 Case Study: Software Bugs Management

The evaluation of our work can be achieved by applying several case studies in order to verify the soundness of the translation process we propose. In this paper, we present one of these case studies to illustrate the translation process: a requirements specification for a software bugs management system. We uses i*, PREview and CREWS to represent requirements models. For the sake of space we only represent i* model (cf. Annex), the translation between i* and PREview and the results of translation between the three models. We compare source models for each type to the models obtained according to the translation rules defined in the previous section.

The comparison is performed using a three rows and three columns translation confusion matrix [16] to calculate the translation accuracy of our solution. Rows and columns respectively represent source models (actual classes) and target models (predicted classes): i*, PREview and CREWS. Each cell $C_{i,j}$ represents the number of concepts instances which are translated correctly from the source model i into the target model j. Afterward, we compute the accuracy of the translation $A_T$ between each couple of models $M_1$ and $M_2$ by applying a simple formula to find the average of translated concepts ratio between any couple of models. Let $C_1$ and $C_2$ be respectively the numbers of concepts of $M_1$ and $M_2$. Let $C_{1,2}$ and $C_{2,1}$ be the number of translated concepts respectively from $M_1$ to $M_2$ and from $M_2$ to $M_1$.

$$R_T = \frac{\left(C_{1,2}/C_1 + C_{2,1}/C_2\right)}{2} \quad (1)$$

Any difference between predicted and actual concepts is considered as an error. In our case study, we apply an automatic translation which represents the most important part of translation without any expert intervention, and then we can improve the translation results by using a semi-automatic translation between RE models.

The case study involves a requirements specification for a system which aims to manage and resolve software bugs. A bug is an "Imperfections in software development process that would cause software to fail to meet the desired expectations" [17]. Therefore a bug can be defined as an abnormal behavior or a malfunction of the software system. To monitor these bugs, the use of a bug-tracker is inevitable to eliminate or at least reduce them. This system aims at providing actors with the possibility to report malfunctions, comment them, track the status of the anomaly, notify other actors of the problems encountered, and suggest solutions or opportunities for circumvention.

## 4.1 Application of Translation between PREview and i*

The translation between RE models of this case study is performed according to translation rules and correspondences C1, C2 and C3 defined in section 2.

To translate the PREview source model to i*, the user of PREview asks the Translator (ConceptsFactory) to translate the different 13 instances of concepts that compose the specification of the case study to target concepts in i*. ConceptsFactory checks for each instance the most suitable correspondence in the target model i*. Table 1 illustrates the results of the translation process grouped by correspondences.

**Table 1.** Translation from Preview to i*

| Source (Preview) Concepts | Target (i*) Concepts | Translation Rule |
|---|---|---|
| 3 instances of Viewpoint concept with their names: {BugManagementViewpoint, BugReportingViewpoint & BugFixgingViewpoint} | 3 instances of Goal concept: {BugsManagementGoal, BugsReportingGoal, BugsFixingGoal} | Automatic Translation using C1. |
| 8 instances of Requirement Concepts: BugReproducibilityDegree-Requirement, BugResolutionPriorityRequirement, BugSeverityDegreeRequirement, BugSummaryRequirement, SuggestSolutionRequirement, TestingRequirement, CommitRequirement, NotificationRequirement} | 8 instances of Task Concept: AddBugReproducibilityDegree Task, AddBugResolutionPriorityTask, AddBugSeverityDegreeTask, AddBugSummaryRequirement Task, SuggestSolutionTask, TestSolutionTask, CommitSolutionTask, NotifyPersonsTask} | Automatic Translation using C2 |
| Concern: {Bug Unavailability} | 4 actors {ManagerActor, ReporterActor, QATesterActor, EngineerActor | Semi-Automatic translation using C3 and the question: 'Who is responsible for'+ Concern |

The overall translation for the 13 instances of PREview is automatically performed to 11 instances in i*, and semi-automatically to 4; i.e. a total of 15 instances if the semi-automatic translation is well performed. Recall that an original source model of i* is composed of 20 instances of concepts. The 5 concepts in i* that are not translated are: Tasks (ReportBugTask, FixBugTask, ManageBugsTask), SoftGoal (Immediate-Reporting), Resource (BugResource). The Source concept (SoftwareSource) is not translated correctly to i* model.

The translation from an i* source model to PREview is performed in the same way with the same correspondences as illustrated in Table 2.

The overall translation of i* model (20 instances) are translated automatically to 11 instances of PREview concepts, and semi-automatically to one instance; that leads to a total of 12 instances if the semi-automatic translation is well performed. Knowing that an original source model of PREview is composed of 13 instances, the Resource and the SoftGoal of i* model are not translated correctly to PREview concepts.

### 4.2 Evaluation

In the evaluation, we compute the rate of translation successes obtained from the source models (Rows) of i*, PREview and CREWS. Table 3 presents the confusion matrix that summarizes the translation results of the models in the case study.

Proceeding from Table 3, we compute the accuracy of translation $A_T$ of the case study when using automatic translation. We apply the formula (1) between each couple of RE models:

**Table 2.** Translation from I * to PREview

| Source (i*) Concepts | Target (PREVIEW) Concepts | Translation Rule |
|---|---|---|
| 3 instances of Goal concept mentioned in Table 1 | 3 instances of Viewpoint concept mentioned in Table 1 | Automatic Translation using C1 |
| 11 instances of Task: 8 mentioned in Table 1 that represent sub tasks for ReportBugTask FixBugTask, ManageBugsTask. | 8 instances of Requirement (mentioned in Table 1). | Automatic Translation using C2. |
| 4 Actors mentioned in Table 1 | Concern mentioned in Table 1 | Semi-Automatic translation using C3 and the question: "What is the concern of"+ Actor. |

**Table 3.** Automatic translation matrix for software bugs management system

| | I* | PREview | CREWS |
|---|---|---|---|
| I* (20[a]) | | 11 | 20 |
| PREview (13[a]) | 11 | | 16 |
| CREWS (21[a]) | 15 | 11 | |

a. Numbers of concepts instances presented in the requirements specification

- PREview to/from i*: $R_T = (11 \div 20 + 11 \div 13) \times 0.5 = 70\%$
- CREWS to/from i*: $R_T = (15 \div 20 + 20 \div 21) \times 0.5 = 85\%$
- CREWS to/from PREview: $R_T = (11 \div 13 + 16 \div 21) \times 0.5 = 80\%$

The total average translation accuracy $A_T$ among all models is 78%. We observe the best translation rate is between i* and CREWS. The translation rate can be improved using a semi-automatic translation.

The case study presents a specific part of defined correspondences. The other concepts are not applied in this case study and have to be used in a future case study.

## 5 Conclusion

This paper presents a solution which allows the translation between different kinds of RE models in order to improve cooperation between stakeholders issued from cooperating companies. The translation is performed using a set of correspondences between the RE models, based on a unified meta-model called UREM. UREM is composed of a set of abstract concepts that represent these correspondences. For a given correspondence, we define translation rules to ensure the translation between concepts from one RE model to another. We present a case study in order to assess the correspondences and the rules that are defined. Unfortunately, we observe that some concepts are not successfully translated. We fix to some extent a part of this problem by adjusting some correspondences such as the concept Actor of i* and Agent of CREWS that can be integrated into the attribute StakeHolder of the PREview Viewpoint concept. Recall that the overall translation accuracy among all models is 78%.

We are currently developing ReqTranslator: it is a web platform which aims to illustrate and apply our solution of RE models translation. The platform proposes several features including translation of different kinds of RE models in addition to ensure the auto-integration of new types of RE models. This integration can be easily achieved due to the structure of the data model proposed for the platform which allows extensibility. Another perspective is to enhance the visualization form tables to graphs which will simplify the representation of requirements. We will also study more complex case studies in order to improve the evaluation of our work.

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# Annex

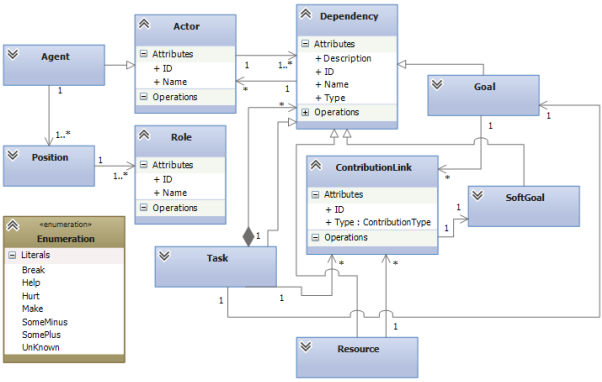


**Fig. 6.** i* meta-model

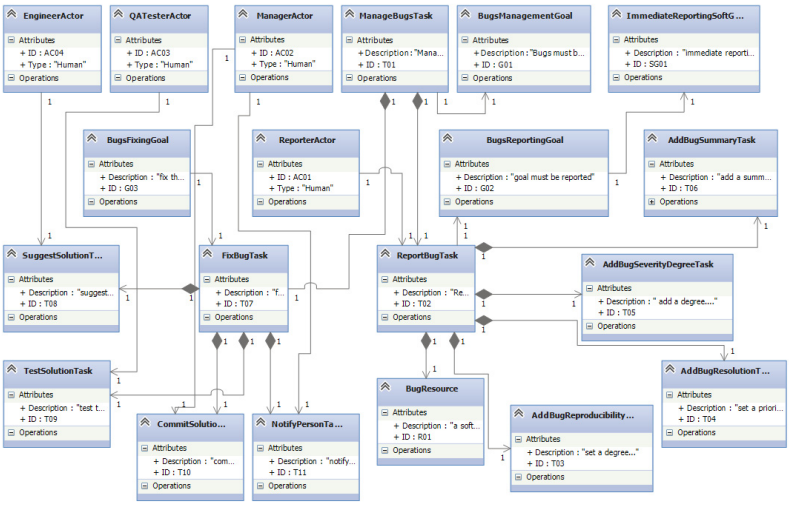


**Fig. 7.** i* Specification for Software Bugs Management System

# An Optimization of Collaborative Filtering Personalized Recommendation Algorithm Based on Time Context Information

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**Abstract.** This paper proposes an improved collaborative filtering algorithm based on time context information. Introducing the time information into the traditional collaborative filtering algorithm, the essay studies the changes of user preference in the time dimension. In this paper the time information includes three aspects: the time context information; the interest decays with the time; items similarity factor. This paper first uses Pearson correlation coefficient calculates time context similarity, pre-filtering the time-context. Through the experiment, the improved algorithm has higher accuracy than the traditional filter algorithms without time factor in the TOP-N recommendation list. It proves that time-context information of user's can affect the user's preference.

**Keywords:** Personalized recommendation, collaborative filtering, time-context.

## 1 Introduction

Recommender algorithms belong to a class of personalized information filtering technologies that aim to identify which items in a catalog might be of interest to a particular user. The scenario is a very important factor for mobile e-commerce personalized recommendation process. User's interests and needs tend to change with time and space associated with situation changes. Therefore, how to accurately predict the information of interest to users has become a key issue in personalized recommendation problems. Traditional collaborative filtering algorithm does not consider the situation. Therefore, it cannot reflect the needs tendency of users due to the different situations. This shortage caused a lack of personality in recommendation process. The length of time will affect a user memory of interest degree, thereby affecting their user preferences. Meanwhile, the mobile commerce environment is dynamical, and the context information are facing constantly changing, thus affecting the user's interest and purchasing decisions.

Based on this, this paper research on the impaction from time contextual information to users interested and the user interest preferences attenuation occurs over time context

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information. This paper provides an UIT (users-project-time) model. The model can achieve precise recommendation and marketing mobile environments. Our research work contributes to three levels: 1) at the method level, we improve the traditional collaborative filtering algorithms, combined with the time context information and collaborative filtering algorithm and improved mobile environment recommended accuracy in traditional collaborative filtering algorithms; 2) at the theoretical level, this study intends to enrich personalized recommendation research of mobile commerce. Currently, most of the research is focused on mobile business mobile business process, trust, risk, and decision-making issue, but consumer behavior, personalized research is still at an exploratory stage. This study also improves the quality of the recommendation system by time context information; and 3) at the commercial value level, the development of mobile Internet and mobile commerce will enter a rapid growth phase, how to provide a valuable service for these users, and then find the right business model is an important strategy for many Internet companies. We provide also a reference model for personalized recommendation in mobile environment.

## 2 Theoretical Background

### 2.1 Personalized Recommendation Algorithms

Collaborative filtering recommendation is the most successful technology. For example, Goldberg (1992) describes the similarity between users using artificial mail processing system. Ringo (1997) uses the social information filtering method and the music recommendation system. Currently collaborative filtering is mainly divided into two categories: User-based Collaborative Filtering, and Item-based Collaborative Filtering (Yang, 2012). The User-based Collaborative Filtering algorithm is the oldest algorithms in recommender systems. Goldberg (1992) has applied User-based Collaborative Filtering algorithm into email filtering system, and Grouplens (1994) has then applied the User-based Collaborative Filtering algorithm into news filter. But the key shortage of User-based Collaborative Filtering algorithm is data sparseness; the diversity of recommend list and the scalability of recommend system. To resolve the problems, professor Sarwar (2001) puts forward Item-based Collaborative Filtering algorithm. Amazon, YouTube, and Hulu are using Item-based Collaborative Filtering algorithm.

### 2.2 Research on time Context Information Recommendation

The traditional personalized recommendation only works with User-Item structure, it does not considerate the context information of user's. It cannot fully reflect the preferences of the user. For example, users like to browse news and information in "morning", like to browse social networks to share information in the “noon”, like to play various entertainment games in the “night”. Some users may order some things without payment online because of the exquisite pictures, but after whole day working, the users feels meaningless and then cancel the order. These user’s preferences changes is due to the context information of user behavior changes. Schilit (1995) divides the context information into three categories, such as computing context, user context,

and physical context. Chen (2000) considers that the time context information is another factor. Jonna (2005) divides the context information into five categories, i.e., physical environment, user goals, equipment application, link to person/service, and equipment connection. Kenta (2006) takes views of user's plan, time, user's friends, and external environment in a restaurant recommendation system. Zhang (2007) devises the context information in terms of user preference and context position, such context information refers to the ability to handle user terminal and wireless network. In a music recommendation system, Kim (2008) sets the context information as gender, age, location, time, weather, temperature and pulse for a music recommendation system. Adomavicius and Tuzhilin (2008) put forward the definition of context information and the different method of the user model when context information is constructed. Other scholars (Wang et al., 2012) also offer some research in the theory, methods, and applications of context aware systems, e.g., the New York University, University of Konstanz, the IBM Institute, and the Microsoft research institute. In summary, the diverse context information is appropriately set according to the specific object of research. We select the context information based on the time dimension, and research the change of time context information under user's interest changes, and then improve the traditional collaborative filtering algorithm. With the development of mobile Internet, the research of context information, especially it has great theoretical and practical significance of the context information in mobile environment.

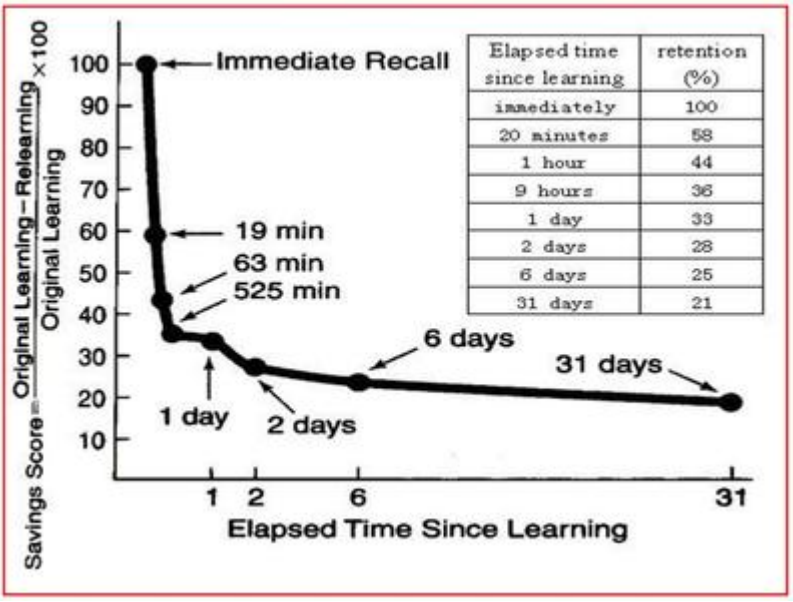


**Fig. 1.** Ebbinghaus forgetting curve

### 2.3 User Preferences Attenuation Mechanism Base on Time

Time window mechanism from Song et al. (2006) believes that the user is only interested in recent accessing behavior. Kubat (2006) and Widmer (2007) have improved

the time window method that the window size can be automatically adjusted with the change of system prediction accuracy changes. The forgetting function principle is the attenuation of the user's interest and preference by forgetting function. Michalski (2009) and Maloof (2010) use this method to achieve attenuation.

Ebbinghaus (1885) describes the speed of forgetting curve in Figure 1. This curve shows the time weight function is similar to the shape of the forgetting curve forgetting, it is a nonlinear function. The time weight function commonly used for linear function and a nonlinear function (Zheng, 2007; Yin, 2012). Hong and Li (2010) find that recommendation results of nonlinear forgetting functions are better than the linear functions. This paper will use the nonlinear forgotten time functions to improve collaborative filtering algorithm.

# 3 Methodology

## 3.1 Data Source and Data Collection

This research work adopts the movies rating dataset of Movielens provided by Minnesota University for our experiment on personalized recommendation. We selected the dataset of Movielens-100K, which contains 100,000 real rating scores for 1682 movies by 943 users. The data sparsity is 6.3%.

This study adopts the accuracy of recommendation as the evaluation index in the other word, the ration of intersection of the TOP-N recommended list and predicting set relative to TOP-N recommended list is better when bigger. The item of predicting set is visited by the user in real world, as defined in Equation (1).

$$p=|\text{List}\cap\text{Test}|\text{N} \tag{1}$$

where N is the count of TOP-N recommended list. N=30.

## 3.2 Improvement on Time-Base Collaborative Filtering Algorithms

Time context information is introduced to improve the collaborative filtering algorithm on the time dimension. Our study takes the time weight function of users' interest attenuation and the time context weight of the user into consideration in the time to describe the impact on the users' preference, base on which the algorithm used to calculate the similarity between items in the collection can be improve. The following are details about how to decide the weight to improve the algorithm.

## 3.3 Improvement on time-based weight

Users' preferences decay over time. Compared with the early behavior, the recent behavior of user reflects a better user's interest, based on which, this paper introduce the user's-visit- time-base weight function describing the preference weight changes over time to improve the importance of recent behavior in recommendation. There are two types of weight function: Linear and Nonlinear. Linear function considers the user's preferences are forgetting linearly. Meanwhile the Nonlinear function thinks

changes of user's preferences are nonlinearly. The research by YuHong (2010) shows that the algorithm of closely forgetting curve is superior to the linear function. That's why this paper chooses the nonlinear time function.

Defined by the curve, the attenuation function is a non-increasing function. Time function is defined in Equation (2).

$$f(u,t) = \frac{1}{1+\alpha|tui-tuj|} \tag{2}$$

where

$\alpha$: decay parameter

tui /tuj : behavior time of user u access the item i/j

f (T) will be smaller when |tui−tuj| is bigger. The value of $\alpha$ can be decided according to the change of system user interest. Lager value means big change since smaller value means small change. The interest degree of user u on item j in the original item based collaborative filtering algorithm is expressed in Equation (3).

$$f(u,\ j) = \sum_{i\in I_u} r_{ui}\, sim(i,\ j) \tag{3}$$

where

Iu means the set of items accessed by user u

j means the predicting item

rui means the interest of user u on item i. rui will be 1 when the user u access the item i. After introducing the time decay function, the interest degree of user u on item i will change over time. K$j$ means the neighbor items collection of item j. It can be calculated by Equation (4).

$$f(u,\ j,\ t) = \sum_{i\in I_u \cap K_j} sim(i,\ j)\frac{1}{1+\alpha|t_0-t_{ui}|} \tag{4}$$

where

t0 means the current time since tui means the time when user u accesses item i.

$\alpha$ can be decided according to the situation.

### 3.4 Improvement on Resource-Based Weight

Because the users' early interest is similar with recent interest, this paper takes the similarity between items to measure the similarity between early and recent behavior. T means the recent time period of the user u. IuT is the set of the items accessed by user u in T. Iu means the whole set of the items accessed by user u. We got IuT⊆Iu. P(u,i) means the item-similarity-based weight since i∈Iu. The average similarity between item i∈Iu and the item j∈IuT can be calculated by Equation (5).

$$p_t(u,\ i) = \frac{\sum_{j\in I_{uT}} sim\,(i,\ j)}{|I_{uT}|} \tag{5}$$

where

| IuT | means the count of the items recent accessed in T.

sim(i,j) means the similarity between item i and j, which can be calculated by Pearson correlation coefficient calculating formula:

$$sim(i,\ j) = \frac{\Sigma_{u \in I_{ij}} \left(R_{u,\ i} - \overline{R}_i\right)\left(R_{u,\ j} - \overline{R}_j\right)}{\sqrt{\Sigma_{u \in I_{ij}} \left(R_{u,\ i} - \overline{R}_i\right)^2} \sqrt{\Sigma_{u \in ij} \left(R_{u,\ j} - \overline{R}_j\right)^2}}$$

By measuring the similarity of the recent and early items accessed, we can figure out the influence on recent interest from the early interest. Sometimes, the interest is forgotten over time. But it can be evoked by the visual or other relevant stimuli, which will impact the users' recent behavior. The resource-based weight can improve the recommendation quality effectively.

### 3.5 Improvement on Time-Context-Based Information

The mobility of mobile device makes the contextual environment of the user changing dynamically. The interest and requirement will be different in the different contexture environment. For example, user will browser the news app after 18:00 on the metric and shop on line or play games at noon in the office and shop or have dinner outside at the weekend. So that introducing the time contextual information of the user into the recommendation system can help to figure out the users' interest and the weight of each interest.

We take the users' time contextual information into consideration to calculate the similarity of the time to decide the users' interest, which provide the useful information for the recommended results. The vector model was used to express the set of time contextual information collected by n time contextual information. Given TContext= {TC1, TC2, …, TCn},in which TCi={tc1, tc2, …, tcn}, tci($1 \le i \le n$) is a time contextual information at time I and tci is an attribute of the information. This paper category the accesses time by week, and calculate the access preference everyday within a week. The time context information can be described as TC={Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday}. Post to the time context information being defined, User-Time Matrix can be added into time division.

In the User-Time matrix, the task T as item I, the value of T is Ti, (i=0..6). The value in the matrix represents that user's interest degree in a day within a week. Base on this, we can get the time series similarity according to Pearson Correlation Coefficient.

### 3.6 Calculate User's Interest Preference Base on Items

This research work considers that user's interest preference changes based on time weight, item similar weight and time weight. Then the results can determine user preferences on items, judge the transfer direction of user interest more accurately and then provides a recommendation list more accurate for the users, improve the quality of recommendation system. Firstly the time context information was pre-filtered. Secondly get the time context information similarity set N(t) was retrieved. Finally calculate time weight function and item similarity weight according to the N (t). In the time weight function Tuj$\in$N (t), items of similar time T$\in$ N (t), then u has access to items #i interest preference value user time context information as defined in Equation (6).

$$H(u,t,i) = \alpha 1 \times f(u,t) + \alpha 2 \times pt(u,i) \quad (6)$$

where
$\alpha$i(i=1, 2)$\in$[0,1] shows the weight under different factors;
$\sum_i \alpha i = 1$ f(u,t) means that user #u interested in item #i attenuation degree with time and the time preference;
p(u,i) is the weight based on items similarity;
H(u,t,i)is user interest preference base on the time context information.

The three functions characterize the time context information influence on the user's interests in different aspects, by adjusting the weight values of $\alpha$i to achieve more accurate recommendations.

# 4 Results

## 4.1 The Results of Experiment

Through many times experiments, we obtain the best weight value combination recommendation accuracy rate is 0.2667, then transform the value of TOP-N, validate the recommendation accuracy under different N value. By adjusting the number of items in the list of recommended, determined recommendation accuracy under different N value, the results as shown in Figure 2.

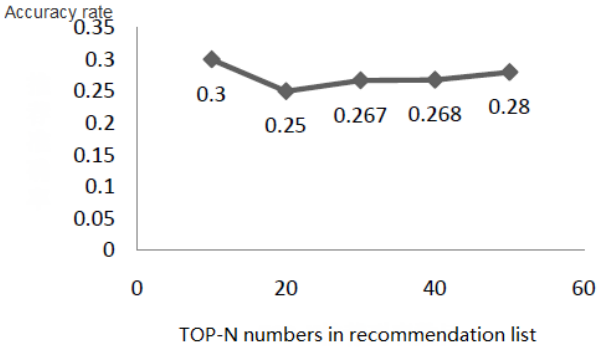


**Fig. 2.** Recommendation accuracy under Time context information

When N=10, the highest recommendation accuracy rate is 0.3;
When N=20, the highest recommendation accuracy rate is 0.25, achieved at a1>=0.8;
When N=40, the highest recommendation accuracy rate is 0.268, achieved at a1>=0.5;
When N=50, the highest recommendation accuracy rate is 0.28, achieved at a1=1.

Compared with the results produced from Yuhong (2010) and Xing et al. (2007) that do not contain the time context information and other scholars' research, our experimental results show that the recommendation accuracy was significantly higher than the accuracy without time context the comparison of the results, as shown in Figure 3.

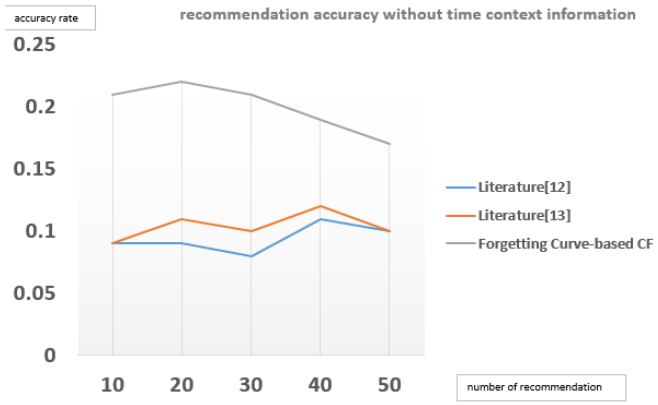


**Fig. 3.** Recommendation accuracy without time context information

In our result, the recommendation accuracy is no less than 0.25 by improved collaborative filtering recommendation algorithm, even if N value changed in TOP-N recommended list, when N=10, the accuracy rate is the highest for the 0.3. This result is same as most of present e-commerce website recommendation number. Thus, it is obviously shows that users have different preferences under different time context information.

## 5 Conclusion

Mobile commerce will change people's life. Accessing to the information users' needs in a short period of time become the key value. In this paper mainly results as follows: 1) Apply the time context information to the traditional collaborative filtering algorithms. Established the three dimensional matrix of user-item-time (U-I-T) by pre filtering function and combining the processing time context information; 2) Convert all times information to one day of a week, and then confirm the user's time interest, and then find the item which was accessed the second time at that time point, these results can improve the recommendation accuracy effectively; and 3) Combined the time function and item similarity. The arbitrary time in the interval time functions is the number of days within a week. This method reflects more clearly that user preference is influenced by time context information. On the other hand, combined with the recent information mining. It can determine the impact of the recent behavior of the current user's interests.

The limitation of this paper is that the data source only can shows the visit behavior online. Therefore, the results of this paper needs more validation in actual scenario, such as mobile commerce. That is what I should improve in the future. And, I will continue to research in these problems: (1) accuracy and diversity of the recommendation algorithm. Currently, most of recommendation algorithms only consider recommending accuracy, while ignoring the diversity of the recommendation. But the user's interests are changeable. Therefore, it is lot of research work need to do on how to balance the two fetors the

future balance is also a big problem. (2) The different explanation on different data sets. Different datasets shows different characteristics, the performance of various recommendation algorithms on these data sets will also have differences, the reason can be the further studied topics.

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# A Meta-heuristic Approach for Copper Price Forecasting

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**Abstract.** The price of copper and its variations represent a very important financial issue for mining companies and for the Chilean government because of its impact on the national economy. The price of commodities such as copper is highly volatile, dynamic and troublous. Due to this, forecasting is very complex. Using publicly data from October 24th of 2013 to August 29th of 2014 a multivaried based model using meta-heuristic optimization techniques is proposed. In particular, we use Genetic Algorithms and Simulated Annealing in order to find the best fitting parameters to forecast the variation on the copper price. A non-parametric test proposed by Timmermann and Pesaran is used to demonstrate the forecasting capacity of the models. Our numerical results show that the Genetic Algorithmic approach has a better performance than Simulated Annealing, being more effective for long range forecasting.

**Keywords:** Genetic Algorithms , Simulated Annealing , Forecasting , Simulated Annealing, Copper.

## 1 Introduction

As suggested by Adrian E. Drake: *"The increasing availability of computing power in the last two decades has been used to develop new techniques of forecasting"*[1]. This paper presents a multivaried based model to forecast the copper price variation. For this purpose, we propose two meta-heuristic algorithmic approaches in order to find the best fitting parameters for our multivaried model.

The first one corresponds to a Genetic Algorithm (GA) which is inspired by natural selection [1]. Genetic algorithms were initially proposed by Holland [2] and have found applications in diverse areas such a process optimization [3], machine learning [4], and so on. Particularly, Recursive Genetic algorithms have been used for time

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series forecasting in [5] while adjusting the parameters of a dynamic multivaried model [6]. The second one, is based on Simulated Annealing (SA) approach. In particular, SA has been combined with artificial neutral networks and fuzzy systems to forecast time series as well [7] [8]. As far as we know, it has never been used in order to adjust a dynamic multivaried model to forecast a financial time series.

Forecasting of copper price is an important task not only for investors, but also for the government and agents who are involved on copper mining businesses. Particularly, mining is one of the pillars of Chilean economy. Chile is the largest copper producer around the world[2] and the production of this product represents the 12.2% of the Gross Domestic Product (GDP)[3].

The price of copper, as well as all the commodities, has a highly volatile, dynamic and troublous behavior making the forecasting a complex task. Antonino Parisi, Franco Parisi and David Díaz suggest that *"…transaction strategies based on forecast of the direction in the price level fluctuation are more effective and can generate higher benefits than those based on a specific price level prediction."*[4].

The proposed model uses both Genetic and Simulated Annealing algorithm procedure to forecast the sign of the variation on copper price. The publicly data used to this purpose correspond to copper price from October 24th of 2013 to August 29th of 2014 and Dow Jones price for the same period. The organization of the paper is as follows.

The methodology and model formulation is described in Section 2.The meta-heuristic algorithms used to fit the model parameters are explained in Section 3. The analysis of the numerical results is explained in Section 4. A discussion section is presented in 5. Finally, the conclusions of the study are presented in Section 6.

## 2 Methodology

In this section, both the management of the data and the model formulation are presented. The non-parametric test and the sign predictive percentage are also explained and mathematically described.

### 2.1 Data Management

The publicly data obtained for copper and Dow Jones price corresponds to two hundred and twenty four observations from October 24th of 2013 to August 29th of 2014. The data was divided in two sets. The first one is used to train initially the multivaried model whereas the remaining data correspond to out-of-sample data and it is used to

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measure the predictive capacity of the model. Several models estimate their forecasting rates based on the entire amount of observations. In particular, the proposed model uses a "*Rolling operation*" methodology which means that the in-sample size remains constant to "$n$" samples. For each iteration, the algorithm includes the next observation and discards the oldest one. The rolling time considered in the present paper corresponds to $n = 45$ observations. By doing this, a recently added sample is considered by the model and the oldest one is discarded. Therefore, our model can predict until a three-step ahead forecasting.

### 2.2 Model Formulation

A dynamic multivaried model is proposed to forecast the price variation of copper considering the past four variations on the copper price and Dow Jones. For this purpose, we first define the variation on the copper price at instant "$t$" as

$$\nabla Cu_t = Cu_t - Cu_{t-1}. \tag{1}$$

Where

$\nabla Cu_t$: Variation on the copper price from $t-1$ to $t$.
$Cu_t$: Copper price at time $t$.
$Cu_{t-1}$: Copper price at time $t-1$.

Similarly, the variation of Dow Jones price at time "$t$" is defined as

$$\nabla Dow = Dow_t - Dow_{t-1}. \tag{2}$$

Where

$\nabla Dow_t$: Variation on the Dow Jones price from $t-1$ to $t$.
$Dow_t$: Dow Jones price at time $t$.
$Dow_{t-1}$: Dow Jones price at time $t-1$.

To forecast the variation on the copper price, we use the past four variations on the copper price, Dow Jones price and the error of the forecasted prices. The model can be expressed formally as

$$\nabla \overline{Cu_t} = \sum_{i=1}^{4} \beta_{d_i} \nabla Dow_{t-i} + \beta_{c_i} \nabla Cu_{t-i} + \beta_{\epsilon} \epsilon_{t-i}. \tag{3}$$

Where

$\nabla \overline{Cu_t}$: Forecasted variation on the copper price.
$\nabla Dow_{t-i}$: Real variation on the Dow Jones price at time $t-i$.
$\nabla Cu_{t-i}$: Real variation on the copper price at time $t-i$.
$\epsilon_{t-i}$: Error on the past forecasted variations obtained as $\epsilon_{t-i} = \nabla Cu_{t-i} - \nabla \overline{Cu}_{t-i}$.

$\beta_{d_1}$, $\beta_{c_1}$ and $\beta_{d_1}$ are parameters determined by using the meta-heuristic approaches.

The parameters are adjusted within three steps as follows:

1) The parameters of the model are obtained for the "n" samples.
2) Then, a one (two or three) step ahead price is forecasted.
3) Subsequently, the new observation is added on the in-sample data and the oldest value is discarded. Steps 1) and 2) are repeated.

This method requires to be adjusted permanently with new real data. The model parameters are not supplied in this paper, but only the sign predictive percentage is reported in Section 3.1.

### 2.3 Sign Prediction Percentage

As it was exposed in Section 1, determining the sign of the variation of copper price is an effective strategy which allows generating higher benefits. To determine the sign variation percentage of each forecasted period we use the following equation

$$SPP = \frac{\sum_{t=1}^{m} \theta(\nabla Cu_t \cdot \nabla \overline{Cu_t})}{m} * 100\% . \quad (4)$$

Where

$SPP$: Sign prediction percentage.
$\nabla Cu_t$: Variation on the price of copper from $t-1$ to $t$.
$\nabla \overline{Cu_t}$: Forecasted variation on the price of copper.
$\theta()$: The Heavyside function where $\theta(\nabla Cu_t \cdot \nabla \overline{Cu_t}) = 1$ if $\nabla Cu_t \cdot \nabla \overline{Cu_t} \geq 0$ and $\theta(\nabla Cu_t \cdot \nabla \overline{Cu_t}) = 0$ if $\nabla Cu_t \cdot \nabla \overline{Cu_t} < 0$.
$m$: Number of forecasts made.

In case, the $SPP$ is lower than 50% the predicted variation on the copper price will have the opposite sign of the model ($-\nabla \overline{Cu_t}$). Due to this the prediction percentage is obtained by

$$SPP = \max(SPP, 1 - SPP) . \quad (5)$$

### 2.4 Non-parametric Test of Predictive Performance

Pesatan and Timmermann proposed a non-parametric test of predictive performance based on the correct direction of the forecasted variable [9] (Directional accuracy). This procedure proves the null hypothesis that the observed variations on the price are independently distributed from the forecasted variations. If the hypothesis is rejected, it means that there is statistical evidence that the model is able to forecast a future variation on the price. The Pesatan and Timmermann test compares the sign of the real variation on the price and the sign of the forecasted variation on the price. In order to obtain the real positive variations on the copper price, we use the equation (6)

$$\bar{p} = \frac{\sum_{t=1}^{m} \theta(\nabla Cu_t)}{m} . \quad (6)$$

Where

$\bar{p}$: Percentage of the real positive variation on the price of copper.

Similarly, the percentage of positive variations on the forecasted price is obtained by means of

$$\bar{\bar{p}} = \frac{\sum_{t=1}^{m} \theta(\nabla \widehat{Cu}_t)}{m} . \quad (7)$$

Where

$\bar{\bar{p}}$: Percentage of the forecasted positive variation on the copper price.

Furthermore, the success ratio index (SRI) when the forecasted variations and the real variations on the price are independently distributed is obtained by means of

$$SRI = \bar{p} \cdot \bar{\bar{p}} + (1 - \bar{p}) \cdot (1 - \bar{\bar{p}}) . \quad (8)$$

The variance of SRI rate is obtained by means of equation (9) as follows

$$var(SRI) = \frac{\left(n(2\bar{p}-1)^2 \bar{p}(1-\bar{p}) + n(2\bar{p}-1)^2 \bar{\bar{p}}(1-\bar{\bar{p}}) + 4\bar{p}\bar{\bar{p}}(1-\bar{p})(1-\bar{\bar{p}})\right)}{m^2} . \quad (9)$$

Consequently, the variance on the success ratio (SPP) is defined as

$$var(SPP) = \frac{SRI(1-SRI)}{m} . \quad (10)$$

Finally, the directional accuracy test (DAT) is given by the equation

$$DAT = \frac{SPP - SRI}{\sqrt{var(SPP) - var(SRI)}} \sim N(0,1) . \quad (11)$$

This test follows a standard normal distribution and it is used to prove the null hypothesis that the forecasted prices are independently distributed. This means, the larger the value of DAT the better the accuracy of the model.

## 3 Meta-Heuristic Optimization Algorithms

In this section, the meta-heuristic optimization algorithms used to adjust the model parameters are briefly described.

### 3.1 Genetic Algorithm

Genetic algorithms were initially proposed by Holland in 1975 [2]. A genetic algorithm is a meta-heuristic approach inspired by Darwin's theory which is based on the survival of the fittest [1]. Genetic Algorithms use a direct analogy of natural evolution. A possible solution is codified as an individual and each individual is composed of variables (or chromosomes). Each individual will have as many chromosomes as variables in the problem. In order to obtain an initial solution for the problem, a population of individuals is generated randomly. The population is modified within each iteration of the algorithm depending on the following operators:

1. Fitness Function: The fitness function (objective function) must be defined. In this particular optimization problem there are no constraints on the optimization problem. Thus, the fitness function is defined as:
$$\max \quad SPP \tag{12}$$
2. Selection: A portion of the existing population is selected. The best solutions are more likely to be selected as parents for the next generation.
3. Crossover: Crossover combines the chromosomes of each parent in order to create new solutions called offsprings.
4. Mutation. Some offsprings are randomly modified by a mutation process. Mutation changes a particular gen on the chromosome. The mutation operator enables the population to explore new zones of the feasible space.

The process is continuously repeated creating new generations of individuals until a stopping criteria is met. In this particular problem the stopping criteria selected was four hundred generations of individuals. In particular, Genetic Algorithms have been previously used on financial forecasting [6] [10].

### 3.2 Simulated Annealing

Simulated Annealing is a meta-heuristic optimization method proposed independently by Scott Kirkpatrick, C. Daniel Gelatt and Mario P. Vecchi in 1983 and by Vlado Černý in 1985 [11] [12]. The Simulated Annealing algorithm is inspired from the process of annealing in the metallurgical industry. It starts with an initial high temperature and then it slowly decreases during the execution of the algorithm. This reduction allows the algorithm to explore the solution space and avoid a possible local optimal. As the temperature is reduced so is the chance of accepting worse solutions. This temperature reduction allows the algorithm to focus on areas of the solution space where the global optimum may lie. Simulated Annealing has not been applied for multivaried dynamic models, however it has been mixed with fuzzy models [7] and artificial neural networks [8] for time series forecasting. Similarly, as in our genetic algorithmic approach, we use the objective function given by the equation (12) and the stopping criteria selected was four hundred iterations.

# 4 Numerical Results

The numerical results are presented in two subsections. The first one summarizes the model results for the adjustment of the parameters using in-sample data while the second one summarizes the forecasting results of the out-of-sample data.

## 4.1 In-sample Data Results

For each time step the model parameters where adjusted in order to maximize the SPP. A total of one hundred and seventy nine different iterations were performed using the multivaried model. Figure 1 shows the values of SPP for each iteration of the model.

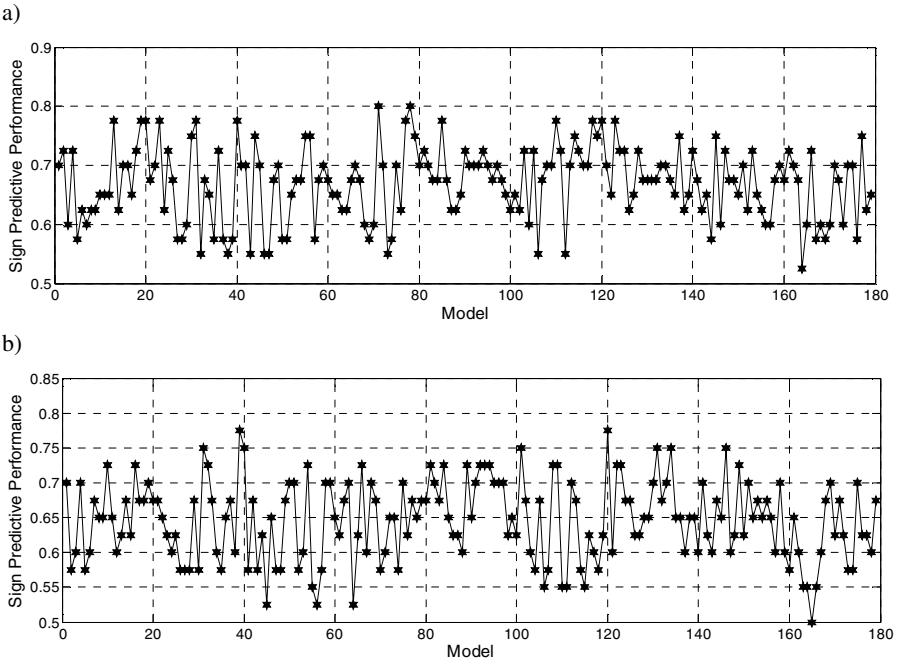


**Fig. 1.** a) Sign Predictive Percentage using Genetic algorithm. b) Sign Predictive Percentage using Simulated Annealing

From the numerical results presented in Figure 1a), the SPP is larger than 50% when using Genetic Algorithms for all the iterations. In Figure 1b), we observe similar trends when using Simulated Annealing approach. For in-sample data the Genetic Algorithmic approach has a sign predictive performance mean of 66.96% while Simulated Annealing has a mean of 64.59%. This clearly shows that the genetic algorithmic approach is more effective.

### 4.2 Out-of-Sample Data Results

With the out-of-sample data, we compute the sign prediction percentage and perform the directional accuracy test for one, two and three step ahead forecasting. Table 1 shows the performances obtained.

**Table 1.** Sign predictive percentage and directional accuracy test for one, two and three step ahead forecasting obtained with Genetic and Simulated Annealing approaches

| **One Step Ahead** | | | |
|---|---|---|---|
| Model | SPP (%) | DAT | p-value of DAT |
| Genetic Algorithm | 57.54% | 2.0282 | 0.05100 |
| Simulated Annealing | 58.10% | 2.1724 | 0.03768 |
| **Two Steps Ahead** | | | |
| Model | SPP (%) | DAT | p-value of DAT |
| Genetic Algorithm | 57.54% | 1.9773 | 0.0564 |
| Simulated Annealing | 50.28% | 0.03135 | 0.3987 |
| **Three Steps Ahead** | | | |
| Model | SPP (%) | DAT | p-value of DAT |
| Genetic Algorithm | 53.63% | 0.9772 | 0.2474 |
| Simulated Annealing | 51.40% | 0.3211 | 0.3788 |

In Table 1, column 1 presents the name of the algorithmic approach. Column 2 shows the SPP values obtained in percentage. Finally, in columns 4 and 5 we present the values obtained for the DAT and p-values for the DAT, respectively. For the one hundred and sixty nine forecasted variations, the Genetic Algorithm has a Sign Predictive Performance of 57.54%, 57.54% and 53.63% for one, two and three step ahead forecasting, respectively. While the Directional Accuracy tests are 2.0282, 1.9773 and 0.9772 for one, two and three steps ahead forecasting, respectively. These values prove that the predictive capacity of the model is useful up to two steps ahead forecasting.

On the other hand, the Simulated Annealing based model has a Sign Predictive Performance of 58.1%, 50.28% and 51.40% and a Directional Accuracy Test of 2.1724, 0.03135 and 0.3211 for one, two and three steps ahead forecasting, respectively. These values prove that the model can be used only for one step ahead forecasting while using Simulated Annealing.

## 5 Discussion

Other authors have adapted their forecasting models by using genetic algorithms [13] [14]. Nevertheless, there are still meta-heuristic approaches which have not yet been tested in order to compare their performances with Genetic Algorithms. Both algorithms used the same model to predict future prices. In the current literature, different models and their advantages to forecast future price of commodities based on the spot prices are well described [15] [16]. However, the algorithms used to adapt these models have not been compared in order to guarantee that the decision of using genetic algorithms is the

right choice. This paper compares Simulated Annealing and Genetic Algorithms in a dynamic multivaried model. Both have been compared for learning problems showing that Simulated Annealing found meanly better solutions than Genetic Algorithms in less computational cost [17] [18]. In this paper, we confirm that the Genetic Algorithmic approach is the right choice as it gives better solutions when compared to Simulated Annealing for short and long range forecasting. Finally, the decision maker can use the adapted parameters in order to forecast future copper prices using the equation (3) proposed in subsection 2.2.

## 6 Conclusions

In this article, we proposed two different meta-heuristic approaches to forecast the variation on the copper price. The proposed model requires to be adjusted every time the copper price changes. An initial adjusted model would not have the capability of forecast many steps in the future if it does not have the most recent information about the copper price behavior. Genetic Algorithms have proved be an efficient optimization approach to forecast time series. In particular, when compared with another meta-heuristic optimization technique such as Simulated Annealing as it has proved to be superior for short and long range forecasting. Forecasting on the copper price can increase the return and reduce the risk associated with the transactions of this base metal. Therefore, this methodology can be used on a real scenario. As future research, we plan to use Genetic Algorithms hybridized with nonlinear model architectures such as Non-linear autoregressive with exogenous input networks (NARX) for long range forecasting.

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# Complexity Management in the Semiconductor Supply Chain and Manufacturing Using PROS Analysis

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**Abstract.** Supply chain complexity is a rising problem, especially in the semiconductor industry. Many innovative activities occur in the daily supply chain and manufacturing, and these changes inevitably bring in the complexities to the organization. But not all of them are valuable to the business goals. Decision makers want to keep value-added complexity and reduce non-value-added complexity. To manage the complexity, we propose a framework with four steps from changes identification towards the final decision making. The core solution of this framework is PROS (process, role, object, state) idea, which provides an understandable and structural way to describe the complexity. A simplified small real example from semiconductor supply chain is used to demonstrate this approach. The results indicate that the PROS idea is able to analyze complexity from different aspects and extract most key information; however, how to measure the structural complexity of a large complex system without complete information is still under investigation.

**Keywords:** supply chain complexity, change management, process model, complexity assessment, semiconductor industry.

## 1 Introduction

The semiconductor industry is considered to be one of the most complex industries. From the raw material of silicon to the advanced semiconductor chips, there are more than 500 processing steps involved in the manufacturing. It also faces a highly volatile and turbulent market due to economic cycles, which bring the challenge to manage dynamic production environments with the pace of change in the industry [1], [2], [3].

The semiconductor supply chain is characterized by long throughput times, high levels of stochasticity, non-linearity in the manufacturing process [4], and short product life cycles. These all lead to complexity to be managed in the supply chain. It is reflected as: network complexity (e.g. multiple production sites and global distribution centers), process complexity (manufacturing and business processes), product complexity (e.g. about 10,000 Stock keeping units and 500,000 order line item buckets), organizational complexity (e.g. many geographic regions with various tax and customs regulations), and

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information complexity (data structure and information flow) [5]. And all of them are interlinked.

Managing complexity in the supply chain adds value to business. According to A.T. Kearney's report, companies can increase their Earnings before interest and tax (EBIT) by 3 to 5 percent on average through systematic complexity management [6]. Many changes via innovations are ongoing in operational, tactical and strategic supply chain activities and thus complexities are added but not all of them are valuable to the business goals. Therefore, we need to distinguish: the "good" complexity which adds value to the supply chain whereas the "bad" one does not. Value-adding ("good") complexity offers ways to meet customer demands and create a real competitive advantage; while value-destroying ("bad") complexity dissatisfy customers and sends the company into chaos and confusion [6], [7]. These two different categories of complexity require companies to employ distinctive strategies. The value-adding complexity should be controlled efficiently to create value; for the value-destroying complexity, the part that does not add value needs to be eliminated, reduced and minimized [8], [9], and avoided in the early phase of generation.

In reality these two types of complexity often occur together and thus a strategic balance is demanding, e.g., lead firms increase complexity by placing new demands on the value chain and in parallel adopt strategies to reduce the complexity of these transactions [10]. This brings the challenges to detect the complexity-added part and then to evaluate them in order to get rid of the non-valuable parts and support decision making.

### 1.1 Research Question

My research aims to manage the complexities from the computer science view. By tracking the changes on the system level, the complexity drivers can be identified and described in a systematic way. After all the key information related to complexity being captured and structured, we can assess the complexity through selected instruments and categorize it as a value-added complexity or not. In the end, the results should be validated and thus can support decision making by applying corresponding strategies (e.g. reduce complexity, avoid complexity, etc.).

### 1.2 Status of Problem Domain and Related Solutions

Much relevant research has been done on complexity management. Literature shows that most analysis is on the theoretical level based on an abstract model instead of operational excellence on the practical level [11]. However, the mapping process from "a real complex problem" to "a defined model for complexity" is not much explored.

Research on change management is mostly analyzed from the organizational view [12], small amount is viewed from the system engineering field, which is more related to the business process re-engineering and process management [13] and provides certain process meta-models or patterns for change management [14].We are more interested in the latter direction, however, the connection between *model of system change* and the *complexity management* is not obvious.

Complexity in a supply chain is often viewed from three aspects: product, process and organization [15], [16], [17]. Research on the complexity analysis usually focuses on certain aspects, e.g. product variety, while it is not common to consider the complexity from a holistic view. Considering the inter-dependencies of different aspects of complexity, we prefer to use a comprehensive approach to capture all the important features of a complex system.

Regarding the methods and instruments of complexity assessment, much research is on the strategic level and only provides qualitative evaluation; some quantitative methods are available but still lack practicability and tools [11], [15], [18], [19]. To support decision making, we are also interested in the implementation details, such as, formal indicators and structural measurement.

From above analysis, it is seen that there is a gap between the existing approaches to handle complex problems and our objective. Therefore, we bring in a framework including 4 steps to manage complexity: 1) Identify complexity caused by changes 2) Represent complexity 3) Assess complexity via developed instruments 4) Evaluate and support decision making. In this paper we address the first three steps on a real problem from semiconductor industry, which are also expected to be beneficial in the last stage of decision making. And in the second step a proposed conceptual model called PROS to describe complexity is highlighted.

## 2 Proposed approach

### 2.1 Identification of Changes and Complexity

Change is one of the main reasons to cause the complexity, so our research starts from the change analysis. The goal of this step is to capture the complexity caused by changes on the detailed level. Two parts related to changes should be considered: the change itself and its impact to the system. The change itself, also referred to as the initial change or one-time-change, means the “effort to implement a change”, which normally only execute once. For the impact of change, it is “the potential consequence of a change on a system or what needs to be modified of a system in order to accomplish a change” [20]. This often requires executing affected processes regularly in order to maintain the change of system. Both change related parts usually lead to increased complexity. The output of this step is the added processes during the initial change phase; and the affected processes during the maintenance phase.

### 2.2 Information Extraction and Representation – PROS Idea

The purpose of this step is to represent the complexity in a structural way without losing any important information. System models are employed to formalize the complexities receiving from the 1st phase using modeling language such as SysML.

The premise to accurately describe supply chain complexity is to define the boundary of the complex system and its environment. We adopt a system delimitation technique from a generic Systems Engineering (SE) methodology to define the environment and intervention system [21], [22]. Some similar approaches, e.g., a knowledge

representation language called Telos [23] can also be used to distinguish the environment in a later stage.

Once the investigation area is reduced, we can identify the elements and their relationships using the system consideration of SE. Then we develop a conceptual model called PROS (Process, Role, Object, State), which defines the basic elements and relationships in a complex system.

The idea of PROS originated from Object Process Methodology (OPM) [24], [25]. OPM defines three basic entities: objects with states and processes. Among them objects and processes are higher-level building blocks, while states are always associated with objects and cannot be state-alone. It can be used to model the complex dynamic systems and embedded into other models for specified application [26].

Also we notice that supply chain is similar to economic, ecological, and social systems, which are characterized by interactive “agents" (roles) [27], [28].Therefore, we assume role is as important as the object and process, while OPM only handles human as an instance of object. Comparing with OPM, PROS also considers the human behaviors and their initiatives.

PROS model is characterized by entities, relationships and constraints.

**Entities**. A Process is a pattern of transformation that an object undergoes; A Role is a person to execute a process. This definition can be extended to: A role could be a person, a department, a customer, a supplier or any other group of persons or a software tool to execute a process. An Object is a thing that has the potential of stable, unconditional physical or mental existence. A State is a situation or position at which the object can exist for a period of time.

**Relationships**. We customize the OPM relationship set [24] for our purpose and define 6 relevant pairs of relations: Process-Process, Process-Role, Process-State, Process-Object, Object-Object, Object-State. For each pair, there are one or more sub-relationships. E.g., there are several different types of Process-State relationships. The attributes of these relationships are also defined: name, direction, symbols, dynamics, etc.

**Constraints**. Two constraints are highlighted: Cardinality and Relationship rule. Cardinality defines 3 types of data structure: one-to-one relationship, one-to-many relationship and many-to-many relationship. Relationship rules imply that all the relationship definitions should follow the rules of the above 6 pairs strictly. The cardinality constraints and relationship rule can be used together.

**PROS Diagram and Prototype**. In working with complex problems we found out that representation is an important goal for PROS. Thus we design a PROS diagram to visualize the entities and their relationships, which can be viewed as the integration of the use case and object diagram of UML notations. We also developed a prototype as shown in Fig.1. The layout divides the canvas into 5 areas, and each contains one independent diagram. In the area marked with 1, the navigation of the whole object diagram is shown. Area 2 shows the navigation of the complete process diagram. Area 3 shows the dynamic object and state diagram for a running process. It reflects the details and changes of the objects during the processing. Area 4 shows the roles involved in the process. Area 5 shows the running step for the process. Area 1 and 2

do not change during the whole process analysis, only the analyzed area of processes and objects is highlighted. Other areas change with the process step in analysis.

PROS analysis normally starts with the process aspect, similar to other system modeling languages like BPMN and UML. Besides this process-oriented analysis, the human-oriented analysis can also be applied. Agent-based modeling and simulation is a widely used technique to formalize the human (agents in broad definition) behavior and their interactions [29]. Another technique is goal-oriented modeling, e.g., *i*-Star approach can analyze the agents from the view of their personal goals and what activities could be done in order to achieve these goals [30].

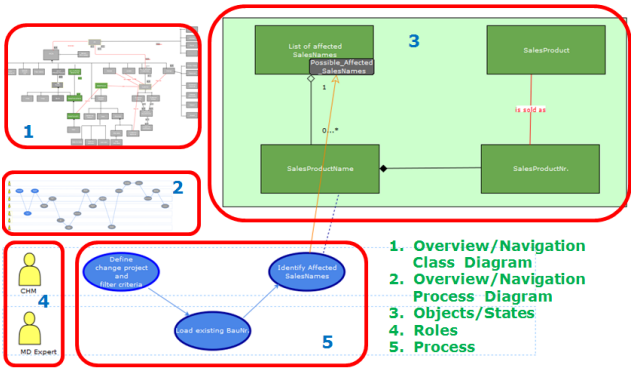


**Fig. 1.** Visualization Prototype for PROS

The results of the PROS analysis contain most key information from a complex system and which can be used as an input for the assessment step.

### 2.3 Structural Complexity Measurement Using PROS

Structural complexity is about the complexity resulting from physical interconnection of components. It belongs to the physical domain and can be directly calculated from the elements and the relationships among them [15], [31]. Since this information can be received from the step 2, we can at least calculate the complexity oriented from elements (states of a system) and the complexity oriented from relationships (number of all connections). A further step measure is to calculate the entropy of statistical complexity based on the Shannon information theory [18].

Besides the basic quantity (size) information, we assume that the structural complexity is also decided by the attributes of each individual element, such as category, importance or diversity, and whether it is interrelated to the rest of system. We also need to highlight the impact of roles (often humans), as their behaviors can lead to uncertainty and thus complexity of the system. To be able to distinguish the complexity impact of different roles, we added a weight value for each role by considering the number of involved processes [32].

# 3 Case Study

## 3.1 Shared reticle vs. Mono Reticle

We select a case from semiconductor manufacturing to explain how complexity is generated. A set of reticles (up to 35) is needed to produce a wafer. In this paper we call the reticle set "reticle" for simplicity. Comparing with the as-is solution with mono reticle, an alternative solution using shared reticle could produce more products on one wafer, and thus reduce the quantity of reticles required. The reduction of reticle costs decreases manufacturing costs substantially.

There is certain degree of truth that, shared reticle technology is cost beneficial, but the flip side of the coin is that the change process from mono reticle to share reticle is not that simple. For example, certain processes need to be updated, people need to be motivated to accept the changes, etc., which leads to increased complexities.

Before making decision to adopt the shared reticle solution or not, it is necessary to assess its increased supply chain complexity and evaluate whether the reduced reticle cost offsets the increased complexity.

The cost saving from the economic view is given on monetary values; however, the change process and its increasing complexity are not systematically assessed. Current Business Process Management (BPM) solution cannot reflect all aspects of the complex problem, while other supply chain process models are not detailed on the operational level. This gap hinders the making of high-quality decisions.

## 3.2 Results Achieved so Far

By following the framework provided in section 2, we have achieved some intermediate results, which are mainly centered on the changes and complexities identification and measurement.

**Changes and Complexity Identification and Presentation**. The change management can be analyzed from the aspects of process, organization (roles) via PROS.

The process analysis follows the supply chain operations reference-model (SCOR) model, the most widely accepted framework for standardization in supply chain management, developed by the Supply Chain Council[1]. It defines the first three levels of supply chain processes. The top level has 5 processes: *Plan, Source, Make, Deliver* and *Return*. Each level-1 process has 10-20 level-2 processes and spans multiple level-3 and 4 processes. Processes below level 3 are defined by the companies themselves. Following the SCOR model, the major processes of shared reticle up to level 4 can be identified.

Considering around all 500 steps of Produce and Test Process (sub-process of *Make*) related to wafer manufacturing with mono and shared reticle, it can be roughly said that 480 steps are not changed. Complexity is mainly added in the Test process (for simplicity step 480 to 490) and the Optical Control process (for simplicity step

[1] http://www.apics.org/sites/apics-supply-chain-council

490 to 500). For the Plan Process, the overall planning including short-term plan and mid-term plan need to be changed; and Front End Plan needs to be rescheduled.

The main affected processes and their added complexities are listed in Table 1. It is important to highlight which types of change the complexity belongs to, as this would be part of assessment on the next stage.

**Table 1.** Shared reticle: added complexity (CT means Change Types, O is one-time-change and R is regular maintenance)

| SCOR Model Layer | Process Changed | Added complexity | CT |
|---|---|---|---|
| 1.1.2 | Make-Front End-Test | Equipment reprogramming in order to manage the changes | O |
| 1.1.2 | Make-Front End-Test | For shared reticle, in testing at least every second product is different and thus the testing process needs to be switched too. | R |
| 1.1.3 | Make-Front End –Optical Control | Equipment update | O |
| 1.1.3 | Make-Front End –Optical Control | Training the operators | O |
| 1.1.3 | Make-Front End –Optical Control | More operators are allocated to work with optical inspections systems | O |
| 1.1.3 | Make-Front End –Optical Control | Monitor the optical inspection systems | R |
| 2.1.1 | Plan- Production Program | Overall planning processes are changed | O |
| 2.1.1 | Plan- Production Program | Execute the changed planning processes | R |
| … | … | … | … |

We also notice that the stakeholders' attitudes towards these affected processes may influence the new solution and thus lead to complexity. Research shows people may not like change or may not adopt changes [33], [34].Therefore, we need to consider the human goals in order to measure complexity accurately in the next step.

Based on the interviews and process analysis, we identify the key stakeholders involved in the change project and assess their interests. Here a goal-oriented modeling approach is employed, e.g., *i*-Star can be used to analyze personal goals and behaviors of alternative solutions [30]. For each stakeholder, first we analyze their goals and corresponding actions, and then we can check how these actions benefit or hurt their goals. By doing that the relationships among stakeholders are detected too. One part of our result shows that, test engineer does not like to accept the change as it hurts his goal while the development engineer is motivated for this change.

The main object involved in this change is wafer and its states are related to the different stages of manufacturing process steps.

PROS approach can be used as a guide to obtain the key elements of processes, roles and objects, as well as different relationships. We could gain this information:

- Description about the stakeholders and their goals
- Description about the changed process

- Description about the objects and their states involved in the processes
- Partial information about the dependencies network

**Complexity assessment**. We can get statistic information from above analysis, e.g., the change includes 4 processes and 10 sub-processes, 7 roles and 2 objects with 10 states. Using the measurement methodology proposed in section 2.3, we can calculate its element complexity. However, for the relationships among these elements, it is not easy to detect all dependencies within a large complex system.

Besides that, we should measure the different types of process changes separately. Table 1 shows two types of changes: the one-time-change needs only to be calculated once, while the regular maintenance needs to be calculated periodically.

To evaluate whether the benefits of a new solution outweigh the added complexity, we could calculate the deviated complexity from two solutions (the changes part) and compare it with the saved costs. For example, if the cost of added complexity is smaller than the saved reticle benefits, we can identify "switch to shared reticle" as a value-adding complexity, otherwise, it is the value-destroying complexity.

### 3.3 Discussion

It is seen from above analysis, PROS approach helps to analyze from different aspects: the processes and their required changes, people and their conflicts. However, for a large complex system, it is not feasible to use an exhaustive method to detect all relationships between elements. How to estimate the relationship intelligently (sufficiently accurate within a given time) is still a challenge for us.

The lessons learned focus on two areas: 1) each aspect of a complex problem can be detailed and deeply analyzed by following a certain model or method - e.g., process analysis with SCOR, role analysis with goal-oriented mode. For large systems the accuracy within a given time is a challenge. 2) The qualitative analysis is not sufficient for decision making, to make better decision we need to quantify complexity oriented from all aspects of a system. The PROS approach is promising but a formula ending up with a complexity number is still missing.

## 4 Conclusion and Future Work

This paper introduces a framework to manage supply chain complexity from computer science view, which sets up a connection between change management and complexity management. We conclude that complexity should be managed from a systematic view instead of the single aspect.

The core part of this framework is the PROS conceptual model, which represents and visualizes the complex system by capturing its important elements and relationships. It can supplement the quantitative complexity measurement by separating it into the elements and relationships part. Calculating the numerous relationships in a large system requires more sophisticated methodologies.

An industrial case from the semiconductor industry with two alternative solutions is analyzed from different aspects and the measurement of added complexity is discussed

in order to select the optimal solution. The framework is not limited to the semiconductor industry or supply chain field and could be extended to a broad area: project management, organization changes, government policy analysis, etc.

In future research we optimize the PROS approach to larger systems and improve the quantitative measurement of complexity. Two aspects will be addressed: 1) Understand and track the dynamic interaction between elements. 2) Investigate the weight value of human behaviors and their impact, and other components leading to uncertainties and thus complexity of the system.

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# Simulation on Resident Individual Trip Choice Decision Making: Based on Modeling of Rough Set and Genetic Algorithms

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**Abstract.** Urban Residents are the evaluation subjects for the transportation policy. It is very important for the scientific development of transportation policy to research on the travel behavior from the perspective of quantitative modelling. Urban residents scientific of individual travel decisions are the prerequisites for group urban residents travel behaviors. This paper analyses the general population travel behavior based on the basis of the actual survey data and uses rough set theory to reduce the residents travel decision influencing factors. The univariate weight matrix and the corresponding weight matrix could be obtained. On this basis, the genetic algorithms objective function and fitness function could be optimized. Finally, an example simulation is given in this paper to verify the validity of the travel decision-making simulation model.

**Keywords:** Travel decision, Rough Set, Genetic Algorithms, Modeling.

## 1 Introduction

Citizens are the most important parts of urban transportation formations. The choice of citizen travel mode will be influenced by the individual competency and preference; meanwhile, it will be influenced by the transportation environment. The aim of the urban transportation policy is to allow the majority of the population could reach their destinations with a faster, safer, more comfortable and more affordable travel mode. Moreover, both the localized and the whole domain liquidity established by the citizens traveling activities should be taken into consideration. A valid transportation policy is determined by the social satisfaction, economic benefit and level of environmental protection. Scientific and rational analysis on various citizen travelling behaviors, such as choosing public transport or non-public transport will help to find the problems in the existing transport policy system and give fair recommendations.

At the present stage, research on resident individual trip mainly involves following fields: commuter and structure of urban space, character of commuter behavior basing on traveling investigation, character of trip chain and trip behavior modelling.

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The researches on resident individual trip behavior theory are very fresh and mainly focus on several fields.

The first field is how to confirm factors that influent individual trip behavior. Iseki Hiroyuki and Smart Michael (2012) invested 2122 residents and analyzed the factors such as age, sex, income, race, religion, private car travel mode and frequency of public facilities using. They found that security is the most important factor for all the residents and individuals with different background will have different attitudes to different factors which will be changed with trip experience.

The second field is to develop the individual trip rules. Abou-Zeid Maya and Ben-Akiya Moshe (2011) proposed a framework basing on dynamic selection to catch the society influence on trip choice. They defined comparison of happiness and proved that comparison of happiness rising from comparison of the individual and others. Hence, the overall satisfaction or utility commute would be increased.

The third field is about the resident individual trip information. Son Sanghoon and Khattak Asad (2011) comparatively analyzed the university students' access and use of information about travel. The results showed that the internet and a wide range of information have great impact on the students' trip choice.

Although research on individual trip behavior has been carried out for several years, the theory supports and application explorations are still weak which could be formulated as following:

In the aspect of subject investigated: there is few study on simulation of individual trip decision. They always focus on degree of satisfaction more than personal preference.

In the aspect of research method: They are always qualitative and learned from other existing results. Most studies focus on the travel factors of specific travel groups and only extract the importance of factors even if using the quantitative methods. Moreover, the method always is a statistical analysis of the factors. The application of modern mathematics is only a minority. Meanwhile, the comparison and analysis of different methods basing on results is lack.

Therefore, this study hopes to achieve a breakthrough in the above areas. The research content focus on the simulation of travel decisions basing on personal preference. In the research methods, combined with statistical theory, the modern mathematical theory, accurately extracting of certain population preferences through rough set theory to establish individual travel decision model based on genetic algorithms and simulation analysis.

## 2 Methodology

The travelers are considered absolutely rational in the traditional transportation trip model. However, more and more research and practical experience shows that the assumption of absolutely rational is incorrect. Hence, the conception of bounded rationality in Behavioral Economics provides new ideas for research on individual trip behaviors and decisions. Bounded rationality means that the travelers will not chase the best travel utility those are always affected by the factors such as trip experience and travel habits. They want to guarantee the difference between actual travel utility and best travel utility to be in an acceptable range. The conception of bounded rationality is of course accepted in

this paper. However, this paper is still taking conception of absolutely rational as foundation in order to carry out the research procession. The assumptions are as following,

1. The decisions are at least 2 when a resident will start travel. That is $n_d \geq 2$;
2. The residents confirm all the decisions before one travel, ignoring all the second decision on the road;
3. The travel utility $U_d$ is different for individual preference. Each resident is always chasing their best travel utility. The best travel utility is marked as $U_{opt}$.
4. The resident decision set $D$ is the independent variable. Travel utility $U$ is the dependent variable. The merits of the decision-making travel decide the effectiveness of travel utility.
5. In this section, the resident decisions set are divided into two categories: good set and bad set. At the same time, more vivid examples could be used to illustrate the relationship between residents travel decisions and travel utility. To make:

$$\begin{cases} D_B = 1 \\ D_G = 2 \end{cases}, \qquad \begin{cases} U_d = 1 \\ U_{opt} = 2 \end{cases}$$

However, it is necessary to cost for resident making travel decision, for example time costs and experience costs. Therefore, d is the explanatory variables of $C$. Good decision-making cost should be higher than the cost of inferior decisions because the merits of the decision-making will lead to changes of the decision-making cost. Therefore, to make:

$$\begin{cases} C_{D_B} = 1/2 * d \\ C_{D_G} = d \end{cases}$$

Residents are always wandering between the worst decision and the optimal decision. They do not want to make the worst decision; Meanwhile, they are also likely unable to make optimal decisions. The reason lays in the uncertainty of complex travel environment. Therefore, residents who have bounded rationality are always making decision between optimal and worst. It is an acceptable decision set for residents. However, this paper only focuses on the personal preference because of the travel environment's uncertainty and complexity. The assumption in this paper is the resident is absolutely rational and chasing best travel utility.

Therefore, this paper will start with the resident individual travel behavior. Firstly, rough set theory will be applied to research on travel decision affecting factors and the contribution of each factor weight or the contribution weight of any two factors could be confirmed. Secondly, simple genetic algorithms will be used to simulate individual residents travel decisions and each genetic operator specific parameters and corresponding fitness function will be confirmed. Finally, modified single urban resident travel decision model basing on rough set and simple genetic algorithms will be established, compared and explained.

Hutchison individual residents y, individual resident's travel decisions affecting factors x supposing there are n factors affecting the individual a trip. The complete

factor set which are affecting individual resident trip decision could be defined as $X=\{x_1,x_2,x_3,\cdots,x_n\}$. The travel utility of individual y is $U_d$. Individual y is always chasing the best travel utility $U_{opt}$. Therefore, y may choose a group of feasible decisions D. He could achieve the best travel utility through the comparative analysis. At the same time, the assumption above for the residents travel decisions here is still applicable.

## 2.1 Pre-processing the Model Based on Rough Set Theory

**(1) Select important factors**

There are some other factors may influent the individual decision expect for some common factors such as safe, comfort, cost and time which are always influencing the trip decision because of the differences in individual preferences, the inequality of individual travel decision quantity and the difference in purposes. Those factors could be defined as $\tilde{\lambda}$

Define the decision $D=f(X)=f_1(Xc)+f_2(\tilde{\lambda})$. $X_c$ is common factor. Meanwhile, $X_c$ and $\tilde{\lambda}$ establish the complete factor set. That is $X_c \cup \tilde{\lambda}=X, X_c \cap \tilde{\lambda}=\Phi$.

The common factors and other factors influence the individual y's decision. However, they could not decide the decision combination of $y$. The final decision of $y$ could determine the individual travel utility $U_d$ in the end.

Define $U_d=g(D)$, in which the best travel utility $U_{opt} \geq U_d$.

Obviously, there are n factors in the complete factors set $X$. There are k factors in common factors set $X_c$. Of course, $k \leq n$. The function of rough set is to reduce the original complete factors set to get an important factors set. Hence, the important factors set is basing on common factors set. The important factors set could be marked as $X_I$, $X_I=\{x_j \mid x_j \in X_c\}$. That means there are P important factors selected.

**(2)Expression of knowledge System**

Generally speaking, a knowledge system could be expressed as an ordered quad $S=\{U,R,V,f\}$ among which, $U=\{x_1,x_2,x_3,\cdots,x_n\}$ is on the field. It is the set of whole samples. $R=C\cup D$ is the set of attributes, among which sub set $C$ is condition attribute set reflecting the characteristics of an object and $D$ is decision attribute set reflecting the categories of objects. $V=\cup V_r$ is the set of attributes values. $V_r$ represents the range of attributes. $f:U\times R\rightarrow V$ is an information function to confirm the attribute of every object $X$ in set $U$. That is, if $x_i \in U$, $r \in R$, then $f(x_i,r)=V_r$. Hence, R is a rough set. $\alpha_R(X)$ could be considered as the accuracy which is approximating the set X under the equivalence relation R.

The original data could be filtered and the invalid data and the inapplicable data will be deleted. Furthermore, a two-dimensional decision information table will be established to describe urban travel choice factors knowledge expression system.

**(3) Calculate the univariate weighting matrix**

The univariate weighting matrix could be obtained by extending the reduction important factors set. $I = \{w_1, w_2, \cdots, w_p\}$.

**(4) Calculate the correlation factor weighting matrix**

The correlation factor weighting matrix could be obtained by the univariate weighting matrix,

$$R = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1p} \\ w_{21} & w_{22} & \cdots & w_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ w_{p1} & w_{p2} & \cdots & w_{pp} \end{bmatrix}$$

Meanwhile, R is a $p \times p$ real symmetric matrix. The weight value on the main diagonal equal the corresponding weight values in the univariate factor matrix, which is $R.w_{11} = I.w_1, R.w_{22} = I.w_2, \cdots, R.w_{pp} = I.w_p$.

The univariate factor matrix and correlation factor matrix will be explained and analyzed. The Genetic Algorithms will be introduced after the confirmation of univariate factor matrix and correlation factor matrix.

### 2.2 Genetic Algorithms Modeling

The decision is not always single when the individual resident y is travelling. Therefore, the set of decision variables is $D = \{d_1, d_2, d_3, \cdots, d_m\}$.

The m is the number of decisions and $d_i = \begin{cases} 0 \\ 1 \end{cases}$

Define the trip objective function of individual resident y is $U(D) = RX_I$. It represents the best travel utility that y is chasing. The fitness function could be marked as $fitness$ and $U_{opt} = \max U(D)$.

The fitness evaluation criteria are:

1. The value of fitness is the larger the better. The larger means the individual travel utility is better and the adaptability is better.
2. The individual travel optimal effectiveness could be selected by selecting the superior individual fitness.
3. The best travel utility $U_{opt} = \max U(D)$ is the maximum value of the objective function and it is positive number.

## 3 Data Modelling, Calculation and Analysis

### 3.1 Research Data Sources

Data in this paper is obtained by questionnaires. Questionnaires were issued in September 2010 to about 1000 and recovered 486 valid questionnaires. The investigation time covered three daily time paragraphs: 7:00~11:00, 11:00~13:00 and 15:00~19:00. The

survey subjects covered all sectors of society in Beijing as entirely as possible including different ages and different occupation. The survey locations covered the major urban areas in Beijing including bus stations, railway stations, shopping street, business office, park attractions, transit hub, as well as subway cars and other places. The questionnaire questions reflected the urban travel choice influence factors. These factors constituted the index system of urban travel choices, as shown in Table 1.The five factors were travel time, travel prices, travel distance, travel safety, traveling comfort.

**Table 1.** Index system of urban travel choices

| Aim | Factors | Index |
|---|---|---|
| Analysis on urban travel options factors | Characteristics | Age |
| | | Sex |
| | | Occupation |
| | | Travel options |
| | | The average monthly disposable income |
| | | The average monthly transport expendi- |
| | | Car or not |
| | Travel time accuracy | The accuracy of the destination arrival |
| | | Peak or off peak |
| | | Waiting time |
| | Travel costs | Ticket price |
| | | Parking price |
| | | Fuel costs |
| | | tolls |
| | Travel distance | Total distance |
| | | Transfer distance |
| | | Number of transfers |
| | Travel safety | Driving safety |
| | | Property security |
| | Traveling comfort | Seat or not |
| | | Crowded or not |
| | | Facilities convenience |
| | | Bulky items or not |

### 3.2 The Knowledge Expression of Urban Travel Factors and Weight Calculation

As seen from Table 1, urban travel choice factors are not only including time, piece and other factors known to public, but also including comfort, safety and other factors.

The resident survey questionnaire orders could be used as research object collection according to the rough set theory. The invalid data and inapplicable data are deleted. The remaining data set is $U=\{x_1, X_2, x_3, x_4, x_5...\}$, $a$ , $b$ , $c$ , $d$ , $e$ represents the importance of the accuracy of the time, the importance of the travel expense , the importance of the total travel distance, the importance of travel safety, and the importance of travelling comfort. It is the public factors set $X_c = \{a, b, c, d, e\}$, which establishing the condition attribute set of urban travel choice influence factors $c = \{a, b, c, d, e\}$ The decision

attribute collection set $D$ is established by the chosen travel mode. Hence, the corresponding figures are used to represent the items in condition attribute as following,

{1=very unimportant; 2=relatively unimportant; 3=general; 4=more important; 5=very important}

Similarly, in the decision attribute, the corresponding set is

{0=bicycle; 1=bus; 2=underground; 3=taxi; 4=car}

Therefore, dimensional decision information table could be established to describe the urban travel choice influencing factors knowledge expression system. As shown in Table2 (Experts):

**Table 2.** Urban travel choice influencing factors knowledge expression system

| No. | Condition Attributes | | | | | Decision |
|---|---|---|---|---|---|---|
| | Time accura- | Cost | Distance | Safety | Comfort | Travel |
| $x_1$ | 1 | 4 | 4 | 5 | 5 | 2 |
| $x_2$ | 1 | 5 | 4 | 5 | 3 | 1 |
| $x_3$ | 2 | 3 | 2 | 3 | 3 | 2 |
| $x_4$ | 2 | 4 | 3 | 3 | 3 | 1 |
| $x_5$ | 3 | 1 | 3 | 5 | 4 | 1 |
| $x_6$ | 3 | 2 | 3 | 5 | 4 | 1 |
| $x_7$ | 3 | 2 | 5 | 5 | 5 | 0 |
| $x_8$ | 3 | 3 | 2 | 5 | 5 | 3 |
| $x_9$ | 3 | 3 | 2 | 4 | 2 | 4 |
| … | … | … | … | … | … | … |

The univariate weight matrix could be calculated result as $I = \{4/27, 8/27, 7/27, 2/27, 6/27\}$ according to the rough set theory. And the corresponding weight matrix could be calculated result as

$$R = \begin{bmatrix} 4/27 & 15/126 & 17/126 & 4/126 & 14/126 \\ 15/126 & 8/27 & 18/126 & 10/126 & 15/126 \\ 17/126 & 18/126 & 7/27 & 10/126 & 14/126 \\ 4/126 & 10/126 & 10/126 & 2/27 & 9/126 \\ 14/126 & 15/126 & 14/126 & 9/126 & 6/27 \end{bmatrix}$$

On this questionnaire concerned, the crowd comprehensive collective preferences are (symbol $\succ$ represents perference and means better tha n)

$$\text{cost} \succ \text{distance} \succ \text{comfort} \succ \text{time accurancy} \succ \text{safety}$$

### 3.3 Rough- Genetic Algorithms Modelling

The cost (C), distances (L), comfort (C, F), time accuracy (T) as well as cost and time accuracy combination(C, T), time accuracy and distant (T, L) are selected as parameters according to the calculation result basing on rough set theory.

$$U(D) = WX = \sum \begin{bmatrix} W_C H(C) + W_L K(L) + W_{C,F} Q(C,F) + W_T G(T) + \\ W_{C,L} P(C,T) + W_{T,L} V(T,L) + \varphi \end{bmatrix}$$

In the formula, $\varphi$ represents the additional satisfaction. It is the utility value of other factors $\hat{\lambda}$ . These factors are generally classified as one group due to the unobserved character.

The objective function is transformed into the fitness function.

$$f(D_j)=\sum_{d_1}^{d_n}[w_t g(t_{d_j})+w_c h(c_{d_j})+w_l k(l_{d_j})+w_{c,f} q(c_{d_j},f_{d_j})+w_{c,t} p(c_{d_j},t_{d_j})+w_{t,l} v(t_{d_j},l_{d_j})+\varphi_{d_j}]$$

A specific fitness function could be given according the univariate weight matrix and the corresponding weight matrix which are confirmed basing on rough set theory.

$$f(d_1,d_2)=8/27*d_1^2+7/27*d_2^2+18/126*d_1^3+17/126*d_2^3-15/126*d_1*d_2$$
$$-4/27*d_1-6/27*d_2$$

## 4 Examples of Simulation, Results and Analysis

The model in this paper is for individual. The data is randomly selected from actual questionnaire in order to fit the simulation results more realistic. This questionnaire is answered by a lady living in Beijing. The average monthly disposable income is 2000 to 3000 RMB. The average monthly transportation expense is from 200 to 300RMB. And she did not have a car.

The simulation follows the travel situation: (1) the travel aim is tourism; (2) no bulky items; (3) no travel this line before. A calculation shows that the cost of travel traffic scope of its disposable income is [6.7%， 15%]. The proportion of expenditure is relatively high.

The trip will be converted to a travel decision model based on genetic algorithms. The decisions that should be confirmed including (1) Travel satisfaction should achieve highest; (2) Line i select sub way, bus or taxi? (3) Line ii select subway, bus or taxi? Conventions decision variable $D$ is taken from [1, 4]. If the value of $D$ is [1, 2） the selection is bus. If the value of $D$ is [2, 3） the selection is underground; if the value of $D$ is [3, 4] the selection is taxi. $d_1, d_2 \in [1,4]$, which are two decision variable. Matlab tool box is used to do program. The following figures are the results of the operation.

Fig.1 shows the individuals which has the best fitness value of each generation. According to fig. 1, the final selections of the individual are: 3.6474 and 3.14209. The corresponding phenotypes are both taxi.

Fig.2 describes the average distance between individual in each generation. According to Fig.2, the average distance among individuals from far to near and from big to small are eventually nearly coincides through the rough –genetic algorithms optimization. That represents the individual selected eventually by the rough-genetic algorithms are high quality.

Therefore, the lady is advised to choose taxi both on line i and on line ii according to the results given by the rough-genetic algorithms. The final prediction is that the lady should choose a taxi directly on this trip and she will achieve the optimal effectiveness.

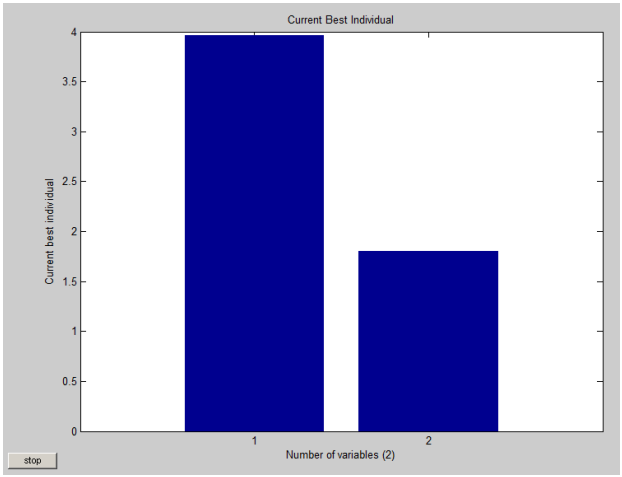


**Fig. 1.** Rough- genetic algorithms simulation results

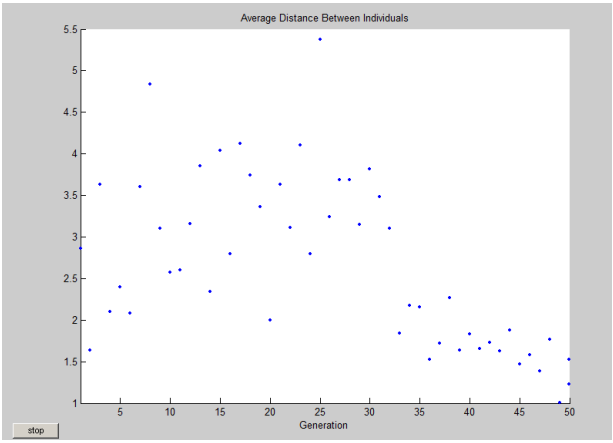


**Fig. 2.** The average distance among individuals in rough-genetic algorithms model

## 5 Conclusions

In this paper, the single factor weight matrix and various factors related to weight matrix are brought out by analyzing the factors of individual residents travel behavior and decisions which are restricting their travel. Furthermore, this paper utilizes the advantage of Genetic algorithm to simulate the individual residents travel decision behavior. An example simulation is given in this paper to verify the validity of the travel decision-making simulation model.

It is contributing for improve the accuracy of the study by combining the rough set and genetic algorithm together in this paper. However, most of the residents could not make the best travel decisions during the travel time. They would choose a group of

satisfaction with the decision-making under common situation. That is to allow the difference of travel utility and optimal utility in the acceptable range. Therefore, in process of the genetic algorithm modeling, the objective function and fitness function should be changed. This is the further research contents.

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# Visualization of the UK Stock Market Based on Complex Networks for Company's Revenue Forecast

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**Abstract.** As an emerging research field, the complex network theory is able to depict the most daily complex systems' topologies, but in terms of financial market analysis, it still needs more attention. We can apply this theory to construct financial networks and detect them both from macro level and micro level to support a company in forecasting its revenue. This paper aims to explore the macro-characteristics of the UK stock market. We examine the properties of return ratio series of selected components in FTSE100 index, adopt the Kendall's $\tau$ rank correlation coefficient between series to write adjacency matrices and transform these matrices into complex networks. Then we visualize the networks, analyze features of them at different thresholds and find evidence of WS small world property in the UK stock networks. All these work follow our research framework proposed at beginning of this paper. According to the framework, more future work needs to be done to achieve the goal and make decision support in a company.

**Keywords:** Complex networks, FTSE100 index, WS small world property, Revenue forecast.

## 1 Introduction

The function of the stock market is to provide a public platform for trading businesses and raise capital for companies. Various information technologies and statistics methods have been engaged in analyzing its dynamics, such as Internet, portable computers, regression analysis and so on. However, the interactions between companies are rarely taken into account, but undoubtedly they play an important role to impact the markets. From inside perspective of a company, forecasting its revenue through the stock market's behavior could be one way to support decision making. In order to achieve this research aim, we propose utilizing complex network theory to visualize and analyze the complexity of the interactions in this paper.

Complex network theory is able to abstract and depict the most daily complex systems' topologies. As an emerging hotspot, this theory has attracted attention of scholars increasingly from various research fields and became one of the most significant tools in social network analysis. Complex network theory has been introduced since decades ago. To date, it has been widely used in the study of social relationships,

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transport networks, biology, ecology, emergency management, power grids, etc., and as a credible and powerful tool to characterize the markets.

Up to now, some scholars have done several researches about the major stock markets all over the world. In 1999, Mantegna [1] proposed a hierarchical tree to investigate the common economic factors affecting the stocks' prices. In 2005, Boginski et al.[2,3] constructed a market graph which followed a power-law model and calculated cross-correlations to reflect the market behavior with the data from US stock markets. Till 2009, Haldane [4], the Chief Economist and the Executive Director of Monetary Analysis and Statistics at Bank of England, first convincingly explained the current financial markets with complex networks in an official speech. Caraianie (2012) [5] analyzed the properties of the returns of European stock markets by complex networks, and found that the networks are scale-free and self-similarity. Zhuang et al. [6] constructed a network of stock prices fluctuations in Shanghai stock market and analyzed its topology. Further, Zhang et al.[7] compared the networks extracted from the original series and return series. They showed different characteristics because of different data. The former one fitted with a power law distribution and was a small-world and free-scale network, while the latter one governed by an exponential degree distribution. For Hang Seng index of Hong Kong stock market, Li and Wang[8] found fluctuation patterns based on the network topological statistic. In these researches, networks from various databases and statistic results are visualized to make texts more visually attractive and help audience understand more effectively.

The aim of this research is to apply the complex networks theory to the UK stock market to forecast companies' revenue. The research framework is shown below (Fig.1). The first two steps are contents in this paper and the others are the future work in our research.

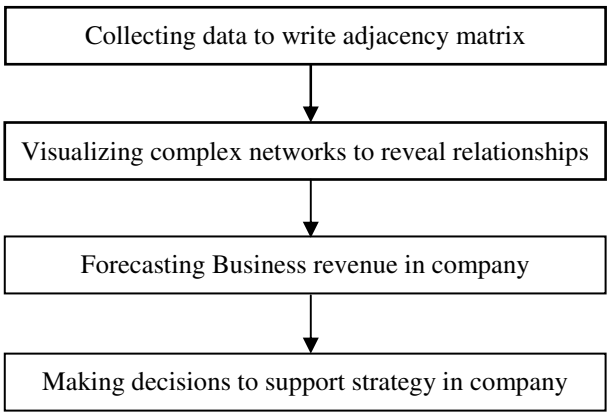


**Fig. 1.** A basic framework to forecast company's revenue using complex networks

In this paper, we investigate the relationship between return series with observations from 2004 to 2014 in FTSE100. We find that return series show significant

non-linear correlations that do not meet strict assumption of Pearson's correlation; therefore we adopt Kendall's τ correlation as edges' weight to construct and analyze networks more accurately.

## 2 Methodology

FTSE100 index, being one of the most professional stock market exchange indices all over the world, has 101 components from various industries. However, not every company contributes to the market during the period we chose. Hence, an analysis of these long term running companies would give us a big picture of the network structure of the British stock market.

### 2.1 Data Collection and Pre-processing

The weighted network is able to describe the nodes and relations between them much more really and clearly than non-weighted network, therefore, a whole connected, no direction and weighted network is constructed in this paper. Within different thresholds, the research will find their macro-characteristics.

The data are extracted from "Yahoo Finance", and the timespan in consideration of this paper is from 1st January 2004 to 10th October 2014. The dates of the public holidays in UK are deleted as stock market is closed, including New Year's Day, Good Friday, Easter Monday, Early Bank Holiday, Spring Bank Holiday, Summer Bank Holiday, Christmas Day and Boxing Day in each year. To reflect facts as real as we can, companies that do not have data in full period are deleted as well. Consequently, there are 86 components of FTSE100 as the vertices in network, such as BP plc (British Petroleum), LSE (London Stock Exchange Group PLC), and LLOY (Lloyds Banking Group PLC) and so on so forth. The edges are the relationships among the 86 stocks and the correlation coefficient is the weight of each edge.

Pre-processing each company's closing price data series is needed. Denoting the original daily closing price of the stock $i$ at time t is $P_i(t)$. These data are calculated as

$$r_i(t) = 100 \times \ln\left(\frac{P_i(t)}{P_i(t-1)}\right), (t = 1, 2, \cdots, n). \tag{1}$$

Then there will be the return ratio data series $R_i(t) = \{r_i(t)\}, t = (1, 2, \cdots, n-1)$, $i = (1, 2, \cdots, 86)$, and the number of data in one series is $\left((a_1, \cdots, a_d), (b_1, \cdots, b_d) \in [0,1]^d\right) n-1$.

The more data we have, the greater extent network can reflect the real UK stock market from results we conclude. Therefore, the components we choose have the most amounts of data during the period. Following this principle, there are 234 178 (2723 per each companies) pieces of efficient data.

## 2.2 Edges and Their Weights

Analysing the statistical characteristics of the return series is the first thing we should do to understand the basic statistic of the return series. Six random return ratio series are shown in table1.

**Table 1.** Basic statistics of six return ratio series

| Company | Mean | Median | Std. Dev. | Skewness | Kurtosis | Jarque-Bera | |
|---|---|---|---|---|---|---|---|
| | | | | | | Statistic | Probability |
| **AAL** | 0.003166 | 0.040642 | 2.760246 | -0.13138 | 10.06153 | 5665.449 | 0 |
| **ABF** | 0.052881 | 0.062794 | 1.341194 | -0.07136 | 10.78818 | 6884.209 | 0 |
| **ADN** | 0.072697 | 0 | 2.347117 | 0.146311 | 10.15676 | 5820.97 | 0 |
| **AGK** | 0.082391 | 0.063191 | 2.350748 | -0.55548 | 29.70248 | 81038.36 | 0 |
| **AHT** | 0.151669 | 0 | 3.27993 | 0.003828 | 14.71018 | 15558.36 | 0 |
| **ANTO** | -0.01732 | 0.060223 | 4.265728 | -19.2306 | 719.1176 | 58352041 | 0 |

From this table, it is clear to see that the means are around 0 and the standard deviations are all over 1, that is to say, there are bigger fluctuations in these return series. Obviously, the fluctuations are depended by the uncertainty of the stock market. Majority skewnesses of data series' distributions, in this table, are smaller than 0, and kurtoses are greater than 6 (twice of 3), which mean the return series show left skewed (thick/fat tail) and high peak distribution. Meanwhile, the probabilities of Jarque-Bera are all 0 and do not accept the hypothesis: the return series are normal distribution. Because of these characteristics, it can be seen that these six return series obey student T distribution, the same as the rest 80 series.

The Q-Q graphs below give evidence of the judgment we made above.

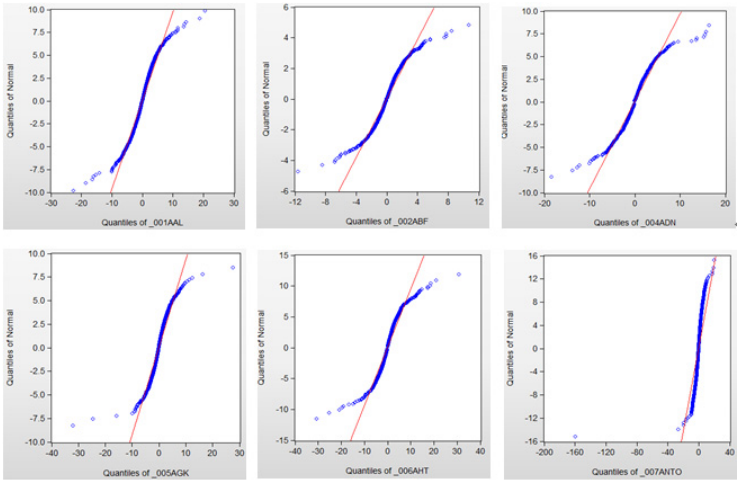


**Fig. 2.** Q-Q graph of return series against normal distribution

As the graphs showed, the return series have the features mentioned above and do not accept the hypothesis of normal distribution.

To examine the correlations among the series, it is calculated the autocorrelation and partial autocorrelation of 21 period-lag of these series. The Ljung-BoxQ value is significant and the results show that there are no significant relations. Therefore, all the return series we chose are independent in the period.

According to the test results, in this paper, we employ the Kendall's $\tau$ correlation as the edges' weights. A correlation coefficient is a measure of the consistency of changes between the variables. Pearson Product Moment Correlation or PPMC (Pearson's correlation, for short), which is a measure of the linear correlation between two variables, is common to see in the correlation research of the stock exchange markets since it is easier to understand and calculate than others. However, there are some limitations for Pearson's correlation. For example, the variables should be normally distributed and it is for linear relationship between the two variables. Kendall's $\tau$ correlation measures the coordination degree of variables that based on the rank of random variables. Therefore, Kendall's $\tau$ correlation coefficient is able to reflect non-linear dependences better without restriction mentioned above.

With these calculations, we can write adjacency matrices. Through the adjacency matrices, we construct complex networks and analyse them with respect to degree distribution, average shortest length path and clustering coefficient.

## 3 Results and Discussion

With Pajek, a social network analysis tool, we transform the adjacency matrices into complex networks.

### 3.1 Network Structure Analysis from Macro Perspective

Visualising networks at a threshold of 0.36 as below: the nodes are the 86 companies from FTSE100 index and the edges are determined by the Kendall's $\tau$ correlations between the series. The network is the whole connected weight network.

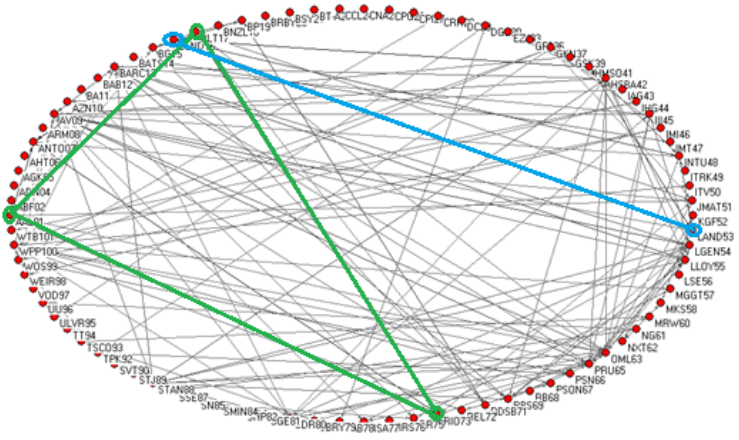


**Fig. 3.** Complex Network of FTSE100 index at a threshold of 0.36

In Fig.3, the darker edges represent the bigger correlation coefficient between the companies. It is noticed that five companies have the strongest relationships and these five companies are formed into two clusters: AAL01 (Anglo American Plc.), BLT17 (BHP Billiton Plc.) and RIO73 (Rio Tinto Plc.); BLND16 (British Land Co Plc.) and LAND53 (Land Securities Group Plc.). The first three companies highlighted by the green are all multinational mining companies. The last two highlighted by the blue are all the property companies and they all turned into a real estate investment trust (REIT) in January 2007. British Land is the second largest REIT in the UK and Land Securities is the largest one. Undoubtedly, the companies in the same industries would be easy to have strong relations.

In order to describe a network from the macro aspect, it is usual to characterise its density and scale. Clustering coefficient and average path length are the indicators to measure these two features.

Clustering coefficient reflects that how close a vertex's neighbors are being cliques, which is the density of a network. Assume in a network $G$, a vertex $i$ has $k_i$ edges to connect other $k_i$ vertices, and these $k_i$ vertices named neighbourhood of $i$. Therefore for each vertexi, there are at most $k_i(k_i-1)/2$ links that could exist in an undirected graph, whereas real number of edges of neighbours in this undirected graph is $N_i$. Then the clustering coefficient $C_i$ is:

$$C_i = \frac{2N_i}{k_i(k_i-1)}. \tag{2}$$

The overall level of clustering $C$ in a network is defined by Watts and Strongatz [9] as the average of all the $C_i$:

$$C = \frac{1}{N}\sum_{i=1}^{N} C_i. \tag{3}$$

Obviously, $0 \le C \le 1$. If $C = 0$, all the vertices in the network are independent. If $C = 1$, any two nodes are directly connected in a network, i.e. the network is a global coupling network.

Average path length is defined as the average number of steps for all possible pairs of network nodes. It is a measure of the efficient of information transport on a network, i.e. the scale of a network. Suppose in a network $G$ Gthe length of any two nodes $i$ and $j$ is $l_{ij}$, which is the shortest number of steps from node $i$ to $j$. The average length of a whole network $L$ is

$$L = \frac{2}{N(N-1)}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} l_{ij} \tag{4}$$

.

$N$ is the number of vertices in a network. We do not consider vertices' own distance in this paper.

Clustering coefficients and average path lengths are calculated at different thresholds with data mentioned before, showing in table 2.

**Table 2.** Clustering coefficient and Average path length at different thresholds

| Thresholds | Clustering coefficient | Average path length | Number of edges |
|---|---|---|---|
| **0.25** | 0.7848 | 1.6426 | 3104 |
| **0.27** | 0.7278 | 1.8666 | 2282 |
| **0.30** | 0.6463 | 2.1320 | 1206 |
| **0.33** | 0.5772 | 2.4169 | 594 |
| **0.36** | 0.6015 | 2.8870 | 250 |
| **0.40** | 0.6744 | 1.3582 | 86 |
| **0.50** | 0.8571 | 1.1579 | 32 |

In table 2, at various thresholds, the FTSE100 network has a small average shortest path length and a large clustering coefficient. With these two characteristics in a network, referencing the research did by Watts and Strogatz[9,10]in 1998, it is a Watts-Strogatz small-world network (WS small-world network for short). With these features, the fluctuation in this stock exchange market would spread rapidly. Specifically, it is found that sharp changes of some influential companies' stocks will spread at a faster pace to a wider range. These two characteristics, small average path length and large clustering coefficient, are two indicators to measure the small-world property. WS small world network is a transition from a complete regular network to a complete random graph.

### 3.2 Thresholds in Networks

Reasonable threshold selection is a crucial step for constructing networks. If a selected threshold is too small, there would be false associations due to the random noise, resulting in the complete connected network; if the selected threshold is too large, more isolated points will make the existence of the network, the network will contain fewer vertexes, and hence lots of important related information will be lost. Under these situations, it is no need to analyse the network degree distribution and clustering coefficient any more. In addition, according to the same interval, when the thresholds change from small to large, if the number of relations among stocks decreases rapidly, the left companies are more significant than others to contribute to the national economy or local economy. Otherwise, there are no more huge differences among companies to make contribution to a nation or a region. So the research with appropriate thresholds can explore real relationship among stocks to the whole system.

In this paper, the research draws 26 complex networks at 26 thresholds respectively, and the number of edges shows in Fig. 4, which reveals a descending trend of the edges. As we all know, even with the same vertices, various numbers of edges can

construct various networks. Based on the specific networks, researches for parameters could be processed, such as the adjacency matrix of networks, the cumulative distribution of degree, clustering coefficient, average nearest neighbour degree, k-core and partitions and so on so forth. For the thresholds of the financial network we construct, it is steadier to the edges' number between 0.3 and 0.4.

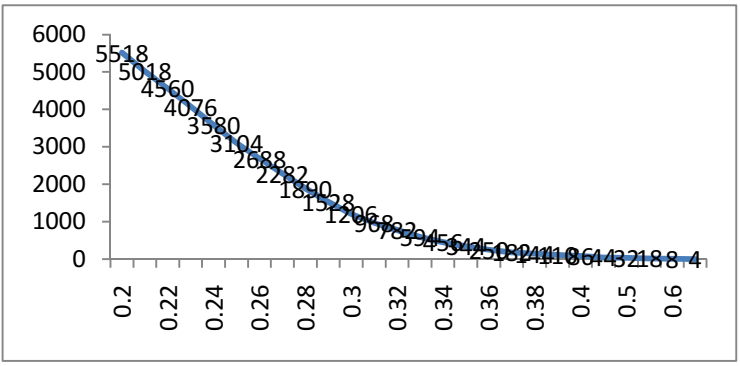


**Fig. 4.** The number of edges at different thresholds of financial network

## 4 Conclusion and Future Work

As an emerging method in economic disciplines, complex networks still needs more attention. In this study, we proposed a basic framework to forecast revenue for a company to make decision support based on complex networks theory. We detected data from the FTSE 100 index and write adjacency matrices to construct networks and visualize them. Based on basic statistics of data, we explored features of networks, and found the FTSE100 index network is a WS small world network and thresholds are playing a significant part in constructing networks. We investigated the UK stock market data independently with other research data. Similarly, the WS small world properties show in US stock market, Shanghai stock market[7], international stock markets[11]and so on. Combining data analysis with visualised graphs, decision makers could do predictions much faster and more reliably to support strategies in companies. Other macro features and in-depth micro research will be conducted in the future, for example, clustering communities, detecting topology changes of networks with impacts from internal and external events in companies. Many networks from stocks markets have been studied, but there are still some important questions need to be answered: what are common features in international stock markets, what these markets differ in each country and how we can visualise them clearly to support making decision, as examples.

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# Creativity Filter and Start-Ups to Resolve the Innovation Paradox

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**Abstract.** The literature on creativity and innovation traditionally focuses on how individuals and R&D teams generate and implement novel ideas and search for opportunities. It also highlights the role of skills, motivation and knowledge as a source of opportunities and innovation. As the gains from skills and knowledge are uncertain, the degree of creativity spillover could be an important consideration. To address this gap in the literature we examine the role of the creativity filter in the relationship between knowledge and innovation in the organization.

**Keywords:** Creativity filter, innovation, knowledge management, skills, inter-organization.

## 1 Introduction

There is an increasing interest in understanding how opportunities and new ideas are created [2], [3]. Firms need new ideas that expand their market share and bring new products [22]. One of the key focus of entrepreneurship is understanding why some firms are better than others to identify opportunities and bring new ideas [3] and why employment of high level skills and knowledge may not result in greater innovation, known as an "Innovation paradox" [17]. While there is a disagreement in the management and innovation literature about the process of creating innovation [1], the central components of opportunities are knowledge, motivation and skills [15], [6], [17]. Fostering skills and knowledge that help to create new opportunities [18], has become the priority for new entrepreneurial firms. New entrepreneurial firms have greater abilities to innovate than established mature firms, as new entrepreneur's ability to identify opportunities is related to knowledge [3], experience and skills. Employment of people within certain functional areas (design, software, and engineering) helps firms to shape knowledge and innovate [14].

Despite extensive theorizing about the importance of various external factors as predictors of new ideas and economic performance, that include education and competences [15]; team creativity and leadership [12]; cognitive styles of creativity [16], [17] extant empirical research misses the link between available knowledge and skills,

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knowledge management and innovation outcomes [7]. In understanding this link scholars have integrated goal orientation theory [13], the knowledge spillover of entrepreneurship theory [3], [4], organizational creativity theory [2], [14] social capital theory [24] and social information processing and exchange theory [12], [17].

Despite all of this knowledge, above theories have not examined availability the role of knowledge management and organizational factors that enable knowledge and skills transformation into new ideas and performance [20], [21].

In this study, knowledge is seen as availability of skills within the company or purchase external skills (e.g. design and graphics, multimedia and software, and engineering and math skills) and human capital that includes both the formal education as well as tacit knowledge from experience and practical learning. Following prior studies [3], [4], [5], we expect that knowledge promotes innovation and economic efficiency. Motivation through a broad range of organizational and inter-organizational practices aiming in developing creativity within the organization and innovative orientation of a firm is likely to moderate the relationship between knowledge and innovation [12]. We aim to understand how characteristics of a firm, in particular skills and education effect innovation of a focal firm. What is the role of knowledge management and firm-specific internal characteristics (further - creativity filter) in the relationship of knowledge management and commercialisation?

This study makes a discussion and contributes into open innovation and creativity literature by unpacking the role of creativity as a filter of knowledge to innovation [1], [8]. We take a firm level perspective, exploring firm-level characteristics as a conduit of knowledge to innovation.

## 2 Knowledge, Creativity and Innovation

Knowledge and skills are the building blocks of creativity [2] and are important to the ability to innovate [8]. They allow firms to deviate from their counterparts and come up with breakthroughs that may change methods of production and processing while promoting the acceptance of innovation. By generating novel ideas that require new solutions, workers with creative skills and knowledge [10] provide their companies with new knowledge that brings new marketable opportunities [5]. The most direct link is reflected in the commercialization of knowledge through the creation of a new business. This relationship lies at the heart of the 'knowledge spillover theory of entrepreneurship' [4]. The combination of skills and ideas is not static, and may respond to changes in the firms organizational and innovation climate. Employing creative individuals and encouraging the expression of their voices increases the likelihood of identifying problems and generating new ideas [14], triggering new ways of thinking and modes of [17]. Traditional measurement of knowledge by the human capital or occupations [10] was found to be correlated with a range of other indicators capturing the formal qualifications of the workforce. Hence it was unclear whether the knowledge captures only education or more generic skills and experiences. We use a combination of skills and a proportion of workforce with scientific degrees as measure knowledge at a firm-level. Both skills and workforce qualification enable firms to

change the way opportunities are defined, and be a source of these opportunities to increase innovation [7], [1] we assume:

*Proposition 1. Firms that deploy skills and employ workforce with scientific degrees are likely to have higher level of innovation.*

## 3 The Innovation Paradox and the Creativity Filter

Despite the importance of skills and formal education for generating new ideas previous management literature has found a neutral or even negative outcomes related to idea implementation [16]Although firms may employ individuals within certain functional areas with the personal attributes associated with idea generation (e.g., creativity) [2] it is unclear whether these ideas and experiences will become innovation. This finding is not surprising given innovation requires out-of-the-box thinking, exploration, risk-taking and tolerance of mistakes. It requires promoting knowledge through firm organizational and managerial practices and channels, creating a conducive environment for innovation in organization [25]. Thus, if the above conditions do not hold successful implementation of ideas becomes questionable [26]. This contradiction inherent in innovation was called "The innovation paradox."

We know that workers often complain that their firms are reluctant to introduce change, and that they find it difficult to work within the existing firm strategy and practices, and so that these practices may impede new ideas to sprout out [17], [8]. Deploying variety of skills (e.g. IT, multimedia, design, math, engineering, graphics, etc.) within certain functional areas may not result in higher level of innovation, as positive effect of some companies will be cancelled out by the negative effects. Workers with skills are subjected to inter-organizational environment and factors that are there to motivate workers and enhance not "enforce" the implementation of new ideas [5]

Social information processing theory [12] and knowledge spillover of entrepreneurship theory [4] could be used to further describe the process linking knowledge, creativity and innovation.

Within the social information perspective, firms acquiring creative for their innovation create certain types of behaviors and performance that gives rise to an environment supportive of creativity [26]. It also conveys expectations of creative performance within the firm. Empirical studies found this dimension is the only significant predictor of innovation novelty [26], as workers may or may not agree to share their idea should the benefits of doing so be uncertain and the working environment hazardous for creativity [20], [21]. A complex of organizational and inter-organizational practices work as a creative environment, which enables more efficient conversion of knowledge into innovation. This mechanism describing the link between knowledge and innovation may be described a creativity and work as a filter to knowledge. The creativity filter is a high-level umbrella construct that captures the impeding or moderating effects of a broad range of organizational as well as inter-organizational mechanisms that may hamper innovation and innovative orientation by a firm through

investment in in-house R&D and other creative expenses to support innovation in-house. According to the social information processing theory, creativity will moderate the power of knowledge. Unlike the knowledge filter, described [4, 12, 47] as, "the inertia inherent in decision-making under uncertainty within incumbent organizations", the "creativity filter" refers to enforcement of organizational and inter-organizational mechanisms and R&D intensity that moderate or hamper innovation [5]. These practices and innovation inputs pose significant constraints on the behavior of employees [25]. First, we expect more creative behavior to evolve through the new organizational and inter-organizational mechanisms (e.g. systems of employee responsibilities, teamwork, de-centralization, integration or de-integration of work, and training) when individuals can access and implement new ideas, perspectives, and knowledge. Second, the employee's creative behavior will be supported by an information exchange with external firms or public institutions (e.g. alliances, partnerships, outsourcing or sub-contracting), provides a platform through which innovation can diffuse. Both activities make up an organizational component of the filter. Another R&D component of the filter represents creative expenditure that improves innovation [23] exposes workers to diverse ideas both internally and through external interactions.

The creativity filter will enforce a higher flow of knowledge and deployment of skills through promoting responsibilities, teamwork, integration, and information exchange resulting in more ideas to sprout-out [9].

*Proposition 2. The creativity filter moderates the relationship between the knowledge and innovation.*

## 4 Creativity and New Entrepreneurial Firms

The mechanism of commercialization of knowledge and ideas is new entrepreneurial start-up described in the 'knowledge spillover theory of entrepreneurship' [2]. Since knowledge tends to be 'sticky' in space, it becomes a determinant of entrepreneurial start-ups.

Drawing on the knowledge spillover theory of entrepreneurship and its human capital component [1] we posit that knowledge needs to be enhanced by someone, whether an individual or a company, who can take a responsibility of ideas and deliver innovation to the market. Starting an entrepreneurial venture spillovers knowledge which otherwise would remain un-commercialized [5]. New entrepreneurial firms are more successful than their old counterparts in enhancing innovation.

Along with the creativity filter, young businesses are better in resolving the "Innovation paradox" by outperforming their market counterparts through creative destruction. Next we consider the time period for knowledge spillovers. We assume up to three year time lag is a sufficient period for any specific information on development decisions, R&D, and new ideas to spread in the market and across all sectors. The speed of information spread and commercialization of a product could be higher for other sectors, such as IT and engineering. We suggest start-ups serve as a conduit of

new ideas and as a creativity filter per se which filters out good ideas resulting in start-ups.

Although new firms moderate the relationship between skills and innovation, the same role could also be performed by existing and more experienced firms operating in innovative fields, like knowledge-based companies (ICT, bioengineering, pharmaceutics). Such firms typically hire highly educated and skilled individuals (engineers, telecommunications graduates) to implement and further develop new ideas and innovations (e.g., Sony, Apple or Microsoft). In measuring the moderation role of both start-ups and established firms, we need to take into account several possible channels of creativity to the market which allows us not to overstate the relevance of any specific type of a conduit.

*Proposition 3. New entrepreneurial firms moderate the relationship between the knowledge and innovation.*

## 5 Measures and Approach

*Innovation* is measured as the percentage of a business's total turnover from goods and services that were new to the market [26]. In line with the management and economics literature [1, 4, 5]. *Productivity* could bhe reflected by two measures. The first measure consists of the gross value added in sales. The second measure consists of the wages and other employment benefits paid to firm's sales.

Our variables of interest are creativity and the creative environment which can either enhance or constrain the creativity. Building on what is needed for individual creativity [11], we follow [1, 20, 21] in operationalizing a firm's creativity in terms of the employment of individuals with skill at any level in the graphic arts/layout/advertising and design of objects, multimedia/web design, software/database development and management, or engineering/applied sciences and mathematics/statistics. Firms may also obtain these skills from external sources for in-house use. Usually a binary answer is obtained for each of the three types of creative skills (0 means skills were not employed, and 1 means skills were employed).

We draw on [26], who originally developed the scale measuring the creative climate supportive for innovation along with [8], [11]. The mechanism describing the link between creativity and innovation may work as a filter to knowledge and therefore termed a creativity filter.

The creativity filter is a composite indicator of complex organizational systems. It consists of an organizational and innovation input (R&D) component. To be able to design and develop the creativity filter researchers jointly with the Office of national Statistics, UK have conducted phone interviews. In the sample 155 R&D managers located in various UK regions representing the manufacturing, service and R&D sectors. 130 responses were interviewed. The results were used to assign appropriate weights to organization component of the filter – introduced by three organizational and business practices (see formula 1 below).

$$F_i = (w_{0.25}M_{1i} + w_{0.5}M_{2i} + w_{0.25}M_{3i}) + RD_i \quad (1)$$

$F_i$ is the size of the filter of a firm *i* in industry *j*. The R&D effort - innovation component of the filter is given as the choice of a firm to invest in in-house creative work undertaken within the business that increases knowledge. This can be for the purpose of developing new and improved products and processes for current or future innovation. The R&D component contributes half of the filter size, which varies between zero - no R&D expenditure - and one - in-house R&D expenditure is undertaken.

The organizational part of the filter is a composite sum of the three types of organizational strategies and practices applied by organization. It aims at raising internal efficiency and the effectiveness of approaching markets and customers. The higher the score, the smaller the size of the creativity filter and the smaller the gap between commercialized and un-commercialized creativity.

Companies that have fewer than 10 employees, have not introduced at least one method of organizing work and business practices over the period of 2008-2010 and companies that did not provide any rank of those practices were excluded. Respondents were asked to rank organizational and business practices by their importance to innovation. Most respondents (102) placed $M_{2i}$, referring to new methods of organizing work responsibilities and decision making (i.e. the first use of a new system of employee responsibilities, teamwork, de-centralization, the integration or de-integration of departments, education/training systems, etc.) as the most relevant component of organizational innovation. More than half of the respondents (70) ranked $M_{1i}$ as the first or second most important component of innovation, which refers to new business organizing procedures (i.e. supply chain management, business re-engineering, knowledge management, lean production, quality management, etc.) and constitutes a quarter of the organizational component of the filter. Finally, the rest of the group ranked $M_{3i}$ as the second or third most important component of innovation, which refers to new methods of organizing an organization's external relationships with other firms or public institutions (i.e. the first use of alliances, partnerships, outsourcing or sub-contracting etc.).

We distributed the weights equally between $M_{2i}$ and $M_{3i}$ by assigning 0.25 of the unity of the organizational components that contribute half of the filter size. This varies between zero (no organizational strategy or practices were introduced) and one (all three types were introduced). The interview method was used in order to shed more light on the relevance of each specific organizational practice to the process of introducing new products to the market. This meant we could be flexible and precise when distributing the weights, rather than treating all new practices as equally important. The organizational and innovation components of the filter vary between zero and two.

In order to test the moderating effects of the filter in linking the process of creativity and knowledge flow to innovation we included the interaction of each type of creative skill in the model. As control variables we will need to include firm size (log of the number of employees and the square of the log of number of employees), UK regions, sector dummy, an exporting dummy, the effectiveness of patent protection (0: patent protection not used to 3: high efficacy), enterprise age.

## 6 Managerial Implications

The model demonstrates firm's reliance on availability of skilled and creative employees both inside and outside a firm. Business start-ups and experienced established companies exploring new opportunities is an important factor shaping creativity into marketable products and processes. On the one hand, establishing a new business is the most efficient and quick way to commercialize creative skills. On the other hand, start-ups are on average less productive than established firms, unless they are successful in employment of individuals with a mix of creative skills to secure higher wages, and add value to their products.

Our creativity filter reveals the importance of innovative and organizational effort when working on innovation. This enables more creative behavior and thereby the smaller size of the filter. The filter is something to be taken into consideration by R&D managers, as it correlates strongly with innovation output. As filter impedes the creative behavior of employees, it also constraints the development of new products. Thus, changes in organizational business strategy and R&D support are important. Managers may find it useful to foster the learning activities of their employees through lean manufacturing, introducing a system of employee responsibilities, promoting the development of team work, the de-centralization of tasks, temporary job placements, and educational systems such as Sigma 6, Invest in People and other similar strategies. Developing team-building and rewarding the implementation of new ideas will perform some conduit of creativity functions. An open exchange of information via the organizational and managerial practices discussed is critical to innovation and the creativity-filter-innovation link.

Within these boundaries, R&D and finance managers may encourage internal research and development in a number of ways, such as by financing it in-house or finding sponsors to fund creative work undertaken within the business. In particular, focus should be on the generation and implementation of new ideas employees both inside and outside of organization. To sum up, the creativity is a multilevel phenomenon, and managers should apply a systematic approach to institutionalized platforms as routines and practices inside their firm. Creativity filter is a conduit of creativity to innovation and it is about both innovation inputs and organizational practices (capabilities) that enables to commercialize creativity mix through recruitment of employees with various creative skills and experimenting to see what works best.

## 7 Conclusion

This study is the first to examine creativity filter as a conduit of creativity in innovative firms, demonstrating that creativity comes before knowledge and skills. Further integration of goal orientation theory, the knowledge spillover of entrepreneurship theory, organizational creativity theory and information exchange theory is needed to release the black box explaining the "creativity-innovation-productivity" links.

Policies targeting an increase local economic growth and tax revenues may focus on better commercialization of available creative skills at the firm level, and by

providing support to new firm start-ups to spillover creativity. Developing a policy to support both extramural and intramural spillovers of creativity could increase innovation. Any increase in the gross value added in sales will accordingly affect the amount of corporate tax collected. To continue growing an entrepreneurial policy that supports both established firms and new businesses start-ups which employ individuals with creative skills at any level is important.

Government policies that enable businesses to implement new management techniques as well as major changes to their organizational structure while increasing their innovation should be further promoted. Having the creativity filter monitored by both shareholders and R&D innovation teams in organizations may help to avoid possible failures in the development and impediment to novel ideas. To enhance radical innovation, our study suggests that innovation and skills policies should encourage the employment of individuals with software, multimedia, math, applied science and engineering skills. These skills could be easily transferred into innovation and profits.

Specifically, policies may focus on setting up a scheme that enables the development of R&D teams at the firm level which are composed of both experienced entrepreneurs and individuals with a creative skills mix. The target of the creativity filter is to ensure that the gap between creativity and knowledge exchange is kept to a minimum and more ideas flow throughout the filter. In embedding the R&D teams with entrepreneurs who can see opportunities and negotiate with "attentive-to-detail" members will intensify the knowledge flow. More start-ups may take place within the organization and benefit the productivity of established firms. The failure in doing so will increase the creativity filter size and increase the number of workers leaving and starting a new business.

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# The Relationship between Flexible Human Resource Management and Enterprise Innovation Performance: A Study from Organizational Learning Capability Perspective

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**Abstract.** Currently the enterprises are facing complex external environment. This paper aims to identify relationships among flexible human resource management, organizational learning capability and innovation performance. The qualitative research through surveys from 250 companies is designed based on organizational learning and flexible human resource management theory. The findings reveal that: 1) functional flexibility and behavior flexibility have significant positive effects on organizational learning capability; 2) extended skill flexibility is not conducive to the improvement of organizational learning capability. Therefore enterprise can use functional flexibility strategy, extended skill flexibility strategy and behavior flexibility strategy to improve enterprise innovation performance. Organisational learning capabilities, on the other hand, act as an intermediate between flexible human resource management and organizational innovation performance. From practical point of view, the research findings provide guidance for practitioners to improve human resource management and enterprise innovation levels.

**Keywords:** flexible human resource management, organizational learning capability, innovation performance.

## 1 Introduction

Knowledge economy and digital age has brought great change into enterprises. Enterprises are facing fierce competition in an uncertain, dynamic and complex environment [1]. These new features therefore require enterprises to have characteristics such as adaptabilities, changes and learning capabilities. In comparison with the traditional human resource management, flexible characteristics, such as cooperation, sensitivity and harmony etc., are more indispensable to human resource management in contemporary society. Employees are encouraged to assimilate and utilize new knowledge in the environment of organizational learning. Knowledge management and integration is necessary to realize organizational innovation to achieve competitive advantage and

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innovation performance. The aim of this paper is to analyze the relationship between flexible recourse management and innovation performance, as well as the function of the intermediary--organizational learning capability.

## 2 Flexible Human Resource Management, Innovation Performance and Organizational Learning Capabilities: State-of-the-Art

### 2.1 Flexible Human Resource Management

Flexible human resource management is a management practice to affect directly or indirectly skills, behaviors and learning capabilities of employees. This is achieved through flexible management such as flexible adjustment of employee structure, employment mode, training plan and incentive plan. The research of human resource flexibility starts from 1990s, which is based on resource theory and core competence theory. Human resource flexibility investigates how enterprises adjust to the changing environment and keep their competitive advantages through flexible human resource management strategy. This flexible management mode provides distinct insights from traditional human resource management in terms of management objective, management role and strategic position [1] (Table 1).

The focus of flexible human resource management lies in enhancing employees' flexibility of functions, skills and behaviors according to organizational needs. This involves a series of human resource management strategies to influence employees' psychology, guide their behavior, and finally achieve and align personal and organizational objectives together. Therefore, this paper divides flexible human resource management into three dimensions: functional flexible strategy, extended skill flexible strategy and behavior flexible strategy. These three dimensions are based on the Beltran [2] and Sanchez [3]'s classification of flexible human resource management measurement. Functional flexible strategy is to foster multi-skilled employees who are capable to undertake multiple tasks in various circumstances and adaptable to work among different departments quickly and with low cost. This will be achieved through employee-participated job (tasks) design, role shift and establishing a cross functional team. Extended skill flexible strategy is to create environment for employees to learn new skills and enhance their flexibility to learn quickly and undertake new tasks. This will be achieved through employee relationships system and training design, such as personnel external allocation, training and socialization. Behavior flexible strategy is to adjust employees' behavior and psychology, enrich behavior patterns enhance employee's autonomy and support the diversity of behaviors in different circumstances. These will be achieved through organization internal motivation and constraint mechanism [3].

**Table 1.** Differences between traditional human resource management and flexible human resource management

| Management mode | Traditional Human Resource Management | Flexible Human Resource Management |
|---|---|---|
| Purpose | To improve the efficiency of enterprises | To improve the dynamic adaptation ability and competitiveness of enterprises |
| Management Function | Job evaluation, performance appraisal, salary management | Employee relationship management, team management, human resource outsourcing |
| Management Role | The one who maintain the organization at "as-is" level | The driver of organizational reform towards "to-be" level |
| Organization Structure | Pyramid type | Flattening type |
| Management Perspective | Employees and the organization are of a labor capital relationship | Employees and the organization are of a cooperative partnership |
| External Environment | Controllable and stable external environment | Dynamic and complex external environment |
| Strategic Position | enterprise strategy executor | The decision makers and executor of enterprise strategy |
| Management mode | Traditional Human Resource Management | Flexible Human Resource Management |
| Purpose | To improve the efficiency of enterprises | To improve the dynamic adaptation ability and competitiveness of enterprises |

### 2.2 Flexible Human Resource Management and Innovational Performance

Innovation is highly dependent on the integration of talents and knowledge, which requires organisational capability of acquiring and attracting talent. Mei's [4] research indicates that flexible human resource management can form an human resource allocation which is difficult to substitute and imitate through embedded into the enterprises' internal situation and external environment, in order to improve their survivability and development capability. Robert [14] holds that flexible human resource management comes from the flexible policies and practices in the related fields of human resource management which facilitate employees to balance job, family and livelihood to acquire senses of safe and support and also post a positive influence on organizational innovation and participation so as to motivate employees to provide extra work to organization in return. Nie [5] considers that flexible human capital and flexible human resource system are the two aspects of flexible human resource. Flexible human capital fully utilizes team knowledge to create new knowledge constantly. On the other hand, flexible human recourse system acts as a coordination mechanism. It supports fast responses and focus on the value and scarcity of the enterprise' flexibility for long term competitiveness [5].

### 2.3 Organizational Learning Capability as An Intermediary between Flexible Human Resource Management and Innovation Performance

The concept "organizational learning" was first proposed by Agyris and Schon in the 1970s [6]. At first, it indicated the procedure that an organization finds mistakes and reframes its "Theories-in-use" to correct the mistakes. Kodama held that the realization of innovation target demanded for flexible staff employment [9]. Cao [7] proposed that the enterprises needed to bring in flexible human resource management according to the features of knowledge workers and adopt flexible human resource management strategies to narrow the knowledge gap and boost the efficiency of knowledge acquisition [7].

Flexible human resource management offers management support in terms of time and technology for organizational learning. The flexible extended skill strategies offers to broaden knowledge and the flexible behavior strategies facilitate the change of working mode. From the analysis above, organizational learning capability stands between the flexible human resource management and innovation performance and plays an intermediate role.

## 3 Research Model and Hypothesis

There is an inner link between the flexible human resource management and innovation performance. The flexible human resource management plays an important role in the process of clearing away of the obstacles for the organizational learning. In other words, the flexible human resource management can affect the innovation performance indirectly through the organizational learning capability. We construct our theoretical underpinning based on existing theories including flexible human resource management [2, 3], organizational learning capability Pilar [15] and the innovation performance [10, 11]. We therefore proposed a conceptual model as show in Fig. 3-1 as well as the measure index for the latent variables. The analysis of the relationships among the variables is presented in details in the later sections. The aim is to illustrate and verify the combined effect of flexible human resource management and organizational learning capability on innovation performance and the mediating effect of the organizational learning capability between flexible human resource management and organization innovation performance.

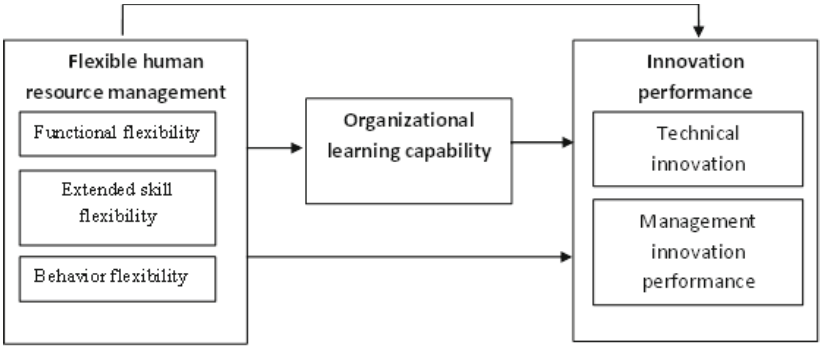


**Fig. 1.** Conceptual Model of organizational learning capability, flexible human resource management and innovation performance

### 3.1 Analysis of the Influence of Flexible Human Resource Management on Organizational Learning

The flexible strategies of human resource are often accompanied by the innovative transformation of workflow and mode. The independent and open culture can be created through enrichment and enlargement of work, job rotation and the feedback of performance evaluation. The employee can obtain senses of achievement, senses of identity, senses of duty and self-development. This can affect the staff's psychology indirectly and make them realize the necessity of constant learning and improvement.

Based on the above, we propose the hypotheses as follows:
**H1: Flexible human resource management (functional flexibility, extended skill flexibility and behavior flexibility) is beneficial to the improvement of organization learning capability.**
H1a: Functional flexibility is beneficial to the improvement of organizational learning capability.
H1b: Extended skill flexibility is beneficial to the improvement of organizational learning capability.
H1c: Behavior flexibility is beneficial to the improvement of organizational learning capability.

### 3.2 Analysis of the Influence of Organizational Learning Capability on Innovation Performance

Organizational innovation cannot be done without the acquisition and utilization of knowledge, and organizational learning is a main way to acquire, exploit and disseminate the knowledge. From organizational learning perspective, organisations could adopt two forms of learning including exploitation learning and exploration learning to obtain competitive advantages. Exploitation learning tries to boost the utilization ratio of current acquired knowledge resource. Exploration learning tries to absorb and create new knowledge and identify new technical and business opportunities. In term of learning range, there are internal learning and external learning. Researches on internal learning propose that there exists an "action community" which can integrate and store knowledge effectively. The external learning emphasizes on the role of customers, suppliers, competitors and other partners to gather, transfer, apply and create knowledge.

Based on the above, we propose the hypotheses as follows:
**H2: Organizational learning capability has a positive effect on the improvement of innovation performance.**
H2a: Organizational learning capability has a positive effect on the improvement of technical innovation performance.
H2b: Organizational learning capability has a positive effect on the improvement of management innovation performance.

### 3.3 Analysis of the Influence of the Practice of Flexible Human Resource Management on Innovation Performance

The influence of the practice of flexible human resource management on innovation performance is often by the help of some mediator to affect the staff's abilities and behaviors. Specifically, flexible human resource management emphasizes the enhancement of knowledge management and formation of dynamic capability to affect the innovation performance.

Resource Based View (RBV) takes an enterprise as a composition of various resources. If an enterprise possesses some unique resource, it then processes the capability of improving competitive advantage. Knowledge acquisition, sharing and creation form the key link of an innovation procedure. Human resource management boosts innovation through knowledge management. The enterprise dynamic capability was first raised by Teece and Pisano[8]. They emphasize the dynamic diversity of environment on the one hand and the adaptability of the capability on the other hand [8]. Modern human resource management uses internal motivation and constraint mechanisms to adjust enterprise's dynamic capability that is able to response to changes in the dynamic environment.

Based on the above, we propose the hypotheses as follows:

**H3: Flexible human resource management (functional flexibility, extended skill flexibility and behavior flexibility) has positive effects on the improvement of technical innovation performance.**

H3a: Functional flexibility has positive effects on the improvement of technical innovation performance.

H3b: Extended skill flexibility has positive effects on the improvement of technical innovation performance.

H3c: Behavior flexibility has positive effects on the improvement of technical innovation performance.

**H4: Flexible human resource management (functional flexibility, extended skill flexibility and behavior flexibility) has positive effects on the improvement of management innovation performance.**

H4a: Functional flexibility has positive effects on the improvement of management innovation performance.

H4b: Extended skill flexibility has positive effects on the improvement of management innovation performance.

H3b: Behavior flexibility has positive effects on the improvement of management innovation performance.

### 3.4 Mediating Effect of Organizational Learning Capability

Kodama thinks that the realization of innovation goal requires fast leaning capability and making use of external expertise, knowledge as well as talents outside the organization, which requires the flexibility in the employment [9]. This flexible employment is helpful to get creative ideas and reduce cost for the organization. The reason of

employing temporary workers is the low cost, but in the meantime the organization can also get competitive advantages by applying the new knowledge and creation.
Based on the discussion above, we propose the hypotheses as follows:
**H5: The organizational learning capability has a mediating effect during the procedure in which the functional flexibility human resource management positively affects the innovation performance.**

### 3.5 The Measurement of Innovation Performance

We hold that innovation performance does not only include technical innovation performance, but also management innovation. The essence of innovation is an insight into the market changes and business opportunities and the integration of products, technology, manufacture, marketing, which can bring the enterprises competitive advantages and business profit. We have designed the measurement of innovation performance based on the existing research on innovation [10,11] . Specifically, the innovation performance is categorized as technical innovation performance and management performance. Technical innovation performance refers to the innovation performance of products, manufacturing process and equipment. The management innovation performance refers to the innovation performance of organization planning, management methods, resource allocation and business models.

## 4 Results and Managerial Implications

### 4.1 Results

This research has used quantitative methods with large samples to verify the relationships between flexible human resource management, organizational learning capability and innovation performance. Through a series of regression analysis, we verify that the flexible human resource management and organizational learning capability have positive effect on innovation performance. Organizational learning capability plays an intermediary role between flexible human resource management and innovation performance. The specific relationships are as follows:

**(1) Functional flexibility and behavior flexibility have obvious positive effect on organizational learning capability. Extended skill flexibility has negative effect on organizational learning capability.**
By adopting functional flexibility strategy (e.g. work design participation, job rotation, trans-department teams, etc.) and extended skill flexibility strategy (e.g. training, flexible employment, mentoring program, etc.), employees normally should be actively involved in the whole process of knowledge absorbing, conveying and integration. The organizational learning capability will be aligned with organizational goals. However, contrary to the hypothesis, the extended skill flexibility is not beneficial to the improvement of the organizational learning capability. The reason may be: when hiring part-time staff, external staff or professional consultants, core internal workers may feel it pose a threat to their feeling of security in the organization. This will leads

to a falling of the psychological contract and worse relationship between the employee and the employers. This potential atmosphere changes may influence employee's s learning motivation and effects.

**(2) Organizational learning capability has obvious positive effect on the innovation performance**

In the structural model equation, the standardized path coefficient between organizational learning capability and innovation performance is 0.16, which is significant in the 0.01 level and indicates that the organizational learning capability can predict the innovation performance. The enterprise can develop its core competence through organizational learning to promote the knowledge acquisition, storage and innovation. Furthermore enterprises can improve management innovation ability through inter-organizational learning that brings in advanced management method as their own management expertise.

**(3) In terms of flexible human resource management, the functional flexibility, extended skill flexibility and behavior flexibility have positive effects on innovation performance.**

Through the functional flexible strategies such as job rotation and across teamwork, the staff has opportunities to develop multiple skills. This is helpful to consolidate core knowledge and transforms into human capital. Through the extended skill flexible strategies such as training, social mentor or external recruitment, it helps staff raise learning ability , achieve their goals and values as well as to improve readiness for innovation. Through behavior flexible strategies such as flexible working time, rational authorization and salary motivation, it is helpful to enhance the staff's behavior freedom and diversities, rouse their initiative and improve the management level and overall performance significantly.

**(4) The analysis of the mediating effect of the organizational learning capability between the flexible human resource management and innovation performance**

From the structural equation analysis, we find that the organizational learning capability plays an intermediary role between flexible human resource management and innovation performance. The enterprise is able to influence the staff's motivation and attitude by using flexible human resource strategies, Which will help to provide management support for organizational learning and improve the whole innovation performance.

## 4.2 Management Implications

By regarding organizational learning capability as the intermediary of flexible human resource management and innovation performance, we verify the importance of flexible human resource management on innovation performance and the mediating effect of organizational learning capability. The conclusion of this research provides guidance for human resource management and the enhancement of innovation capability.

**(1) "Couple hardness with softness" in management**

Flexible human resource management should be combined with rigid management properly. Although the flexible human resource management provides good elasticity, it demands higher level of management. In most cases, it depends on a mature human resource system to acquire the compatible mechanisms and appropriate environment, which is essential to maximize the effect of flexible human resource management.

**(2) Apply flexible motivation in organizational learning**

Flexible human resource management has a long-term feature because it aims to meet the employees' demands for future development. On one hand, the leader should highly appreciate the need of flexible human resource management. On the other hand, it requires the enterprises to pay attention to the employees' psychological needs and motivate employees through specific flexible strategies, in order to transform organization goal to the employees' spontaneous behaviors. The flexible motivation is very beneficial to individual and organizational learning. For example, in performance improvement, the flexible improvement plan, such as performance communication, performance feedback and flexible training programs, can make up the deficiency of employees. Learning capability of employee should be an important target of the performance improvement. It is necessary to push the stuff to enhance their learning capability, especially of learning from the mistakes and experiences, and to lead the stuff to the way that is helpful to the development of the enterprise. Again for instance, through tuning the proportion of internal and external payment, more attention can be paid to the motivation of employees' personality developments and value realization by internal payment.

**(3) Identify both enterprise' characteristics and its environment**

Both the flexible management and rigid management have their pros and cons. In the practice of flexible human resource management, the enterprise needs to determine appropriate flexible strategies according to its characteristics, stage of development, external environment and development objectives. Especially, since most of the related theories of our present flexible human resource management come from western countries, , the enterprises in China should consider the differences with the context of theories and the implication environment.

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