Engineering principles for open socio-technical systems

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Abstract

Engineering Information and Communication Technology (ICT) for robust information sharing is the fundamental area of investigation in thesis. Robust workflow based information sharing systems have the potential to be part of robust information infrastructures providing positive effects for the individuals and teams as well as opportunities for societal and economical gains.

Challenges in design and implementation of open socio-technical systems include identifying engineering principles empowering individual and team using the systems as well as supporting flexibility in design and maintenance. Of specific importance are principles supporting semantically correct information sharing. Information sharing in open socio-technical systems is given affordances due to coordination and exchange of services. Approaches ensuring robust semantically correct information sharing and user empowerments are key requirements especially since changes in context, roles and intentions are the rule and not the exception in socio-technical systems.

Empirical observations of behaviours have been important for identifying critical patterns in workflow. A configuration of models and methods under the umbrella Participatory Design has been used including Ethnography and approaches based on Situation Theory, Knowledge Engineering, Interaction Design and Computer Supported Cooperative Work. The results of the configurations of methodologies are context sensitive since the methodologies are domain dependant.

Three cases illustrating engineering support for empowerment of individuals and teams in open socio-technical systems are presented. Two cases are based on studies performed in Sölvesborg and concerns engineering principles towards empowering individuals with cognitive impairments via ambient assistance. In the third case the focus is on hand-over situations and ontologies/abbreviations assuring semantically correct information sharing in distributed handling of critical emergency calls in Swedish Emergency Service Centres (SOS centres).

The main contributions in this thesis, methodological contributions included, are engineering principles for open socio-technical systems from an empowerments perspective. The principles support understanding of workflows, information flows, interaction models, data models, semantics of information, trust, resilience, validation and training as well as assurance mechanisms in hand-over of critical operations. Identification and validation of key service qualities including mechanisms for improving performance critical tasks of semantics in information sharing are contributions. Service, Agent based and sensor approaches presented are final contributions.
1 Setting the scene

Developments of ICT have a large influence on the gains on productivity and prosperity that society has seen in recent years [9]. This development is responsible for software being in control of increasing numbers of systems whose failures may have critical consequences – for infrastructure, economy, or the safety of human lives.

These systems are becoming increasingly distributed and decentralized, assembled as dynamically changing orchestrations of autonomous services, expected to adapt to continuously changing requirements and environments. Following a terminology that was coined in the 1950’s in areas of organisational theory, we call *socio-technical systems* those *software-intensive systems* that involve complex interactions between software components, devices and social components (people or groups of people), not as users of the software but as players engaging in common tasks.

Design, implementation and maintenance of systems supporting situation awareness, information sharing and empowerment of teams are increasingly important in society-critical settings such as rescue management, health care and emergency call centres. The following *Figure 1* depicts main components and views of these Socio-technical systems:

![Figure 1. Main components and views of socio-technical systems.](image)
From Figure 1 we infer that socio-technical systems firstly are information processing systems that support workflows at workplaces, that is, the social aspect. Furthermore, requirements can be separated into high-level requirements taking into account the needs and expectations of stakeholders involved. Those needs and expectations are translated and implemented onto the technical support system at hand. That is, the support system’s requirements/affordances should be tailored to meet the high-level requirements. The systems as such must also be economically feasible. Economic analysis of information sharing systems models and investigates related to business models as Service Level Agreements (SLAs). However, we will not address business related topics further in this thesis. In Figure 1, some models and techniques supporting requirements engineering aspects are depicted (ethnography, participatory design, info sense aspects (how to make sense of information), empowerment, semantics of information exchange, resilience, information flow and trust aspects). Ontological and pattern aspects are focusing on modelling concepts and relations bridging the stakeholder’s concerns and how to meet the system affordances (services) into Service Level Agreements (SLAs) as well as supporting required reasoning and semantics. The SLAs implement coordination of services in a Service Oriented Architecture (SOA). Validation and training are modelled as important aspects from a quality assurance perspective. Some models and methods of system engineering are also depicted in the figure.

A key property of socio-technical systems is that they need to adapt to changes that occur in the domain in which they operate in order to ensure that they deliver the services or control the behaviour of the components. For instance, one can think that a software component assigns different permissions to different categories of staff when controlling a given piece of equipment. Hence, in the case of health systems, if a doctor replaces, say, a nurse during an operation, the software should adapt itself to the operating conditions that correspond to the change of interactions.

In a recent report Interlink1 funded by the European Commission, the following terminology is introduced to discriminate between two types of socio-technical systems:

- **Physical ensembles**: are intimately connected to the physical world in space and time.
- **Societal ensembles**: are closely connected to humans, e.g., smart cities or global virtual enterprises.

In our applications we will address both types of socio-technical systems: Physical ensembles will be addressed in the Sölvesborg case studies, whence societal ensembles are in focus in our SOS alarm case study.

Engineering socio-technical systems has to address several challenges. A particular difficulty in engineering adaptive socio-technical systems derives from the fact that given organisational rules might need to be violated for the system to reconfigure itself to operate in what are non-normative or sub-ideal situations.

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From *Figure 1* we can infer that in order to design, implement and maintain socio-technical systems we must configure a set of methodologies and tools to support the following activities:

- **Address socio challenges** Identification of workflows and their information support, *identification* of proper interaction models to support the users of the system.
- **Development of high-level requirements** translating the user needs and expectations from the phase above into high-level design descriptions.
- **Matching** high-level requirements with affordances from the supporting infrastructures.
- **Validate** the solution against specifications of functional and non-functional types.
- **Support** maintenance and training.

In this thesis we focus on issues and challenges related to high-level requirements and maintenance, but also issues of validating assurances.

## 2 Challenges and research questions

In this thesis we focus specifically on aspects related to ensuring semantically correct information sharing in socio-technical systems. Our starting point is *Figure 2 below*. To that end we have to develop and use appropriate configurations of models and tools to support requirement analysis and engineering in different domains.

We will return to those models and methods later in the thesis *Section 4 Methods, Models and Tools*. However, we first take a closer look at challenges related to semantically correct information sharing *Figure 2 below*.

![Figure 2](image.png)

*Figure 2*. Architecture, components and hurdles in semantic correct information sharing.

In *Figure 2* we model information sharing between a *Sender* and a *Receiver* in a given *Context*. The information exchange is *artefact mediated*. The information is given by a Sender through an interface to the artefact and (after processing) mediated to the receiver. The information processing is
facilitated by the Context model (context representation) and the input message. The Sender has an intention with his message and the Receiver interprets the transformed message at his end.

Semantics concerns meaning, most often used in ordinary language describing the definition and interpretation of a word. In certain contexts, such as in numerical calculations, the Context Model (CM) of Figure 2 could indeed be purely syntax based, i.e., the syntax of numerical calculations fulfills the needs we have on the context model whenever we need to do numerical calculations! In short, numerical calculations in any context obey the same syntax based rules. In fact, numerical calculations are examples of algorithmic applications where the reasoning power of the computational artefact is syntax oriented and the interpretation of the relevance of the computations in a given context lies in the agreed upon modelling principles and interpretation by the sender and receiver at the two interfaces of Figure 2.

Real semantics are to be seen from the perspective of two persons exchanging information agreeing upon the understanding of each other’s communications. Real semantics are achieved in an information sharing context. With humans agreeing upon the meaning of a word or expression, knowing enough about the definition of the word and the intention of the communicating party enough to be able to act upon it. Creating real semantics based on communication that is grounded in an information processing artefact is a challenge. This since the contextual knowledge about the work practice and the workflow mostly is limited in the information sharing system, as well as the dynamics of adaptation to the specific situation at hand. The interfaces connecting the sender and receiver via the information processing artefact are critical since they should provide enough information to be trusted to perform an act upon. An important part in this process is the relation between the sending person’s act and the functions that it triggers in the information processing artefact. Sometimes it is possible to predict these functions, and finding out if there are any causal relations that are stable, or patterns that can be useful to build upon. Causalities are an important part in creating a trustworthy information exchange and are further described in section 4 and 5. Identifying such structures can be a productive way to gain support for a semantically correct information sharing.

Semantics can be explained with logical reasoning, and there are different approaches on how to consider semantics, some are based on formal language, natural language and there are other approaches. In this thesis the focus is on socio-technical systems, where semantics are seen from a workflow perspective. If the workflow is maintained, then the semantics hold true. Thus the work practice perspective is of importance as well as the ability to structure and classify the workflow in a robust way. Being aware of the context, the workflow with expected outcome, the possible situations and the resources available we can consider how to use syntactical structures to support a correct semantic outcome. Devlin [13] gives us the structure of language from a semantic perspective where the situations are in focus.

Hence, there are several notations of semantics, but given the nature of openness of future socio-technical systems we will use the following definition that allows an engineering approach of semantics.

**Definition 1**: The information sharing is semantically correct if and only if the intention of the sender is correctly interpreted by the receiver in the given context.

We note that semantics in this definition is determined by a *truthfulness relation* between sender and receiver in a given context. The *machine readable semantics* is the relation between the two interfaces of Figure 2. There is, of course, a big difference between the true semantics and the machine readable semantics in artefact mediated information sharing. Current R&D on, e.g., semantic web technologies is focusing on this difference and its ramifications. We will return to this topic in the Section 3 *Semantics of information exchange and resilience*, where real semantics and artefact mediated information sharing are considered.
Furthermore, information sharing systems also require the following systemic criteria:

- Support of workflows
- Support of validation of procedures (protocols)
- Support of trustworthiness
- Support of trusted change and self-healing
- Support of learning in teams

There are several aspects of trustworthiness of systems, tasks or services. Specifically we adopt the following definition of assured services.

**Definition 2.** A service is assured if and only if the corresponding service level agreements are validated against stated requirements.

The purpose of a supporting ICT system is to empower users in performing their tasks. The following definition captures the challenges.

**Definition 3.** Empowerment aims at increasing a performance quality of a stakeholder in performing tasks related to identified workflows.

Given the definition of semantics of information exchange and assurance of services we address the following research questions.

**2.1 Research questions**

We have identified the following four research questions related to challenges in designing and maintaining future socio-technical systems.

**RQ 1:** Identify models and methods that support semantically correct information sharing in socio-technical systems.

**RQ2:** Model workflows and interactions in open socio-technical systems that supports semantically correct information sharing.

**RQ3:** Identify and validate key service qualities in socio-technical systems.

**RQ4:** Identify models and methods supporting empowerment.

**3 Papers and outline of the thesis**

The work presented in this thesis has been reported in eight papers and a licentiate thesis. The following table gives an overview of the matching between the research questions of Section 2.1 and the contents of the papers and thesis.

1. Lundberg, Jenny, Gustavsson Rune, *Challenges and opportunities of sensor based user empowerment*, The 8th International Conference on Networking, Sensing and Control, ICNSC 2011, Delft, The Netherlands


In table 1 below, the X, address the connection between the contributions and the research questions. The specific section numbers (4 and 5) mark where in thesis the research questions are further developed and the relation to the contributions.

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**Table 1**: Table Mapping of research questions and contributions.

Engineering principles for open socio-technical systems includes identifying proper mechanisms based on a thorough understanding of the domain of application and intention of system. Finding proper mechanisms includes using methods, models and validation approaches of relevance. We have identified and modeled workflows in the licentiate thesis [0] and considered how to validate service

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2 The validation chapter in licentiate thesis gives implications towards validation structures in chapter 4 Models and methods, and 5 Experiments in this dissertation.
qualities in socio-technical systems. The workflow perspective was built upon contributions in article [4] and [5] and has been further developed in [3]. In this thesis we further develop and consider the validation approaches presented in the licentiate thesis [0], considered in contribution [1][3][4][5].

Assuring semantically correct information sharing is of importance in open socio-technical systems. In articles [1][2][3][5][6][7][8] we have worked with methods and models of supporting semantically correct information sharing in socio-technical systems. Support for empowerment is of importance when handling tasks in critical domains. In [1][2][4][5][7] we have worked with models and methods to support empowerment. From Figure 1 we deduce that we need models and methods supporting understanding of the workplace, specifically supporting identification of workflows and information flows. The preferred models are described in Section 4. Those models support our high-level system requirement engineering, including validation models of semantically correct information exchange (Figure 2) and models supporting testing and validations.

4 Methods models and tools

From the discussion of Section 2 it follows that the conceptual models of Figure 1 and Figure 2 have to be supplemented by more detailed models in order to address the four Research questions of Section 2.1. Furthermore, the models should be supported by suitable methodologies and tools, From Figure 1 and Figure 2 we deduce that the socio-challenges could be addressed by methodologies addressing Ethnographical aspects, Participatory Design, Info sense aspects, and aspects of Workflows and Data management related to Information sharing.

Specifically, we need the following set of models addressing:

- Workflows in different domains
- Information flows
- Interaction models and protocols between stakeholders
- Protocols and data models
- Trust and trustworthiness
- Trusted change of contexts

To support assurance we furthermore need methods and tools supporting:

- Validation
- Training
- Empowerment

4.1 Methods and tools addressing Ethnographical aspects and Participatory Design aspects

The methods used in the thesis are grounded on ethnographically collected data [0-8]. Ethnography is a qualitative empirical method, belonging to the field of social science. It concerns participation in people’s daily lives, for an extended period of time, overtly and overtly collecting as much data as possible [9]. The rationale of selecting ethnography is to support of getting a real world holistic view of the domain, including systems and complex, sometimes contradictory, findings. We cannot afford just to be satisfied with quick explanations that first meet the eye or data collections that are already structured from an ideal organisational perspective or engineering structures. Ethnographical findings cannot solely give implications towards design, fundamentally since ethnography is a descriptive methodology. The ethnographical method needs to be complemented with other methods and tools to provide a foundation for potentially strong socio-technical contributions. It is possible to use
ethnography to describe a setting, identify issues or shortcomings in workflow, then perform changes in the socio-technical system to improve the issues identified, and use ethnography as a validation tool. In this thesis a collection of methods and tools has been used, with ethnographical basis.

From an analytical perspective, reflecting upon the use of ethnography and related methodologies[6], aiming at presenting a qualitative contextual system perspective upon the domain and the focal tasks, the skills of the ethnographer are important and can colour the results of the studies. It can be an advantage if the person performing the ethnography is skilled in computing and engineering since it may be more visible where to make improvements if having computing and engineering skills. However, the computing and engineering skills can also be a risk if not properly handled, since if not being aware, having a technological agenda can of course limit the scope of ethnographical focus towards an engineering solution, not identifying proper contextual perspectives in organisational or other aspects.

**Participatory Design**

Participatory Design [35] approaches have been used in the cases in section 5. Participatory Design is an approach towards actively involving stakeholders in the design process. The main motive for involving the stakeholders in the design process is to make sure that the design really suits the stakeholders. One of the most important issues to consider when using Participatory Design methods are that the ideas and design suggestions from the stakeholder can vary and sometimes be directly contradictory. However if properly used, well-founded design decisions and evaluation, participatory design input can provide important contributions. In section 5, in cases 1 & 2 the stakeholders have included users and support team. In case 3 both individuals with operative responsibility as well as management has been involved.

Conclusively the PD approach is a vital approach that needs to be taken with consideration i.e. the results of PD needs to be seen from a critical perspective. PD input can be included in the requirements specification with the qualification of input interpretation. That PD based requirements can be contradictory and that it is not possible to engineer to please every individual, compromises and generalizations need to be made. Furthermore it needs to be included in an iterative process including validations to provide proper input as changes in design process occur, we return to this in section 4.6.

**4.2 Methods and tools addressing Information sharing and Empowerment**

Traditionally information processing artefacts have been built upon problem solving and rational behaviour, following logical structures. However, now the systems need to be based on information sharing, and the rule for the behaviour are to be “street smart” as in acting correctly according to social behaviour. This poses challenges on how to engineer computing systems, including the social perspective, as an important factor [22][27][28]. How social rules and acts may influence the outcome and how the interplay with rational behaviour can form a basis for decisions and acts. However when engineering social behaviour, an important issue to consider is to see that social behaviour is adaptable, and engineering the social perspective can have social consequences in itself. An example of “street smart” behaviour can be that just selected persons, competent of interpreting and translating the information to other persons get the updated information in a certain situation. Or that the information is re-structured dependent on the person and the situation that the person is in, thus increasing the chances for the person to interpret the information correctly and act further upon it. Supporting different roles is another such important social/organisational issue. Supporting socially, as acknowledging high production can potentially be such a rule.

In computing contexts the term information sharing refers to one-to-one sharing of information. Our definition is extended to include open systems supporting teams with many-to-many, one-to-many and many-to-one in the information sharing definition. Information sharing concerns the sharing of
information within the team, as in the SOS experiment presented in section 5 and specifically contributions [3][7]. Information sharing is based on dialogues grounded in common awareness and common ground. Information sharing can be a complex process where the anatomy of information is of importance as well as patterns of information sharing, where roles are an important part. In this thesis we have considered anatomy of information by using Info sense. Info sense concerns a perspective upon information that can be critical in order to share information, thus reaching the goal of semantically correct information exchange, corresponding to mainly RQ1. As a consequence, correct information sharing is one of the fundamental aspects for empowerment corresponding to RQ4.

Keith Devlin [11] has provided a semantic based logical framework supporting understanding and structuring of information (InfoSense). The logical framework has been influenced by the work of Barwise and Perry [12] at Stanford in the 1980’s. They developed their theories in order to understand human languages as communication of meaning, semantics and pragmatics. Suitable adaptations of the theories will provide us with models and techniques to address types of situations. Devlin’s logical framework in structuring of information can preferably be seen as a high level description of information exchange. The connection between Information (understood, or interpreted, by a human agent) and its Representation is captured by the following equation:

\[ \text{Information} = \text{Representation} + \text{Interpretation} \]

The equation describe that information are visible via a representation. The representation could for example be a book, a computer system or similar. The Interpretation describes the interpretation capabilities of the receiving agent. As an example, we have a situation of a fire, and a rescue person sees smoke. The rescue person makes the general assumption that there is a fire, since smoke implies fire. Thus the understanding of the rescue person’s knowledge about smoke and fire makes him understand that this ‘type’ of seeing smoke, are related to the ‘situation’ fire. One of Devlin’s basic contributions in InfoSense is to clarify the relations between representations and the proper interpretations by users to identify the intended situations (contexts).

The exchange of information between a sender and receiver can be described as follows. The sender, in figure 2, wants to inform the receiver of a Situation S. The Representation of the situation is described by a sequence of abbreviations A_s (based on a suitable ontology) that is fed into the Sender interface of the artefact. The sequence A_s is processed by the CM and produces an output sequence of abbreviations A_r. The receiver interprets A_r and can infer the Situation S. If we assume that the syntax based processing is correct and A_s and A_r have agreed upon semantics then the sender has successfully informed the receiver about the situation S and proper actions can be taken. Agreed upon semantics of situations are denoted common grounds [11]. Common ground between stakeholders thus enables correct abbreviation based semantic information exchange related to situations. Trusted coordination in those teams can thus be assured by proper training of skills mapping between situations and sequences of abbreviations. Abbreviations can thus be seen as coordination mechanisms in rescue centres and similar applications [3]. In the next section we continue the focus upon abbreviations.

**Empowerment**

Empowerment according to Oxford online dictionary [24] ‘concerns the process of enabling individuals and/or groups to participate more fully as rights bearing entities within a society and state.’ We use this definition and focuses basically on finding engineering principles for open socio-technical systems to enable empowerment. Empowerment in open ICT probably needs to be seen from the perspective of rethinking business models, seeing sharing of information and competences without clear initial business aims, thus seeing the potentials in open connection and technology enabled sharing of information.
The empowerment model we advocate, Figure 3 is focusing on empowering the ability of the agent. This ability can change when adding training, tools, mechanisms and structures to enable increased empowerment. The ability need to be put in relation to the task that is to be carried out. The information from the environment that is needed to carry out the task in focus is of vital interest. The relation between environmental input and the ability to solve the task can be critical. For example if there is a need to be frequently updated about the environment, the input from the environment may be of importance. If on the other hand, the task is knowledge intensive, focus on the ability might be of highest priority. Our basic view upon empowerment concern the individual persons need, identify and validate suitable empowerment solutions for the individual.

![Diagram of empowerment model](image)

**Figure 3:** Empowerment model where the ability of the agent is taken into consideration and the information from for example sensor based input of the environment support the agent to be able to carry out the task.

Training is a foundational method for supporting empowerment in establishing, increasing and maintaining skills, knowledge and competences. More specifically in article [5] we present a systemic perspective upon how to handle functional and non functional requirements to engineer socio-technical systems from. The contributions concerns methodologies, tools and standards for empowerment contributions in requirements handling in software intensive socio-technical systems. Furthermore in article [7] we present alternative ways to the everyday interfaces of searching, representing and relating information. Empowerment includes exploring alternative information structuring possibilities both from an individual and a group perspective. Furthermore in article [2] and [4] we consider software agents as an empowerments method. In article [2] the empowerments framework basically contributes towards semantic understanding from a workflow perspective. In contribution [4] we consider it from an allocation perspective. In [1] sensor and sensor networks technology are considered as tools for empowerment. Interwoven in these empowerment contributions are issues presented in thesis, that is trust, validation issues etc. Empowerment issues are further considered in section 4.6 Validation and Training.

### 4.3 Methods and tools addressing Semantics of information exchange and Resilience

An important part of a correct semantics of information exchange is to understand what the other person really means, having a thorough understanding of how that person define the words used, and what intentions the person has. Support of semantics of information exchange can be done by highlighting and focusing on abbreviations. Abbreviations can be seen as strong ontologies that are used frequently enough that they have been shaped into abbreviations. In [0][3] we showed that the semantics are both a strength and a weakness. It can make communication smoother and faster, but when changes in contexts occur, the abbreviation can be a hinder. We have presented robust support for changes in context and related abbreviations. In [2] we have presented a framework for ontologies, typically including abbreviations, towards support of semantics in information exchange.
In an attempt of understanding changes in contexts and when semantic mistakes might appear [3] we can consider and analyse the following example from a context were correctness in semantics is of vital importance. It concerns the domain of aircrafts where mistakes in communication can give severe consequences.

In 1981, on February 17, Air California (AirCal) Flight 336, a Boeing 737-200 that was flying from San Jose California to John Wayne Airport crashed upon initiating a go-around. In this example, the air traffic controller and the pilot misunderstood the meaning of the abbreviation ‘holding’ [45]. From a high abstraction level, i.e. the real-world conversation was more complex, the basic misunderstanding in the conversation was as follows, where the air traffic controller “asked” the pilot;

- Are you holding?
The pilot confirms with:
- Roger, we’re holding.

The core in the misunderstanding was the contextual definition of the verb hold. Which always means “stop what you’re doing” in standard aviation parlance, but can mean “continue what you’re doing” in idiomatic conversational English. The air traffic controller used the word hold to mean ‘stop’, in its aviation meaning, while the pilot and officer in the airplane understood hold as in ‘hold your course’ in ordinary English.

They unfortunately misunderstood each other due to the unsuccessful establishment of an agreed-upon meaning of the word “holding”. A closer focus upon the situation, and the fact that they had two different contextual definitions of the word could most probably have avoided the loss of lives. There are other aviation examples where miscommunications have had severe consequences such as the disaster in December 1995, of American Airlines Flight 965 from Miami to Colombia that resulted in a loss of 159 human lives.

Having a correct contextual basis to ground the information exchanged is of importance. To enable a principled change of contexts in abbreviation based coordination a first step is to identify the corresponding set of situations that underpin the workflows at hand. Coordination is a basic information process pattern [13]. Coordination could be at different system levels and between different system components. We describe coordination further on in section 4.4 from the perspective of interaction models, protocols and data models.

Traces of group activities via workflow can be of importance when handling cases. Being able to monitor where in the process the other persons are can increase the chances of getting prepared for a hand-over of tasks. The issue of how to measure and monitor activities have been a focus in [8]. How much of the measurement that should be automated of the process are an issue of consideration. In the CSCW community, in the focus of articulation work, much work has been done in describing how smooth cooperation basically within teams meeting face-to-face are performed. Transforming face-to-face monitoring of activities into distributed monitoring is an important challenge furthermore, understanding and relating the task that a person is performing and mapping it against the semantics of the information exchanged are of importance. Tracing of individual and group activities can also be an important source in predicting individual and group activities. A way of considering predictions is to focus upon causalities which are further explained in section 4.5. Another perspective towards tracing of group activities has been presented in [7] where the tracing of group activities are visualised in the shared interaction, revealing patterns of information structuring in shoulder-to-shoulder collaboration. Traces of group activities are further described in section 5.1 case 3.

Resilience

From a self-healing perspective, resilience is an interesting approach to consider. Resilience according to [17] concerns elastic, hardwearing, with the ability to recover. In the thesis resilience is considered
from a workflow perspective, i.e. the ability to recover the tasks according to the workflow. The general threats against workflow can be categorized as normal changes in systems, changes in context, personnel, services, automation, information etc. causing misunderstandings according to the hurdles depicted in figure 2. Basically it generally concerns situations with no malicious intention but nevertheless with risks for causing damage in the workflow. The quality of service should remain according to the workflow assuring that there are no semantic misunderstandings. Basically workflow includes intention and tasks to be performed towards an intended goal.

Resilience is applied in critical infrastructure on control systems where state awareness is an important part to consider in how to make a system resilient [14]. Basically the state needs to be known, as threats potentially can change the state to an undesired state. Prediction of undesired states needs to be considered to give a robust resilience perspective. Generally the focus is on how to avoid malicious threats and not on how to recover from general threat with unintended malicious motives that can cause disturbance or breakdowns. Our focus is on different ways to recreate the normal state instead of finding ways of how to avoid malicious threats. Basically state awareness has some features such as: it has to be given for any measure or threat consideration affecting normalcy, it must be viable for unexpected and expected threats, and need to allow supervised subordinates autonomy for faster control response. From these definitions one way of considering requirements for implementing resilience are to define the normal state, expected changes from normal behaviour and weaknesses in system needs to be found. Furthermore recovery plans of how to return to the normal state must be established. In essence identifying potentially situations that are critical are a part in a resilience approach. Basically the resilience perspective concerns hurdles for correct semantic information exchange, according to figure 2.

From a resilience perspective identifying normative behaviour, states, transitions between states and potential threats towards the normative behaviour and mechanisms for resilience, i.e. identifying workflow, information flow, situations, interaction models, protocols and data models are of concern. Identifying potential critical situations towards performing correct workflows are of interest. The hand-over situations are example of such critical situations. Furthermore other situations potentially critical concerns changes in workflow and tasks. It could concern new tasks, new personnel, new information and structuring of information. In open systems these types of changes will most probably be more uncontrolled and span over more diverse situations than in closed systems. Thus the resilience perspective includes identification of possible changes of context. In section 5, we have modelled states and transitions between states as a part in resilience approach. In article [3] we have presented a robust approach for change of abbreviations.

4.4 Methods and tools supporting modeling Workflows and Information flows

A fundamental structure derived from ethnographical data concerns the workflow. The workflow is a structure that has intention built in, and are made up of tasks that are to be performed to fulfill fundamental goals. Workflow is a collection of activities (tasks) organized to accomplish a process. A workflow defines the order of activities invocation, the condition under which such activities must be invoked, and activity synchronization and information flow [34]. The importance of solid understanding of workflow has been emphasized in [42]. The identification of the domain specific workflow are not solely an ethnographical finding, but are derived both from the structuring perspective of using the ethnomethodological perspective [0], where the members methods are in focus, revealing patterns and structures in the ethnographically collected data. Furthermore the info sense perspective and CommonKADS methodology [19] with the model suite have been considered when understanding and analyzing workflow. Support of correct workflow can be made with different tools. In this thesis we focus upon the specific workflows that are domain dependant, and the information flow that is how the information are flowing, that is the normative flow of information, according to a correctly handled case. In section 5 the workflow of the three cases are modeled and concerns the fundamentals of the approach in the thesis.


**Information flow**

According to [29] a definition of information flow can be formulated as follows:

“Information flow results from regularities in a distributed system.”

[29]

Where distributed system is defined as systems of sharing information, implying that the information is flowing from one part to another. Information flow includes regularities in our definition the regularities in the information are dependent on the workflow tasks. The relation between workflow and information flow is that information proceeds and most often connects the workflow tasks. Furthermore the system includes states and transitions between states, connecting back to previous section of resilience. In paper [1] the state and transitions between states are further emphasized as an important issue in sensor applications, where the transition triggers the sensor activity. The states and transitions can be part of a situation, where situation refers to the outline of the existing circumstances often with a relation to the action that is likely to follow (causal) [31]. That is, understanding and modeling the basic situations, sharing of information with the possibilities and limitations according to model 2 would include the states and transitions.

The structure of information according to Info sense based on Situation Theory [11][12] was described in section 4.2. Interaction models for exchange of representations of information in form of data models and protocol for holding information sharing structures are an important part of information flow and need to be further described.

**Interaction models, Protocols and Data models**

In this section interaction models, protocols and data models are considered. Interaction models concern the way individuals and teams interact, see figure 2. Understanding of and having a high-level model of this both from an individual and team perspective are of importance. In section 5, cases focusing on these issues are presented. Interaction models are of importance both for an understanding of how interactions occur, revealing patterns of interaction behaviour between individuals in teams and how interaction occurs via use of interaction with artifacts and how this can be useful for engineering support for the individual and team. When considering the interaction models in encountering the Pond [7] the interaction concern relating information in this case representations, that is pictures of the cover of the CD’s with music that has the same artist. Basically the interaction models concern many persons interacting shoulder-to-shoulder sharing information in a tactile visual shared information device i.e. the Pond. Interactions are visible and a team effort can be supported since the individuals can structure and work with the information they find interesting as well as observing what the other person are doing, articulation work. Engineering the correct interaction models according to the workflow can be of importance. Thus these high level structures of coordination points can be an important foundation for measuring the performance.

Based on the interaction models, interaction protocols can be made. It contains a protocol for how the normative interactions should be performed. If divagation according to the protocols occurs, it needs to be considered. The information flow are dismantled and presented from a high-level perspective including protocols basically consisting of what kind of data models that is what type of information that is exchanged, and according to which protocol, basically in which format, when and to whom the information is sent. Furthermore, within the protocols, data models need to be considered, that is the kernel of the data that are being exchanged within the interaction. Basically data models concern an abstract model of how data are represented and accessed from a socio-technical systems perspective.

In contributions [2-4] the data models are particularly in focus. The reasons for focusing on data models are several. Seeing data models from the perspective of work flow, the data models constitutes the kernel in the information exchange. In section 5 data models are further handled. The interaction
models concern teams and the representation of the data in the SOS case concerns abbreviations. Basically in the SOS case, the data models concerns abbreviations, they are represented in XX.XX.PXX. structure and can be accessed using decoder that is trained by the operators, see further case 3 Team. This is a knowledge intensive data model, indicating that training and learning are of vital importance to be able to code and decode this type of data model. In the Sölvesborg case, where the interaction models concern individual, the basic data models concerns 1 or 0. That is, if the artifact is in use i.e. ON a 1 is sent and if the artifact is OFF a 0 is sent. The basic data model in the Sölvesborg case doesn’t contain any data that is hard to code or decode, but the contextual knowledge built into the structure of what the 1 or 0 means, and when and from where that data model is sent are of vital importance for decoding the 1 or 0 i.e. the check against the communication protocol is of highest importance, to semantically understand what the information is about.

Interaction models and protocols with stakeholders

With interaction protocols we mean description of actions performed in a time sequence. The fundamental protocol concerns the Service Level Agreements (SLA). From a service provider it may be of interest knowing the borders and quality of the service. That is, to be able to fulfill the service with high enough quality. From the service receiver perspective trusting that the service will be fulfilled is of main concern. The interaction models are of course an interesting input in these structures, that is, knowing how the interaction structures between service provider and service receiver normally are performed can be supported in putting up a good SLA. According to definition 2 previously described a service can be assured as the SLA are validated against stated requirements.

Based on the interaction models and protocols with stakeholders, the workflow, information flow, protocols and data models can be a basis for a trustworthy exchange of services. Considering orchestrations, that is automated arrangements and structuring of services, according to SLA are an interesting approach to consider. Information sharing in complex adaptive systems based on social roles is of interest and orchestration of such services could be suitable [22]. Demands for how the services are collected and coordinated could be of further interest in such approach. Methods and models for trust are of importance for such arrangements and are considered in next section.

4.5 Methods and models supporting Trust (causalities)

That trust is an important principle when engineering open socio-technical systems is also clear. Trust is worth modelling since there is a risk in socio-technical systems that the outcome from interacting with the computing system is different than what the user expects. An important substance in trust concerns expectations of causalities. Causalities concern the relationship between two events, where the second event is a consequence to the first event. Since trustworthiness is a decision by the user, based on assessing relevant information a challenge is to convey the information that the system indeed meets the concerns articulated by the user by communicating appropriate signs conveying the right information [18]. In the trust model below Rindebäck presents important relations in trust. We have considered trust in relation to functional and non-functional requirements in [5]. The bottom line in the trust model is that potential users of the offered service express their trust concerns related to whether to use the service or not. Those concerns are then classified into different information types. A goal of designing and implementing trustworthy systems is to identify and implement mechanisms that can be communicated to the user via signs in a way that reflects her specific concerns regarding using the service at hand, that is, assessments whether or not the stakeholders concerns have been adequately addressed. In all our applications several trust concerns related to information management have emerged. Typically, those trust concerns addresses one or more of the following issues:

- Adequacy and integrity of information. Do we have the information we need and can we trust it?
• Non-disclosure of information. Is the information protected from non-intended use?
• Availability of information. Will I get the right information at the right time?
• Common situation awareness. Have we all the same situation assessment for appropriate actions to fulfil the mission?
• Breakdowns. What happens if something goes wrong? Can I be accountable or liable?
• Traceability. Can my actions be recorded by the system? A blessing and a threat!

The first three concerns are commonly referred to as the CIA (Confidentiality – Integrity – Availability) concerns of information security and are in focus from information security engineering perspective. However most of those contemporary efforts and solutions are context independent whence we emphasize the importance of the mission context to allow for customized solutions. The last three trust concerns mentioned above have, however, very little attention in R&D efforts at the moment. This is partly due to fact that the rapid emergence of new application areas, based on computer-enabled interaction between groups in missions, does not have a clear research agenda at the moment.

![Trust model highlighting the relations between trustworthiness assessments, trust concerns, mechanisms, and signs.](image)

Both model 2, concerning the semantic hurdles in semantically correct information exchange, and model 4 the trust model highlights the importance of context dependant communication of information in designing and maintaining trustworthy systems, or rather services. The outcome of the assessment clearly depends on the context in which the service will be used and how well the interpretation of signs meets the trust concerns. Using the trust model of figure 4 is one interesting approach to find, pinpoint and handle trust issues. From our perspective engineering trust in open socio- technical systems concerns causal behaviour. A mechanism to handle trust issues is to open up for inspections considering critical points in an interaction, where inspections need to be considered [1]. Basically inspecting the relations in a process and pointing directions for future behaviour, that is the relations included might not necessary be of causal nature, and that is perhaps one of the reasons why trust may be so complex. If there just were chains of causal relations, then prediction models would be fairly easy to present. However when there are relations included where the effect is not given, issues of trust may occur.

### Causalities

Causality is the relationship between two events, where the second event is a consequence of the first event. Extensive work has been done focusing on revealing the sometimes complex system of relations within causal events [22, 25, 26]. Acknowledging causalities as a key factor in trust are relevant. Trusting what new state a transition leads to. The cause – effect issue, or rather controlling which desired effects a cause can have has been considered in computing contexts. In the late 1980s and the early 1990s the frame problem generated a great deal of work in logic-based AI [23]. Basically the technical frame problem consisted in the problem of representing a dynamical domain in logic without explicitly defining which conditions that will not be affected by the action. That is, the basic problem was that a desired transition from one state led to transitions in other states (perhaps undesired!). Some of the solutions to the frame problem from a logical computing perspective are
basically to infer rules about how transitions in one state may impact and make transitions in another state. Just to mention a few solutions, rules about when transitions in state 1 can impact state 2 can be to specify in which situations transitions in state 2 may occur (the fluent occlusion solution). It is also possible to specify that state 2 will not change if it has been stable before and there is no specification that state 1 will change it (event calculus). Setting up rules may be one way to handle to control causal actions, identify structures of how actions may impact from a systems point of view is also possible, as in network structures, calculating probabilities based on relations between tasks. These relations are not necessary causal, or perhaps, one of the reasons for using networked structures are since there are hard to understand how the relations. Understanding the effects triggering a function is an important ingredient in trusting the function. Identifying causal relations basically predicting actions based on previous actions can give the agent a sense of control, inferring trust. Identifying causal relations as a method are an important contribution to solving the complex issue of trust.

4.6 Methods and tools supporting Validation and Training

Validation and training are important perspectives, assuring that the workflow tasks are properly performed. In the licentiate thesis [0] a validation approach on how to measure and validate results against stakeholders demands are presented. In this thesis we continue the validation approach adding new perspectives dependant on stakeholders and workflow. Furthermore support for training is explicitly considered in thesis. An implicit general perspective upon training is that engineering good computing solutions do not require training aspects. That lack of training can be seen as a quality mark, appealing to that high intuitive interface solution requires no training. However in our approach training is an important part of the systems engineering perspective.

Validation

Validation focuses upon external quality criteria that concerns if stakeholder requirements are fulfilled. That is, the stakeholder is the one deciding if the quality meets the expected requirements. In the validation process for example the stakeholder/s can consider if the product suits his/hers/their needs. Thus validation aspects can be measured according to stakeholder’s external measurement criteria. In this section validation are considered from a semantic empowerments perspective, from a process perspective and two validation approaches are seen from a workflow performance perspective.

In model 5 below the validation approach towards semantic empowerment are considered. This approach is grounded in article [3]. It is an answer to research question 3, validation of service qualities in critical situations. The perspective here is on sender and receiver of information. In our model 5 of how to assure the semantics of the message in information exchange, concerns that the semantic of the message are to be handled as a relation and not an object. Thus it is to be validated both against the sender of the message and the receiver of the messages context. This can be done in a dialogue, discussing what type of intention the sender has got with the message. The contextual situation of the sender is of importance for understanding the semantics of the message. The receiver of the information understands the message by connecting it to his/her own context, but also to the expected context of the sender. If the sender and receiver have a common awareness and common ground, that could include the knowledge about each other’s contexts, and how it differs in relation to their own context. Mechanisms for these contextual perspectives are considered in section 5 case 3. The ability for the receiver to understand the message of the sender is of course based on competence. However, competence needs to be updated, and being competent at handling the task, without being updated about the new context can create communication errors as described in the flight example in section 4.3. Being aware of that semantic need to be seen as a relation and not an object are an important issue to stress, since it poses fundamentally different approaches upon validation than if it were seen as an object.
Figure 5: Model presenting trustworthy sending and receiving of message. Semantic is seen as a relation and not as an object. The validation aspects include validation according to context, given definition 1.

Based on this validation approach, trustworthy implementation of ontologies can be made. That is, we have assured how a message has been connected to the context of the sender and the receiver. Using the validated ontologies in relation to the correct interaction and data model, building protocols can be a possible interesting approach.

The process model have used for performing validation are the risk driven spiral model in CommonKADS. The risk driven spiral model that we have used in figure 6 below is as follows:

![Risk Driven Spiral Model](image)

**Figure 6:** The risk driven spiral model, simplification of Boehm’s spiral model.

Basically it is a simplification of Boehm’s full spiral model [19]. The full spiral model includes both waterfall aspects and prototyping and is more directed towards large costly projects and software development processes. We have used it in this simplified version towards validation. The main strengths are included in this simplified version. But it is more generalized, suiting socio technical engineering, including software but not excluding other computing solutions [20]. We have used
ethnography as the grounded method for collecting data in the validation approach. The spiral model has been used as a validation model alongside with the ethnographical findings during the process including the stakeholders and staff and persons related to the stakeholder in the process. We have performed validations within the spiral model process to validate if the changes in socio-technology really are suitable for the individual and/or team. Furthermore, if necessary make adjustments towards the workflow and the intended goals. It may be necessary to use more detailed models on the socio-technical aspects to reengineer, but those models need to be shaped from the upcoming needs/stakeholders perspective, for example prototype validations. The closer to the software engineering process the more of the original Boehm’s spiral model and coding process. If hardware products with pre computed software solutions is the answer, the less of the coding. As for example in the case studies 1 in the next section assurance, alternative interface is part of the solution, the simplified version is enough. In case study 2, the coding part would lie in the process with the monitoring of the workflow activities as for example implemented in rule-based structures, then the original model would be more suitable.

Training

Training is a foundational method for supporting empowerment in establishing, increasing and maintaining skills, knowledge and competences. That is, to empower the individual and team in handling the tasks, where training of hand-over, context models and abbreviations, potentially can assure the shared semantics concerning the situation. Establishing a trained and shared context model including ontologies for semantically correct information sharing in distributed contexts is of importance. The training perspective is specifically highlighted in [3] where a robust perspective upon changes in abbreviations is considered.

Training in open systems may require demands that differ from that of closed systems. Issues concerning intentions, competences, roles etc. may need to be further considered. In closed systems such issues usually is known. In open systems mechanisms for handling these issues may be of importance, given that there is a need for directing special recourses towards a specific goal. The potentials of open systems [2] include more actors and sources of information and possibilities for agents available to create rich and perhaps also novel inferences or patterns of information. However critical factors to consider are the risk of wrong information or lack of competence towards the focal task. Mechanisms for assured information sharing in open systems would include training.

In next section, section 5 case 1 training in adaptation to new signs and trusting functionalities are of vital importance. Training in receiving and understanding information in case 2 is emphasized. Figure 3 presented in section 4 are the basic model we advocate. That is to identify abilities, consider how to make information from the environment intelligible to handle the task in focus.

5 Participatory design

We have conducted two participatory design cases related to different phases of development of socio-technical systems (Figure 1 and Figure 2) and a third case based on participatory design findings. The two participatory design cases based on physical ensembles (the Sölvesborg cases) are aiming at validating some ethnographical based findings related to requirement engineering. The third case concerns improving performance critical tasks of semantics in information exchange (the SOS case), societal ensembles. The two Sölvesborg cases focus on the individual, and the third SOS case focuses on team. The empowerment model we use for the cases, figure 3 is a part model from figure 1 and 2. The model captures the basic components, the ability of the person/agent and the information from the environment for the agent to be able to perform the task. The information from the environment is of vital importance. In cases 1 and 2 computing sensors are recommended as support for environmental based empowerment [30]. In case 3 the individual person senses for him/herself when to send out information based on his/her own availability to receive new tasks.
5.1 Case 1 & 2 Physical ensembles

The case studies have been performed in Sölvesborg a municipality in the south of Sweden. The persons to be empowered are living autonomously in their own apartment but have different degrees of support from a support team. The cases concerns physical ensembles with the intention of empowering the two persons in focus. In both cases the Participatory Design perspective has been of importance, including different professional teams from the municipality of Sölvesborg in Blekinge Sweden and, most important, the end-users together with their families and other important persons in their daily life. The first case concerns a cognitive problem, and the second concerns issues in coordination of activities. The structure of the first two case studies is as follows. The case study with focus is presented and the workflow is modeled with states and transitions between states. Identification of user specific barriers in following/understanding crucial steps of the workflow is performed. Furthermore identification of sensor based information mechanisms to empower the individuals is presented. Validation and training aspects are considered. After the two cases, a discussion concerning scalability and sensor systems application are made.

Case 1 Assurance: Physical ensembles

The first case concerns person P, she is born 1982 and diagnosed with Aspergers syndrome with some special language and sketching skills. P has the responsibility to contact staff when she needs assistance, but two times a week staff visits her just checking that everything is ok. Her dysfunction basically concerns obsessive compulsive behaviour (OCB) [21], which is common when a person has got Aspergers syndrome. Her OCB problem consists in that she gets stuck by the door assuring herself over and over if she actually has locked the door. The ethnographical studies show that after she has locked the door, she repeatedly pushes the handle down and pulls the door towards her, getting stuck in the loop of repetitive behaviour.

Historically she has had this problem for many years, and has been on cognitive behaviour therapy, but the problem remains. According to P, a quantitative estimation of how frequently this problem occurs, she claimed that about 6-7 times out of 10 she gets stuck by the door. Except for the anxiety that the disorder gives her, she runs the risk of missing the bus to work or other planned activities. P has previously had difficulties with a tap, being compulsive about not turning the handles tight enough afraid of the risk of dripping water. This behaviour of constantly checking if the handle is tight enough has been solved by her mother putting a plastic bag over the tap (i.e. a sign that the tap wasn’t leaking). However the issue with the door has not been solved. In conversations with P about the issue, she explained the problem in her own words:

"I just have to check to make myself assured that it is locked…”

When modelling the workflow four situations depicted in figure 7 are of importance, where situation 1 and 2 constitutes the loop P is stuck in. The door has the same state i.e. locked all through the loop however P continues to check that the state is true. She has observed that she cannot push the key further since the bolt is already pushed into the door frame. Furthermore she has got feedback when trying to open the door, that it do not open as she press the handle down and tries to pull the door towards her. Furthermore a sound of a “click” as the bolt is in locked state is heard. These different feedbacks from the door indicate to P that the door is locked. However for some reasons she becomes uncertain, and a silent action takes her back to situation 1 where she wants to reassure herself that the locked door is actually locked.
Figure 7. Situation and actions performed by P.

The situation constituting the issue in workflow concerns P’s mental state. P gets stuck in assuring herself over and over that the door is locked. P gets out of the loop if she is assured that the door really is locked. Today this issue is basically solved by having the mother to act as a sign indicating that the door really is locked in situation 3. P trusts her mother as a sign and goes into situation 4 where she is certain that the door is locked. However finding more sustainable support for P is necessary. The solution, below, is basically to replace the mother sign by an icon given by a SmartKey (sound sensor network) as depicted in figure 8. Change of assurance mediator i.e. the sign that the door is locked, from mother to SmartKey.

Figure 8: Situations and actions performed by an empowered P.
With the new icon picture in figure 8, situation 4, it is possible to change sign visualizing if the door is locked by receiving data from for example a sensor placed in the door frame. Sensing if the bolt is in place i.e. if the door is locked or not. The information about the bolt state can be captured, enhanced and visualized by a sign, for example a locked or unlocked padlock, preferably displayed on a small digital mobile device that P can bring with her keys or in her cell phone. The mobility and visualization of the SmartKey can remind her anytime anywhere that the door really is locked, avoiding getting stuck by the door in an assurance loop. Small digital devices with visualisation possibilities that fit into the key ring in closed systems exist on the market. The digital device has some connection rate, and when the “key” is out of range from the sensor, the old picture holds.

As for back-up possibility, staff monitoring perspective could be considered. If the SmartKey needs to be complemented, monitoring solution could be suitable. Monitoring will only be necessary if the sensor is activated repetitively in a short time period. If for example, more than 3 re-locking of door within a time frame of 20 seconds an alert can be activated to staff. Further monitoring of how long she is stuck by the door could guide the type of response. Based on the type of ‘alert’ and knowledge base about P, staff could select suitable responses, making a phone call, send text message or physically go to P.

Training and validation

From both a training and validation perspective trust aspects upon the SmartKey is of importance. The icon indicating that the door is locked has to be trained to become a sign with equivalent meaning as the information presented by the mother, the former trustworthy sign that the door is locked. The icon is a representation of information, not information in itself. For the representation to become information to create a basis to perform correct actions upon, training the information and correct actions based on the information and context needs to take place. Initial training can with advantage be done in cooperation with the mother, the former sign and assurance that the door really is locked.

Having a qualitative approach towards validation is necessary. The validation approach considered in section 4.6 is to advocate, that is validation perspective 1 including that the stakeholder uses the new technology in the real world workflow. In combination with the ethnography and the risk model validating if the new affordance mechanism is really suitable. Validating the service qualities such as how well the artifact is mediating the sensor information to P, how resilient the system is based on states and transition between states, how the workflow and information flow are understood and handled. Interviews and enquires would not be sufficient validation approaches for this case. In a real world training and validation it will be visible if the new artifact is suitable for stakeholder, P. She cannot pretend that the SmartKey supports her, either she can use it after having performed training, or she continues to get stuck by the door. Initial validations have been made, that is discussions with the staff and with P and they turned out to be positive. However validations according to workflow are still necessary and shouldn’t be replaced.

Analysis

With this sensor based physical ensembles approach we have empowered P to decide on her own when the task of locking the door is completed. Empowerment by introducing an action sensor in the environment that informs her about the current situation, supporting her to take the right decision in context.

Based on the identification of situation where enhancement of activity is needed, in case P the locking/unlocking of door, proper type of sensor needs to be selected. For an unambiguous sensor based input, sensor suitable to the situation in focus is needed. A touch sensor is possible since there is a high probability that it will become activated only when the door changes status when locked/unlocked, resulting in a stable and trustworthy causality model.
We have identified the workflow based on ethnographical studies and the most important situations and the information flow by using Situation Theory. We have used participatory design approach for P and stakeholders related to her everyday life. The interaction model, the data model and interaction protocol has been considered by use of CommonKADS. Based on the current signs mediating that the door is locked, and the assurance support in form of mother, we have focused on changing the sign indicating that the door really is locked. We have used the empowerment model according to figure 3, presenting information in a way that has been considered personally suitable and adapted to person P’s need. We have considered back-up solutions, from resilient perspective, where counting and monitoring possible undesired states are in focus. Furthermore, we have suggested a robust training & validation structure potentially increasing the chances for a suitable solution and acceptance. The trust aspects have been considered and the new sign is mobile and given that, she can use any person suitable as assurance support. The connection between the new sign that the door is locked and sensor indicating the physical locking of the door gives even further evidence for a strict trustworthy causal relation. From a resilience perspective the most important states are identified within the situations. Conclusively the undesired states, that of being stuck by the door are also identified and the solution with the SmartKey is a solution avoiding getting into the identified undesired situation.

Conclusively: Adding a sensor enhancing the information that the door is locked could be a reasonable empowerments solution for P.

Case 2 control: Physical ensembles

Person M is in his late twenties and has been diagnosed with mild to average mental disability, his issue concerns catching the bus getting to work in time. He has disabilities in estimating time, planning and making predictions of how long time things take. The support team visits twice in the morning waking him up, then returning after approximately 15 min to make sure that he gets to work. He is attended every working day, but not on the weekends, except for a visit by staff on Sunday evening.

The workflow of M concerns performing a set of activities without coordinating the activities against the clock i.e. not synchronizing and changing behaviour according to how much time is left. M has his routines in the morning, starting with getting up as the alarm clock has been active, going to the toilet, taking clothes, taking a shower, getting dressed, going to the kitchen, preparing breakfast, eating, putting the dishes together, brushing his teeth, taking money and cell phone, putting outdoor clothes on, taking the keys, locking the door and walking towards the bus, waiting for the bus to come. At no time during his activities is it possible to see that he checks what time it is. He just turns the alarm off (the alarm is an attempted solution to this issue and is further explained in the next section) without paying further attention to the clock. Furthermore it is neither possible to see that he hurries or slows down in his performance according to how he is performing related to the schedule. His morning routines take as long time as they takes. No breakdowns are visible, neither is inflexible behaviour of M visible.

Attempt of solution

Attempted solution towards solving the issue of getting in time to work using several different types of clocks has been performed. One of the clocks is a special wrist watch, the C clock4. It is manually preset with audio alerts at set time, repeated until manually turned off. Text information as below is also presented:

> 7.45 Outdoor clothes<

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4 Furthermore he has got a wall clock that can be pre set to display or in voice send certain messages at a decided point in time, but this clock is seldom used.
As he performs his morning activities before going to work, his C clock alerts him several times so he has to focus upon the clock, turning the alarm off before it sounds again. The clock suggests him to put his clothes on, but he says that he cannot do that since he is having his breakfast. At 7.35 the clock tells him to perform some actions, but he has just sat down by the table to eat his breakfast. He concludes that if he were to follow the C clock, he would have to wait too long for the bus at the bus stop. Basically the clock is not synchronized against his real world situation based individual morning activities.

**Analysis and consequences of attempted solution**

When analysing this attempted solution, the workflow activities have been modelled as a linear order of activities. M has then been informed that the presets of alarms are instructing him about which tasks to perform based on this identified linear order of activities. Basically the clock is not synchronized with his individual workflow where the tasks can vary in order and length. Neither is the information presented in a situation when he is susceptible to receive information, since he is performing other tasks, not focusing on getting to work in time. Furthermore it seems as though M doesn’t want to follow external control. The effort of supporting him in getting in time to work i.e. by using the alerts, are handled by him as just more tasks to consider. A consequence is that the workflow tasks that he needs to handle are increased, since additional tasks in the form of turning off alarms from the clock that is supposed to support him are to be handled. Solutions supporting but not interfering with his everyday tasks would probably be more suitable. Seeing the workflow from a Participatory Design perspective towards a solution for M is suggested in the next section.

**Solution**

In this subsection an alternative solution based on Participatory Design is presented. This solution concerns ambient support based on sensing M’s morning activities. According to *figure 9* we model the general activities in the workflow as a set of activities and identify the last activity before going to work. Basically the set of activities are performed and the last activity is identified as the critical path task. This last activity needs to be performed before a certain time, if he will have a chance to get to the bus in time. According to M’s identified workflow, the critical path concerns taking money and cell phone. Basically we turn the workflow around. Instead of putting the burden on M to keep track of the tasks, the workflow is automated and keeps track of itself based on sensor input from M performing critical path activity, costing no effort but to perform his everyday routines.

![Figure 9](image-url)

*Figure 9*: The performance of the actual workflow triggers sensor activities, sending info to the team. The team responds to the sensor activation of ‘critical path’ task. The team sends info to M about how much time is left until the next bus leaves.

Identifying the workflow of M gives insights in how and where to support workflow activities by finding when critical path occur. The first data model, *section 4.4*, as described as sensor output to
info team are concerns ON/OFF functionalities. That is when M is performing the critical task activity, identified as taking money and cell phone, the sensor activation is made, and the support team is alerted that the sensor has changed status from OFF to ON. This sensor activation can be engineered in various ways, based on the physical removal of the wallet and cell phone, or the physical motion in the area of placement, or the motion of carrying them in the physical surroundings and more. In figure 10 below a prototype, SenseMS [44] is developed with the aim to suit M’s needs of support in getting in time to work. The SenseMS system is basically consisting of pressure sensor FSR-154NS (CP45) that are activated when removing cell phone (and/or money) and a USB experiment card VM110/K8055 for interface card to computer. A PC with XP OS for support team to monitor as support team receives information based on the sensor triggering, support team can choose to display information about bus and time left before bus leaves to M on Android OS in smartphone.

![Figure 10: The prototype SenseMS that is activated by pressure sensor as the physical removal of smartphone is made.](image)

The second data model, i.e. the data in the info transmission that is to be sent by the staff based on the triggering of sensor is knowledge intensive, in the sense that it has to be adjusted to M’s capability of reading and understanding information. It concerns sending of information about when next bus leaves when he is in a situation capable of and interested in reading this specific information. From a monitoring and back-up perspective based on this sensor input they can see if he has a chance of catching the next bus, or the support team can synchronize and support so M catches the next bus or take other actions. As he has performed the critical path task, a sensor triggers the staff to send information in the form of a message (counter, icon) to his cell phone, smartphone, wristwatch or other info device suitable showing how much time he has left before the bus leaves. In having sensors to sense this activity, he is in control just by performing his everyday workflow, and the information is sent without him having to perform an extra activity for sending the information, or turning off alarms. The prior responsibility of performing extra tasks lying on M, changing it to staff sending information without extra effort of M.
Figure 11: The view for the support team, seeing that the sensor has been activated. To the right the prototype SenseMS in Android application activated by the sensor in simple style with icon for bus and a counter.

In Figure 11 above the prototype SensMS with the view of the support team to the left, visualizing that a sensor has been activated, and the actual displaying of the information in the smartphone based on the sensor activation and the support team response.

The staff sending information to him when he is in a situation available for receiving information, thus performing his activities in his own pace is being supported, acknowledging information ecologies [43]. If irregularities according to workflow occur and if desired by the involved stakeholders, the support team can respond appropriately based on the sensing of information. From a further back-up systems perspective, a sensor indicating that he has opened and closed the door could be reasonable. Thus indicating that he has left the apartment or not, and at what time, making reasonable assumptions that he will catch the bus.

Training & Validation

The ‘sensing’ of critical path could increase M’s abilities to focus on performing the workflow tasks. Training in M’s case concerns informing him about how to open, access, read and understand the information that is being sent to his information device, such as cell phone or clock. The information about the bus should be in a format that he can easily access and understand. This information is knowledge intensive holding information to be engineered according to empowerment model 3. The sensing of critical path to staff need to be presented in suitable way and training of the team/staff for monitoring M if desired would be of importance. Including not only what a certain type of information really means according to the workflow, but also resilience issues, as how to consider changes in workflow and possible triggering of information outside workflow protocol. Interaction models, data models etc. need to be considered. In the training of the team/staff, ethical considerations should be handled. The good intention of support should be seen from the perspective of the person in need of support, and trust issues should be handled continuously. The suggested PD case has been discussed with staff. Validation specification cannot be made by inquires or interviews solely with M, such validations should be seen as complements. Validation needs to be performed according to workflow and use according to workflow validation in combination with the spiral model. In this case, as in P’s case, the stakeholder cannot perform workarounds or pretend that the system works properly. Thus validation should include qualitative methods to create an understanding if the system functions or not, and what adjustments to make, if any. Semantics of information exchange and information sharing are important qualities to focus on in the validation process. In validation, motivational aspects should be considered, as if there are other aspects than just not being able to estimate how long time things take that may impact, such as motivations for going to work.
Analysis

The main contribution in this case is the adaptation to the situation based individuals’ needs and behaviour. We have identified prior solutions, modeled the current workflow and information flow, critical path, data models and interaction protocols and by using Participatory Design considered how the workflow and information flow could be performed more ideally towards M’s needs. Basically we have turned the workflow around towards ‘sensing’ M’s everyday activities. Knowing when to send what information as responses based on automated triggering of information from M. The resilience perspective includes the state and transitions between states, and understanding how to act if sensor activities can perform irregularities, not following the workflow protocol. Trust aspects are considered both from M’s perspective basically in the structure of information but also in training and validation, and from staff/team perspective. Part of this issue is to display the information in correct time with correct structure making it intelligible and suitable for M.

Conclusively: Adding sensor to M’s last task before going to work, triggering relevant information in right situation could be an empowerments solution for M.

Prototype

Prototypes are in essence design verification tools. The process perspective upon prototypes is usually to design, test, evaluate and then modify the prototype based on the analysis made of the prototype in use. Development of prototype can have several advantages. The prototype can be tested and evaluated against workflow, using a prototype make it more concrete in how it could support workflow. Engineering prototypes can open up for PD contributions. PD aspects can thus be considered based on using the functional prototype in its intended context. Opportunities for the person/s that the prototype is designed for to test and see the functions of the prototype in actual use situations are benefits. We recommend the prototype is to be used in the workflow, or at least close to workflow and/or within selected parts of workflow. New design and application ideas, usability issues, infrastructural, technical, setting-up, implementation and related issues can emerge during set-up, since as theory is put into practice, practical issues emerge.

Scalability

From scalability engineering perspective the concrete example of sensor-smartphone based prototype can be applied to case 1 as-well. Adding sensors in door frame and a picture of a locked, un-locked padlock or other suitable visualization are basic possible solutions. The principles in section 4 are a reasonable foundation for a scalability approach. Scalability in engineering open system engineering structures with icons, sensors, information, communication and functions suitable for different computing formats to be selected based on modeled individual needs are reasonable. Different control structures with possibilities to turn off sensor monitoring and information sharing based on roles, social structures etc. are then of importance. Sharing the sensor based activities in different social platforms or other media structures can be possible and adding social relations protocols such as, mother can monitor individual actions during weekdays but not on weekend, and friends are most interested in activities on weekends. In essence, control is to be seen from the perspective of the individual.

Case 3 Team: Societal ensembles

This third case concerns societal ensembles and is based on ethnographical studies in Swedish Emergency Service Centres (SOS centres). In the licentiate thesis [0] we identified workflow in SOS centres, basically, the normative workflow consists of the following states: Classification of call – allocation of recourses – detachment – monitoring and subtasks belong to those tasks, see figure 12 below.
The workflow is initiated by an incoming emergency call and the tasks in the rectangles in figure 12 above are connected via abbreviations. The answering operator begins with classifying the call and if a dispatch is to be performed a request is sent out to other operators that support is needed. The structure of how the hand-over is made today is via listening-in that is sending an audio connection with a listening-in to the ongoing call. The listening-in is usually directed towards that/those person/s that are potentially most available to perform the task. However this availability assessment is most often based upon in centre monitoring of other persons working status, based on observing articulation work within the centre, both via computer support and observing actions in the physical room. An available operator responds to the request and listens into the ongoing conversation with caller and answering operator. Answering operator and the operator working with allocation of recourses i.e. dispatching operator, can discuss the case live, both operators can listen to the caller, but only one operator can communicate with the caller. Dispatching operator can tell the answering operator to ask specific questions to the caller.

In [0] we focused on increased cooperation between centres in clusters that are sharing of emergencies, mainly concerning resources and competences between centres. Basically an operator at one geographical centre can cooperate with another operator at another geographical centre. Levelling out peaks and falls in workflows, and sharing of competences and resources between centres with increased performance are the expected gains. PD methods have been used specifically focusing on this cluster issue. The identified hand-over of tasks with correct semantic understanding of the case are critical issues and has been considered in [2] and need to be considered further. Basically to get the increased performance gains that the cluster structure can provide, semantic issues need to be considered. In short, the challenges that needs to be considered when handling emergencies in clusters are identified as:

**Challenges:**

1. Minimize the time span of the workflow
2. Assurance of the quality of information flow. On the surface those two requirements seems to be in conflict.

Introducing mechanisms [10] for assurance could be an interesting approach for further improvement in quality in semantics. Focusing on assuring a semantically correct communication, a focus upon the interaction model is of interest. Adding a mechanism for semantic support in the complex and important process of categorizing a case is considered. The current sending of listening-in are kept and extended with dispatching operator sending a categorization suggestion of the case to the answering operator. This mechanism would mean that the answering operator categorizing the case will have a second opinion of how to categorize the case, with a minimal cost, since the dispatching
operator already has most of the information given from the caller via listening-in to the conversation. Thus we extend the dispatching operator to take an active part in the categorization of the case, acting as a quality assurance in improving this performance critical task of semantics.

In the sequence diagram in figure 13 below, coordination between classification and allocation of subtasks are presented.

![Sequence diagram: coordination between classification and allocation of subtasks.](image)

**Figure 13:** Sequence diagram: coordination between classification and allocation of subtasks.

The dispatching operator responsible for allocation of resources can prepare for a dispatch, but cannot perform the dispatch before the person responsible for classification of calls has classified the case. The gain is increased quality input based on second opinion of information that already is in the system, yet not made inferences and articulated i.e. made into a classification.

The effectiveness of this three-way-handshake in hand-over for semantically assured categorization is not directly dependent on, but related to the quality of display in status of operator previously described. Presenting a protocol based on this three-way handshake interaction model with included proper display of status can potentially be an interesting assurance approach, improving performance critical task of semantics, i.e. improving a semantically correct hand-over of task. In short the complete proposed structure for improve semantics and gain more full effect of a cluster structure is presented in short below:

**Solution:** Introduce parallel handling and hand-over process in the normative linear workflow model with three-way-handshake mechanism in the hand-over subtask, and include mechanism for displaying status of operator.

In this solution the tasks of getting important information and allocating resources are continuously performed in parallel, basically in order to be more efficient in time and quality and to keep a better focus on the initial task and to synchronize information flow between the tasks. Furthermore this behaviour is based on the social structure of dividing persons into holding roles with different kind of competences. This behaviour can be maintained but extended in its dynamics, basically holding different roles based on the situation. Furthermore the strong pattern of information structured in
abbreviation form in the system most specifically in the transitions between the states can be kept with these mechanisms.

**Verification and validation**

With these mechanisms as a solution we have identified and suggested how to increase key service qualities, that is performance critical tasks of semantic. Verification and validation of the solution are to be recommended to strengthen the solution with an evidence based approach. A presentation of verification performed and validation approach recommended is done in the following sections. Below verification by proof is presented.

**Verification by proof**

1. listening        classif (call_id) || alloc (call_id)
2. classification   classif (call_id, classif_id)
3. proposed classification alloc (call_id, classif_id)
4. coordination    alloc (call_id, classif_id)
5. hand-over        alloc (call_id, classif_id, detachm)

if [classif_id = abbrev_id]

Correct semantic:
At every hand-over the abbreviations are compared and approved. Basically if the classif_id corresponds to the in-system implemented abbreviation_id, then the semantics hold true.

**Call efficiency due to parallelism**

Concerning call efficiency, in the normative case the time needed for the call is:

\[
\text{Total time} = \text{time class}(c,c_e) + \text{time alloc}(a,a_e) + \text{time detach}(d,d_e) + \text{time finish}(f,f_e)
\]

Connecting back to figure 13 and the events presented there.

time class = time event2 – time event1

Parallelism is effective if and only if time event3 > time event2

The time saved is:

time_saved = time event3 – time event2

If event2 are performed before event3, then time is saved, since op2 has had time to prepare for the allocation of resources to be made. In the same way, potential saving of time due to parallelism can be applied to every hand-over, which are shown in Total_time.

The suggested solution of introducing parallelism in the workflow combined with a structured handshake mechanism in the hand-over process in the workflow have been proven to resolve the mentioned conflict and will indeed support a faster and more reliable workflow in this case.

**Further support structures**

Support via mechanisms improving the semantics in team work, including semantic assurance mechanisms. In this section further support structures status/availability of operator, extension of blackboard mechanisms, context and workflow indicators are presented and recommended.
Focusing on the critical action of hand-over situations, a consideration of focus is adding of sensor system in the initiation of the hand-over process. The importance of displaying status in team work has been in focus in [8]. When working in cluster distributed, the articulation of the ongoing work needs to be supported in the computing support system. The basic structure is that the answering operator sends his/her request for support via listening-in to one or several operators, the first available operator that answers the request gets the request. In this hand-over process, a possible delay in not finding an available operator, having to resend or take the dispatch him- or herself, are an issue mainly in time, but also in quality. Introducing sensors displaying the availability of the operators is a possible solution. The basic reasoning needs to be that the operator him/herself senses when he/she is available. Having this mechanism in hand-over process would rule out the persons unavailable and increase the performance since the process of selecting persons to send the dispatch to would probably decrease. Furthermore, if as previously mentioned the case could be that all operators are unavailable and a new process of asking for availability of operator would have to be performed again, potentially prolonging the process. Basically it would be sufficient to send request for support to one available person instead of sending it to several persons with unknown status. And if no one is available for hand-over, the process of searching for unavailable persons wouldn’t have to initiate a search and the allocation of recourses could start immediately. Based on the efficiency of statuses, a critical issue to consider is to what extent this sensor support can be automated. If the operator is having another conversation / taking another phone call or typing, those tasks could potentially be automation tasks causing unavailability, but not necessarily so. How to display levels of availability is another issue to consider, and the time for the sensor display of status needs to be included in the overall calculation.

The basic mechanisms for information sharing today are blackboard, basically every person in the team are sharing which task they are performing on a blackboard structure so the other persons can see the articulation work. Keeping and extending blackboard mechanisms, including for example making preparation of tasks that may require some extra effort visible in blackboard style are reasonable solution. Including pictures in the blackboard support, as in [7] could be of interest. Not only from within the centre but also from the scene, making the work more visible and transparent. Of course training in capturing pictures and interpretation possibilities and limitations are necessary.

Models supporting change are of importance, adding change of context indicators could be a support. Basically in exchange of information the persons can have different definitions of a word. For increasing chances of semantically correct exchange of information, such different perspectives need to be handled. An indication of which person that holds the definition of the word based on the situation could be of importance. As a suggestion for solving semantic mistakes like in the air traffic accident in section 4.3 could be to present indications of which definition of the word that are the dominant perspective. Basically for this solution to be functioning, the dominant definition of the word would have to be somewhat known by the other person. Identifying situation and which definition of the word that is the dominant would be of importance. This semantic ownership can be of vital importance to state. Combined with selected critical situations this could be an important mechanism for supporting correct semantic understanding. This change of context indicator is further identified in article [3].

A workflow indicator based on the workflow model presented in figure 1 with the main high-level tasks constituting a normative case with hand-over, basically displaying where in the process the person is performing which tasks could be an interesting contribution. Critical for this type of support is to consider how to measure which task a person is performing, and if it should be automatically monitored or manually by the person him- or herself. Furthermore displaying of task may well be selected for just the tasks that are critical, for example the task preceding a hand-over. Interaction protocols and data models could be a basis for this type of support.
Validation by experiment

Experiments have been performed, however the experiments are to be considered as a learning process and the results from the experiments will not be presented. For administrative reasons the setting up of the experiment couldn’t be performed optimally. However the setting-up, performance and analysis of experiments provided insights in how to perform proper experiments in the future, basically it provided basis for a sound experimental model. In following sections a discussion concerning important issues to consider when setting up, running and analyzing scientific computing systems experiments.

Setting up, performing and analyzing computing systems based experiments

In performing experiments that are to be used in a scientific context, the importance of proper setting up is vital. The type of experiment that is in focus concerns computing systems experiments, involving multiple persons using computing systems to perform the tasks in focus. One basic and problematic issue concerning experiments in computing systems is the issue of resetting the experiment providing the exact same computing systems settings for all the persons performing the experiment. The experimenter, i.e. the research worker conducting the experiments, has the responsibility of providing the exact same computing settings, and just resetting the computing system between the experimental sessions, erasing the input data is not enough. This since the previously performed experiments may have changed some data within the system, making the setting for the performance of the experiment different between the persons undergoing the experiment. The complexity in computing operations in computing systems, just consider operating systems complexity, can potentially impact the performance results, an example could be that it could be that the performance are increased, perhaps it takes more time for the computing processes based on changes in the data based on previously performed experiments on the experimental platform. This issue is to be considered as important as the logging facilities providing proper systems of actually measuring the data.

Another important issue in setting up experiments concerns the issue of having the experimental platform to be suitable to the actual issue that is to be the focus for the experiment. That is the experimental platform needs to be adjusted so the experiment can be performed in correct way with the correct prerequisites and the correct support from the system. This is potentially a complex issue that can have major consequences upon the performed experiments. An experimental platform is seldom engineered just to perform one experiment, thus the platform need to hold the flexibility to be able to run the different experiments. The experimenter and the engineer of the experiments may be separate persons and most likely groups of persons. Validation and verification processes needs to be suitable and considered to maximize the scientific value of the experiment.

Validation by use in real world situations

The validation approach from a qualitative perspective that is suggested are to further involve the stakeholders using the new technology, mechanisms in real world cases, that is if suitable in real world situations. If not suitable, in situations mimicking real world situations, gradually improving the new technology, mechanism into real world based on findings from properly performed experiments.

The approach towards semantic validation presented in section 4.7 methods and tools supporting validation and training can be suitable. Based on this semantic validation approach, we can consider patterns of behaviour and validation aspects towards those ends. This validation approach of information exchange between sender and receiver can thus be a grounded perspective for implementation of ontologies and trustworthy exchange of information.
Furthermore validation towards workflow is recommended. That is validation according to normative workflow, inventing structures and mechanisms for identifying when patterns of normative behaviour are followed. Validation according to workflow in this case concerns identifying the right interaction model, data model and base a protocol on the interaction model and compare the workflow against the protocol. The right protocol holds the right interaction model, it concerns the right form of the information, the right information type, the right time, the right communicating parties and the right structure in exchange of information. For open interaction models, comparing the interaction to the already stated interactions could be of interest, identifying that this is an open interaction. Adding identification of competences in open systems according to the validation and training sections 4.7 could be of interest.

**Training**

Training persons in handing over cases using the recommended mechanisms is of importance. Understanding that training is an important aspect for successful implementation of mechanisms for increased performance is of importance. Engineering proper training platform is an important aspect to consider. Thus a training platform is a part of a principled approach towards engineering socio-technical systems. Since the hand-over situations are potentially difficult, and the abbreviations are vital, we have based the experiments on these interaction models, protocols and data models. Support for parallel and sequential handling, and comparisons of performance in the order that the information is presented can be of interest when assuring a proper workflow. Training offline saves time online and it is an important method to enable trustworthiness and trusted change of context and use of abbreviations.

**Analysis**

In this section case 3 team and societal ensembles are presented. We have modeled and identified the workflow with abbreviations and hand-over situations. Introduced parallel handling and hand-over process in the normative linear workflow model with three-way-handshake mechanism in the hand-over subtask, and included further mechanisms for increased semantics in team cooperation. Furthermore we have presented verification, validation and training approaches.

Using the principled approach in section 4, this case with team perspective in critical settings can with advantage be applied. Structures for assured semantics are of vital importance. Identifying and modelling workflow are a critical issue, capturing the vital parts of the workflow and on right level of abstraction. Understanding where semantic issues may appear and how to invent structures, mechanisms, tools, how to select, combine and use methodologies are to be carefully considered. Understanding and pointing towards engineering open socio technical systems in a proper way acknowledging team aspects are of importance and has been considered.

**6 Conclusions**

In Section 1 Setting the Scene we introduced the main components of a socio-technical system (Figure 1). The models and methods to support high-level requirement engineering were introduced in Section 4. Challenges and Research Questions related to semantically correct information sharing in socio-technical systems was introduced (Figure 2) in Section 2. We also gave definition of semantically correct information sharing, assured services and empowerment in our context in the same section.

In section 2.1 we identified the following research questions to be addressed.

**RQ 1:** Identify models and methods that support semantically correct information sharing in socio-technical systems.
RQ2: Model workflows and interactions in open socio-technical systems that supports semantically correct information sharing.

RQ3: Identify and validate key service qualities in socio-technical systems.

RQ4: Identify models and methods supporting empowerment.

We have addressed RQ1 in the following steps:

1. Identification of Situations and workflows between Situations and actors using ethnographical methods (Section 4.1)
2. Identification of information flows within and between Situations (Section 4.2).
3. Identification of hand-over tasks between Situations (Section 4.3)
4. Validation of assured hand-over in workflows (Section 4.4, Section 4.6 and Section 5)

In article [6] and [8] we made contributions by identifying and learning how to use ethnographical methods. In article [2] and [3] we have identified situations and the importance of ontologies and that abbreviations are of high importance when supporting semantically correct information sharing. In article [5] proper models and methods concerning requirements are identified. In [7] information sharing in shoulder-to-shoulder constellation is identified. In the verification and validation in case 3 a contribution towards verification by equation is performed, and suggested validation approaches concerning sound experimental model and real world validations are presented. The combination of different validation and verification processes is thus a contribution.

We have addressed RQ2 in the following steps:

1. Identification of Situations and workflows between Situations and actors using ethnographical methods (Section 4.1)
2. Identification of information flows within and between Situations (Section 4.2).
3. Identification of methods and tools supporting resilience of information exchange (Section 4.3)

In licentiate thesis [0] we have modeled workflows and interactions. In article [3] we have considered resilience of change in abbreviations. Furthermore we have considered how to streamline emergency services in [4]. In [5] we have identified models and tools for supporting knowledge engineering and elicitation.

We have addressed RQ3 in the following steps

1. Identification of Situations and workflows between Situations and actors using ethnographical methods (Section 4.1)
2. Identification of information flows within and between Situations (Section 4.2).

In licentiate thesis [0] and in [1] we have identified workflows, key service qualities and validation structures. In [3] we have identified that changes in abbreviations need to be handled in a robust way. In [4] we have suggested agent support for allocating proper support for emergencies, a key service, where automation can have potential to increase the quality. In [5] we have presented validation structures concerning vital requirements.

We have addressed RQ4 in the following steps:

1. Identification of Situations and workflows between Situations and actors using ethnographical methods (Section 4)
2. Identification of information flows within and between Situations (Section 4).
3. Identification of trust related concerns (Section 4.5)

Models and methods supporting empowerment are further considered in [2] where frameworks for handling abbreviations in open socio-technical systems are considered. Basically modelling is about:

- Catching the important events
- Support of the right decision making (by letting the environment inform the user via sensor networks

In article [5] we have presented empowerment structures in the form of trust models. In [1] we have identified models and methods for empowerment based on two cases focusing on individual empowerments. In [7] interaction models towards supporting empowerment are presented. Using interfaces and interaction models supporting group activities in shared ICT interaction spaces are probably increasingly interesting for the future from an empowerments perspective. The insights of mechanism in case are a foundation for assurance mechanisms in a three way hand shake thus assuring the categorization in the case, empowering the categorizing person in performing correct categorizations. Semantic empowerment is a critical factor to consider not least in distributed and open systems, and mechanisms for supporting correct information sharing are thus needed. Furthermore the insights that training is of importance and how training platforms can support in this, alongside with identification and presentation of competences are further contributions. We can conclude that using qualitative methods are of importance when having a contextual perspective.

In conclusion, the principles for open socio technical systems are as follows: Engineering open socio-technical systems includes semantically robust communication. Identification and modelling of workflow with intention including information flow is the initial approach. Based on robust methodologies to capture the workflow and information flow, ethnographical methods is used, furthermore Participatory Design methods is used for including the stakeholders and users in process. Methodologies for understanding how to make sense of information are of importance. These structures of Information Sharing and understandings of semantically correct information exchange are vital for engineering in open socio-technical systems. Engineering for empowerment of stakeholder/user of system are of importance, and this approach aims at possibilities in that direction. Making the system resilient, that is returning back to the initial state when responding to threats to normative behaviour is of importance. Trust aspects upon use are of importance, and are closely connected to understanding of engineered causal behaviour of computing system. Validation and Training are important perspectives and should be included in the systems engineering process.

7 Future work

Continued attention towards engineering principles for open socio-technical systems is needed. Maturing socio-technical principles building on the work performed in this thesis and related, producing socio-technical principles in the style of Denning’s computing principles would be a great outcome for possible future work. Complemented and based on specifically three perspectives, sensor, communication and business:

Sensors and actuators

Future work focusing on sensor based information which is collected and measured by smart equipments, adding to context and state based decisions are an interesting approach. Actuators converting the sensor input energy into motion can be of interest for providing different kinds of measurements, information triggering. Given that we have the updated sensor measurements, the historical data and other information sources to relate to, the given question is how to analyze the information, and what kind of implications and foundations for future acts that can be made. That is knowledge based approaches in updated CommonKADS style would probably be of interest. Pattern based, evidence based, inference based analysis and engineering perspectives combined with intention based workflow, information flow perspectives could be probable structures to consider. Furthermore
we can extend the information exchange, and make changes in physical ensembles in distributed places. Thus the sensor input can add to information structures but also to changes in physical objects.

**Communication models**
Future work focusing on assured communication would be of interest. The more sophisticated and complex the services are the more important to focus on how to structure and form services in an intelligible way. The less knowledge about the person to use the service, the more important to structure the communication structures in a semantic intelligible way. Affordance of services, that is, how to trustworthy connect to signs representing information structures with expected results are key issues. A specific focus upon training and evidences based on training could be of interest. Experiments focusing on automation aspects such as choreography, auction and orchestration could probably be of concern. Automation structures including social models and interaction aspects could be of interest. Contextual understanding would be further emphasized in this approach. The structure of web 2.0 applications with the basic contextual information connecting with people, giving short text based information about context, state of mind and interest could be interesting to elaborate with further. Applied in health care could be of interest, continuing focused work in for example in SBAR [40] communication style.

**Business models and empowerment**
New business models based on social exchange of information etc. where how to value efforts in open systems are a critical issue. The business perspective is of relevance since the support from different computing communities can be of high quality and given when needed, adding value to the knowledge base and competence mass on different levels of expertise. Identification of social structures, competence building based on topic and structure of open socio-technical systems would be included. Experiments, tests, measurements and value models of competences would probably have to be reconsidered to suit the business perspective of open systems. New interaction models, discoveries of how intention shapes in open social group and technical support for reaching the intended goal would be interesting aspects to consider in this future work approach.
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9 Glossary

Assurance – according to Oxford English online dictionary [24] assure is defined as “To render safe or secure (from attack or danger)” furthermore “to make sure to oneself, make sure of” and “to make secure against change or overthrow; to make stable, establish securely. In this thesis assurance mechanisms are identified and to be implemented in the exchange of services to secure a proper service exchange.

Assure services - where assured services means support for semantically correct information sharing, and ability to select from different activities and or services based on situations.

Closed systems – have clear owner, purpose, task, intention, stakeholders and borders. Open systems do not have the built in structural “limitations” that the closed systems have.

Critical – critical as in crucial, decisive, in issues concerning important societal functions, can include time critical as parameter. For example if a function not handled with in time and with high enough quality, disruption or breakdowns in societal important functions, perhaps resulting in loss of life, can be the effect.

Critical path - The concept critical path is used in project modeling technique contexts. Focusing on a task where any delay on the activities on critical path directly impacts the planned project completion date (there is no float on critical path, where float is the amount of time that a task in a project network can be delayed without causing any delays on the subsequent tasks or project completion date).

Cognitive impairment – weakened cognitive ability

Data model - data models concern an abstract model of how data are represented and accessed from a socio-technical systems perspective.

Engineering – According to Encyclopedia Britannica [32], where they refer to the Engineers council for professional developments in US definition, engineering concerns: the creative application of “scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination or to construct or operate the same with full cognizance of their design; or to forecast their behaviour under specific operating conditions; all as respects an intended function, economics of operation and safety to life and property”.

Empowerment – According to Oxford online dictionary, empowerment concerns the process of enabling persons or groups to participate more fully as rights bearing entities within a society and state. We agree to this definition and focus on ICT tools and training for empowerment.

Information flow –the information in a flow generally precedes and connects the workflow tasks. The flow implies that the tasks are continuing as intended.

Information sharing – traditionally in computing contexts the term information sharing refer to one-to-one sharing of information. However, in our definition we include many-to-many, one-to-many and many-to-one in the information sharing definition.

Interaction model – interaction model is a model describing interactions, it could be between persons and/or artifacts (including software components).

Mechanism – according to Denning, [10] established sciences like physics and astronomy use the term mechanism for the part of their fields dealing with the behaviour and structure of components, the so called case and effect relationship. Denning adopts this term to computing. “Computing
mechanics deals with the structure and operations of computing. With the universally occurring phenomena that appear in computational processes and hardware and software components. It does so with stories for algorithm, Turing machine, grammar, message entropy, process, protocol stack, naming, caching, machine learning, virtual machine, and more. The stories group into the five categories of computation, communication, coordination, automation, and recollection.” [10] Together with design the mechanisms constitutes the principles of computing.

**Figure 14:** Denning, P. J. principles based portrait of computing.

**Open system** – open systems allow interaction between internal objects and the environment, as opposed to closed systems that only allow interaction between internal objects. Purpose, owner, task, can be example of objects in socio-technical systems.

**Orchestration** – orchestration [41] refers to an executable business process that can interact with both internal and external Web services. Orchestration represents control from one party’s perspective. It can be seen as automated arrangement of coordination of services and complex computer systems.

**Protocol** – A protocol specifies the order in which the tasks are to be performed.

**Semantic** – the relation between signs, words, symbols, phrases and what they stand for, i.e. what they mean.

**Sensor** - a sensor is a device collecting physical quantity, transform it to a signal to be read by a human or machine. A sensor can trigger transition in state.

**Situation** - Situation refers to the outline of the existing circumstances often with a relation to the action that is likely to follow

**SLA** – service level agreements, basically a contract between a service provider and receiver, defining the relationship i.e. how to exchange and handle services.

**Socio-technical systems**– social and technical systems are delimited to ICT systems, basically technical platform with affordance and requirements to meet social systems, examples of main components of socio-technical systems are depicted in figure 1.

**Software intensive systems** – we have the same definition as according to EU expert thematic group ftp://ftp.cordis.europa.eu/pub/ist/docs/fet/strat-6.pdf, 2006, Software intensive systems could be defined as, systems that depend on software that controls the behavior of individual components and
the interaction between components, and on software that interacts with other software, systems, devices, sensors and with people.

**State** – a state can hold and or change via transition to another state or the same state.

**Workflow** – the definition we use are domain specific and intention based. Generally we share the same definition as [34] thus in the sense of that ‘a workflow is a collection of activities (tasks) organized to accomplish a process. A workflow defines the order of activities invocation, the condition under which such activities must be invoked, and activity synchronization and information flow.’

**Figures and tables**

**Figure 1:** Main components and views of socio-technical systems

**Figure 2:** Architecture, components and hurdles in semantic correct information sharing.

**Table 1:** Table Mapping of research questions and contributions.

**Figure 3:** Empowerment model where the ability of the agent is taken into consideration and the information from for example sensor measurements of the environment are support to enable the agent to carry out the task.

**Figure 4:** A trust model highlighting the relations between trustworthiness assessments, trust concerns, trust mechanisms, and signs.

**Figure 5:** Model presenting trustworthy sending and receiving of message. Semantic is seen as a relation and not as an object. The validation aspects include validation according to context, given *definition 1.*

**Figure 6:** The risk driven spiral model, simplification of Boehm’s spiral model.

**Figure 7:** Empowerment of cognitive memory loss, Mother acts as a memory, assuring that the door really is locked.

**Figure 8:** Empowerment of cognitive memory loss switching assurance mediator from Mother to SmartKey.

**Figure 9:** Model of M performing his morning activities in a sequence in situation A. He performs his last activity and comes into situation end where he puts his outdoor clothes on before going to work.

**Figure 10:** The prototype SenseMS that is activated by weight sensor as the physical removal of smartphone is made.

**Figure 11:** The view for the support team, seeing that the sensor has been activated, and the prototype SenseMS in Android application, activated by the sensor on the right. The Android application in simple style with icon for bus and counter.

**Figure 12:** Based on the workflow model from licentiate thesis, selected and highlighted parts from *figure 1.*

**Figure 13:** Sequence diagram: coordination between classification and allocation of subtasks.

**Figure 14:** Denning, P. J. principles based portrait of computing.
10 Appendix

The articles presented are in original text and figures however, layout has in some articles been changed, and comments after article [3] have been added.

0 Principles of workflow support in life critical situations

The prime objective is to investigate how technology and work organisation can support the workflow in handling time critical emergency calls, having the prerequisites of giving the highest priority to saving human lives and minimizing the effects of emergency situations. The challenge is to maintain and improve the quality of service (QoS) during and after a proposed technology driven organisational change. This thesis is based on empirical work including extensive ethnographical studies of emergency call handling at Swedish Emergency Service Centres, SOS centres. Today the SOS centres are basically organized as independent centres. The proposed technology enabled organisation concerns the contingency of handling emergency calls nationwide, in SOS clusters. One of the desired outcomes of this reorganisation is that peaks and falls in the handling of emergency calls will be levelled out. It is assumed that any operator will be able to handle the call independent of the location of the emergency situation, opening up for a more efficient handling of incoming calls. In principle, introducing new information technologies enables this reorganisation of SOS centres. However, the basic claim of our investigation is that a transition to the new organisation has to take into account systemic requirements, to support a non-disruptive change.

The first of the three main results concerns essential aspects of technology based organisational changes. From the empirical work, we have concluded that the tasks constituting the workflows at SOS centers are conducted in parallel, and that the coordination of the tasks can be modelled using a risk-driven blackboard-based spiral model. We have also concluded that there is a rich face-to-face communication and body language situation within the centers supporting coordination of workflows. This coordination is context-dependent thus the means of creating awareness of the overall situation in the centre support the acquisition of important extra information in the specific case.

The second result concerns methods and models to increase the quality of the requirement specification process. The principal approach is to specify assessments and systemic requirements. Furthermore, issues such as how to validate empirically based workflow models, as well as how to measure groupware usability and how to support the information sensitive change are considered. Suggestions concerning methods and models that could provide means to that end are presented.

The third result concerns identification of relevant research and development challenges coupled with new insights about combining ethnographical approaches with system modelling. Identification and suggestion of suitable experimental platform design, enabling testing of service qualities, including a suggested role for agent technologies are presented.
Challenges and opportunities of sensor based User empowerment

Jenny Lundberg, Rune Gustavsson

Abstract—Sensor and sensor networks technology are becoming an increasingly important part of information management infrastructures. Challenges related to collection, processing, analysis and user-centric presentation depending of context are of particular interest. Furthermore, design and implementation of proper respond actions to sensor based information is gaining interest in many applications. In this paper we focus on robust application of sensor based systems. With robust we mean in this context supporting user empowerment and allowing adaptations. Two case studies of critical operations for individuals with cognitive impairments are presented. A comprehensive methodology supporting empowerment of users is outlined. The methodology includes ethnography-based analysis of workflows to identify user dependant barriers as a basis for design and implementation of mechanisms supporting empowerment. Identified challenges and opportunities of sensor based user empowerment is a contribution. Requirements engineering, from a user empowerment perspective including user specific barriers and sensor based information mechanisms, as a part of the systems developments process is another important contribution. User-centric training, as an important validation of implemented solutions in given context, is part of lessons learned. Sections on challenges and opportunities as well as of future work conclude the paper.

1. INTRODUCTION

Robust information sharing and decision support tools based on sensor input can potentially provide a win-win situation with positive effects for the individual as well as opportunities for societal and economical gains.

We focus in this paper on sensor systems supporting user empowerment. The sensor systems envisioned aims at supporting users’ traditional senses of sight, hearing, smell and tactile input to access, process and act purposeful in a given environment. The information processing to that end is only partly understood but different cognitive models such as the Belief-Desire-Intention (BDI) model have been used to model and implement different kinds of decision support system (DSS). Of particular interest to us is Multi-Agent technologies based on the BDI model, e.g., JACK [17].

By user empowerment we understand in this context individually tailored support systems aiming at supporting the users understanding the present context and to take proper actions. In particular we focus, in this paper, on users that have different kinds of cognitive impairments. Present evolutions of sensor networks in Smart homes and in Health care are of particularly interest and usefulness for this large group of users [10][20][22][25].

The contemporary models and techniques of DSS, e.g., knowledge engineering meet a clear barrier when it comes to model and implement decision systems constrained by the capabilities of users with special needs.

We suggest and illustrate in this paper a methodology whereby design of proper sensor systems combined with user-centric evaluation and training can remedy some of the barriers related to different cognitive impairments in designing and implementing proper DSS in those contexts. Our methodology is a configuration of different methodologies under the umbrella of Participatory Design (PD). PD is a design approach attempting to involve all stakeholders in the design process where the main aim is usability.

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2. Related work

Related work focusing on understanding and finding patterns of everyday tasks adding sensor input to DSS exist, however, usually the methodological approach typically do not include PD approaches [23][24] or lack focus on applications involving users with cognitive impairments [26]. Related work focusing on sensor based DSS towards persons with cognitive impairments exists [27]. However, work on PD approaches having an individually tailored focus towards semantically correct information sharing and with validation and monitoring aspects are mainly absent at the moment.

3. Case Studies

We have conducted two case studies of people with special needs in their day-to-day living. The scientific studies were conducted by researchers from Blekinge Institute of Technology (BTH) specialized in computer science, knowledge engineering, ethnographical studies, interaction design, and Human Computer Interaction (HCI). Other team members were different professional teams from the municipality of Sölvesborg in Blekinge, Sweden and, most important, the end-users M and P (introduced below) together with their families and other important persons in their daily life.

Case 1 addresses a cognitive related problem of person P having Aspergers syndrome. Her dysfunction basically concerns obsessive compulsive behaviour (OCB) [8]. Her OCB problem addressed is when she is getting stuck by the door repeatedly assuring herself that she has actually locked the door.

Case 2 addresses remotely synchronization of activities of a person M. M has been diagnosed to have “easy to average cognitive impairments”, and his main concern is catching the bus in time getting to work. His impairment concerns estimating time, planning and making predictions of how long time different tasks will take.

Persons P and M are living on their own in regular apartments with assisted living support. They are very concerned of their impairments (as expressed above) to handle daily activities. Their families and other support persons are also constantly worrying about their situations.

4. Towards sensor supported empowerment

The following Figure 1 captures our generic architecture of Decision Support Systems (DSS) based on trusted information sharing supported by inputs from sensor networks and actions grounded in the physical environment.

The main system components are; Context model, Information processing artifact, Interfaces, and Sensor networks. The users of the system are denoted by Sender and Receiver and the whole system is situated in a Context.

Figure 1. A generic architecture of sensor supported Decision Support systems empowering users.

The overall challenge of system analysis, design and implementation is to provide a semantically correct and trusted information exchange between the different users. We have addressed several aspects of these challenges elsewhere [12][13][14][15][16][19].
The specific challenge addressed in this paper is proper design and implementation of DSS when the user-receiver has cognitive impairments.

The suggested approach has cycles of activities including the following:

- Identification of workflows to be supported
- Identification of user specific barriers in following/understanding crucial steps of the workflow
- Identification of sensor based information mechanisms to empower the user
- Training and validation

The general idea is to empower the user with easy-to-understand signs eliminating cognitive demanding reasoning, by users, that usually is the corner-stone of traditional knowledge based systems.

5. **Towards a configurable methodology**

Our approach is grounded in analysis of workflows aiming at capturing the intentions and barriers of users. The requirements process is based on Ethnography [1] and PD [2] approaches. The information perspective is grounded in info sense [4], built on Situation Theory [3]. Knowledge Engineering perspective has been built on CommonKADS methodology [28]. Design of empowerment mechanisms are based on interaction design capturing the intent of the user while harnessing the identified barriers. Implementation of the support mechanisms are based on principles of service oriented systems and sensor based mechanisms. Training assuring user acceptance of the solutions supports assessments, and validations are included in the process.

The requirements and validation approach is supported by an iterative use of Boehm’s spiral model [18] for software engineering development processes. Validations have been performed continuously during the processes, however the end implementation and validation in real world has not yet been performed.

Similar configurations of methodologies are used in both cases; however, the outcomes differ since the solutions are domain and user dependent.

6. **Findings**

Following our approach outlined in Section IV we have for our Case I with user P and Case II with user M.

6.1 **Case I Empowering P to leave locked door**
Modeling of critical workflows of situations from the user P’s perspective:
In Figure 2 we illustrate the OCB behavior by P leading to getting stuck in repeatedly locking the door and then forgetting about this immediately after, unless she can be assured by observing the proper sign from her mother.

Our suggested solution is to use a “smart key” that is triggered by a signal from the lock when it is closed, Figure 3.

The signal is represented as an icon showing that the door is locked. The icon is then replacing P’s mother as a confirmation, to P, that the door is indeed locked. Of course, the trust in the icon has to be trained with P to be accepted and trusted by P as a valid substitute of her mother’s sign.

As assurance system NumberedOutTime protocol, indicating too many re-locking of door under to short amount of time can be alerted for the support personnel.

6.2 Case II Empowering M to catch the bus in time

In order to support M in his planning and doings, his support team has beforehand identified the different steps to be performed by M from waking up, preparing himself for the day, having breakfast, brushing teeth, picking up his money, mobile and leaving his apartment to get to the bus stop.

The durations of the different activities has been measured and sequenced. In order to help M the team has prepared a corresponding set of signals that were transmitted to his wrist-watch. When M heard the clock signal he was supposed to look at the message and thus synchronize himself to perform remaining tasks and keep the time to get the right bus.

However, during our ethnographical studies of his workflows and the role of the reminders by the clock, our main findings were:

1. M routinely switched off the clock without looking at the message.
2. M was disturbed by the implemented monitoring and synchronization efforts

The good intentions of supporting M in his planning and execution of daily morning activities, by pre-defined remote monitoring and intervening, were in fact a failure and a frustration to M.

Our approach of empowering M was based on identifying a ‘critical path’ in M’s workflow activity that would trigger a signal from his activities to his support team. The support team could then estimate the time to the next bus departure and inform M about this by sending one suitable message to his mobile phone/information device.

The starting point of the critical path could be triggered by, e.g., M picking up his mobile phone from a predetermined place. Furthermore, a confirmation signal to the team could be sent when M is closing his door leaving his department.
In short: Instead of remotely trying to remind M of the steps of an intended workflow we suggested that a well identified action should tell the support team when that happened and thus synchronize them to give relevant information to M “just in time” about departure time of his bus. Furthermore the team could estimate the time to and signal of that M has left his apartment.

Our suggested solution will empower M without unnecessary infringement of his integrity. Again training by M is necessary to accept this sensor-based support.

7. Challenges and opportunities

The main contribution in our approach is proper identification of workflows including user-specific barriers and mechanisms supporting empowerment. Furthermore, the following challenges and opportunities of sensor-based empowerment have been identified:

Challenges:
- Semantic understanding of sensor based information sharing connected to situations.
- Monitoring and affordance of sensor input/output.
- Causal activities based on sensor input (Trust and complexity).
- Empowerment models.
- Social aspects, roles and information exchange possibilities.
- Training and validation models.

Opportunities:
- Cost effective update of information and situation in comparison to constant monitoring.
- Flexibility of ambient support.
- Enhancement and distribution of information perspectives.

Creating robust information infrastructures individually tailored empowering persons with cognitive impairments built on sensor based DSS, these challenges and opportunities need to be taken into consideration. In [6] these issues are further elaborated. Based on our PD workflow approach the intention is the initiating and read thread during process.

Understanding the fundamentals of semantic for assuring correct information sharing, Devlin’s logical framework [3][4] of structuring of information can preferably be seen as a high level description of information exchange. The connection between Information (understood, or interpreted, by a human agent) and its Representation is captured by the following equation:

\[
\text{Information} = \text{Representation} + \text{Interpretation}
\]

The equation describe that information are visible via a representation. The representation could for example be a book, a computer system or similar. The Interpretation describes the interpretation capabilities of the receiving agent. Given this, we are aware of the emphasis that can be necessary to put on semantics.

Semantic understanding of sensor based information sharing can include implementation of ontologies based on the model of what situation the information are exchanged in, what the focal situation are and what the information means for each person in the situation in focus. After clarifying workflow, situation and context based relations, ontologies can be implemented. Basically semantics are seen as a relation not an object, figure 1. Knowledge models including cognitive impairments can be an important contribution in this process.

From a high abstractions perspective the situation [3] are a critical issue, thus in our approach the quality of understanding the situation are based on the sensor type and application. Suitable sensor types that disambiguate causal models are of importance. Robust connection of sensor input is created when relating the sensors to the situation framed by identified acts related to physical room and/or artifact. Given the situation base, robust identification of interaction models, data models and protocols is fundamentals are considered.

The affordance given in the interface, in figure 1, for the person with cognitive impairments sending signal to service person should be integrated in workflow. The affordance of the information
artifact is sent by triggering of sensor (automated or by human agent) received by the persons with cognitive impairments is to be based on the impairment modelled in empowerments model where the ability, context and information required of the person are included.

Monitoring aspects including workflow of support persons are of importance. Being mobile, the sensor input alerts should be adapted to that specific situation. When using the mobile device the support persons usually are supporting other persons, so tactile, sound alerts and extended automation support could be suitable for that situation. When stationary the documentation and analysis support can be extended.

Training and validation approaches including the person to be empowered are necessary to perform against workflow preferably in cooperation with persons that are trustworthy, service personnel, parent, or other proper mediators to the new information application. Based on the performed iterative validations, reduction of complexity when describing the sensor system for the end users, i.e. is most probably necessary.

Sensor systems from a high-level abstraction are basically cause – effect relations. Modeling causality based reasoning [30] and controlling so it is stabled implemented in real-world following the model are critical issues. Trust issues are connected to causal reasoning, i.e. how to make predictions of effects based on functions i.e. human behavior based [11].

Agent solutions based on impairment, sensor input, sensor protocol, social inferences and causality models are reasonable. In the social aspects, data structures, interaction and data models based on ‘street smart' social behavior can be of relevance [9][30]. It could include implementation aspects taking into consideration if several staff are available, which staff is most socially suitable to the individual in focus.

8. Future work

Future work has been initiated and will include implementation of the empowerments approach.

Resilience structures [31] are of importance and infrastructure perspectives including robust connectivity, energy sources, update and scalability issues are fundamentals. On software application level resilience are closely connected to protocol update from customer input based on Service Level Agreement (SLA) such as activating/deactivating and adding/removing sensors and based on that, coordination between sensor network inputs and inferences. Cloud solutions where identification of suitable channels, and possible inferences between documents based on the support person’s situation are reasonable.

Web 2.0 solutions [21] can be considered in sensor systems based on this PD approaches since integrity and trust issues are possible to integrate and identify in the methodological approach [5][11].

9. Conclusions

The ongoing evolution of smart homes and related health care will be even more net- and knowledge based, Figure 1. The challenges of inclusion of people with special needs are key topics internationally. Not the least within EU. However, traditional models and methods for requirement engineering and system design and implementation have to be supplemented with methods and tools identifying user specific barriers (focus of empowerments) models and techniques understanding how sensor-based information can be transformed and utilized to support user empowerment.

In this paper we have illustrated some methodological issues related to two case studies. We have given solutions whereby users with cognitive impairments can be empowered by suitable sensor networks to handle their daily tasks in a way that respects their integrity. Challenges and opportunities of sensor based user empowerment are critical to consider towards robust sensor and sensor networks technology infrastructure.

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2 Framework for dynamic life critical situations using agents

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Abstract. In this paper, we present a framework incorporating a multi-agent system (MAS) that enables aid for international effect-based operation in emergency situations. The outcome is to empower emergency personnel, which can support collaboration between different international services by informing them about the emergency, matching competences and resources of the teams and volunteers. The challenge in emergency contexts is the abbreviations forming an information-carrying structure, which is especially important when abbreviations are exchanged between different services like rescue, military and emergency. We propose a framework, which provides the right information, rescue team, and services at the right place. The MAS can support information dissemination in dynamic situations in context, based on the information extraction and matching of the contents of the underlying ontologies. In the framework the system poses a sensible solution to the international rescue teams' need of a high quality handling of life critical situations.

Keywords: Multi-agent systems, intelligent agents, emergency

1 Introduction

International support in emergency services is necessary to handle natural catastrophes like the earthquake creating a Tsunami in the Indian Ocean 2004. Many countries were suffering from this catastrophe, with approximately 223,000 fatalities, mainly due to citizens were taking vacation on the coasts of South-East Asia. The rescue actions from the Swedish government failed and from an investigation it was found that it suffered criticism due to the lack of an organisation managing such serious crisis. But the criticism also concerned lack of understanding the extent of the disaster, the collection of relevant information and coordination of measures [1]. Presumably, a closer connection between international rescue organisations in the involved countries can build a ground for a solid unified action of accurate force to meet disasters that pose immediate negative effects on several countries. Therefore, we need proper ICT systems to support disaster relief [10]. Multi-agent systems in emergency contexts have been used [2] [11] [12], but it is desirable to develop a framework with agents and ontologies to handle dynamic emergency contexts.

To receive comprehensive information and disseminate it fast, the emergency operators write abbreviations in the system, which is translated into for nationally rescue teams, commonly utilised and understandable language. This language needs to be interpreted by international rescue teams. We suggest using Multi-agent system (MAS) to support the dissemination of the information to international teams. From the input of comprehensive information to MAS, the agents handle the conversion of abbreviations into understandable language and translations into other languages.

In dynamic emergency areas, the use of acronym and abbreviations are widely spread, such as, Air Traffic Control, operator control of critical infrastructures and several other medical applications [9]. Abbreviations are context sensitive [13], and as early as 1975, Woods [3] stated the importance of
semantics and not only syntax. In this paper, we work with an awareness of syntax and semantics as we apply multi-agent systems in the real world context of international emergency handling.

2 Scenario

To develop MAS, we look at a future scenario based on the real world Tsunami 2004: Sweden and other related countries become alerted about the Tsunami through the early warning systems, and establish contacts with Thailand’s SOS centres, simultaneously as the earthquake starts, which is approximately 2 hours before the wave hit the shore. Sweden sends Jumbo jets with rescue service and nursing staff, and communicates with Thailand via international language on board the Jumbo jet. They plan the rescue action and make strategies for the rescue, match competences and communicate with local rescue services. When the Swedish rescue force arrives, vehicles are waiting for them for quick transport to rescue areas, hospitals and collapsed buildings. Swedish SOS (at the scene and in Sweden) must control which other international resources are available and match their recourses and competences. They must also identify a large number of volunteers without rescue education. These will be given quick training on place. Since it is a tsunami this training is lead by rescue competent personnel. The matching of rescue competence against the requirements in the action plan is made in a unified process including search for proper rescue leading competences. Furthermore, when all the rescue teams arrive on the scene of disaster, the cooperation is established and will be maintained with responsible person in charge.

3 The Multi-Agent System

The MAS need to handle several different data representation forms and solve problems quickly. Each agent has a task to accomplish but a result is reached when several agents have found their piece of the information, which is assembled to constitute a result. The task for the agents in our research is to inform, search, match and group information in different parts in the framework, see Figure 1, to be able to combine the extracted information to get more comprehensible and understandable information. The ontologies form a framework for the agents to act upon, selecting the most suitable ontology matching the intention of the agent. The abbreviations are a natural part in the ontologies, however to be treated with specific concern. When extended information is needed, the MAS provide a possibility to search and find it externally, i.e., the web.

![Figure 1: Simplified architecture of the multi-agent system.](image)

The task is performed in episode in which the agents perform a single task. The call to the system is divided into parts, and each part is processed by an agent. For each time the system is invoked with new or more information, the agents must find solutions according to that information. Finding several solutions can granulate the output, which in comparison can support the system to give more accurate output that is more correct according to the situation. In these situations, where searching can be simplified and speeded up using several agents, multi-agent systems are useful [4] [5]. The agents in the multi-agent system must coordinate information from several different sources from which they can produce and deliver more complex information in right time to the right place [6], to the appropriate users. The output is the description of the critical situation in international language, as
well as, priority of the cases. The information is directives to the rescue services, from which the services can evaluate the situation and determine what kind of service is needed at the scene.

Agents can allow searching for information in several different ontologies and support reasoning with the findings [7]. We need this distributed problem solving to search for information in ontologies and priorities in the cases. The agents search for information from several different ontologies and correlate it to match the context of the scene. The international abbreviations are the same, but the interpretation of them, leading to different actions. As for example a drowning situation requires rescue service action in the form of finding, lifting up the human and securing the area preventing other injuries. The ambulance service focuses on Heart-Lung-Rescue, and on giving proper drugs to save the persons life.

4 The Agents

We suggest intelligent agents that learn by being sensible to new or changed environments in combination with using meta-agents. The meta-agents are built on the agents linked to the ontologies, constituting high-level connections between different possible definitions, and matching them to the information collected for the case. The system is launched by the input, which is performed by the agents needed for the task. All the types of agents are invoked to perform their assignment see Figure 2. The “inform” agents work with information and matching the abbreviations to their corresponding words and notify the rescue teams. Some words are explaining seriousness in the case and therefore, some words are used for prioritising.

The "Search agents” search for competence and other teams to work with and “Match” agents perform matching to find right competences for right situations. The agents collect and build up information, which is describing the life critical situations corresponding to the information from the emergency call.
In emergencies several ontologies are to be used, see Figure 3. The agents’ combination of the content of the ontologies determines the situations in which the emergency has arisen. They consist of types, properties and relationships are the knowledge foundation on which the agents perform their work. If a person have a heart stop and do not breathe, Heart-Lung-Rescue actions are to be initiated. From the information, the required services with specific equipment are called. If suitable, the meta-data learn the combination and can be reused for future combinations. These meta-agents are built on the successful agents’ performances. Successful agents are the agents that give correct information according to emergency services.

In the organizational ontology that is depicted as the military, ambulance, rescue, and healthcare ontology in figure 3, the different parts of the organization are defined and interpreted with the semantic connections including organizational rules. The produced outcome by the agents as they act upon the ontology is: the rescue team that can handle an ambulance case, and the number of operators that should cooperate in handling the accidents. The ontologies are based on measurement of behaviours, such as operator coordination patterns. Another part is structure, which is based on operators own tagging of related information, as used in web 2.0. And example cases of normative behaviour are included.

The medical index ontology contains of index with instructions about the support that should be given to minimize possible injuries as consequence to the event. For example, the instructions can be how the operator can give Heart-Lung-Rescue support via phone, or which special precautions to take if the person has got diabetes. In the categorization ontology, there are structures for how the cases are to be categorized (not to be confused with the ontologies relationships). In the geographical ontology there is special support for geographical spots that can have several different names, such as a town park. A town park can have several names, a name on the map, a popular name, and yet another name of the park in relation to its location or surroundings. Alignments tools such as minimal mappings can preferably be used however validations assuring correct connection to the domain need to be performed.

In the categorization ontology the abbreviations are defined. The example of an abbreviation is: H1.11.23. For the trained operator H1.11.23 is: Human, highest priority, animal bite, and unconscious, which mean that a specific ambulance, with correct equipment and geographical location has to be dispatched. In the healthcare ontology, organisational healthcare rules are defined. Snomed7 [8], a national specialist language for healthcare is connected. The multi-agent system works with ontologies, internally in the system, to find words and produce messages corresponding to the abbreviations, and, externally at the Web, to find geographic location with waved ground. Relations

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7 Thus, Snomed is not an ontology but a human readable conception system, which (most probably) can form a solid basis for a machine readable ontology.
and rules that are not already defined and connected are stored in a database and then further used and updated in suitable ontology. Furthermore, the evaluation of the result of the agents is made in relation to the debriefing session, were also the actions of the agents are collected and evaluated.

5 Conclusions

In this paper, we provided a multi-agent technology to support international handling of life critical cases. The agents act upon input data from the scene of accident, and match information from the ontologies, which are processed to meet the demand. The agents search, match, group and inform the rescue team about the situation, and are implemented by using BDI model. This article is a contribution to the empowering of emergency personnel in life critical contexts performing effect-based operations on an international arena.

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3 Robust approach towards context dependant information sharing in distributed environments

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Abstract: In the paper we propose a robust approach towards context dependant information modelling supporting trustworthy information exchange. Shortcomings and challenges of present approaches of syntax-based information modelling in dynamic context are identified. Basic principles are introduced and used to provide a robust approach towards meeting some of those challenges. The approach has a main aim of reducing brittleness of context dependant information and enabling intelligible information handling in distributed environments. The application domain is Emergency Service Centres, where the distributed handling of emergency calls in life critical situations of future change is in focus. The main contribution in the paper is a principled approach of use of abbreviations in dynamic emergency situations. Points of interaction for coordination are introduced as a tool supporting mappings of abbreviations between different contexts.

1 Introduction

Design, implementation and maintenance of digital support for handling of tasks in life-critical situations are a challenge. We have addressed some of those challenges even for distributed organizations such as Emergency Service Centres (Lundberg, 2007). The operators handling emergency calls rely on proper ICT systems supporting their everyday work. In this life-critical context abbreviations are commonly used mainly as a way of saving time, but also as a quality assurance method by introducing structured action-types related to calls in a semantically unambiguous way.

Abbreviation-based information exchange is common in many life-critical situations such as dealing with emergency calls (the main application of this paper), Air Traffic Control (ATC), operator control of critical infrastructures, and in several medical applications. There are some clear benefits of abbreviation-based information sharing in teams but also some inherit, and potentially catastrophic, limitations of this approach. In the following Section 2 Setting the scene, we illustrate those aspects and identify some challenges towards ensuring semantically correct context dependent information exchange in teams. The reminder of this paper is organized as follows. Section 3 present our robust abbreviation approach based on changes of context with a specific focus upon information modelling, common ground, coordination, situations and work-flows. Other approaches are shortly described in Section 4. In Section 5 we revisit our challenges of Section 2 and summarise our approach with some pointers of future research. The paper ends with references, presented in Section 6.
2 Setting the scene

To illustrate the challenges addressed in the paper, we introduce a well-known example of using abbreviation-based reasoning. That is reasoning based on results done by handheld calculators as depicted in the following Figure 1. The result obtained by the calculator is the depicted numeric value 1.41421356237095. This value is calculated using the displayed equation including ordinary numeric calculations and the value of \( \cos(\pi) \) and \( \sqrt{2} \).

![Figure 1: Reasoning based on support by calculators](image)

The semantic information (value) can, however, only be assessed by the user of the Calcul Engine in the given context. Different contexts typically entail different semantic information from the same calculated value. In fact, this example illustrates the power of algorithmic numerical calculation where the syntax determines the semantics of the abbreviations used, i.e., numbers, numerical operators, and numeric functions. The power of algorithmic calculations is that they are context free and the interpretation of the results, by the users, is separated from the calculations of numbers. In fact, the power of mathematical models (reuse in modelling different applications) is due to their independence of semantic meaning! To further illustrate the strengths and weaknesses of using abbreviation based reasoning, we now take a closer look at workflow support in Emergency Service Centers (ESC) and Air Traffic Control Centers (ATC). The workflow within individual ESC can be described as a sequence of states.

- **State 1**: Classification of incoming calls
- **State 2**: Identification of appropriate actions.
- **State 3**: Deployment of teams
- **State 4**: Debriefing and reporting

The tasks of each state are governed by a set of abbreviations. The operators within the individual centers understand how to faithfully code and decode these abbreviations due to continuous training and evaluation. Abbreviations support efficient quality assured workflow support with possibilities of parallelisms between states. That is quality and efficiency. The power of this type of abbreviations is also a weakness. Inherent in the power of abbreviations is a stable set of action-types corresponding to the abbreviations and a closed group of users to enable efficient training and other means of quality assurance of the shared intended meaning of the abbreviations. When connecting geographically separated centers, and/or changing tasks to enable more dynamic call centre handling, the mechanisms of abbreviations becomes an obstacle against changes and hence an issue to consider in depth (Lundberg, 2007). In short, how could we, in a principled way, handle context changes in abbreviation based information exchange?

The following example illustrates the critical dependency on a common understanding of context-dependencies in abbreviation-based information exchange. The example of misunderstanding in coordination is due to the fact that the two main actors involved didn’t succeed in handling two implicit different contexts with overlapping abbreviations.
In the example, an air traffic controller and a pilot misunderstood the meaning of the abbreviation ‘holding’. In December 1995, the disaster of American Airlines Flight 965 from Miami to Columbia, resulted in a loss of 159 human lives as a direct consequence to this misunderstanding. Part of the conversation was as follows, where the air traffic controller asked the pilot;

- *Are you holding?*
  The pilot confirms with:  
- *Roger, we’re holding.*

They misunderstood each other due to the unsuccessful establishment of an agreed-upon meaning of the word “holding”. Did it mean holding latitude or holding rate of decent? The air traffic controller and the pilot had different contexts and interpretations of what ‘holding’ meant. As the air traffic controller understood the holding as to holding latitude, the pilot understood it as holding rate of decent. A closer focus upon the situation, and the fact that they had two different contexts could most probably have avoided the loss of lives.

Those two examples illustrate the following two inherent weaknesses with abbreviation based information sharing:

- Problems associated with changes of contexts
- Problems in understanding and discovery of implicit sharing of abbreviations in different contexts

The following Figure 2 captures the semantic hurdles of mapping of intentions between a sender and a receiver.

![Figure 2. Semantic hurdles in semantically correct mappings between sender and receiver](image)

We have highlighted in the figure the challenges related to introduction of an information-processing artifact between the sender and receiver. The face-to-face communication in natural language has thus been disrupted with a processing unit with two interfaces and a context model (CM) used by the processing unit to perform syntax based (rule-based) translation between the input format at the sender interface and the output format at the receiver interface. In Figure 1 the Context Model is the numeric calculation algorithms of Calcul Engine.

In short, how can we model and trustworthy convey meaning of artifact-mediated information in distributed environments when change is the rule and not the exception?

The essence of this challenge is addressing the semantically correct mapping of the intention of the information (by the sender) to the proper actions of the receiver. This challenge has been in focus of
researchers in the fields of natural languages, cognitive science, Artificial Intelligence, Cognitive systems engineering, Knowledge intensive systems engineering and HMI engineering since decades. In the case of abbreviations the sender and receiver agree about the semantic meaning of the abbreviation and the tasks it should and could/could not handle. Furthermore, the contextual meaning of the information at hand has been reduced to the syntax of the abbreviation. The remaining part of the context is shared interpretation of the abbreviation between sender and receiver as illustrated in using hand held calculators (Figure 1).

As we have earlier noted; in certain contexts, such as in numerical calculations, the Context model (CM) of Figure 2 could indeed be purely syntax based, i.e., the syntax of numerical calculations fulfills the needs we have on the context model whenever we need to do numerical calculations! In short, numerical calculations in any context obey the same syntax based rules. In fact, numerical calculations are examples of algorithmic applications where the reasoning power of the computational artifact is syntax oriented and the interpretation of the relevance of the computations in a given context lies in the agreed upon modeling principles and interpretation by the sender and receiver at the two interfaces of Figure 2.

However, turning to knowledge-intensive applications, such as support systems in real-world decision-making, the situation is fundamentally different. Let envelope, Env(CM), denote the set of computations enabled by the Information processing artefact in Figure 2, given the Context model CM. Let Comp(C), denote the set of desirable computations by the actors of Figure 2. Clearly we always have that Env(CM) is a subset of Comp(C). In the examples of abbreviations and algorithmic application we can cope with this difference by adding agreed-upon context dependant semantic interpretation to the computational results. In general this is not the case for knowledge-intensive applications due to the (unintended) change of context. The difference between Env(CM) and Comp is sometime denoted the brittleness of the CM model.

Despite this inherent shortcoming of machine readable context models there have been considerable efforts devoted to formal models and ontologies of different domains. An ontology is a syntactic specification of concepts and their relations in a given domain. An ontology defines a formal semantic of a domain. Large amounts of resources have been spent on efforts creation of, for instance, enterprise ontologies.

The purpose of having a shared or at least intelligible enterprise wide semantic is to enable an understanding of the business both within the company as well as with customers and business-to-business. However, this approach has not produced the intended success (Hepp, 2007). One of the main reasons for this back-lash is due to the lack of understanding how changes in business processes entails proper and controlled changes in the corresponding CM as well as the specifications and changes of the interfaces of Figure 2. For enterprises in development and change, a control of ontological framework and support for change of contexts and interfaces is crucial for success. Our Robust abbreviation-based approach supporting change (Section 3) gives some pointers to those ends.

3 Robust abbreviation-based changes of context

As illustrated in our examples of ESC and ATC in Section 2 abbreviations can be seen as compiled support of context dependent workflows. The compiled version of workflows is sets of states. In order to control and support changes of abbreviation-based support we need to have a more abstract model of states, that is situations, and information flows to support robust changes of Context Models, Interfaces, and Contexts (Figure 2).

The remaining part of this section is thus addressing the following issues:

Section 3.1 Information modelling
Section 3.2 Common ground and coordination
Section 3.3 Situations and workflows
Section 3.4 Our approach of robust change
3.1 Information modelling

Keith Devlin (Devlin, 2001) has provided a semantic based logical framework supporting understanding and structuring of information (InfoSense). The logical framework has been influenced by the work of Barwise and Perry (Barwise and Perry, 1999) at Stanford in the 1980’s. They developed their theories in order to understand human languages as communication of meaning, semantics and pragmatics. Suitable adaptations of the theories will provide us with models and techniques to address types of situations and hence workflows (Brandt, 2007; Östlund, 2007).

Devlin’s logical framework in structuring of information can preferably be seen as a high level description of information exchange. The connection between Information (understood, or interpreted, by a human agent) and its Representation is captured by the following equation:

\[
\text{Information} = \text{Representation} + \text{Interpretation}
\]

The equation describes that information are visible via a representation. The representation could for example be a book, a computer system or similar. The Interpretation describes the interpretation capabilities of the receiving agent. As an example, we have a situation of a fire, and a rescue person sees smoke. The rescue person makes the general assumption that there is a fire, since smoke implies fire. Thus the constraint of the rescue person’s knowledge about smoke and fire makes him understand that this ‘type’ of seeing smoke, are related to the ‘situation’ fire. One of Devlin’s basic contributions in InfoSense is to clarify the relations between representations and the proper interpretations by users to identify the intended situations (contexts). The exchange of information between a sender and receiver can be described as follows (Figure 2): The sender, in figure 2, wants to inform the receiver of a Situation S. The Representation of the situation is described by a sequence of abbreviations A_s that is fed into the Sender interface of the artefact. The sequence A_s is processed by the CM and produces an output sequence of abbreviations A_r. The receiver interprets A_r and can infer the Situation S. If we assume that the syntax based processing is correct and A_s and A_r have agreed upon semantics then the sender has successfully informed the receiver about the situation S and proper actions can be taken. Agreed upon semantics of situations are denoted common grounds (Devlin, 2001).

3.2 Common ground and coordination

Common ground between stakeholders thus enables correct abbreviation based semantic information exchange related to situations. In abbreviation based information exchange as in our examples ESC and ATC the common ground is the agreed upon interpretation of sets of abbreviations. Trusted coordination in those teams can thus be assured by proper training of skills mapping between situations and sequences of abbreviations. Abbreviations can thus be seen as coordination mechanisms in ESC, ATC and similar applications.

3.3 Situations and workflows

In Section 2 we identified that the workflow in a ESC could be identified by 4 states. These states are in fact compilations of corresponding four context dependant Situations; S_1, S_2, S_3, and S_4. To enable a principled change of contexts in abbreviation based coordination a first step is to identify the corresponding set of situations that underpin the workflows at hand. These are complex tasks, not the least from a validation perspective. In our ESC case we have identified and validated a proper set of situations covering the relevant workflows. Proper methods and tools to that end include: work practise, ethnography, and situation theories (Lundberg, 2007, Brandt, 2007, Östlund, 2007, Barwise-Perry, 1999, Devlin 1991, 2001).
3.4 Robust change of contexts

We propose a robust approach for context dependent information modelling in critical information infrastructures. A basic information process is coordination (Chen, Sharman, Rao, Upadyaya, 2007). Coordination could be at different system levels and between different system components. In Figure 1 we model coordination at the highest system level, that is, between system actors (agent or users).

![Figure 1: Coordination at the highest system level.](image)

To be more specific, we introduce, in Figure 3, interaction points in dialogues between agents to enable support for different coordination aspects of Figure 2.

Overlaying the interaction points with basic information sharing of Figure 2 we recognise that the lower abbreviation based interactions, of Figure 3, are facilitated by the Context Model processing of data. The interpretation of those results is by the sender and receiver in the given context and the shared common ground supported by the abbreviations.

The main reason for introducing interaction points is that they give a natural structure of coordination between sender and receiver. High-level interaction points are focusing on the contextual information sharing, whence low-level interaction points are related to the information processing system. Complex coordination can be modelled using interaction points. Furthermore, interaction points capture the critical coordination challenges we have to address and maintain at the levels of common ground and processing. We also have to address the trustworthiness of translations of sequences of abbreviations between those levels.

Our model supporting robust change of contexts in abbreviation based information exchange is founded on the following steps:

1. Identify the set of situations and corresponding workflows that can be inferred from the set of abbreviations.
2. Validate mapping from situations, workflows to sequences of abbreviations
3. Describe the new context and workflows given the identified set of situations
4. Make a mapping of the new workflows on sequences of abbreviation
5. Validate mappings and introduce training of mappings among teams.

Furthermore, our approach to abbreviation based CM handling can be a basis for further investigations on causes of brittleness, and establishment of common grounds as well as off- and on-line training of skills. Principled maintenance of CM due to changes of contexts is also supported.

4 Other approaches

Ongoing research and development on Web services and Semantic web are focusing on ontologies and schemas, i.e., on syntax-based structures (Hendler, 2008). Message passing between web services
are facilitated by SOAP messages encoded in XML. A SOAP message between a seller and buyer could have the message:

\[
\text{<orderstatus>confirmed</orderstatus>}
\]

The issue here is to have a consistent interpretation of the abbreviation “confirmed”. Again we have the problem of abbreviation-based semantics! The works on syntax-based (ontology-based) abbreviations in semantic web have the same shortcomings as abbreviations discussed in Section 2. However, those ontology-based abbreviations could be very helpful in defining the corresponding Situation-based information flows, supporting semantics in a given context, as outlined in Section 4. Approaches as (Veale, 2008) where the focus area is limited have a clear and well defined approach. However, most of the current approaches are still based in the syntax area. Our top-down approach to shared semantic based information takes a supplementary view.

5 Challenges revisited and conclusions

In Section 1 and 2 we identified two challenges in abbreviation-based information sharing in teams:

- Change of context
- Misunderstandings

In Section 3 we outlined how we can identify the abstract Situation types and information flows in corresponding Context. A shift from localized context to a distributed one is facilitated by implementing the derived situation-based workflow and defining a new set of abbreviations to support the distributed information exchange as depicted in Figure 2.

Dealing with misunderstandings due to identical abbreviations can be solved by identifying those ambiguities using the common ground. Resolving ambiguities can be established in several ways. One way is to distinguish the different contexts by prefixes. For example; pilot-holding and tower-holding in the given example presented in section 2.

The process outlined thus establishes a robust model supporting abbreviation-based changes of contexts. It can with advantage be used in training situations as-well and to identify implicit brittleness (Nardi, O’Day, 1999).

Future work includes more elaborated models and tool supporting translation of abbreviations into rule sets and information types. Taking into account cognitive modelling and building rules from info senses constraints would be an interesting approach to consider.

6 References

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Additional comment, the example in American Airlines flight 965, 1995, this example should point to another airline disaster, that of Flight 336, 1981. Furthermore it should be stated that the conversation was from a high-level perspective as described in the cover example in this thesis. However, the focal aspect remain, that miscommunications occurs and that semantic assurance are of vital importance.
4 An approach towards using agent in multi-agent systems to streamline emergency services

Jenny Lundberg, Anne Håkansson

Abstract—In emergency services, the evaluation of a situation is performed, manually, which includes synchronizing the services for each situation. However, the work requires divergent and decisive decisions resolved from several points of views, which would benefit from automating parts of the work. Using computer systems in life-critical domains can involve careful consideration of the work practice and of the situation components. In this paper, we propose using agents, intelligent agents and meta-agents, to streamline emergency services. The intelligent agents respond to both static and dynamic input in a flexible and structured way and perform required actions. From these actions, the meta-agents are created in which the divisions of dynamic and static information have an impact on the structure of the calculations but also on the outcome produced by the meta-agents. As an example application, we provide a scenario of agents and meta-agents in multi-agent systems, where the meta-agents hold systemic properties. The scenario has a strong grounding in the emergency service domain, in which we highlight coordination issues related to the multi-agents and the meta-agents.

Index Terms--Emergency Services, Intelligent agents, Meta-agents, Multi-Agent Systems, Systemic Properties

1 INTRODUCTION

Streamlining emergency services is important to give the correct treatment in time. Usually, dispatching emergency services is principally a manual process with many vehicles and stations involved. Selecting the most suitable vehicle for the specific emergency is a critical issue. Characteristics, such as competence of the crew, available equipment and the most suitable road, i.e., speed and availability (queues or obstacles), have to be matched. Moreover, prediction of future events is sometimes necessary to select the most appropriate vehicle for properly handling several accidents, closely located in time and geography. The predictions are based on past history of events at particular spots. Keeping track of all information is tedious job and streamlining parts of the process could assist the operators in their decision-making.

Traditionally in computing, more specifically in automation contexts, streamlining has been defined as increasing the automation and decreasing the manual handling of tasks. However, streamlining can be much more than just automating a process. It includes making processes more efficient to produce more with the given resources or by increasing the use of resources for a given result. In this paper, the definition of streamlining concerns not just increasing the automation in the task handling, but also to use the streamlining process to open up a more contextual view, where automation are used to capture the complex reality. Basically, the agents constitute a supporting tool to capture the different complex views necessary to make a correct decision. Thereby, it is possible to produce a result aiming for the goals according to streamlining.

Functional requirements such as speed and availability can be easy to measure, but also the systemic properties need to be considered. There are systemic properties such as up-to-date information, trust, dependability, efficiency, robustness and reliability. From such requirements, we can draw the structural perspective to organize the information in multi-agent systems (MAS). Furthermore, finding the most suitable static and dynamic inputs is of high importance as well as social training and interaction aspects merit consideration.

Complex applications can become realisable with features, such as information dissemination to facilitate emergency services. The main concern, in this paper, is streamlining the parts of the emergency service dispatching process. As the work of connecting the approximately 20 different centres in Sweden into a virtual network of competence and resource sharing, the process of defining proper automation processes and levels in the core tasks are important. In our work, we use intelligent
agents in MAS for the parts of the dispatching process, i.e. the process of allocating the most suitable resource, which are, in most cases, vehicles. The agents work in parallel and to keep track of the agents’ performance, we use meta-agents. The meta-agents collect the agents’ perception of the environment while working with the task. Then the meta-agents analyse and forward the different solutions to the users. The optimal solution is determined in the MAS, and in emergency services, optimal is the best suitable service in the shortest time cost. In addition, since optimal solutions sometimes include several vehicles, the agents in the system need to share other agents’ goals.

The outline of this paper is as follows: It begins with a related work section where basic relations are made. These relations concern multi-agent approaches in emergency service and other automation attempts that have been made within the domain. The application domain is presented in the third section, with the focus of providing acceptable paths in the domain context. The two following sections concern intelligent agents and meta-agent aspects in coherence with the focus of providing acceptable paths. The culmination of the paper consists of a scenario, implementing the aspects of intelligent agents and meta-agents. A conclusion and further work marks the end of this paper.

2 RELATED WORK

There are some approaches of using multi-agent systems in combination with knowledge-based systems for supporting emergency decisions. For example, Molina and Blasco (2003) designed a multi-agent organisation of a computer system to assist operators in decision-making in flood emergencies [1]. Multi-agent techniques are applied to interpret data, predict future behaviour and recommend control actions. Four different kinds of agents are used: hydraulic agents, problem detection agents, reservoir management agents and civil protection agents. These agents are used to provide information about behaviour of physical processes, evaluate flood risk, present exploitation strategies for the reservoir and provide different types of resources according to the problem [1]. In our work, we use a pure multi-agent system with two types of agents, i.e., ground-level agents and meta-level agents. These agents provide the most strategically correct resource based on the location, time, type of resource and traffic load as well as handling simultaneous and predictable events.

Another approach is WIPER [2]. WIPER is a MAS for emergency response. The system assists in detecting possible emergencies but also suggests and evaluates possible actions dealing with the emergency situations. The system aids emergency responders by detecting anomalies such as traffic jams, crowds and call patterns of crises. The system also proposes custom-tailored mitigation strategies and provides information on the location of the cell phone users. The mobile software agents convert the data stream from the format of the service provider of the cell phone to a summarized form [2]. In our work, besides detecting anomalies in the traffic, like jams, we need to detect anomalies in the environment that necessitate of types of services. We also need to decide which geographical location for the emergency service is optimal to use in the situation.

There have also been attempts using expert systems to automate the process of allocating recourses [3]. However, in one such example, the users of the system ended up not trusting the list of recommended units. In this case, the algorithms were based on the vehicles home station regardless of their current availability. Basically, the matching was made from each fire stations response area, against the selected address of the help seeking person. One reference from the response area emphasise the importance of selecting proper criteria, suitable to the actual task to be solved. This scepticism has to be resolved and the most suitable service must be provided for the situation at the hand, which is the basis for our approach.

In emergency services situations, the response must be immediate because the time is critical for saving life. A benefit of using MAS is parallel computing, that is, several agents can perform a task simultaneously. The simultaneous work can speed up the search for solutions in the network and render possibility of parallel computing. Additionally, the system must exclusively be stable and the information valid. A system must assure continuous execution with as few bugs as possible and with several back-up systems. Also it is crucial that the system gives valid results.
3 APPLICATION DOMAIN

The application domain is emergency services synchronizing services for every situation. Services mainly concern the handling of emergency calls and one of the main tasks are the allocation of resources [4]. Generally, the handling of emergency calls can be divided into four main tasks. The tasks are classification of calls, allocation of resources, detachment, and monitoring. The task classification of calls handle issues such as the type of accident and number of people involved in and affected by the accident. The second main task, i.e., allocation, deals with the allocation of resources, status and geographical position of vehicles. The third and fourth tasks, i.e., detachment and monitoring, handle resource specific information concerning the connected resources. These tasks involve sending and receiving information to and from the selected vehicles and monitoring the progress for possible occurrences.

For the work in this paper, the main focus concerns the second task, i.e. the allocation of resources. In addition to allocating resources, the task involves the current status, accident and the vehicles geographic positions, as well as subtasks. For example, the dispatcher uses the event code that corresponds to the categorization and priority of the case. This event code needs to be matched according to the action plan where predefined rules are specified. Also the geographical location of the vehicles in relation to the event, and the status of the vehicle have to be considered.

The required vehicle combinations are numerous. In some cases only an ambulance has to be dispatched; in other cases several ambulances and other rescue vehicles and/or police or resources, such as, sea rescue or helicopter have to be dispatched. Here we consider five different combinations. In the first combination only one ambulance unit is needed for dispatch. In the second combination both an ambulance and a rescue vehicle are needed for dispatch. The third combination is only one police unit and the forth an ambulance and a police unit. Finally, the fifth combination is an ambulance, a police unit and a rescue vehicle. All these combinations are presented in figure 1.

1: A = Ambulance
2: A + R = Ambulance + Rescue
3: P = Police
4: A + P = Ambulance + Police
5: A + P + R = Ambulance + Police + Rescue

Fig. 1. The five different combinations.
The motive for using different combinations is both for mirroring the reality, but also showing the importance of relating different vehicles in a case to each other. The choice of combinations is significant since earlier study has shown that the selection of vehicles sometimes is made according to the relation between the vehicles [4]. The relation consists of vehicles complementing each other with resource facilities or with staff skills needed for the accident. Additionally, the relation represents units that work closely together due to organisational considerations.

In a current computer system used by emergency service, the so-called CoordCom system, the combination tasks are principally made manually. The manual part, basically, consists of matching the current scenario to the most suitable vehicle. The automatic part, basically, concerns the visualization of the current status and the vehicles. The vehicles’ geographical position and status are displayed on a GIS system.

4 MULTI-AGENT SYSTEMS

The trends in multi-agent systems are increased delegation and intelligence, which requires that the system operate independently and act in such way that it represents the best interests while interacting with other humans or systems [5]. The combination of vehicles requires each vehicle to operate as an agent, which has to independently operate according to the environment with long-term restrictions or temporary hindrances or obstacles. The MAS system needs an overview of the contents since it has several different allocation sources to cope with and locating the vehicles in the environment provided by a GIS system.

In the MAS, the agents interact with each other, typically by exchanging messages among each other and between the systems, i.e., MAS and GIS. In the most cases, the agents will be representing or acting on behalf of the user with very different goals and motivations and the agents will also cooperate, coordinate and negotiate with several agents. Thus, the agents are of different kinds: intelligent agents that search for vehicles but also the software agents that represent the vehicles themselves. These need to communicate to find the positions of one another and negotiate the best solution for moving to the position of the accident, considering time-wise and safety issue, at the same time keeping track of other rather regular situations and possible accidents.

Multi-agent applications can use networks and graphs as carriers [6, 7], which well correspond to the concept of multi-agents [8]. In our MAS, the agents operate in distributed systems and deal with problems locally. The agents can search in large graphs and find solutions even without knowledge about the content or context [5]. Thus, the agents must interpret the knowledge in the graph and incorporate up-to-date data to act intelligently in response to the information. This is especially important in our system since the agents need instant access to information to work properly in a constantly changing environment. Hence, the agent must calculate the accurate time for the correct environment and for the right purpose.

Multi-agent systems have many different interrelationships among the agents, e.g., delegation of tasks, transferring of data and synchronisation of actions [8]. These characteristics are important for the agents in our system. The system must be able to divide the task into smaller parts and delegate those tasks to the agents. Each agent has its specific task to execute in the system without requiring external control. Thus, the agents must be capable of autonomous action and decide for themselves what they need to do in order to satisfy their problem objectives [5]. However, the agents must be aware of the assignment, which can be user-given knowledge about part of the problem that is of interest.

Besides operating under autonomous control, the characteristics of intelligent agents include perceiving the environment, persisting over time, adapting to change and taking on another agent’s goal [9, 10]. In our system, the agents can rely on prior knowledge in a semi-dynamic environment [7] with static characteristics and dynamic characteristics. The static restrictions of constraints are problems that always are present in the environment, for example a dead-end street or operational
areas of the emergency services. The dynamic hindrance or obstacles are temporary problems that can be solved within a foreseeable time. Examples of these are road construction or traffic jams at particular hours. The agents perceive their environment by considering the constraints and obstacles and act under the conditions that affect the agents’ performance, at the same time learning the static constraints. If the constraints and obstacles in the task change, the agent needs to adjust to the changes. The agents need continuously to check the dynamic characteristics and quickly adapt to the changes while the static characteristics are learned and only require reconsideration from time to time.

Persisting over time is key issue for the agents. The system has to persist since saving lives depends on the system’s certainty of delivery but also on the system’s reliability, correctness and speed. An important facility is to adapt to changes in the task and environment. New agents can be involved in the system and these have to be considered by the system but also the task can change or several tasks can happen simultaneously. Actually, some characteristics in the environment can request a change of a mission. Agents can be closer to another target than the current tasked agents, which might request the agents to reconsider their missions. This might require re-tasking some of the agents. Hence, taking on other agents’ goal is important if these agents already have been assigned for a mission. Using only ground-level agents is not enough for keeping track of all the agents there are in a system, especially when the assignments for the agents change. Therefore, we need an overall structure that has insight in the agents’ position, task and goals.

The synchronisation of actions is the manner the agents are time-related [8]. Thus, the actions need to be performed in the right order and at the right moment. Synchronisation is to provide for coherence in the system and to prevent interference between actions. In a network, an event can cause agents to start operation [12], which we make use of in our system. The event can either be user-given or command from another agent. The agents can cause new events to take place, e.g., if the agent does not fulfil the task, it can command the next agent to start executing. Thus, as long as the agents are working with finding solutions, several agents are involved in the process. As mentioned in section 2, a benefit with spreading agents in a network is that they can work simultaneously and find solutions at lower computation costs. The computation cost is the most important factor in our work since the system needs to find solutions in a fast response time to support the users to respond quickly to an emergency. What is optimal in the MAS is, of course, in the eye of the beholder [7], and in our system it is best suitable service and the shortest time cost.

5 META-AGENTS

Meta-reasoning is reasoning about reasoning. When utilising the meta-reasoning facility in MAS, the system is able to reason about its operations [13]. This reasoning can be handled by meta-agents, which can decide the strategy for ground-level agents. In particular, the incorporation of a meta-level reasoning mechanism can handle individual agent organization, plan generation, task allocation, integration, and plan execution [14]. In our system, the meta-agents are developed from the intelligent agents, e.g. different services allocation of resources and the structure of the catchment area. These meta-agents record the structure of the agents together with their performances. For the catchment area, a meta-agent seldom contains only one intelligent agent’s actions, instead it comprise a chain of several possible actions of the agents performing a task. Some of the meta-agents in our system will also include the ground-level intelligent agents, i.e., the current status and accident position, involved in finding the optimal solution. From this information the meta-agents can plan the actions of the
agents to best perform the task. From this plan, the meta-agents can present the solution to the end-users but they can also be used to control the ground-level intelligent agents and their behaviour. A meta-level control can support the service vehicles moving towards the target by adapting the path of the service vehicles to the ground-level intelligent agents’ computation [15]. Accordingly, the meta-level agents resemble a horizontal layer on top of the ground-level agents. By the horizontal layer, the meta-level with a bounded computational overhead can allow complex structure of agents to solve problems more efficiently than current approaches in open dynamic multi-agent environments [6, 16]. The meta-agents can be used to provide the control over agents and collect the information from successfully performed agents but they also stop the execution of other agents when further execution is not needed. Meta-level agents at a horizontal level can avoid using the intelligent agents that have an unwanted path like running into an alley. It would be a catastrophe if the meta-level agents lead the service vehicles into dead-end streets in emergency situations.

For time computation, the meta-agent can only have one copy of an intelligent agent but one intelligent agent can be copied into several different meta-agents. The single copy in the meta-agent makes it unique, which supports parallelism in the computation. As long as the search carries on looking for goals, the meta-agents continuously are built up and grow. The system stops executing when the system has satisfied a goal or goals. The number of goals depends on the number of different services are required in the task.

By establishing unique meta-level agents it is possible to calculate the optimal path between two nodes in graphs [6]. Thus, calculating the optimal path through the graph involves producing several meta-agents over the ground-level agents’ performance, considering the nature of the agents and comparing the cost of the meta-agents. In our system, the meta-agents need to calculate an optimal path for each service. Thus, there will be just as many best paths as service vehicles needed for a task. The limitation is that the agents are not allowed to find and make use of the same vehicles if two different vehicles are needed. The need for several vehicles implies there may not be only one optimal path through the system unless the vehicles are found at the same place from the beginning.

The costs are the collected time it takes for the agents involved in the task of finding an optimal path for an appropriate service vehicle. The costs include static and dynamic constraints and obstacles that affect the path. Depending on the degree of difficulty of constraint or obstacle, the cost will be affected differently. High degree of impact gives high costs and vice versa.

Except planning, the meta-agents can support the system’s ability to reason about its operations. These meta-agents can reason with other meta-agents to solve tasks. The benefit with this facility is that the meta-agents can exchange information and switch tasks if it is needed. For example, if reinforcement is needed and a service vehicle can be exchanged by another vehicle that is closer, they can switch tasks. The meta-agents keep track of these vehicles and can suggest a switch to the end-user. However, the meta-agents are not allowed switching without supervision.

Moreover, by applying multi-agents we can utilise parallel computation both at the ground-level and the meta-level. To fully utilise the parallel facility, we duplicate the agents for each connection in the road, i.e., that has two or more computing agents waiting. The number of computing agents decides the number of duplicates. In this way, the system can continue to execute all the agents without needing to explore one at the time.

6 SCENARIO
To clarify the use of agents, we present a domain-based scenario that illustrates an application of agents in a multi-agent constellation with meta-agents. In this scenario, called case C a traffic accident needs response from an ambulance, A, rescue R, and police P. The accident, marked with a star has occurred in a crossing. Three vehicles (one rescue, ambulance and police) are to be dispatched for the accident. The agents, marked as dots, are invoked from the star to search for most suitable vehicles, see Figure 2.
We have a starting position based on the case C with x, y coordinates, the star, and we send out several agents each returning a value as they meet a suitable vehicle or service station. The user has to insert the positions for the accident and the type of accident. Then, the agents search for nearest services or services stations. Information about the location of these services and stations are provided by the system.

The ground-level agents start from the position and travel all possible ways from the accident to the available services. At each corner, new agents start running, this implies that the number of agents is equal to the number of roads that is possible to drive. This makes the ground-level agents unique and possible to distinguish from the others. Observe that the agents need to check that none of the roads are one-way roads. This is to check the roads while the agents are moving from the accident to the services but it is to check the opposite direction of the agents since the services will move to the accident.

When the agents are moving, they also collect environment information, which will be stored with the ground-level agent. This continues until the agent reaches a corner or a goal (i.e., particular service) and, thereby, built up the structure: <agent ID, road number, lanes (static), traffic (dynamic), start pos, goal pos>.

When the ground-level agents begin to execute, the first meta-agent is initiated, i.e., one meta-agent is initiated per each ground-level agent. These meta-agents collect the ground-level agents that had moved to end positions, e.g., hit the corner or a particular service. Hence, each meta-agent makes a copy of itself and then expands it with the new ground-level agent. This continues until the system has reached all the services needed for the accident. Each meta-agent ends up containing all the agents for a particular service, with the structure of <ground-level agent₁,... ground-level agentₙ>.

The meta-agents are reduced into a set only containing the agents that have been successful and which of the roads that were the fastest. As long as the system is executing, the agents are working. As the agents have found adjacent points that are representing suitable vehicles, the other agents are aborted.

Synchronisation of actions is, as mentioned above, important when several different services are involved in a situation. These services need to be synchronised to collect information about the different service forces to avoid misunderstandings and misuse of the services. It is a coordination of the facilities and the services provided to minimise sending redundant service facilities. For the case C, there are three different ambulances A, nearby. If only one of them is needed, i.e., possibility to take care of the injured person, only one of these should be activated.

The coordination between services, for example the equipment issue, needs to be considered. Basically, the equipment issue is to great extent stable, the ambulance for example has its regular equipment. However in specific emergencies, both extra equipment and/or extra personnel, as for example nurse anaesthetic, need to be included.

Handling these emergencies can be solved by meta-agents with the ability to select the ground-level agents that return the correct value based on the prerequisites of, e.g., anaesthetic nurse. Additionally, the meta-agents hold other case relevant information for coordination, and can check, for instance, if it is one or two accidents, based upon the geographical position. The meta-agents can also check the event code and, if possible, identification of persons involved. Furthermore, regarding the allocation of resources, the coordination of dispatch able resources also needs to be considered. A calculation and matching has to be made concerning equipment, e.g., which vehicle is most close to the hospital to collect the anaesthetic nurse. This is based on a match of the position and of the closest most suitable hospital or other health-care institution.

If for instance, in case C, the accident involves two cars of which one is on fire and two injured people and one choking. The emergence service needs two ambulances, one police and one rescue
car. The agents can find the closest police car and the closest rescue car, and then calculate which two of the ambulances have the equipment needed and are the fastest to the scene of the accident. Moreover, the agents need to keep track of possible accidents that can happen almost simultaneously. There are high accident rates at common places. Likely accidents can be problems at an elder home care centre. For the scenario, in Figure 2, there will be one optimal meta-agent for police with two ground-level agents, one to the corner from P and one from the corner to the accident. The structure is meta-agentP( <agent 1, road number, lanes (static), traffic (dynamic), start pos, goal pos>, <agent 2, road number, lanes (static), traffic (dynamic), start pos, goal pos>). There will also be one optimal meta-agent for rescue with three ground-level agents. Finally, for the ambulances there will be three different meta-agents, containing four, five or six ground-level agents. The system needs to compare the performance of these three meta-agents and decide which one are the best to dispatch.

These agents can be related to the work of knowledge-intensive mechanisms. On a meta-agent level, the control issue can be related to meta-level control architecture [16].

7 CONCLUSIONS AND FUTURE WORK
In this paper we have presented an approach towards using agents in multi-agent systems to streamline the emergency services and select the most appropriate emergency services for accidents. The contributions concern a multi-agent perspective grounded in the rich fieldwork in the domain of emergency services. Basically, we show a possible agent solution to handle services such as emergency calls. We present how the meta-agents structure is based, as well as, the coordination issues on agent and meta-agent level. The core issue concerns the connection of the emergency service centres. Where automation aspects most probably need to be extended, thus, avoiding risks with information overload and misinterpretations of information. In addition, we have addressed one of the core issues in emergency handling, that of allocating the best possible recourses. Included is the issue of coordinating the agents in supporting the coordination processes in the real-world domain of emergency handling.

In this paper, we have focused on allocating resources to the accident but not from the accident to the hospital. This is the next step in our research. Planning the best way depends on the classification of accident with the type of injuries and numbers of people injured. It also depends on the geographical position of accident, which is also the position of the vehicles, and the detachment and monitoring, i.e., sending and receiving information to and from the selected vehicles and monitoring the progress for possible occurrences.

Considering the MAS, the possibility of relating the detailed specification of environment to the service approach could be an interesting way to continue beyond the scope of this paper. In Weynes et al., (2007) [18] it is stated that the services are a part of the environment in MAS. The notion of environment in MAS is understood to some degree, however, not well defined. Parts of the definition are that “several classes of MAS use the environment as a means for agents to share information and coordinate their behaviour”. Furthermore researchers and engineers associate the environment with an amalgam of resources, services, infrastructures and so on. An interesting approach of using the multi-agents approach with meta-agents would be applying the meta-agents onto a service-oriented structure considering functional and non-functional requirements [19] since it could perhaps open new possibilities and questions, both from a MAS perspective as well as on a domain – business perspective.
8 REFERENCES


5 Functional versus non-functional requirements considered harmful

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Abstract - Requirement elicitation and requirement engineering are crucial steps in system design, implementation, and maintenance. In addressing software intensive distributed socio-technical systems such as trusted workflows in life-critical situations or information sharing support systems, we claim that the traditional division between functional and non-functional requirements is difficult and even harmful to maintain. We propose in this paper a more principled and context dependant approach towards requirement engineering and high-level system validation.

Keywords: Requirement elicitation, Requirement engineering, non-functional requirements

1 Introduction
We have during the last decade designed and implemented software intensive systems in the areas of distributed healthcare [16, 30, 31], critical infrastructures [17, 18, 23, 24, 25, 26], workflow support in life critical situations [4, 22, 39], and information sharing [38]. Lessons learned from those investigations are that a principled approach of requirement elicitation and requirement engineering is an important ingredient in designing, implementing, and maintaining trustworthy socio-technical systems. As a matter of fact, the most crucial requirements underpinning user acceptance and trust falls within what traditionally is termed non-functional requirements. A simple example, stakeholders involved in system specifications might have concerns related to information security (can be classified as a non-functional requirement). However, a mean to implement information security is to apply cryptography (a functional transformation of information). This coding is typically a result of applying an algorithm. That is, a nonfunctional requirement has in the design and implementation phase been transformed into a function (algorithm) that in turn has to compete with other algorithms for resources at runtime. Another important lesson that follows from this typical example is that we cannot focus on “an important class of functional requirements” when designing and implementing systems and hope to add other requirements as add-ons. All system-sensitive requirements have to be addressed properly from the outset of the system engineering efforts. We argue that the present classification of requirements into functional or non-functional requirements has at least the following shortcomings:

• Presupposes a fixed ontology of functional and non-functional requirements independent of stakeholders and context.
• Might focus on non-relevant issues found out at later stages of the system development process.
• Does not easily allow assessments of trade-offs between requirements.

These shortcomings might lead to focusing on wrong and/or non-important requirements while not detecting important requirements when designing and implementing trustworthy software-intensive systems. In short, we regard the current principle of distinguishing between functional and non-functional requirements as harmful much in the spirit of Dijkstra’s remarks on the harmful effects of...
using the GO TO statements in programming [8]. He argued that this “natural” programming style in fact produced programs that were difficult to validate and maintain. To remedy a similar perceived concern related to requirement engineering of systems we propose a configurable methodology supporting requirement elicitation and engineering based on a clear ontology and addressing related epistemological issues in a principled way. The remaining part of the paper is organized as follows. In Section 2 Background, we give a personal view of issues related to the concepts of functional and non-functional requirements including motivations and issues brought forward in literature. The section ends with a list of shortcomings related to the dichotomy of requirements. Those shortcomings are the starting points of our presentation in Section 3 Our approach towards quality assured system development. The paper ends with Section 4 Conclusions and further work and Section 5 References.

2 Background

The mathematical model of computing is the Turing machine from 1936 [34], later implemented using the von Neumann architecture that is mainly with us today [28]. That is, a computation is modelled as:

\[
\text{Computation} = \text{Algorithm} + \text{Abstract machine (1)}
\]

Equation (1) explicitly states the ontology related to computation. That is, \{Computation, Algorithm, Abstract machine\}. A natural set of epistemological issues is \{Development and performance of algorithms, Relations between Algorithms and Abstract machine\}. The von Neumann architecture of the programmable Turing Machine introduced the implementation ontology of \{Memory, Control unit, Arithmetic Logic Unit, Input, Output\} and corresponding epistemological issues. The algorithms were later implemented using suitable programming languages that could be interpreted or compiled into machine executable code. In fact, during the decades 1940’s to 1960’s the main efforts in computer science and later software engineering were devoted to defining suitable languages, programming methods and corresponding abstract machines and compilers for new classes of computations. The predominant classes of computations in the beginning were scientific computations (assembler, Fortran) and basic administrative computations (COBOL). The main difficulties addressed were to develop, implement, and maintain correct and efficient algorithms for batch computing in well understood application domains. That is, requirements related to the (implicit) ontology related to equation (1). Correctness of algorithms (doing the right thing) is of course an important requirement (later a functional requirement). At the same time efficiency (performance) is an additional requirement (sometimes later called a non-functional requirement) that could and should be measured. During the 1960’s we learned how to utilize trade-offs between algorithms and data structures to improve software engineering (doing the things right) as well as performance for certain classes of computations, e.g., real-time critical computations or data base applications. During the 1970’s new kinds of computations appeared such as distributed computing (client-server models), networking, and standalone knowledge intensive expert systems. In short new types of system requirements surfaced due to new kind of applications (not so well understood) and/or new models of connectivity where new kinds of end-users could get access to computing power (the PC and Macintosh). Needless to say, the early rather clear-cut division between functional and non-functional requirements became more blurred and several attempts were made to clarify the concepts. In fact as computation (programs) become embedded in applications serving a broader class of users new user related, system related, and business related requirements were added in a rather ad-hoc way. In principle the computational model, or ontology, behind (1) was not explicitly changed reflecting the new kinds of computations. The concepts of Users, Markets, Systems are evidently not parts of (1) nor corresponding epistemological issues from which we can derive models supporting, e.g., requirement engineering in a principled way.

& Techniques [21] from 2002, and Modeling Architectural Non Functional Requirements: From Use Case to Control Case [37] from 2006. In the first book there is still a sharp division between functional and non-functional requirements whence in the second book the author use the labeling of quality attributes to cover a broader spectrum of requirements. In this book there is also a more comprehensive view on requirement elicitation and on stakeholders. The paper that is specifically addressing nonfunctional requirements is focusing specifically on Use Cases to that end. In short, system requirement elicitation and engineering has during the last decades since long in practice surpassed the ontology focus of equation (1) above. In a paper [35] Urrego-Giraldo’s acknowledges the considerable work done in the field of Non-Functional requirements in the last ten years. Urrego-Giraldo’s own contribution to this discussion is an approach in the same direction as we propose, that is, aiming to integrate functional and non-functional requirements in the same analysis process. Similar attempts can be found in [19] where the authors argue that non-functional requirements is necessary to implement in the design process as early as possible, and in [6] where means of managing the impact on functional changes upon non-functional requirements are presented. There are four principal views of requirements, corresponding to the natural stakeholders developers, users, and owners, that is:

1. The (software) product view: Requirements related to the services that the product should achieve.
2. The (software) process view: Requirements on the process to achieve the proper product.
3. The end-user view: Requirements from the user to achieve user acceptance.

Furthermore, we have stakeholders representing regulators and infrastructure owners. Typically those stakeholders provide constraints on system use and performance. In the following we will focus on the first group of stakeholders. We argue that present day classifications of functional and non-functional requirements are not derived from concerns by stakeholders, but from rather ad-hoc assumptions that often mixes the concerns of the (implicit) stakeholders. The now classical division in functional and non-functional requirements has several shortcomings as a basis for a configurable and comprehensive methodology supporting requirement engineering of future software intensive and trustworthy distributed systems. A short list:

1. Ad hoc classification principles manifested by different types of classification schemas.
2. Implicit ordering of importance. Typically a “non-requirement” is of lesser importance than the basic “requirement”.
3. New requirements might appear late in the system development cycle.
4. Difficulties to assess trade-offs between requirements.
5. Difficulties to address proper validations or assessments of requirements.
6. Focus on validations of requirement documents rather than assessments on a systemic level.

In the next section we present our approach of requirements elicitation and engineering to remedy some of those shortcomings.

**Our approach towards quality assured system development**

Our starting point for a principled approach of requirement acquisition and requirement engineering are identifying concerns by stakeholders. That is owners, developers, and users. The epistemological issues are related to which concerns we can gain knowledge about and validate of the socio-technical-economic system at hand. Ontological issues underpins the modeling we need to support requirement elicitation and requirement engineering. We propose a service-oriented view of socio-technological-economic systems [4, 5, 11, 12, 13, 14, 15, 17, 22, 38, 39]. A system provides a set of services that are used to carry out a (general) business purpose. System components typically consist of hardware, software, data, and workers. Systems are specified by the services they provide along with other requirements such as reliability or low cost of ownership. A system design consists of specifying
components, their attributes, and their relationships.

3.1 Ontological and epistemological frameworks

Our starting point is the CommonKADS configurable methodology that supports design and maintenance of knowledge intensive systems [1, 33]. The methodology focuses on the type of applications we are targeting; we can then configure the methodology accordingly. As a starting point of this configuration, we decide about the relevant worldview, that is, the relevant epistemology and ontology for the system at hand. Epistemological issues have two dimensions. Internal epistemology related to what the system should be able to know about itself and/or its environment. External epistemology related to what a user and/or maintainer should know about the system. In short, the internal instrumentation determines the abilities of self* services, whence the external instrumentation determines the user views of the systems as well as the possibilities of the system administrator to control and support proper system behaviour. The targeting of the worldview towards the goal system (the “Common-KADS pyramid”) includes choices of appropriate theories, methods, and tools to support the engineering of the system at hand. In fact, the Methodological pyramid of Figure 1 replaces equation (1) above as the notation of: software intensive socio-technological-economic systems as the goal system (2) The corresponding identification of ontologies and epistemic issues are parts of our configurable methodology (Section 3.2).

![Figure 1 The CommonKADS methodology pyramid. The main product components and processes of the methodology are indicated](image)

The CommonKADS methodology leaves open the implementation process as such but advocates implementations of rule bases since the original methodology aimed at stand alone, or well separated, knowledge systems. The use of a model based as well as a risk driven approach to system development makes CommonKADS the methodology of choice (configurable and comprehensive) in development of knowledge intensive systems [32, 33, 31, 34]. The second source of our methodology is the IEEE standard 1471-20002 that addresses the activities of the creation, analysis, and sustainability of architectures of software-intensive systems, and the recording of such architectures in terms of architectural descriptions. The IEEE conceptual model includes: Mission, Environment, System, Architecture, Stakeholders, Architectural description, Rationale, Concerns, Viewpoint, View, Library viewpoint, and Model with relations. The standard enforces a principled way of designing suitable architectures.

3.2 A configurable methodology supporting requirement elicitation and engineering

The main activities in the initial phases of our methodology are (c.f., Figure 1):

- Identification of the goal system and worldview including ontologies.
- Identification of stakeholders, their roles and needed competences.
- Identifications of concerns by the stakeholders individually and systemic concerns.
- Identifications of epistemological issues supporting analysis and modeling of concerns.
- Identifications of requirements related to concerns as well as ontologies and epistemologies supporting elicitation, engineering, assessments, and validation of measures ensuring system behaviour respecting concerns.
- Instantiation of the methodology supporting system requirements engineering, design, implementation and maintenance based on the generalised CommonKADS methodology and the IEEE standard.

We now shortly address issues related to identification of stakeholders concerns. We have developed a trust model to support design and maintenance of trustworthy systems, or rather, trustworthy computer artifact mediated services (e-services), [30, 31]. The model was developed and partly implemented in a project on trust in e-services in distributed health care [16]. Our specific concern in that setting was trusted delegation of tasks and proper system support to that end. The following Figure 2 captures the main components of our trust model. The bottom line in our trust model is that potential users of the offered service express their trust concerns related to whether to use the service or not. Those concerns are then classified into different information types [2, 7]. A goal of designing and implementing trustworthy systems is to identify and implement mechanisms that can be communicated to the user via signs in a way that reflects her specific concerns regarding using the service at hand, that is, assessments whether or not the stakeholders concerns have been adequately addressed. In all our applications several trust concerns related to information management have emerged. Typically, those trust concerns addresses one or more of the following issues:

- Adequacy and integrity of information. Do we have the information we need and can we trust it?
- Non-disclosure of information. Is the information protected from non-intended use?
- Availability of information. Will I get the right information at the right time?
- Common situation awareness. Have we all the same situation assessment for appropriate actions to fulfill the mission?
- Breakdowns. What happens if something goes wrong? Can I be accountable or liable?
- Traceability. Can my actions be recorded by the system? A blessing and a threat!

The first three concerns a commonly referred to as the CIA (Confidentiality – Integrity – Availability) concerns of information security and is in focus of information security engineering. However most of those contemporary efforts and solutions are context independent whence we emphasize the importance of the mission context to allow for customized solutions [17, 18, 25, 26]. The last three trust concerns mentioned above have, however, very little attention in R&D efforts at the moment. This is partly due to fact that the rapid emergency of new application areas, based on computer-enabled interaction between groups in missions, does not have a clear research agenda at the moment. The purpose of this paper is to outline some important steps to that end. Since trustworthiness is a decision by the user, based on assessing relevant information, a challenge is to convey the information that the system indeed meets the concerns articulated by the user by communicating appropriate signs conveying the right information [24, 26, 30, 31].
Figures 2 and 3 highlights the importance of context dependant communication of information in designing and maintaining trustworthy systems, or rather services [2, 7, 27]. The outcome of the assessment clearly depends on the context in which the service will be used and how well the interpretation of signs meets the trust concerns. We thus have to investigate the anatomy of information, language and communication in order to design and maintain trustworthy information management agents. These issues have been addressed in several recent thesis works published by our research group [4, 10, 22, 24, 38, 39].

3.3 Requirement engineering of information centric critical systems

The main activities of our requirements elicitation and engineering methodology are as follows:

1. Identification of work practices
2. Identification of workflows
3. Identification of supporting services to workflows
4. Configuration of workflow services and supporting middleware services in a Service Oriented Architecture
5. Configuration of Service Level Agreements to support coordinate and to monitor execution of services
6. Configuration of mission oriented applications

Figure 3 illustrates the use of Environment models (organization, tasks, agents) of workflows and the mapping (Model Based Design) onto the SOA architecture. The Coordination model and Communication model constitute the interfaces (protocols and data models) to be agreed upon and maintained by the SLAs (Service Level Agreements). The output from the activities are: (1) Identification of work practices and (2) Identification of workflows are input to activities related to Figure 3. That is, (3) Identification of supporting services to workflows, (4) Configuration of workflow services and supporting middleware services in a Service Oriented Architecture, and (5) Configuration of Service Level Agreements to support coordination, monitoring, and execution of services.
The set of models supporting high-level requirement engineering of services and corresponding SLAs supports Model Driven Development (MDD) of software systems [9]. Similar ideas can also be found in efforts on Meta-Model based approaches to information system engineering [36]. Service level agreements are in focus of several ongoing Grid projects. A generic reference is CoreGrid5. Complementary work based on web services are conducted by the W3C consortium specifically on web services activities and coordination6. The workflow support are mostly focused on issues related to Business Process Execution Language for web services (BPEL4WS). In our approach we have to address a richer SLA context (Figure 3) than the Grid or W3C efforts that focus more on a bottom-up approach. Furthermore, agent enabled coordination enables also a more flexible and intelligent SLA management, e.g., supporting self healing of missions [14]. We have focused our R&D on dependable and secure socio-technical systems (information-centric MAS) on protecting system, and specifically software, execution. To that end we have developed tools and methods of experimental online engineering supporting design, implementation and maintenance of dependable systems. There are four different types of interfaces to the system [10, 11, 18, 24, 25, 26]:

- Support for experiment set up, execution, monitoring, and evaluation
- Support for configuration and maintenance of missions
- Support and monitoring of the entire system
- Support for different views of the system by different users and user groups

In our methodology the mission is first modeled and partially implemented articulating the dependability issues at hand. The relevant inspection points supporting monitoring of dependability aspects are identified and properly instrumented. The behaviour of the system is observed and assessed. Proper steps for the next development cycle are identified (risk based evaluation) constitute the requirements for the next cycle.

### 3.4 Validations of requirements

We are addressing different views and concerns on socio-economic-technical systems exemplified in Section 1. The concerns related to the socio-aspects can be summarize as trustworthy support of workflows, whence the economic concerns are focusing on the economy of service oriented business processes related to in- and outsourcing of services and maintenance and new businesses. The concerns related to the technical systems are related to dependable and resilient system behaviour. We have outlined how we can translate the different concerns into system requirements highlighted in Figures 2, and 3. Figure 3 depicts also the architecture for our validation experiments. In the experiments and validations different operationalisation of the SLA component of Figure 3 are implemented. As we earlier have noted is the SLA component the bridge between the high-level workflow support and the low-level system services. In effect we have the following main types of
validations:

1. Validation of requirement engineering. Are the concerns related to workflows properly captured and captured into SLA and supporting services?
2. Validation of business processes. What is the core services underpinning the business processes? What are the trade-off between in- outsourcing of services in maintenance our creating new business processes (new services)?
3. Validation of dependable and resilient system behaviour of software intensive systems!

Validations of the approach outlined in this paper are addressed in the thesis works of Patrik Brandt, Jenny Lundberg, Per Mellstrand, Christer Rindebäck, and Louise Östlund [4, 22, 24, 31, 39]. Validations of proposed workflows against ethnographical findings are specifically addressed in [22]. Identification of workflows at new Call Centres is particularly addressed by [4, 39]. The role of situation semantics and mapping on services are in focus of [4], whence aspects of core business services and issues of in-sourcing and out-sourcing and maintaining team competence are in focus of [39]. Models and techniques supporting design and maintenance of trustworthy services are in focus of [31]. Experimental support and methodologies supporting validation of trustworthy execution environments of software intensive systems is addressed in [24].

4 Conclusions and further work

We have presented a configurable methodology supporting the whole life cycle of dependable network enabled systems. We have specifically addressed requirement elicitation and requirement engineering for software intensive information centric systems supporting trustworthy workflows in critical situations. The methodology is supported by a set of models and tools as well as environments supporting simulations and experiments. The architecture of the methodology can be expressed using IEEE standards. Furthermore our methodology allows imports of technologies such as agent technologies at appropriate places of the system life cycle. In the paper we have focused on identified shortcomings of present day requirement engineering models, that is requirement engineering and implementation of trustworthy service oriented systems. Our configurable methodological approach involves proper choices of methods, models and techniques as exemplified in the paper. The models (meta models) are the results of the requirement process and input to the design and implementation phases. A key component is the Service Level Agreement (SLA). The SLA implements functional aspects of the requirements onto services but also provides means supporting non-functional aspects of the system. Agent technologies plays important roles at different stages of the development processes:

- During requirement analysis the high-level multi agent modeling supports the ethnographical and information centric analysis of work processes.
- The requirements and design of SLAs benefits from techniques and models from architectures and models from MAS, that is agent capabilities and coordination models.
- Design of services again uses selected models and techniques from MAS.

The work reported in the paper is naturally on work in progress. Our focus is now on the requirement engineering processes and on validation challenges, not the least on trust aspects, semantics and self-healing.

5 References


Abstract
An upcoming change of technological platform opens possibilities for the emergency community to find new ways of handling emergency calls. Instead of seeing the emergency centres as 20 more or less isolated centres, the centres can be networked into a big centre, nationwide operator cooperation. Enabling the operators to share resources and spread the workload between the centres. In this paper I will examine how emergency calls are handled today using second generation of Activity theory as analytical tool. I will use third generation of activity system to analyse possibilities of handling the calls nationwide. Concluding, I will use descriptions of how an emergency call is handled, and apply implications to the case, containing issues for nationwide cooperation. The conclusion of this paper is that I have used second-generation activity theory as an analytical tool, made design implications using third generation activity theory, and try to confirm the implication by using a real world case as analytical frame. This has been done to ground them in the ongoing everyday work of the operators, but not to restrict the implications to the current technology in use. This leading to implications on how to reflect upon issues for designing new technology suiting the need of the user, an active participant in the community of emergency handling.

Keywords: Emergency calls, operators, centres, heart-lung-rescue case, activity theory

1. Introduction
Changes occur for different reasons, in the technology we use, in our work places, in our everyday life, in our communities. In high technology dependent work places changes in technology can have profound impact on the work. The users of the technology have to cope with the changes, changes have always been here, and are here to stay. Changes can improve or make worse the handling of the tasks at hand, enabling a workflow, or force the users to create workarounds. (Bowers et. Al, 1995, pp55-61) Many attempts have been made (Greenbaum, Kyng, Design at work, 1991), (Karasti, 2001, pp211-246) just to mention a few. Still, the issue of how to design new technology suiting the needs of the user is important. One way to get to the design is to find implications, bridging the work practice into new design. Therefore, the research question in this article is:

What design implications need to be taken under consideration changing the operators’ task from handling local emergency calls to handle nationwide calls in centre-to-centre constellation.

The workplace the Swedish Emergency Service Centres (SOS centre) is high dependent on technology, basically meaning the dispatch system with information, communication and documentation support for distributed and mobile units. The SOS centres are about to change their technological platform. This change will impact the operators’ work of handling emergency calls hopefully in a positive way.

3 Methods
The methods of data collection used in this paper are field studies, ethnographic studies made for collecting case relevant information, discussions and interviews with operators and PD methods. The studies have taken place in five different emergency service centres in Sweden. Basically consisting of listening to and observing how emergency operators handle emergency calls. Field studies have also been made at one Swedish Ambulance Unit including studies in dispatched ambulances
(Mobitex technology in use – status and priority, Lundberg, 2002). Three workshops with operators have taken place. The time spent at the different sites and on analysis of the data is ongoing and started over two years ago.

4 Swedish emergency service centre

There are 20 emergency service centres in Sweden, with the main duty of handling emergency calls. A majority of the centres are responsible for dispatching ambulances, informing rescue service and police. The computer system in use the CoordCom, are a digital form based system, enabling the operators to choose and display the information, the action plan, the dispatchable units, the ongoing events etc. A computerized map, presenting the current geographical position of the vehicles available, also complements the system. Paper documents in different types and forms, such as the medical index, the event plans, the paper maps etc are some of the tools that the operators use to perform their tasks.

4.1 Change of technological platform in SOS, and future development

Today the SOS centres handle the emergency calls in their area of responsibility quite independent. Cooperation between centres is mainly made when handling occasional overflow calls. Basically this means that in case of huge amounts of calls to one centre, due to bigger emergencies or catastrophes, another centre can take over the calls that the operators doesn’t have time to answer, the overflow calls. The centre handling the overflow calls select the calls that could turn into cases, and return them to the original centre. There is an ongoing change of the technological platform. One of the main reasons for the change of technological platform at the 20 SOS centres is an estimated lack of spare parts in the future. There is also a desire to work closer between the centres, to extend the cooperation for sharing of resources between centres, like higher medical expertise, or to include dispatch in the handling of overflow calls. In this article I will focus on the issue of including dispatch in the sharing of resources between centres, this opens the issue of statuses, i.e. meaning what operator at which centre that have time to handle the dispatch.

2.2 Handling emergency calls

The handling of emergency calls, and how the computer support is used in the centres are operator individual and case specific. Tough patterns of how the operators’ behaviours handling the calls, and characteristics of the calls can be revealed. To capture both how emergency calls generally is handled and the specifics of how one call is handled I present both a general description and a case specific description of emergency call handling. I will start with the general, divided into the answering and categorizing of the call, the responding and division of labour, and finally the monitoring and updating of the call. Following that, the specific heart-lung-rescue case is presented.

The answering and categorizing of the call: The emergency call has come into the centre, the beep, indicating that it is an emergency call is heard from the CoordCom system and the visual representation appears on the screen. The operator selects and highlights the call in the queue, pushes the answering button and answers the call.

1 An ongoing project, NOVA 2005, aiming to change the technological platform
2 The centres have different version of the system, and the systems functionality differs between the centres, such as the receiving of Mobitex statuses.
- SOS one, one, two, what is your emergency?

The operator types the emergency event and does a request for the address, checks the address with the caller, id-number, and categorizes the call into an event code. In this dynamic ongoing discussion with the caller, the operator uses the computerized forms to structure the written test, the medical index in paper as a support for categorizing the event, the phone number for the search in the address database, and the event code system in the computer support for the event code. The other operators present in the room or other staff reachable through the system are also used as a support for the decision-making and categorization of the operator.

The responding and division of labour: For the resources to be sent, the dispatching operator uses the categorizations made and searches for the most suitable units for the case. Suiting both to the priority of the case, the action plan and to the geographical state of the dispatchable units. The operators use the paper maps, the computerized map and different forms in the computer, such as the available units form. If there are several different vehicles to dispatch there often are different operators working with the case.

The monitoring and updating: As the units are assigned for the case, the operators take the role of monitoring the case. They receive statuses from the vehicles and answers calls made from the units. The calls often concern geographical or coordinative issues. If the resources in the case are sufficient, meeting the case needs and are not re-dispatched for another case, the case is closed as the dispatched units signs off the case after completing their assignments.

3 Introducing Activity theory

The activity theory basically consists of a triangular model, structuring a human activity system. To be clear about how I intend to use the triangular model, I will use a few lines from Gordon: “The main point I am trying to emphasize here is that the purpose of any model is to serve as a tool or instrument of scientific investigation. … The real test of a model, however, is whether it works effectively as a scientific instrument, not to the degree to which it replicates the real world.” (Gordon, 1991, p100-110) In using the activity theory, for modeling the emergency operators activities handling emergency calls, the triangular model is a tool of analysis, not a replication of the real world. The model of the second-generation activity system is used as a tool analysing how the operators are working today. The third generation of activity system are used for modelling how handling of emergency calls could be done with the new technological platform, focusing on issues for design. Furthermore, the use of the activity systems are not to be seen as modelling activities of emergency operators using all activities in the handling of the emergency calls, neither do I claim to have used the second and third generation of activity theory to fully extent, I have just touched upon it. There is more to be explored using activity theory in emergency settings.

3.1 Activity theory

In this paper I use activity theory to analyse how operators work today and how changes in technology and community could change the operators work. Engeström (1996, p131-135) makes a description of the development of activity theory, starting with the Russian psychologists Vygotsky, Leont’ev and Luria. They initiated the cultural-historical activity theory in the 1920s and 1930s. In the evolution of the activity theory, upon which developmental work research is built, three theoretical generations can be discerned. In this paper the second and third generation is used. The second generation basically centres round a model of a collective activity system, the third generation has developed conceptual tools in order to understand dialogue, multiple perspectives and networks of interacting activity systems. The model of the third generation is expanded to include minimally two systems, interacting via a potentially shared constructed object.
3.2 Using second generation activity system for current handling of emergency calls

Basically, the second generation of activity systems uses six nodes, the tools, the subject, the rules, the community, the division of labour and the object that is the outcome.

In SOS, one of the outcomes is the handling of emergency calls. In the handling of emergency calls, the subject, the operator is the one deciding if the incoming call is an emergency call or not. If the operator categorizes the call as an emergency call he or she use the tools such as the computer system as a support in handling the call, categorizing and documenting the call. In working with the call, the operator has different rules, such as categorization rules, which medical advice they can give, which vehicle to dispatch. As the operator has categorized a case, according to the categorization system, he or she have to follow the medical index in giving medical advice, and when using the event plan for dispatching vehicles he or she has to select the vehicle most available for the case. The community is in basically the operators working in the centre, but the ground service, i.e. the paramedics, rescuing teams and police are to some extent part of the community. The ground service belong to the community since an involvement of them is vital in handling an emergency call that needs response concerning health, rescue or police issues. The division of labour are partly formalized and even

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DWR is an educational research paradigm where educational institutes are work places
implemented in the computer system (creating case, listening-in functionality) and the most evident division of labour is the answering-dispatching operator constellation.

3.3 Using third generation activity system for design implications

In the third generation of activity system, the triangles of the second-generation activity system meets via the network connections, the shared constructed object. The tool for handling the emergency calls, the computer system, would then extend the centres as to become a more nation wide centre. The implemented technological platform could then be seen as the platform for communities of emergency, sharing technology, one big community with the same goal, handling emergencies. But connecting centres demands some work of setting trials for information that has to be exchanged, otherwise it is hard for communication, coordination etc. to take place. The space of information flow needs to be crossed by means of concrete trails between places. (Engeström et Al, 2001, p47)

![Figure 2. Third generation activity system, the main relation between the triangles](image)

Using the activity system, what would change due to the new technological platform are the tools, the rules, the community and the division of labour. The object and subject would stay basically the same. I will make an attempt to analyse how it could look like, modelling with two centres, centre A and centre B. The tools, specifically the computer support and main system, would be more networked than today. Using networked computers and the web as a means of information sharing opens up possibilities of cooperation, sharing of databases opens up even more possibilities.

If for example operators at centre A would have to dispatch vehicles in centre B’s area of responsibility, the tools that the operators at centre B uses to handle the calls had to be available for operators at centre A. Basically operator at centre A would have to have all the dispatch plans with numbers to the ground service, the maps, the units etc, covering the geographical area of response for centre B. But what would be gained from this if the dispatch of vehicles were just transferred from the local centre to another non-local centre? Just changing geographical area would probably be of no specific gain. To analyse this further, seeing how the centres could handle the calls in a more sophisticated way, gaining the extra of having the capacity of evolving the least busy operator, in a capacity of operators at 20 centres, the issue of division of labour has to be taken in consideration.

If operators at centre A informed operators at centre B that he or she was available for work, then operator at centre B could specifically ask the operator at centre A for assistance, perhaps the operator with special competence in handling the emergency. If we take the same situation but turn it, if operators at centre B would ask for assistance they would probably also need some response from centre A, since centre A could have an overload also. This raises the question of some sort of status indicator at the centres. The centres showing how busy they are at the moment, so the overloaded centre could choose a centre that is not that busy, or at the operators level, the most available operator with specific competence. This raises the question of when is a centre or an operator is busy? An easy way of measuring how busy the centre are could be how many emergency calls they handle.
But the amounts of emergency calls are not always an indication of how busy a centre is, since there are differences in how long emergency calls take to handle. Often, the emergency calls are false calls, a person dialling the wrong number, aware or unaware of it, and these calls are selected as non-emergencies. Other emergency calls, occupy operators for quite a long time, with several issues to be taken care of. Ways of measuring how busy the centres are could be, how many emergency calls they answers, how many ongoing emergency calls they are handling at the moment, and how many ongoing dispatches there are.

Focusing on the division of labour, operators could share one case, sitting on two different centres. This networked cooperation would pose the question of articulation work, shared material. If the operators were divided into competence or interest groups, operators most interested in or with specific competence in could subscribe to get the ongoing calls of interest, i.e. the ambulance cases or the rescue service cases.

The rules for handling the calls would probably be the same rules as today, the call has to be answered within 10 seconds, one operator has to be case responsible, etc. The responsibility issue has to be taken under extra consideration if several calls concerning one and the same case are answered in different centres. As it is today, often the operators first answering the call gets case responsibility. This means that the other calls are “associated” to the first call. Minimizing the risk of dispatching too many vehicles for one accident, assuming that there were several accidents. Today the operators overhear each other in the centre, and the operators saying aloud in the centre, “it’s my case”, or “I’ve got it”. In a networked cooperation this actions would not make sense, and the computer support should have to mediate the geographical information about the incoming calls.

3.4 The Heart-lung-rescue case

This case is about an old man that probably has got a heart attack and is in need of an ambulance for treatment in hospital. The incoming call is answered by receiving operator (RO) she does the first conversation with the caller. The caller is the son of the unconscious 83-year-old man.

1 RO SOS 112
2 HS Yes hello, my name is Lars Persson
3 RO Hello
4 HS I could need an ambulance
5 RO Yes, what is your emergency?
6 HS It is my father, he has fallen (HS exhale)
7 RO He has fallen, yes.
8 HS (unhearable) he, went to the basement, yes I heard a bump you know…
9 RO Have he fallen from the cellar stairs?

Translation of conversation, the original conversation was in Swedish

All personal identifiable information is changed, such as name and address.
10 HS No, probably he has got a heart attack or something like that
11 RO Aha, is he awake?
12 HS No, he is unconscious.

In this first section of conversation RO are trying to state what is the caller’s emergency. As this is going on, RO simultaneously categorises the case, typing in the event type for the event code, M1.23. The M is for an event with a person involved, the 1 is the priority for the case, the highest priority, meaning acute case, and event type 23 means unconscious. RO sends the position to the address over to the computerized map system, and the exact location of the house has got an X, Y coordinate position, visualized on the computerized map system. Meanwhile, the dispatching operator (DO) (physically located sitting next to RO) starts to work with the case, opening the event plan for the case, searches for the most available ambulance and dispatches the ambulance X967, marking with an x in the event plan that this is made. She puts a time surveillance on the ambulance to make sure that the paramedics receives to the case. If not, the system will remind her that they haven’t answered. Meanwhile RO continues the conversation, makes sure that the old man are breathing and enters his name. Checks the phone number and address (visible from the address database) and gets a narrow road description of how to get to the house. She asks for which road is the best road to take according to the son, since there are at least two different ways for the paramedics to get to the house. The close road descriptions are of vital importance since this address is situated on the country, with small roads and houses that can be hard to find. The son says that his father doesn’t breathe and RO starts to prepare the son for a mouth-to-mouth rescue. She types the comments, fallen, doesn’t breathe, HLR in the system and DO sends a mobitex message to the paramedics. As ambulance X967 has acknowledged the case, Do dispatches the second ambulance for the case, X992 marking the dispatch in the event plan. At this time RO is initiating a HLR for the old man.

6 Event plan, is the plan based on the event code that the is presented in the CoordCom system
7 Mobitex, data sent to the paramedics via Mobitex system, case relevant information is sent such as the position of the person in need of help
RO Can you put your ear next to, and listen if you hear him breathe and look at his breathe?
HS No, it is bad with that…
RO If you now try to blow down… if you yourself take a deep breath and put your lips over his, and then blow down two times…and you have to squeeze the nostrils too…
HS Yes
RO Have you squeezed the nostrils?
HS Yes I did that yes
RO … and then you do two hard in blows almost as blowing up a balloon
HS (silence)
RO Have you done that?
HS Yes we try (silence approx. 80 sec, you can hear that he does the mouth-to-mouth method
RO Yes, can you see if the chest rises now?
HS Yes, little he did… he has a wheezy chest
RO It does …and… if you then, because then we have to do some conclusions. Has he got something on, has he got a shirt or something?
HS Yes, he has a t-shirt
RO Yes, can you pull it up?
HS (rustle)
RO … and then you have to stand on your knees then, close to the chest…
HS Yes
RO put your hands on top of each other on his chest
HS yes
RO in the middle between his nipples
HS yes
RO and push powerfully down with straight arms and pull up again fifteen times in a row
HS yes
RO … and then you count, one-and-two-and-three fifteen times, one-and-two-and-three
HS (rustle in 30 sec)
RO (here you can faintly hear breathings and that RO talk with paramedics on the dispatched ambulances. ”Could you interpret the address?” RO asks the paramedics, after the position has been sent)
8 Medical, meaning heart conclusions
HS Yes
RO Yes, that is good work
HS Yes
RO Can you see if, is his chest raising?
HS No
RO So we continue, it is two blows again. First you have to make sure that you have taken a big breath
HS (sound of deep inhalation)
RO It is good, really good
HS Now the chest have risen again
RO Good, then it is 15 pushes again
HS (rustle 40 sec + beeps from the phone) hold
RO Yes, you are very good, is it hard?
HS Yes (unhearable) phone
RO Yes, now you have done the conclusion again and then you continue. I am with you all the time
HS Yes, I have to put my phone down…
RO Yes I am with you all the time
HS (rustle, breathing, the man speaks in the room)
RO (talking with DO, does 67 know where to go? … yes can you connect them? It is Sjömå halt, towards Tranå, a sign to the right where it is a yellow house (paramedics talk is heard in the background)
HS Here comes my sister here
RO Yes, that sounds great now when there are the two of you, she can take over while you are resting
HS Yes
RO Because then you can help each other then, if one of you blow and the other pushes
HS Yes she is a nurse
RO They are approaching now the paramedics
HS Yes, I can go outside…
RO I don’t think so … does she do anything now?
HS She goes
RO Now you have been working so well…
HS Go!
As RO has got the road descriptions, she starts to give the son advices on how to perform mouth-to-mouth rescue, and how to do heart-conclusions. RO asks DO to call the paramedics dispatched in the case. On row 128-129 and on row 149-151 DO is talking to the paramedics active in the case. Orally she gives the closer road descriptions to the team in ambulance X967 and to the second ambulance that has some difficulties in finding the way. RO continues the HLR and the daughter to the 83 year-old has arrived and assists the son in making heart-lung rescue, simultaneously one of them does the inhalation and one the heart massage. The ambulance arrives and probably continues with the rescue. Unfortunately operators involved in the case assume that the old man died despite the attempts to rescue him. A heart attach at his age can be life threatening.

3.4.1 Case analysis

This case is an emergency case, the operators involved in the case has to react and respond quickly, selecting and dispatching units. AO doesn’t type extra road descriptions into the system to the paramedics, sending them to the paramedics, instead she asks the DO to call the units up so she can give them the descriptions orally. Reasons for this can be that she is in the middle of giving HLR advices, making the calculation that talking with the paramedics would save more time in the effort of getting the ambulance to the old man, than typing in extra road descriptions. When having addresses on in the country, which the paramedics perhaps have not been on before, the operators give extra road descriptions. To avoid misinterpretations, the operators usually types short, if the road descriptions are long, the typing takes time, and so does the reading and interpretation for the paramedics. Calling the paramedics gives them the opportunity to ask for extra road information, perhaps being connected to the caller, getting other important information about the case.

3.5 Conclusion

In this paper attempts has been made to give insights to the question of implications for design of new technology suiting the needs of the user. For doing this, the focus is on a specific community, the emergency community. The use of ethnographical methods for data collection, presented general and case specific data, and use activity theory for analysis. The second generation for analyzing how they work today, and third generation for analyzing implications to be taken under consideration in design. If the implications would lead to a usable design of technology suiting the operator, is another question, of importance though.

9 Always at least two paramedics for a case, one driving and one taking care of the person in need of help
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ABSTRACT

In this paper we describe The Pond, a system used to search for and visualize data elements on an engaging tabletop display. The Pond uses methods of unencumbered interaction and audio feedback to allow users to investigate data elements, and supports shoulder-to-shoulder collaboration with the physical Pond artifact mediating the collaboration between those people gathered around it. The user interface is based on an ecosystem metaphor, presenting data elements in the form of shoals of aquatic creatures inside a virtual 3D pond. The Pond is an interactive system offering an appealing and novel way to search for and interchange information. We describe the motivation and design choices behind The Pond, the system as it stands today, details of its implementation, and observations from a study of The Pond in use.

Keywords Database, visualization, searching, virtual environment.

1. INTRODUCTION

The constantly increasing amount of information and media available in electronic form leads to a growing demand for new methods for searching and browsing. Traditional text based database queries can be limiting, requiring a user to know exactly what it is she is looking for, and rely on the use of a standard computer interface, typically that of a mouse and keyboard. Furthermore, most computer applications written today are single user applications. Systems that support group collaboration are traditionally run on multiple workstations communicating across a network. In The Pond design we have moved away from the conventional desktop metaphor and established notions of how information systems should be accessed and manipulated. Instead we have made an attempt to build a tool that is easy and intuitive to manage, and exciting and beautiful to experience. The Pond is a desk-based display system that can be used by several users to search for data elements in some information set, e.g., on the Web. It presents the search results and allows user interactions via a graphical and aural user interface. One intention with The Pond is to support co-operation on equal terms around a single display. The Pond is designed to be more fun and social in its use than precise and analytical.

2. MOTIVATION

The work on The Pond draws heavily on two earlier locally developed systems, and concepts and experiences can be traced back to these systems. The Web Planetarium, a three-dimensional interpretation of HTML structures in the form of a graph [18], and the Library Demonstrator, an information landscape constructed from the contents of an online library database [8], were both interfaces to active online information. Common features of these systems were the spatial arrangement of data elements, navigation around these data elements and the introduction of new data elements into the display.

While these systems were successful in presenting information to end users, they were not necessarily easy to use. When using the Web Planetarium new information was only introduced as a result of
explicit interaction (clicking) by the user and novice users could be too shy to discover this fact and not load new information. The positioning of this new data could also be problematic. In the Planetarium the user must be observant otherwise she may miss the introduction of the new data element. The Library addressed this problem using animation and self organizing models to show the emerging relationships between information, and it is this approach we build upon in The Pond with its shoal metaphor. Navigation around the data used a point and click method, automatically transporting the user to (or close to) the selected object. The core of this navigation technique was to adopt an object centric philosophy where users were explicitly freed from the overhead of having to manage their navigation and movement in three dimensions. This restriction of the overall freedom of movement meant that users were able to focus on the exploration of the information space. However, users still had problems navigating the structures. It could range from getting completely lost to not being able to look upon the data in the way they wanted. These systems were also subject to single user interactions and did not encourage a social atmosphere for the exchange of gathered information.

When we started the work on The Pond, the objective was to design a multimedia user interface where users without any prior knowledge or acquired competence should be able to easily handle both single as well as groups of objects in an affordable and easy way. The objects in turn should be able to represent any type of information or media. They should be able to present themselves in a natural fashion at the users convenience. Also, they should disappear in non-obtrusive fashion when no longer needed. The user should be able to select, move, sort and explore objects of interest without having to confront the rigid hierarchy that is the hallmark of traditional file handling and database applications. Instead of using colour, form or position to indicate group or class membership we wanted to use motion dynamics of objects to indicate these properties. If new information is requested, objects should just float to the surface. Objects no longer relevant should slowly sink to the bottom and quietly disappear. The viewpoint stays fixed above the pond surface. In this way we would achieve a function that did not require the users themselves to navigate.

An observation made early in the design process was the difference in the behaviour of users when confronted with a horizontally placed display vis-à-vis a vertically placed one. When a group of people gathers in front of a vertically placed display – be it a big screen TV or a wall projection – immediately a somewhat authorial situation tends to develop. The person in control of the display content is perceived as a teacher or lecturer. The rest of the group will play the role of an audience or school class. When, on the other hand, the display or projection area is positioned horizontally people will gather on a more equal basis. With inspiration from as disparate sources as roulette tables, billiard tables and the military’s “classical” tactical war gaming board it was decided that The Pond should use a horizontal display and that none of the sides of the physical artifact should be more important than any of the others.

3. RELATED WORK
Tabletop displays have been in use for a number of years now, for example in visualizing information [16], for command and control scenarios [11] and augmenting physical objects [15]. The table provides a natural centre for interaction to take place around and encourages collaboration between the users while they are interacting with the table [2]. The developments in plasma display technology coupled with touch sensitive surfaces now make it possible to dispense with potentially clumsy projected displays in favor of a neat, compact display. Interaction with The Pond is object based, using physical tags to load information into the application by placing them around the edge of the table [14,22]. Unlike other approaches where the physical objects are placed directly on the table and manipulated [21,9,19], the tags used in The Pond are passive. They make it possible to load and store information, but do not manipulate this information any further. Interacting with the contents of The Pond is supported through direct manipulation of the virtual Pond objects [20] using a touch screen display. Typically, interactions with the tabletop systems discussed above make use of stereoscopic glasses, data gloves, and magnetic position trackers. These techniques are not used in The Pond as our aim was to create as easy and direct an interface as possible and not to encumber the user with devices needed to experience the material presented.
Approaches to improve access to online information and to visualize it in an intuitive manner have been under development for a long time. Examples of systems that display information graphically in three dimensions include VR-VIBE [1], QPIT [6] and BEAD [5]. All of these systems require (at least to some extent) the users to use navigation to access particular objects, because objects may obscure each other or may be out of view. However, navigation within 3D spaces is known to be difficult [13], especially if the navigation needs to be precise. The Pond design makes use of a static view of the information space, making viewpoint navigation unnecessary.

4. THE POND
We now describe The Pond system in detail, examining its construction, both in terms of the physical artifact and the underlying software, and the way in which it is used.

4.1 The Pond ecosystem metaphor
The Pond uses a user interface based on an ecosystem metaphor. The objective was to present an aesthetic that would hide the work chore aspect and act as a complementary backdrop for dialogue. When interacting with The Pond, the users see a 3D presentation of a virtual pool or pond, an aquatic environment in which the information objects resulting from queries are presented as shoals of marine creatures. The visual presentation is complemented by a sound environment, consisting of a number of bubbling, splashing and whirling sounds, indicating various active processes inside the pond virtual environment. Each information creature inside the virtual pond has a simple navigational behaviour. For instance, creatures belonging to the same shoal, and thus query, attempt to group together, while at the same time avoiding creatures from other shoals. These types of simple rules make the virtual pond a dynamic environment, where shoals of information creatures move around in tight groups, avoiding each other as well as the pond walls, and reacting to interactions from the users. The Pond does automatic garbage collection, which means that one or several of the shoals that exists in the virtual pond environment may be removed. This may happen for instance if the pond is too crowded or because a particular shoal has not been interacted with for a long time. A shoal that is selected for removal by the system will sink down towards the bottom of the virtual pond, where it will disappear. However, should a user interact with a sinking shoal, e.g., select one of its creatures, the shoal will return to the surface and another shoal might be removed instead.

4.2 The Pond example application
To investigate the concepts behind The Pond we developed an application that allows users to search for and browse music content on the Internet. The music theme was chosen to maximize The Pond’s visual and sonic impact, being a theme common to most potential end-users. However, The Pond is not limited to this domain and is adaptable to any other database resource. A search task is initiated by a user providing a keyword string, for instance the name of an artist, group, or perhaps a musical genre. This keyword must exist on a preconfigured RFID tag (the creation of arbitrary queries is not currently supported at the user level). The Pond “forwards” the keyword to an Internet search engine and presents the resulting album hits as a shoal of creatures, each representing one specific album. The virtual creatures are represented by simple geometric shapes, which are texture mapped with the albums’ cover images. By interacting with a creature, users are able to access the album data (e.g., title) and hear samples from the tracks. The virtual pond itself consists of a 3D model of a deep, narrow shaft that extends down from a watery surface. The music oriented Pond application was selected since we wanted an application that would allow us to explore and evaluate the ideas behind The Pond without having to implement a lot of advanced search functionality, and which would also be interesting and enjoyable to use (e.g., looking for and listening to your favorite music). Furthermore, the size of a “typical” query result was expected to be less than 50 items, which would allow us to present a number of simultaneous shoals in the virtual pond environment without making it appear too crowded.

4.3 The hardware platform
The physical Pond artifact has the form of a large desk, on top of which a large touch-sensitive plasma display is horizontally placed. On top of the display surface is a wide wooden frame with an irregular curved outline, which represents the bank of the virtual water pond rendered on the display. The frame is covered by pieces of thick carpet so that users standing around it can comfortably lean over the display when interacting with the virtual pond environment (Figure 1).

Built into The Pond frame are a number of speakers that are used to output various sounds and music samples. The use of audio is an important feature in interacting with The Pond, and the sound system consists of several devices including a sampler, subwoofer and amplifier. The Pond frame also encloses several RFID tag readers. Each reader is entirely embedded into the frame carpet and uses three light-emitting diodes to indicate its position and state to The Pond users. Users may initiate queries by placing a RFID tag on such a reader. The tag’s identifier, sensed by the reader, will identify a query keyword or phrase and the query will be initiated. The RFID tags can be seen as a hardcoded subset of queries.

4.4 The software platform
The Pond software platform consists of three different components:

- A visualize that renders the view from the virtual pond environment on the plasma display.
- A Java program (the query application) that interacts with web servers, sending queries and analyzing results in the form of web pages.
- A Java program (the pond application) that accepts query keywords from the users and communicates these to the query application. This program also uses the results from the query application to introduce and control shoals of creatures in the virtual pond. The visualize and the pond application are built using the DIVE [10] distributed VR system from SICS. The virtual pond environment is in fact a DIVE virtual world, shared by the visualize and the pond application. The pond and query applications communicate using a TCP socket connection, through which the pond application sends query keywords from the users (via tag readers), and receives query results in the form of music record information (record titles, artists, links to music samples etc.). Such information is used to create and animate DIVE objects representing creatures in the virtual pond environment. The pond application also handles the audio output (music samples, sound effects, etc.) to The Pond table speakers (see Figure 2).
5. INTERACTIONS

Users standing around The Pond table are able to interact with it in several ways to perform various tasks. In the absence of keyboard or mouse devices, the users perform most interactions by tapping or stroking the touch-sensitive display surface. Furthermore, prepared tags that are spread out on top of The Pond frame allow users to input information about queries without having to type on a keyboard. The conscious actions that may be performed are the following:

- Initiating a new query
- Accessing information about query results in the form of shoals of pond creatures
- Zooming down on a shoal to get a closer look at the creatures
- Building a selection of creatures from various shoals
- Saving a selection for later use
- Uploading a saved selection into the pond

These actions will be described in detail in the following sections.

5.1 Initiating queries

Queries are initiated by placing tags on the tag readers in The Pond table frame. When a tag is placed on a reader, the reader senses the tag’s unique identifier, which is pre-mapped to a query keyword or phrase. As soon as a query is initiated, an empty shoal appears inside the pond, representing the ongoing query. The shoal is indicated by a circle and a text string specifying the query keyword, as seen in Figure 3.

The circle will commence to “float” inside the pond environment, bouncing off the pond walls and avoiding other shoals. When the query results are initially delivered, creatures start to appear inside...
the empty query shoal. Each such creature represents an information element from the query result; in this case a CD album. As soon as a particular result creature has been created, it will begin to move around. However, since all creatures resulting from a particular query stay close together, different query shoals are easily identifiable, even with a vastly populated pond environment. When all the results have been delivered and the corresponding virtual creatures created, the shoal circle label will change to only display the query keyword (see Figure 4). Shortly thereafter the shoal circle and label will disappear, leaving behind only the creatures visible to the users. However, it is possible for users to make the circle and label visible again, something we describe in the next section.

![Figure 4: A shoal representing the results of a query using the keyword “Dylan”. The shoal circle and keyword text are only visible for a couple of seconds.](image)

5.2 Accessing query results

Each shoal member represents an information element that is part of the result of the corresponding query. Users are able to access this information by manipulating the creatures in different ways.

![Figure 5: A selected creature](image)

A user selects a creature by tapping on it on the display, and is then able to see the information identifying the artist and title of the corresponding CD. This information is presented as a virtual text string, encircling the 3D-creature and moving alongside it (see Figure 5). The text will only be visible for a brief period (around five seconds) and will then disappear. The frame of the creature will become green to indicate the selection, and will remain so until changed back to white again when another creature is selected. Tapping once more on an already selected creature activates playback of audio samples from the CD. Sample data is streamed over the network; the creature will then float up to the surface, presenting itself in more detail. (Figure 6).
5.3 Zooming
By default, the viewpoint in the virtual pond environment is placed above The Pond, looking down, and at a distance from where the view is always guaranteed to include all the creatures currently inside the pond. In this way the users are able to get a good overview of all the activity within the environment. However, this also constrains the creature representations to be rather small (as seen on the plasma display), which might present a problem when trying to identify the creature graphics of the CD albums they represent. In order to allow users to get a closer view of one of the shoals, a zooming mechanism allows for the translation of the virtual viewpoint to a position close to a shoal centre. The view port is just large enough to encompass the whole shoal with the benefit of making the creatures in that shoal together with their associated text strings and images, appear larger. As a result, other shoals may end up out of view, not visible from the new viewpoint position. Another feature of the zooming mechanism is that, while zoomed, the viewpoint is attached to the shoal, which means that it will move as the creatures within the shoal moves. In this way the viewpoint will always stay centered on the chosen shoal, even as this shoal changes its position within the virtual pond. While zoomed, the shoal creatures may be interacted with in the same way as before, e.g., selected to initiate replay of the music samples. Placing a query tag on a reader, whose corresponding shoal already exists in the pond environment, triggers the zooming mechanism. Removing the tag from the reader will reset the viewpoint to the default overview position. Thus, if a user places a tag associated with the keyword “Dylan” on a reader while a “Dylan” shoal exists in the pond, the viewpoint will change to a position close to this shoal, and stay there as long as the tag is on the reader. Whenever the tag is removed, the viewpoint is reset. Only one user at a time can use the zoom mechanism. If a zoom is active while a user initiates another zoom the viewpoint state won’t be overridden and the second request is ignored.

5.4 Building a selection
As users initiate more and more queries, older shoals may have to be removed in order to incorporate newer ones. To prevent a particular creature from being removed from the pond environment, it is possible for users to move individual creatures to safe areas, called creels. This is done by touching the creature with the finger, and then dragging the finger (and thus the creature) along the surface and releasing it over the creel area. Creels exist in several places in The Pond environment, close to the tag readers. Once inside a creel, a creature is constrained to move only within the creel boundaries. By moving several creatures, possibly from different shoals, into a creel, a selection shoal is formed consisting of creatures that a user finds interesting for some reason. Since this particular action shows an interest from the user in a specific data element, this instantiates an extra functionality. A more focused query is automatically launched pertaining to that particular record (usually resulting in fewer hits and consequently a smaller shoal), thus further populating the environment. The creatures in the creels may be interacted with in the same way as other creatures (e.g., tapped on to play music samples), the only difference being that they won’t be removed from The Pond environment as long as they stay inside the creel. Creatures that are dragged out of a creel will return to their native shoal, or form a new shoal if their native shoal no longer exists.
5.5 Saving and uploading a selection
By using a recordable tag, it’s possible for a user to save the contents (i.e., creatures) of a creel selection shoal. A recordable tag is a RFID tag which is not pre-mapped to a search keyword (see “Initiating Queries” earlier). Placing such a tag on a tag reader next to a creel creates an association between the tag and the creatures within the creel area. When the tag is then removed from the reader, the creel’s selection shoal will disappear from The Pond environment and may be regarded as being stored on the tag. By placing the same tag on a reader at a later stage, the creatures of the “saved” selection will reappear, added to the corresponding creel shoal. Thus, creels and recordable tags allow users to save references to specific albums, which may be accessed on a later occasion or shared with others.

5.6 The Pond audio environment
The sonic environment of The Pond consists of two different parts, the “soundscape” and the interface sounds. In accordance with The Pond ecosystem metaphor, the nature of the soundscape is founded on a family of aquatic whirring sounds and a deep, obscure mumbling giving the impression of the data elements ascending from an abyss of ooze or mud. These ambient sounds fade out when samples from a selected creature starts to play, and fades smoothly in when the music stops. The interface sounds acts as a feedback mechanism to indicate user interactions like selecting/unselecting, clicking, dragging etc. This collection also originates from a number of concrete water sounds. Samples from different types of bubbles, a dripping tap, whirlpools etc. are heavily processed to suit their particular purposes. Examples include:

- When a user initiates a query, the appearance of the query shoal is accompanied by the sound of sluggish bubbles rising from the bottom.
- When a sound file is retrieved over the network, the waiting time is masked with a bubble vortex that after a few seconds is smoothly merged with the music sample.
- When the user removes a RFID tag from a tag reader, the action is accompanied by sounds of a cluster of bubbles being rapidly inhaled by The Pond itself.
- When the user draws his finger across the touch screen to drag an object, a glass organ sound reminiscent of drawing a finger along the damp edge of a crystal wineglass is heard.
- The visual zooming in of a shoal is illustrated by the familiar bubble sound gradually “magnified” through lowering of the pitch. When zooming out, the process is taken backwards. Every time an interface sound needs to be played, The Pond system will randomly choose a sound from a collection of sounds available for the particular interaction.

There are ten query sounds, ten RFID sounds, ten dragging sounds, etc. The idea is to give the impression of the sonic interface being somewhat organic and unpredictable. The precise spatial placement of every sound is achieved through a built-in high quality 4-channel sound system. A subwoofer in the table foot produces a deep and suggestive bass. The computer controlled software mixer makes it possible to physically move sounds around and to create expressive musical gestures.

6. OBSERVATIONS FROM USE
To test out The Pond a number of sessions were held with external participants in the expectation that some qualitative assessment of the effectiveness of the Pond could be made. In all six sessions were held with a total of nine users, each session lasting for around an hour. A video recording was also made. In addition to the test subjects one of the Pond developers participated in each session, initially presenting The Pond but staying close by in case of questions or problems. Our participants were mostly familiar with computer use, though not familiar with alternative interfaces like The Pond. The focus of the studies was on the technology-in-use [4], i.e., the sequences of interaction within which The Pond came to be used in real time. The emphasis is placed not on “the user”, nor on usability strategies as conceived in HCI, but on the “lived work” that users and developers engage in together, in order to make the technology work in situ [7].

6.1 Encountering The Pond
In encountering The Pond (Figure 7), users had little difficulty in seeing the sense of The Pond – see its potential utility – as a result of the practical course of instruction into its use. In other words, The Pond became a readily intelligible artifact. Users engaged in various activities, together and alone, such as selecting CDs, listening to samples, transferring CDs to RFID tags, and transferring CDs from RFID tags. Not only did the users see the sense of The Pond but they also recognized the relevance of The Pond to naturally organized activities of playing music. People are ordinarily constrained by the physicality of musical formats (CDs, audio-tapes, vinyl, etc.), which individualize music and control access to it. The Pond, on the other hand, affords in principle quite a radical alternative: users can select music from a large data-base holding tens of thousands of CDs; they can interrogate and select items of interest to them; they can load music onto portable devices, and they can add new music to The Pond, for example. As one user explained it:

“Place it in a Virgin Megastore, it can be used as a jukebox. Perhaps you should specialize it more so it fits into a category like film, books, articles, and radio. And you should be able to tell The Pond which CD you want and then be able to put it into your shopping basket.”

Figure 7: Three users exploring The Pond during one of the evaluation sessions.

6.2 Interacting with The Pond

In some sequences of interaction it is noticeable that the sound of The Pond worked as functional feedback. After the users had recognized the connection between the function and the sound, the sound worked as a support for the user in interacting with The Pond. This can be seen in a sequence when a user experienced difficulties in dragging a CD out from her own creel. In the sequence the sound that is heard as her finger passed the sound border of the creel made it clear to her if she had succeeded or not. The Pond is engineered to support hands-on experience and ease of use, i.e. mainly its touch surface and object oriented presentation of the information displayed. Its simplicity of use is one of its key usability features as seen and understood from a user perspective:

“The main good thing about The Pond is that the interface doesn’t require any special level of computer skills for using it.” (User of The Pond)

Comments such as these indicate that not only did the users see the sense and recognize the relevance of The Pond, but that they sought to appropriate The Pond. By that we mean that the users
could envision its future use for practical purposes in their daily lives, changes withstanding. These changes are crucial to The Pond’s appropriation and eventual implementation in practice.

6.3 Shortcoming of The Pond

Our studies identified a number of problems with The Pond, areas that future development work should concentrate on.

- The ability to manipulate objects requires improvement. Currently users experience some practical difficulty in dragging and turning objects on the interface. In other words, the touch screen needs to be more sensitive and responsive to user actions.

- One of the major challenges users identified was the need to be able to search the Pond in a dynamic fashion. For example, it is currently not possible for users to issue custom search queries.

- Related to the need to perform active searches is the issue of extending the services offered by The Pond. Thus, as the quote from the user above suggests, there is need to add and develop other services related to music and entertainment.

- A multi-interface version of the touch screen is required, enabling users to work individually. The development of multiple-user touch screens should solve this.

- Having found objects of personal relevance, appropriation relies on the implementation of multiple means of taking things out of The Pond. This poses the challenge of adapting or devising mobile devices.

The issues emerging from the user studies provide concrete input into an ongoing Cooperative Design process [3]. Conducted with an eye towards an iterative prototyping life-cycle, analytic attention has been paid to the sense and relevance of The Pond as understood from a use perspective, and the practical troubles and tangible future possibilities that impact upon appropriation of The Pond in practice [17].

More general observations, not drawn explicitly from the recorded sessions, showed that the main drawbacks of The Pond are its limited interface flexibility for more elaborate queries and single user touch screen interaction. However, once The Pond is populated with reasonable query data its strength of design of concept comes through. The technology did not become obtrusive, and could function as an appealing backdrop and overview when not directly interacted with. The present day Pond artifact does not provide any other means of input other than pre-designated tag keyword searches (identified above). We aimed towards non-intrusive forms of interaction and avoided introducing keyboard type input. The RFID tags do serve well in cases where a hierarchical, finite and discrete database structure exists, as the music database in our case. Notice that The Pond is in the most part populated by relations and not exact matches, so we force exploration on the users. It proved at times frustrating for users not to be able to directly summon the artist or track of their choice, and at times gratifying in discovering alternative music of their liking.

7. SUMMARY AND FUTURE WORK

We have presented The Pond, a multi-user system for browsing information (currently CD record data) on the Web using an engaging tabletop display. Users input musical search keywords (typically names of artists or groups) using RFID tags and are presented with matching Web information in the form of shoals of aquatic creatures inside a virtual 3D pond. The virtual pond environment is presented on a big touch-sensitive plasma display, which is placed horizontally to better support shoulder-to-shoulder collaboration between those people gathered around it. By touching the surface of the display users can interact with the creatures to access the information they represent, e.g. play music samples from the corresponding CDs. A series of users studies have provided initial insights into the utility of The Pond. The results indicate that the device and metaphor are easy to understand.
and use, but also identify a number of problem areas. For instance, the touch sensitive display doesn’t currently support multiple simultaneous interactions, which sometimes caused the users’ actions to interfere with each other.

The Pond has been demonstrated to members of the research community as well as to the public on numerous occasions. The feedback and observations from these sessions have been used to refine The Pond under an ongoing evolution process. Future ideas include support for multiple simultaneous interactions on the display surface, using a voice input system for entering search keywords, and using PDAs to extract and input information to and from The Pond environment.

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9. REFERENCES

8 Mobitex Technology In Use: Status and Priority

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Abstract. This article presents how operators and paramedics use categories in their work. Two categories are in focus: status and priority, both used and play an important part in the cooperation between operators and paramedics. The two categories are presented in its use context, the operators’ work at the Swedish Emergency Service Centre and the paramedic’s work at the Swedish Ambulance Unit. The mobitex technology that enables the sending and receiving of statuses and priorities are presented. A case, Case: priority 1,5 from the SOS centre with an analysis of the categories status and priority from the case is presented. The conclusions of this paper are that in the case priority 1,5 the operator wanted to categorize the case in a category that didn’t suit the ones defined in the system. And the paramedics and operators used alternative technology to complement the categories when working with the case. A general conclusion to be drawn could be that in geographically distributed work mediated via text based technology, no classification system is more suitable to the work practices in cooperation than the closeness to richer descriptions.

1 Introduction
This article presents how emergency service centre operators and paramedics use categories in their work handling emergency cases. Two categories are in focus: status and priority, that both are important parts in the cooperation between operators and paramedics. Other categories are used in operators and paramedics’ cooperation, but the status and priority are selected for different reasons. The status and priority are both used as the operators’ dispatches an ambulance for a case. Sending and receiving of statuses are the main reasons for sustaining cooperation after initiating a case. And the priority is the most important category in labelling a case, the actions taken by operators and paramedics are to great extension related to the case priority. For handling and classification of events, categories are used. Which categories that are chosen can in some parts mirror how events are valued. In using categories nuances between specific events is lost in favour for, in the situation, more important issues such as handling events comprehensive. Bowker and Leigh Star describe the classification concept that is an all-embracing term for the system of categories as following. “A classification is a spatial, temporal, or spatiotemporal segmentation of the world”. (Bowker, Star, 1999) They present three properties that distinguish a classification system. In an abstract ideal sense a classification system exhibits the following properties:

1. There are consistent and unique classificatory principles in operation.
2. The categories are mutually exclusive
3. The system is complete

They add that: ”No real-world working classification system that we have looked at meets these “simple” requirements and we doubt that any ever could.”(Bowker, Star, 1999)
According to Bowker and Star there is no real-world working systems that follows the three simple requirements that distinguishes a classification system. After the presentation of the properties and the explanation of classification systems they add that they in their book have an even broader definition of classification systems. It includes also the systems that are treated as classification systems: “For the purpose of this book, we take a broad enough definition so that anything consistently called a classification system and treated as such can be included in the term.” (Bowker, Star, 1999) So instead of focusing on and defining the perfect classification system from the criteria of fulfilling the properties or definition of classification systems, it can be interesting to examine what makes a classification functional. To find out if a classification system is functional or not, you can look at how the users work with the system, i.e. look at the classification system in use. An interesting aspect of classification system is to examine how the system meets the demands of the work practice that it is developed for and used in. For this purpose we may need to look at how the term work practice are defined. As Dourish puts it, explaining the work practice from the researchers point of view:

What the “working practice” researcher observe is the actual, practical business of making processes work involves a considerable amount of approximation, invention, improvisation and ad hoc-ery. … Practice is always dynamic, arising as a way to mediate between the processes and the circumstances in which they are enacted. (Dourish, 2001)

One way of viewing categories connected to the work practice can be to look at how integrated and shaped the categories are for the “working practice”. The integration and shape don’t necessary mean that the limit of the criteria if having chosen good categories is that the categories is used as it is designed to be used. It can also be a matter of if it works according to how it is used. When it suits what it is aimed to suit, that is mainly, for the use of classifying events enabling them to be handled comprehensive.

2 Methods
This article is a result of cooperation between Blekinge Institute of Technology and Swedish Emergency Service Centre. The methods used for this paper are to great extent field studies, taken place in five different emergency service centres in Sweden. Basically consisting of listening to and observing how ongoing emergency calls are handled. Field studies have also been made at one Swedish Ambulance Unit including studies in dispatched ambulances. Discussions and interviews with operators and paramedics have been conducted. Three Work shops with paramedics and operators have taken place. The field studies have been inspired by the ethnographical approach and the part of the analysis of the material have been inspired by the ethnomethodological approach. “The ethnomethodologically guided orientation to ethnography begins from the point of view of the social actor acting within a socially organized environment: that is, working within a culturally recognized environment.” (Harper, Randall and Rouncefield, 2000:68) The time spent at the different sites and on analysis of the data has been going on for over two years.

3 Domain specific categorization
Since this article is directed to classification systems in use, more specifically focusing on two categories, the real world domains where the categories are used are of importance. To say that we humans think in categories and categorizations of events in the everyday life can prove that, and be an articulation of how we think, is to go beyond the aim of this article. The descriptions of categories in this article are domain specific. As earlier mentioned the domains are the Swedish Emergency Service Centre and the Swedish Ambulance Unit, and the specific focus is on the use of the categories status and priority in the technological mediated communication. Jack Whalen1 have made studies and worked with 911 calls, the American equivalence of the Swedish 112 emergency calls. Categorizations in work practical use of handling emergency calls describes as follows:

To be actionable, a worldly trouble or event has to be representable in organizational terms or categories; the categories become a means of summoning the organization into action. Thus it is in
and through the selection of an incident code that central aspects of call screening and prioritisation are embodied as courses of action.
(Whalen, J 1995)

With these sentences he argues that the categorisation of events makes them actionable and embodied as courses of action. As an example of category he mentions the incident codes as a category for prioritisation. How priorities are categorised and used at Swedish Emergency Service Centres is as mentioned, a category chosen as a topic of this article. How the prioritisation is embodied as courses of action in cooperation operator – paramedic is presented further in this article. Interwoven in the description of the priority 1,5 case.

3.1 SOS and ambulance domain: status and priority
At the Swedish emergency service centres the operators handle calls made to the emergency number 112. At the ambulance unit they handle cases that need ambulance transport to, for example hospitals. The operator’s tasks include answering, categorizing emergency calls and dispatch ambulances. The paramedic’s tasks include receiving cases, and driving to the person/s in need of ambulance and transport the person/s to suitable treatment. If needed, they also make life saving treatment at scene.

Cooperation between the operators and the paramedics is fundamental if the emergency call is categorised by the operators as a call that needs ambulance response. In the cooperation between operators and paramedics there is a need to exchange information. For various reasons the exchange of information is mainly presented asynchronous. Since the operators and paramedics are geographically distributed and the time for handling information in emergency situations is limited, small amounts of information are exchanged. The easier and the faster, the better. The categories used in handling cases need to be easy interpretable and understandable by both operators and paramedics. The categories status and priority that is in focus in this article are two of the categorizations in exchange operator - paramedic. The statuses are the categorization of the paramedic’s tasks of relevance to the operators. The priority is the categorization of how important a case is and how fast it should be handled. As the operator has categorized the call as a call that will become a case and needs some sort of response from ground service resources available, the work with prioritising the case has begun. The priority of the case is built on the operators’ categorisation work of the conversation with the caller. The operator ask the caller questions that will be of help in getting the case to fit in the priorities available in the computer system. The operator’s priority of the case affects how the operator and the paramedic’s treat the case. The operators use three levels of priorities in cooperation with the paramedics. The categories for priorities are priority 1, that is the highest priority. This
priority is for emergency calls that have to be treated as time critical and needs immediate response. How fast the person in need gets help can be a matter of life and death. The second priority priority 2 is for emergency calls that is not that time critical but needs response as soon as possible. The third priority, priority 3 is for emergency calls that more or less just need ambulance transportation. These priorities are the ones that is used in the computer system and displayed in the Graphical User Interfaces as either prio 1 or the figure 3. If the operator and paramedic needs to complement the information sent and received via the system neither the operator nor the paramedic uses the systems prioritisation verbally. Thus it is differences in how the priorities are called in the interaction via the system and how it is called in the conversation operator - paramedic. In conversation they use the words: emergency, immediate or transportation. This according to the following translation:

Priority 1 = emergency (In Swedish, Akut),
Priority 2 = immediate (In Swedish, Omgående)
Priority 3 = transportation (In Swedish, Transport)

As the operator has prioritised and is working further with the case, the operator makes another operator, the dispatching operator, aware that an ambulance has to be dispatched in the case. The dispatching operator makes the case assignment. The dispatching operator searches after a suitable ambulance to dispatch for the case. Which ambulance that is dispatched for the case is mainly based on the status of the ambulance. When the paramedics are assigned a case the operator sends the priority and the status assigned telling the paramedics that they have been assigned a case. The operators then receive the paramedics answering of statuses, and when at the scene, also the confirmed prioritisation or the re-prioritisation (if suitable treatment has improved the persons condition). The operators receive the statuses until the paramedics fulfilled their tasks in working with the case and sent the disposable status then the operator signs the ambulance off the case. Statuses available in the system for the operators are the following:

D= disposable (dispatchable at station) (In Swedish: disponibel (gripbar på stationen))
DT= disposable on the phone (In Swedish: disponibel telefon)
DR= disposable on the radio (In Swedish: disponibel radio)
DRP= disposable on the radio/personal seeker (In Swedish: disponibel radio/p-sök (person sökare))
DRT= disposable on the Mobile phone/Mobitex (In Swedish: disponibel MT/Mobitex)
The status sent from the paramedics describes the categorized task that the operators currently are working with. As earlier mentioned the interface where the paramedics interactively meet the operator is the Mobitex button display. The button display has one button for each status and priority that is set for this ambulance in this county. The 13 statuses and the 3 priorities that the paramedics can put the vehicle in are the following:

Mission, At scene, Loaded, Leaving patient, Prio 1, Prio 2, Prio 3, Meal, Mission disposable, Disposable station, Disposable radio, Not disposable, Nurse anaesthesia accompany, Radio test, Message received, Patient 2

### 3.2 Mobitex system

For sending and receiving statuses and priorities there has to be suitable technology that makes the sending and receiving possible. The technology that is used in the operator – paramedic cooperation is the Mobitex system. How the Mobitex technology is built affects the technical handling of data and affects the shape of the interface and the manual handling of the data. The Mobitex is a text radio, with a network that consists of interconnected cells, each of which is served by a radio station. The network breaks the data stream up into small packages (packet-switched network), each of which can be sent across the network individually. Each data packet contains the destination address and can be routed dynamically as network conditions change. The Mobitex uses narrowband data-only network, so that data transfers cannot be blocked by voice calls (www, 020110). The system renders the possibility for the operator and paramedics to handle statuses and priorities without using telephone (stationary or mobile) and/or radio. In the operators and paramedics’ use of the Mobitex system for cooperative purposes, it is interesting to focus on the interfaces. This is the border where the operators and paramedics “meet” each other though geographically separated. The interfaces where the operators and the paramedics meet each other via the Mobitex technology is for the operators both on the computer screen in the CoordCom system application and on the screen for the digital map application. As for the operators, the statuses and the
priority are visible in the CoordCom system via the digital forms, for example via the call queue were the Mobitex calls can be selected and answered down by the operator. And on the Mobitex row, the row situated on the bottom of the application. From this row the Mobitex calls are answered and connected to the unit, which in its turn is connected to the case. It is also visible at different digital forms such as the ambulance and rescue vehicle form, the basic form, available units form and ongoing events form. On the digital map application both status and priority are visible by the representation connected to the GPS positioning of the ambulance vehicles. The main interface for the paramedics is the Mobitex button display presented on the picture below. And a more detailed description of the case is also printed on the Mobitex printer. On the paramedics personal seeker the priority is visible.

Figure 4. Button display in use at Swedish ambulance unit.

In this case the buttons Mission and prio 2 are active. This is visible as the activated buttons glow extra much compared to the other inactivated buttons. The paramedics have just received a case. Then the paramedic’s presses the Message received button as they have received the Mobitex note, and presses Mission and Priority as to confirm and inform that they got the case, are sitting in the ambulance and are on their way to the current address. They press the button At scene to show that they have found their way to the address (but also to show that they soon will get out of the ambulance and cannot be reached by the radio). As they have loaded the patient they press Loaded and re-prioritises the case. As they reaches the hospital, as in this case, they pushes the Leaving patient button and has this button pressed until they are ready for the next call. Then they push Disposable station.

3.3 Case: priority 1,5
This case is an authentic case handled at a SOS centre. The case is of interest for this article since it is a case were the paramedic contacts the operator via the telephone, i.e. the Mobitex system is complemented with a telephone call. And the priority in the case changes from prio 1 set by the operator to prio 3 set by the paramedics at scene. The emergency call is answered on one of the bigger Swedish emergency service centres xxxxxx, the case was created xx.xx.xhh at terminal x. A 112 call is presented in the call queue. The operator at terminal x answers the call. It is an older woman that states that she has problems in breathing and is about to faint. The operator asks the woman for how long she has felt ready to drop and if she suffers from any disease. The woman answers that she has felt like this for a long time and that she should be eating pills against fainting. She hasn’t eaten the prescribed pills neither yesterday evening nor earlier today. The woman also says that her lips are blue. The operator has problems to get in contact with the woman, since she isn’t always contactable, not always answering the operators questions and breaks the conversation several times with sentences spoken with a nervous noise saying, “I am about to faint” “I cannot breathe” and “my lips are blue” The operator asks the woman if she has got chest pains but don’t get an answer. The operator categorises the case as: priority 1, chest pains, unclear problems. The woman sounds hysteric and repeats over and over again that she is about to faint. After a while the operator gets in contact with her and asks her again if she has got chest pains. The woman says that she doesn’t have that. So the operator re-categorizes the case from M1.08.04 to M1.19.04, which means a change from
chest pains to tendency to faint. The operator asks the woman about her address to compare it with the address already in the system, founded through a database search. The operator sends listening-in to the operator dispatching the ambulances and tells the woman that her colleague is dispatching an ambulance at the same time as they are speaking. The woman says, as an answer to this information that she will go outside to meet the ambulance. The operator tells the woman that she has to stay indoors in the department. It is important that she doesn’t step outside (it is cold and has been snowing). After the operator has said this it sounds as if the woman starts to cry. And she tells the operator that she has worked in a hospital herself. The conversation continues and the woman sounds very hysteric. She repeats that she is fainting and that her lips are all blue. The operator tells the woman repeatedly, with a calm and steady voice that she has to calm down, stay inside and wait for the ambulance to arrive. Before the call has closed the dispatching operator doesn’t just dispatch the ambulance on the station, but also reinforcement, which means that a nurse is accompanied in the ambulance. The dispatcher mark ambulance Q911 in the event plan. This is made after the case orally has been sent via radio to the station. The dispatcher then sends the filled ambulance form to Mobitex writer and button display. The information is presented to the paramedics in the Mobitex paper note and on the button display. On the row of comments for the case the dispatching operator can see the receiving operators comments:

HARD TIME BREATHING. BLUE LIPS. AFRAID OF FAINTING.

These comments has now reached the paramedics, so has the status Mission and prio 1 presented at the button display. For this status the operator puts a time surveillance, which means that if the paramedics don’t acknowledge the case in 1,5 minutes the textual presentation of the case becomes red and a sound is heard in the traffic room. After 1 minute the operator receives an acknowledgement form the paramedics. The receiving operator answers the Mobitex message down. After doing this she stops the time surveillance manually. Right after 03.27 after the Mobitex has been sent and before the paramedics sends the status loaded the paramedics call the SOS centre. The receiving operator chooses to answer the call. It is one of the paramedics and he wants to have additional information. He wonders how serious the state of the woman is and if the woman suffers from any disease. The operator tells the paramedic that the state of the woman was that she was very upset and that she wasn’t in a condition to answer that question. He then asks questions such as if the woman were taking any pills and how much contact the operator got with the woman. The operator tells him about the pills that the woman should have taken. The operator also mentions that the woman have worked in hospital care. After approximately 4 minutes the paramedic receive the mission that they are on the scene, on scene. The woman lives just a couple of blocks from the ambulance station. The operator approximates that the paramedics has a 5-10 km drive to the woman. The operator receives the status Loaded and a new priority, prio 3. The operator turns to the computerized map, and says aloud in the traffic room that she thinks that it has been reprioritised to a
prio 2. She discovers then when looking closely at the computerized map, that it has been prioritised as a priority 3. The paramedics send the status **Leaving patient** and 4 minutes later they report themselves and the nurse sign themselves off the case. Two seconds later the receiving operator signs off the case.

### 3.3.1 Analysis
To get more information about the case for analysing it, I discussed the case with the receiving operator, focusing on status and priority. On the question why she thought that the paramedics called her instead of just sending and receiving statuses she said that the paramedic wanted to have more information about the woman’s medical state. She also mentioned that the paramedic was quite new. Since it was hard to establish contact with the upset woman she didn’t have that much more information about the woman’s medical state to give the paramedic. On the question for the change of priority she said that she wanted to prioritise the case as priority 1,5, since she neither thought that it was a priority 1 nor a priority 2 case. But the system doesn’t hold the category priority 1,5. The operator didn’t say anything about the case getting a prio 3 by the paramedics. But worth mentioning is that the paramedics work on the scene can lower the priority from being an acute case to just a transportation case. And the priority isn’t the only categorization of the event. The priority is a part of the event code (the 1 in M1.19.04 for this case) and the paramedic also had the comment on the comment row on the mobitex note (HARD TIME BREATHING. BLUE LIPS. AFRAID OF FAINTING). In discussions about how the communication worked before the mobitex system, the operators said that, the communication was mediated via telephone and radio. The operators compared the different ways of communicate and all agreed that they spent less time on the communication now with the mobitex system. The communication went smoother, but they sometimes felt a loss of feedback from the field about how the case was completed. Before the mobitex system the operators always got feedback from the field by the paramedic calling for completion of case.

### 4 Conclusion
The exchange of small amounts of data in emergency domains can have many advantages. In emergency situations it is important to react fast and accurate. There isn’t time for neither the operators nor the paramedics to get lost in categorization work, difficult interfaces, systems functionality or technological delays. Neither is it time for misunderstandings between the domains or lack of data. This article has focused on the categorisation work of handling statuses and priority. It can be said that the exchange of the representations of these two categories as they are used today are made quite fast and with a small amounts of data exchange. It doesn’t take that much time to send or receive the data and both the paramedics and operator gets a lot of “things said” without saying anything. Though this beauty in exchange of information lay on a quite fragile foundation. Part of the fragile foundation is the different domains knowledge about each other. The knowledge which tasks and which difficulties there are in the different domains. Which problems and difficulties the operator can face as prioritising a case. Or the paramedics work of preparing themselves to the condition of the person/s at the scene without being able to put themselves in the status of preparing, **more info needed** as for the analytical state that they are into when preparing for whatever they might meet at the scene, and wants more information. There is a great need of flexibility if a misunderstanding arises or if there is a need of complementing information. Today this means that mobile or stationary telephones or radios are at hand for the paramedics and the operators, enabling them to contact each other orally. With flexible technology, in this context different technologies, and the operators and paramedics knowledge about each others domains tasks (making the categorization work interpretable in the different domains), even the others domains work practice the beauty in the quick and simple exchange of data can keep it’s beautifulness. As a summons of this article a general conclusion to be drawn could be that in geographically distributed work mediated via text based technology, no classification system is more suitable to the work practices than the closeness to richer descriptions.
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Posters

SHINE - sustaining health and interaction in networked environments

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Brief description of the SHINE system is presented, covering basic usability motive and technological issues. The SHINE system is developed in the SOCLAB9 within the SOTDS10 project. In essence, we have developed a system supporting cooperation between the main user i.e. the patient, private care organization, municipality and the county council. Fulfilling needs of mobile home support teams in distributed health care organizations, by means of technologies that enable mobile access and peer-to-peer connectivity as well as visualizing multiple views of the same underlying (home health care) system on a given platform. The platform, SOLACE11, manages issues of scalability and decoupling in complex systems of mobile service. For supporting the SHINE system in development and analysis of behaviour for the complex systems of mobile services the DISCERN12 system is built.

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Towards Declarative Electronic Decision Support Systems focusing on patient security

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Abstract: The main contribution in this paper is a structured approach supporting validated quality of information sharing in Health Care settings. Protocols, at different system levels, are used as a method to design and implement intelligible information sharing structures. Our approach can preferably be seen as a context dependant information modelling framework that could be implemented using, e.g., web 2.0 techniques in a professional context. The main challenge is how to trustworthy convey and analyze the huge amounts of information available in Health Care contexts. Our innovative information health channel concept provides an approach to analyze and structure information as well as a contextual support towards increasing patient security.

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