Designing Situation Awareness
Addressing the Needs of Medical Emergency Response

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Abstract: The effective support of Situation Awareness (SA) is the core of many applications. In this paper, we report a progress on the research towards the complementing of the existing studies with new knowledge, on engineering of SA in particular keeping in mind a complex multi-stakeholder context of existing and future knowledge intensive intelligent environments. A medical emergency response use case is used as an instantiation example to evaluate our engineering thoughts.

1 INTRODUCTION

The importance of Situation Awareness (SA) has been firstly recognized for crews in the military and aviation domains. The most prominent and complete work in this direction is a Theory of Situation Awareness studied and consolidated by Mica R. Endsley (Endsley, 1995). In her work the theoretical model of situation awareness and in particular its role in human decision making is defined. From the application point of view this research addresses mostly the needs of various time-critical environments, such as air traffic control, large complex manufacturing systems, some medical systems and tactical and strategic systems. These systems are in a sense closed systems of single provider supporting strict top-down design and development approach and aim at addressing the needs of a “single operator”.

On the other hand the increased availability and robustness of sensors, the wide-spread use of the internet, as well as intensified research in the area of the content convergence and social media have led to the definition and acceleration of various research fields and phenomena that draw on the advances of these technologies, Pervasive computing, Ambient Intelligence and Internet of Things (IoT), as well as cloud computing, which define a vision where in the future distributed services and computing devices, mobile or embedded in almost any type of physical environment all cooperate seamlessly with one another using information and intelligence to improve user experience. The support for Situation Awareness is equally important in this new context. The value of SA can be found in the product manufacturing domain, emergency management, design, supply chain management, and equipment remote maintenance, to mention a few applications. The Situation Awareness requires applications to support management of data, knowledge and related services in an integrated and sustainable way. Mastering of “simplicity” and “openness” will be deterministic for the digital products, application and services successful in the future. Openness in the creation of products and services allowing various independent networks of stakeholders to participate in the services creation process will enable the complementary bottom-up approach in smart systems development. Simplicity is demanded by users. Simplicity is related to usability and there is a trend in industry to conflate these terms as much as possible. Better usability will increase user acceptance of technology, which is crucial for products take-off in many contexts. The purpose of the system may play an important role in defying of respective elements that influence system acceptance from the end-user as well as the developer and business point of view.

In this research we aim at extending the existing studies in the field looking on SA according this new context. A medical emergency response context is used as an example to instantiate and to evaluate the respective design thoughts. Various stakeholders

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dealing with Situation Awareness, such as end users of the system (i.e. emergency responders), application developers and business actors are examined. By applying the user-centred approach to elicit the requirements for patient safety during emergency medical response, one of our contributions to the state of the art is to extract the "simplicity" hidden in apparently complex emergency context. Our second contribution lies in the resulted domain model and respective knowledge oriented architecture, which are defined to guide the development of desired situation awareness.

In the following section, the related studies on SA as well as the motivation for this research are further discussed. The aim is to capture challenges and needs still to be addressed in developing of SA and therein to facilitate innovation and more substantial system design. In Section 3, we discuss a model based SA design for medical emergency response context. Conclusions are summarised in Section 4.

2 SITUATION AWARENESS

SA originated with aviation practitioners. After the research has spread to other environments, such as air traffic controllers, nuclear power plant operators, anaesthesiologists and automobile drivers in particular addressing cognitive tasks that operators in such environments may face, thus extending the theoretical model defined by Endley (Endsley, 1995 & Endsley, 2003).

Looking on the relevant advances in research in the area of pervasive ubiquitous computing environment and IoT, a related concept to SA is the notion of Context Awareness (CA), which is defined as "any information that can be used to characterise the situation of the entity" (Dey, 2001). The term Context Awareness and Situation Awareness are used interchangeably by some authors as they mean the same, however there is an important difference in their usage. The CA aims to enable better service delivery through proactively adapting use and access of information, physical resources and multi-modality feature of human-computer interaction process with respect to available context information (Soylu, 2009; Schmidt, 2012). In contrast, SA is the perception of the elements and "events" in the environment related to the entity (i.e. user) or in other words, it is simply about knowing and understanding what is going on around. This understanding may lead to some action taken by the user.

While the methodology towards the developing of context-aware applications for various intelligent environments has appeared (Dey, 2001; Hong, 2009; Perera, 2013), there has been a little focus put to support the situation awareness in this new context (Chen, 2012). The existing approaches aim mainly at the addressing of development of domain specific applications and improvements of existing technology according to the theoretical models introduced earlier (Endsley, 2003). For example, the SA needs of an operator in road traffic management domain are enhanced by developing a number of ontology based applications (Baumgartner, 2010). The machine learning algorithms towards the recognition of situation are presented in (Häussermann, 2010). A role of semantic technologies in improving SA is discussed in (Smart, 2007). In the domain of emergency management, the research has been mainly focusing on tackling of organizational aspects to achieve a sufficient shared SA (e.g. Sapateiro, 2007; Seppänen, 2013).

The existing approaches lacked the touch of widely adopted software engineering practices where the requirements to SA engineering are mastered by examining various design-view points, actors involved, and the domain specific aspects such as standards and accepted work practices, as visualised in Fig.1. Developing the effective and sustainable Situation Awareness necessitates the availability of respective Model, which is created to build the description of the problem domain in software engineering and to define the system development process. Models are very much associated with the domain they present. Accordingly, in the following section we illustrate our approach to the design of Situation Awareness by researching and developing the domain specific model to tackle the needs SA in a medical emergency response context.

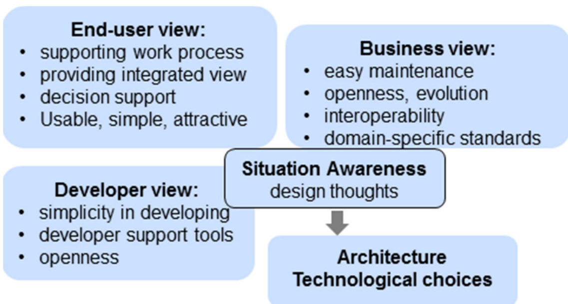

Figure 1: Design views in SA engineering.

3 EMERGENCY MEDICAL RESPONSE

The information systems for emergency management are based on information provided by various actors, by diverse collections of sensors in the field and information supplied by human volunteers. The information may come in different forms such as field reports, images and remote sensing information. In order to achieve SA, various knowledge and information models need to be aligned. It is widely acknowledged that good SA leads also to good decision making (Feng, et al. 2009). Moreover, as various actors (and accordingly various heterogeneous information infrastructures) are involved as information providers in the emergency management context, there is a demand for the means to support the interoperability among different information sources towards their access and information reuse and further acceptance of the system by business and earlier adopters.

3.1 End-user View

The methods for the collection and analysis of general emergency response user needs towards the creation of domain model involved literature and clinical practice reviews and face-to-face interviews with stakeholders (e.g. the London Ambulance Service, the Vienna Red Cross, the Sofia Military Medical Academy). This led to the codification of the principle five spaces, related actors and their actions directly linked to medical emergency response: (1) Initial Alert: the phase, where the initial alert is being managed, usually a 112 call center or Public Safety Answering Point (PSAP); (2) Emergency Medical Service (EMS) on the Way: the phase, in which an EMS team is dispatched to emergency event's location; (3) Field Management: the event's site where the people requiring urgent medical help are located; (4) Transport: the phase, in which an EMS team takes patients to a First Receiver; (5) First Receiver: the phase, in which the First Receiver, usually hospital, prepares for and later takes over the care of the patient. The emergency responders working in each of these five phases/spaces have sets of patient-related tasks, which are the same, irrespective of country or type of incident. These are the tasks that form the basis for the generic set of requirements for technology and situation awareness and decision supports, discussed next. The more the actions across the spaces are interlinked by effective information sharing technology and the more provisions for mutual visibility, early situational awareness, and decision support are provided, the more the phases are enabled to run in parallel, therefore saving time and becoming more effective in saving lives.

3.1.1 Situation Awareness Model

A Common Information Space (CIS) introduced to maximise the quality of available information and its outcome across five operational conceptual spaces of emergency medical response, Decision support points and Information sharing patterns constitute the Situation Awareness model. The Situation Awareness model is represented in form of the sequence diagrams in Fig. 2. The purpose of these sequence diagrams is: 1) to clarify the decisions that different actors make during the course of an incident and explain how the system supports decision making; 2) to illustrate the collaborative nature of decision making and represent what kind of critical information is required to support different actors with their tasks; 3) to represent the important information flows that potentially exist between involved actors mediated by a knowledge management system in form of notifications and alerts.

The emergency management process is started as PSAP receives a call to the emergency telephone number. Usually, the caller provides basic information about the incident including the type and the location of the incident and injured if any. PSAP staff reports the received information to the CIS system and determines also a priority dispatch code for the event. The inserted information is transmitted to the Decision support system that should be able to analyse the data and to generate recommendations for resources that should be invited to manage the incident. The recommenda-tions are returned to the CIS system, which in turn should notify PSAP staff about the recommenda-tions. Subsequently, PSAP staff may analyse the recommendations to make the final decision about the resources that are invited and dispatched. Next, PSAP staff communicates the dispatch information to selected EMS staff members and, additionally, informs hospitals through the CIS system. After that, both EMS staff and the field commander should compare the incident details (e.g. the number of patients) against dispatched resources and evaluate whether the required resource estimations are accurate and justified. If necessary, both of the aforementioned actors can decide to dispatch additional resources for the incident. The field commander also performs task allocation for EMS staff members. The Decision Support system may support this activity by creating

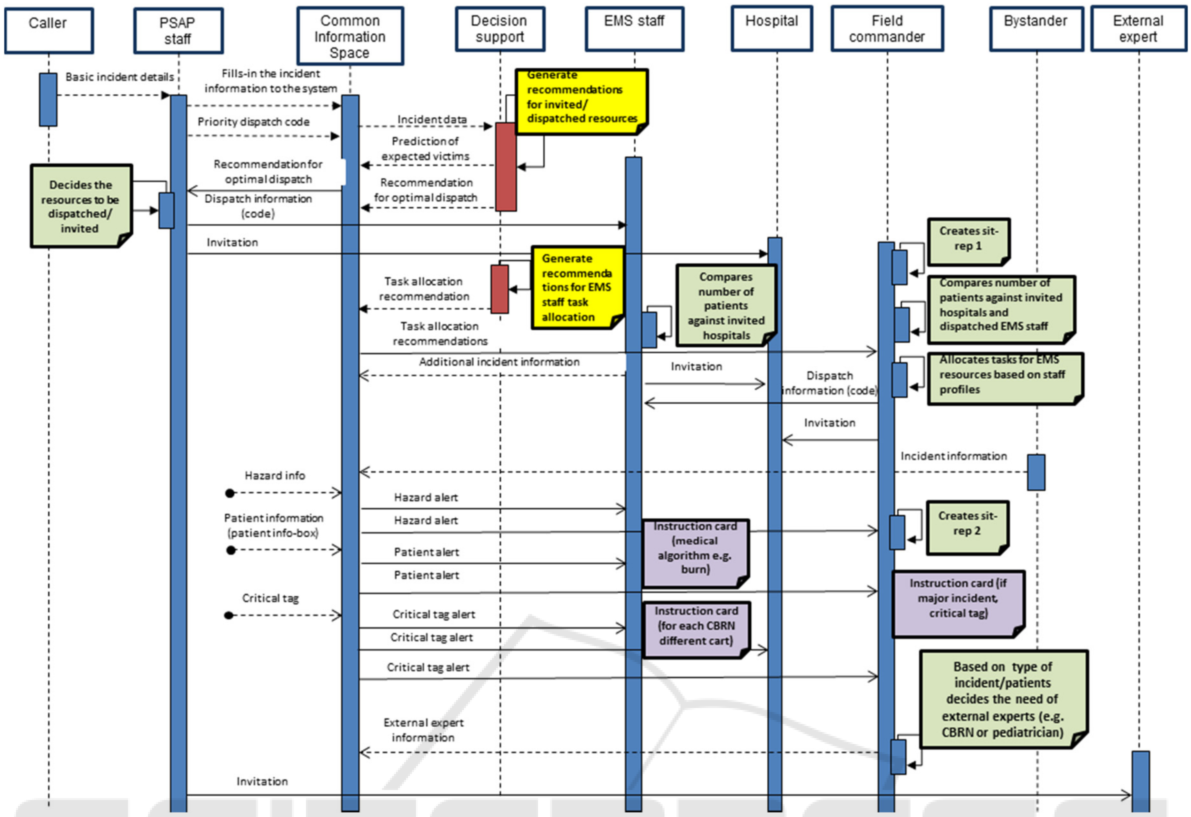

Figure 2: Sequence diagram of a collaborative decision making in an incident situation.

recommendations for task allocation utilizing, for example, personal profiles that describe the capabilities of involved EMS staff members. Actors can also set critical tags to the system to indicate that the incident involves potentially dangerous chemical, biological, radiological or nuclear materials. The final decision making point presented in the Fig. 2 considers whether external experts should be invited to the scene of an incident. Based on the incident type, injuries of patients and/or the existence of possible hazards and critical tags the field commander may decide to insert information about required external experts to the CIS.

The activities, decisions and communication flows that are usually executed in the following phases of an incident management process are not illustrated in the sequence diagram due to the space limit, however they are explained in the following. Once EMS staff has examined the patients, patient data (e.g. the results of triage) is reported to the CIS. Next, the received information is analysed by the Decision support system towards the generation of recommendations for allocating patients to hospitals. The recommendations are constructed by comparing patients' reported injuries against available hospital data including provided specialities, location and the number of available beds. Based on the received recommendations EMS staff can decide the patient allocation and is able to send allocation alerts to hospitals and medical transportation. The allocation alerts include the IDs of the patient and the hospital receiving the patient. In the next phase, the CIS system may communicate the location of hospitals and current traffic information to the Decision support system that should be able to process the information and to generate route recommendations for transportation vehicles. Once a patient arrives to the hospital the hospital personnel downloads a patient form from the CIS system thus acknowledging the arrival.

Typically, the transportation personnel and responders in the field also utilize specific cards that offer guidance and thus facilitate the treatment of different kinds of patients or allocation of required resources.

The defined Situation Awareness model is used as a basis to formulate the required knowledge models for the Common Information Space and to propose the overall architectural pattern that can be used to achieve the desired SA functionality. The proposed architecture and knowledge models, which take into account the developer- and the business-views are discussed next.

3.2 Developer and Business Views

Glossaries and vocabularies play a significant role in emergency management due to the importance of clear communication during disaster response. It is a good practice to use standards if available to enable information sharing interoperability. Several standards addressing data modelling and data exchange formats related to medical emergency response have been designed so far. Based on the conducted research (Kantorovitch et al. 2015), OASIS EDXL based models (EDXL, 2015) appear more promising to address the needs of medical services in the context of emergency. To date, it is the most complete and mature effort to facilitate emergency information sharing and data exchange across various actors - public, commercial and also medical involved in the process of emergency management. Consequently the EDXL-based vocabularies have been selected as the central knowledge models to utilize. Obviously there is no possibility of universal agreement on any conceptual scheme including EDXL, however it is argued that a practical common ontology does not need to have universal agreement, it only needs a large enough user community to make it profitable for developers to use it as a means to general interoperability, and for third-party developer to develop utilities to make it easier to use.

In addition, in order to support evolvability, the system solutions have to take into account requirements that arise from anticipated changes on environment, technology and stakeholders' needs. Fortunately there is already accumulated knowledge of well-known general software design principles presented as architectural tactics and patterns that can be used to guide design. Architectural tactic is a characterization of architecture level decisions that can be used to achieve a desired quality attribute response. Evolvability is typically associated with modifiability, which can be addressed by a tactic localizing changes by increasing cohesion, preventing ripple effects of changes by reducing couplings, and deferring binding time to support dynamic adaptability (Bachmann et al. 2007). Studies have identified several architectural patterns supporting evolvability, most important examples being layering, Model-View-Controller (MVC) pattern, and use of plug-ins (Bode and Riebisch 2010). Based on the best practices identified, the architecture of the system is designed to adopt layering and Model-View-Presentation (MVP) architectural pattern that itself is a derivation of MVC. Layers defined in MVP pattern are presented with shades of blue in Fig. 3.

Model layer captures the information on problem domain i.e. individuals of incidents and their participants. The model stores dynamic data into RDF store, which directly manages its logic and consistency with axioms and rules. The Incident ontology is the core ontology of Model. Model is constructed using both domain specific and generic ontologies shown as grey layers. The Incident ontologies and EDXL concepts are structured in an extensible way and constructed according to Linked Data (LD) principles. Both, the developed Incident ontologies and EDXL vocabularies are released as an open source to GitHub software repository for their further reuse (COncORDE, 2016).

Presenter layer typically retrieves data from the model, and formats it to be useful in the views (facilitated e.g. by REST API/JSON format). In the emergency context the presenter layer contains queries that report the overall situation and also may enable alerts and notifications presented in Fig.2. Presenter layer also supports queries and reasoning based on generic ontologies for time, location and organization or personal information. When other external vocabularies are utilized by Model, new presenters for them can be added. In addition, Presenter Layers is designed to support other functions and services of the system, such as ontology-assisted information extraction, decision support algorithms and overall management of heterogeneous incident related content.

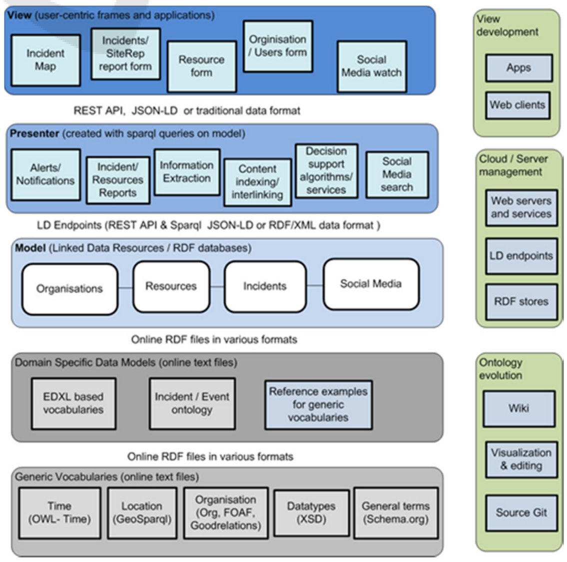

Figure 3: The knowledge oriented architecture.

Finally, a *View* can be any output representation of information, such as a diagram or it may contain multiple views, such as a map with several information visualization layers.

Layers on the right shaded as green represent stakeholder specific development, maintenance and evolution related aspects of the system with examples of supporting tools. For instance, ontology evolution is supported with version control using GitHub with wiki as a means for documenting the rationales for changes in ontology. In order to ease version control, ontology source is developed using textual Turtle format.

The proposed framework utilizes two of the main strengths of linked data technologies. First is that the evolution of ontologies used by models can be opened to collaborative work among developers. Second is that the models themselves can be extended and tailored for the specific needs of systems and user views by choice of external vocabularies and ontologies.

4 CONCLUSIONS

This paper has provided the detailed technical description of a model based approach aiming at achieving Situation Awareness and support for decision making in a dynamic medical emergency response context. The effective exploitation of domain models, architectural tactics, linked open data technology and domain specific vocabularies aim at the interoperability, better acceptance and evolution of the developed system. The use of Web standards and a common data model makes it possible to implement applications that operate over the complete integrated data space. The focus of our future work is put on further prototyping of the proposed SA framework. The developed decision support services are based on the mathematical modelling of optimization problems for timely allocation of resources and on semantically supported domain knowledge modelling, as well as on the machine-learning-based prediction of emergency incident expected victims and subsequently demand for resources.

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REFERENCES

Chen, L., Rashidi, P. (2012). Situation, activity and goal awareness in ubiquitous computing. International Journal of Pervasive Computing and Communications, Vol. 8 Iss: 3, pp.216 – 224

COncORDE incident ontologies and EDXL vocabularies (2016). https://github.com/OntoRep/COncORDE

Baumgartner, et al (2010). Editorial: BeAware!-Situation awareness, the ontology-driven way, Data & Knowledge Engineering, v.69 n.11, pp.1181-1193

Bachmann, F and Bass, L. (2007) Nord, Modifiability Tactics, SEI Techical Report

Bode, S. and Riebisch, M. (2010) Impact Evaluation for Quality-Oriented Architectural Decisions Regarding Evolvability, Proc. of ECSA conference, Copenhagen

Dey, A. K. (2001*).* Understanding and Using Context*. Personal Ubiquitous Computing*, 5 (1), 4-7

Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Human Factors, 37,* 32–64.

Endsley, M. R., Bolte, B., & Jones, D. G. (2003). Designing for situation awareness: An approach to human-centered design. London: Taylor & Francis

Feng, Y-H. (2009). Modelling situation awareness for Context-aware Decision Support, Expert Systems with Applications 36, 455–463

EDXL (2015). OASIS emergency management standards.

Häussermann, K., et al. (2010). Understanding and Designing Situation-Aware Mobile and Ubiquitous Computing Systems.Vol.14 No.1, pp.329-339

Hong, J., Suh, E., & Kim, S-J. (2009). Context-aware systems: A literature review and classification. *Expert Systems with applications* 36 (1), 8509-8522

Gartner, M. (1986). Situation awareness: Let's get serious about clue-bird, Draft.

Kantorovitch, J., Milis., et al. (2015). Knowledge modelling framework - towards user-centered medical services delivery in the emergency context. In Proc. of ICT-DM conference, Rennes, Brittany, France

Sapateiro, C (2009). An Emergency Response Model Toward Situational Awareness Improvement In Proc. of ISCRAM – Gothenburg, Sweden

Schmidt, A., (2012). Context-Aware Computing Context-Awareness, Context-Aware User Interfaces, and Implicit Interaction. *Online education*, retrieved 2017

Seppänen, H., et al. (2013). Developing shared situational awareness for emergency management, Safety Science 55 (2013) 1–9

Soylu, A. et al. (2009). Context and Adaptivity in Pervasive Computing Environments: Links with Software Engineering and Ontological Engineering. Journal of Software, 992--1013

Smart, P. R. et al. (2007). Semantic Technologies and Enhanced Situation Awareness. 1st Annual Conference of the International Technology Alliance (ACITA), Maryland, USA.

Perera, C., Zaslavsky, A., Christen, P., Geogakopoulos, D. (2013). Context Aware Computing for the Internet of Things: A Survey, pp. 1–41