Ontology-Based Inference to Enhance Team Situation Awareness in Emergency Management

Yasir Javed
Institute of Information & Mathematical Sciences, Massey University, Auckland, New Zealand
y.javed@massey.ac.nz

Tony Norris
Institute of Information & Mathematical Sciences, Massey University, Auckland, New Zealand
t.norris@massey.ac.nz

David Johnston
Joint Center of Disaster Research, Massey University, Wellington, New Zealand
d.m.johnston@massey.ac.nz

ABSTRACT

In this paper, we propose the use of an ontology-based and semantic technologies approach to improving shared situation awareness amongst teams dealing with emergency situations. We have also identified that shared and team situation awareness tends to be viewed only in terms of cooperative task completion and so we have tried to describe their important relationship with team decision making. The applicability of our approaches is demonstrated by a case study of mass evacuation in the case of a tsunami event. We show how ontology can be used to represent context-based situations and how the axioms and rules can improve team situation awareness.

Keywords

Emergency, team decision making, team situation awareness, shared situation awareness, context, ontology.

INTRODUCTION

In recent years, the significant increase in the intensity of natural disasters such as tsunami, earthquakes, floods, etc, has led to a corresponding increase in the number of communication and intelligent systems supporting the coordination, situation awareness, and overall decision making of emergency managers (Gadomski et al., 2001; Tufekci, 1995; Ye et al., 2008; Yoon et al., 2008). The diversity of information sources and the sheer volume of information they supply, can readily lead to overload and make it difficult for emergency managers to understand the providers' intentions. Contextualizing the information can markedly improve the performance of such systems by allowing emergency managers to process essential information and make effective and efficient decisions in the available short time scales. These decisions require managers to have and to share a high level of situation awareness. In this paper we analyze how semantic technologies might be used to address these challenges.

We suggest that an approach featuring domain ontology, reasoning capabilities, semantic queries and semantic integration techniques, can provide the basis for an integrated framework to improve the situation awareness of a team. We also propose an extension to our ontology that can be applied to team and shared situation awareness and used to investigate the prediction of future states of concepts and relationships that can assist team decision making. Team decision making is important at every phase of emergency management but its relationship with the development of shared situation and team situation awareness has not previously been explored.

EMERGENCY MANAGEMENT

Emergency management is a discipline concerned with avoiding and dealing with risks(Haddow et al., 2007). It involves preparing for disaster before it happens, disaster response (e.g. emergency evacuation, quarantine, mass decontamination, etc.), and disaster recovery, which involves rebuilding society after disasters have occurred.

Reviewing Statement: This full paper has been fully double-blind peer reviewed for clarity, relevance, significance, validity and originality.

Decision making is key to all of these phases.

Research has shown that the decision making process in emergency situations is different from business or other "normal" situations (Roosen, 1997). In emergency situations, managers have excessive but incomplete information, and short times for decision and action. Stress levels are also high as lives and infrastructure are at stake. In addition, emergency situations are mostly unique and are continuously evolving. Frequently, the number of participating organizations managing the emergency is large and the managers are from diverse backgrounds with different working cultures, expertise, experience, and objectives. These managers have to process sub-optimal information to get an overall picture of the state of the emergency since the decisions to deal with it are based on an understanding of the current (but dynamic) situation. One of the many problems in such situations is therefore effective communication and coordination amongst the managers to achieve the shared situation awareness that is considered a prerequisite for good decisions.

SITUATION AWARENESS AND EMERGENCY MANAGEMENT

Definition of Situation Awareness

Situation Awareness (SA) is a critical element of emergency decision making in a variety of operational contexts. Improved SA can benefit operational effectiveness by facilitating the planning process, improving the quality and timeliness of decisions, and offering better feedback on the appropriateness of actions arising from such decisions. Accurate understanding and assessment of the situation is essential to normalize it.

At a very basic level, SA is the outcome of the process to understand what is going on around us. Although developing situational awareness is something we do unconsciously all the time, the concept is complex and we need a more nuanced definition to understand how we can improve it. The most widely cited and accepted definition of SA is the generic model proposed by (Endsley, 1995):

"Situation Awareness is the perception of elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future"

These essentially sequential levels, '*perception of the elements*', '*understanding of their meaning*' and the '*projection of future states*', are all processes of situation assessment that are needed to achieve SA which, according to Endsley, is their product or outcome that she refers to as a "*state of knowledge*" (Salmon et al., 2007). In contrast, Fracker (1991) describes SA as the process of *"combining new information with existing knowledge in working memory and the development of a composite picture of the situation along with the projections of future status and subsequent decisions as to appropriate courses of actions to take"*(Fracker, 1991). At a more abstract level, Smith and Hancock (1995) suggest that SA is *"the invariant in the agent-environment system that generates the momentary knowledge and behavior required to attain the goals specified by an arbiter of performance in the environment"*(Smith and Hancock, 1995).

A more detailed model (Endsley, 1995) of SA incorporates factors such as limited attention and working memory, mental models and schemas, pattern matching and critical cues, and links SA to automatic action selection, categorization, data driven and goal driven processes, expectations, and dynamic goal selection.

The greatest advantage of Endsley's model is its product emphasis, which allows the measurement of SA as the continuously improving outcome of the progression from perception to projection (Graham & Matthews, 2000). Fracker (1991) combined situation awareness with the assessment of various options or courses of actions to achieve improvement. This contradicts with the generally accepted Joint Director of Laboratories (JDL) data model of data fusion (Steinberg et al., 1999). The JDL data model divides processes into five levels; sub-object data assessment, object assessment, situation assessment, impact assessment, and process refinement. This division implies that situation assessment and analyzing the impact of various actions are different processes at different levels. The perceptual cycle model (Smith and Hancock, 1995) has sound underpinning theory and refers to SA as both process and product but it has failed to get the attention that Endsley's model has, as its description of SA makes measurement of the construct difficult. Though all definitions and models of SA have their limitations, we base our discussion on the Endsley SA and JDL data fusion models since these commands the widest acceptance.

Situation Awareness, Team Decisions, and Collaborative Tasks

In a group or team of emergency managers each member of the team has their own awareness of the crisis that confronts them and their individual responsibilities defined by the training and skills they have for carrying out specific tasks. Clearly, however, a team's decisions and actions are likely to be sub-optimal unless the individual SAs are shared and the individual responsibilities are coordinated in some way.

The concept of shared situation awareness (SSA) is defined by Endsley (Endsley and Robertson, 1996) as "*the degree to which each team member has the same SA or understanding of a situation*". The SSA is therefore the collected components of the individual SAs held in common by the individual team members (Wellens, 1993). The individual SAs and the SSA are clearly the essential pre-requisites of an accurate collective picture of the emergency, and the basis of team decisions since they bring together and share individual perceptions, understandings, and predictions.

To implement a team decision as a collaborative task, however, the team members must bring to bear their individual responsibilities and this requirement invokes the concept of team situation awareness (TSA). Endsley and Robertson (1996) define TSA as "*the degree to which every team member possesses the SA required for his or her responsibilities*". TSA is therefore a partly shared and a partly distributed understanding of a situation (Shu and Furata, 2005) that aims at cooperative action to provide solutions to problems.

Bolstad and Endsley (2000) later described TSA as a means of conceptualizing how teams develop high levels of SSA across their members. In essence, the combined concepts of SSA and TSA imply that each team member must be aware of the information needs of others as well as his/her own needs (Nofi, 2000). The higher the levels of SSA and TSA, the better the decisions and the actions based upon them.

Several studies (Bolstad and Endsley, 2000; Salas and Prince, 1995; Stout et al., 1999; Wellens, 1993) have endeavored to develop tools to measure TSA but there is little work on the relationship between situation awareness, decision making, and task execution. However, the above definitions and discussion allow us to propose a simple model of emergency management that incorporates these elements and suggests a model or framework for systems design.

The first stage of the model is the acquisition of real world data that leads to individual situation awareness (SA). Team members then share their discrete knowledge via direct and indirect (e.g. information systems) communication to develop shared perception and understanding (SSA) of the emergency situation. The model then proceeds to team-based decision making based on the SSA. The decisions reached are typically based on previous experience, expert opinion, and authority(Robbins and Finley, 2000)and lead finally to collaborative task execution in which team members participate according to their individual responsibilities and skills (TSA). Figure 1 illustrates the model sequence.

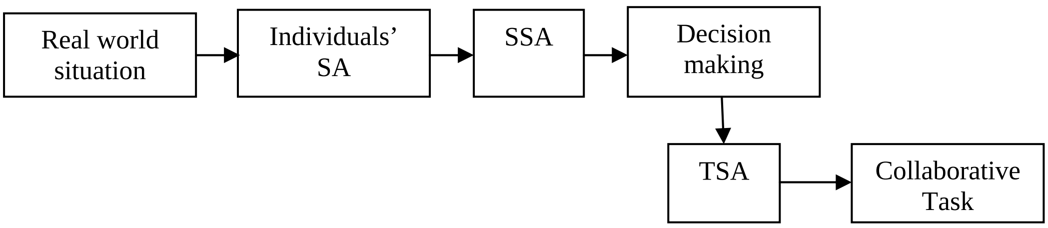


Figure 1. Model demonstrating relationship between SA, SSA and TSA

A significant aspect of the model is that SSA but not TSA is necessary for decision making. TSA is essentially an implementation requirement. This distinction is important since the decision makers may be different from the implementers. There are also important implications for systems design and implementation.

Conceptual model of a computerized emergency management system According to Shu and Furuta, (2005), in team situation awareness:

"Two or more individuals share the common environment, up-to-the-moment understanding of situation of the environment, and other person's interaction with the cooperative task."

These authors postulate that TSA includes two basic elements, individual situation awareness and a differentiated form of shared situation awareness that they refer to as mutual awareness (MA). Mutual awareness describes the awareness that individuals have of each other's activities, beliefs, and intentions (Shu and Furuta, 2005) in a cooperative environment. Thus, an individual team member should have in addition to their own SA of a situation, beliefs about the other members' SAs (i.e. how they see the situation) and beliefs about how these other members see the individual's SA. If any of these beliefs is missing or inaccurate then the TSA is incomplete and collaborative action is likely to be sub-optimal.

Shu and Furuta (2005) suggest that mutual awareness can be achieved in two ways; explicit communication (e.g. direct face to face verbal exchange or conversation through some telecommunication device), and inferred or implicit communication (e.g. from observed external actions). We propose a model of an emergency management information system in which the inference role is delegated to a computerized situation agent that processes the situational information and interprets it according to domain knowledge and reasoning rules.

Once the situation agent displays its situation interpretation and future implications along with logical reasoning, team members can choose options ranging from 'fully agree', 'partially agree' (with changes) or 'disagree' and provide logical reasons for their selection. Other team members can review the selection and rationale so that they can supplement or correct the inferences as required. The situation agent's knowledge base will also be updated with new information and rules. The agent then provides an updated situation analysis along with the reasons for change. In this way, team members' updated SA and belief will be communicated to other members helping them to improve their TSA.

As well as a situation agent, the proposed system has a second inference agent, namely a task agent designed to use the profile information of the team members, e.g. roles, tasks and their requirements and interdependencies, to provide the guidance in real time. The conceptual model is illustrated in Figure 2.

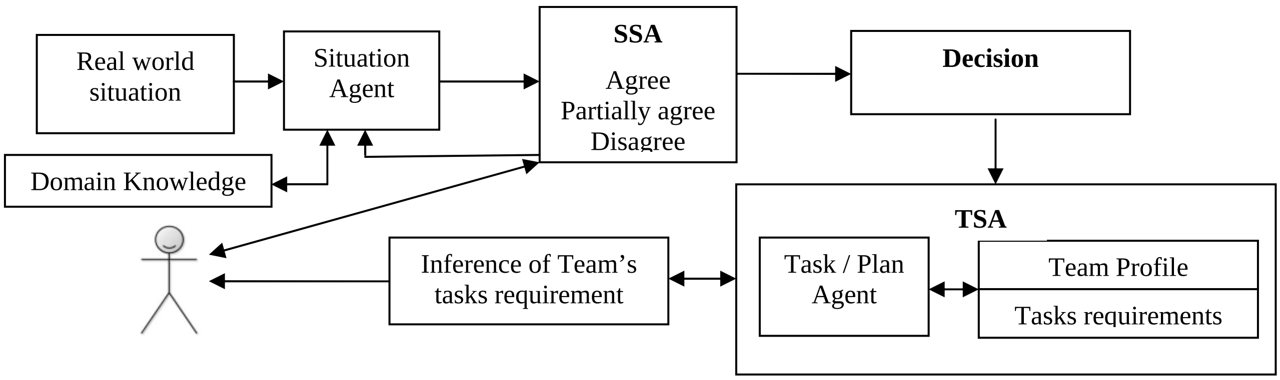


Figure 2. Conceptual model of a computerized emergency management system

We intend to implement such a system and test it with data gathered for various scenarios related to mass evacuation after the threat of tsunami and volcanic eruption (Javed et al., 2011). These information requirements are classified according to the various team roles, e.g. planning and intelligence manager, logistics manager, operations manager etc. at different phases of emergency management.

ONTOLOGY-BASED INFERENCE FOR TSA

The design and successful implementation of the system discussed depend fundamentally upon the concept and operation of the inference agents. To assist with the design requirement we invoke an ontological approach (Matheus et al., 2005)which offers a conceptual framework for modeling application domain knowledge and the flexibility to update it in real time.

Ontology is commonly understood on two levels: (a) as a knowledge base for a specific domain and (b) as a vocabulary, which uses appropriate terms to describe domain entities or agents, and the protocols for the relationships and interactions between them (*cf* the context model). Ontology therefore describes the domain knowledge and provides a consistent understanding that can be shared by users. If the domain is an emergency situation, then an ontological description can conceivably facilitate shared situation awareness.

Several studies (Matheus et al., 2003; McGuinness, 2003; Horney et al., 2003; Boury-Brisset, 2003) have proposed ontology-based SA systems. They also provide higher-level situation ontologies to capture generic situation descriptions that can be contextualized to derive more domain specific ontologies. Our approach extends these concepts to the use of ontology for SSA and TSA by modeling context and situation information.

The elements of a situation can be expressed as ontological concepts (Endsley's Level 1 SA). The relationships between the concepts map onto the comprehension Level 2 SA where an agent or observer relates the concepts to make sense of them. The axioms and rules governing the interactions between the concepts then comprise Level 3 SA allowing an agent to make predictions about future states. Figure 3 shows diagrammatically how this ontological approach relates to Endsley's description of SA and TSA. We are also using ontology to infer the SA requirements of other team members so that required information support can be provided in a timely manner. Ontology is also being used to infer the information needed to perform various tasks according to different situations and phases of a crisis.

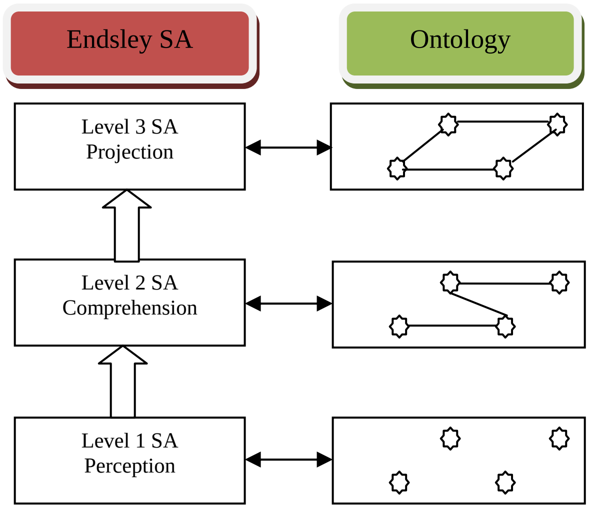


Figure 3. Ontology based situation awareness, adopted and extended from Matheus et al. (2003)

Several major projects ("BeAware" (Baumartner et al. 2010), "AKTiveSA" (Smart et al., 2005), "Information fusion for Natural and Man Made Disasters" (Rogova et al., 2006)) have successfully used ontology-based SA in real-life situations. Our approach is looking at extending the existing SA ontology for shared and team situation awareness. In situations like volcanic eruption, floods, tsunami etc, when expert opinion is required for decision making (e.g. when to evacuate, which area to evacuate first etc.), it is often difficult for emergency managers to understand the terminology used by scientists and other experts. Similarly, emergency team members are often from diverse backgrounds with different goals and background knowledge. In these circumstances, the necessary levels of SSA and TSA are not achieved. Ontology can provide a common vocabulary that is equally understandable by all participants. In this way, they can see how the current situation affects their objectives in relation to other members of the team. This reduces the chances of misunderstanding and the emergency managers can fully understand how a situation is evolving and its implications.

System Architecture

The architecture of an ontology-based SA system is designed to deal automatically with context acquisition, representation, and blending. Domain ontology has all the concepts and relations between them (object properties) to model all aspects of domain depending on the goal. Context ontology contains context information about the various actors, such as information providers and consumers, so that the central inference engine knows their information needs. The context sub-system has unambiguous rules that specify appropriate actions depending on the current situation. Situation ontology is the instance of any specific aspect of domain ontology.

For practical implementation, all of these ontologies use semantic web rule language (SWRL)[1] to define the rules. SWRL is a proposal for a semantic web rules-language, combining OWL (web ontology language) with those of the rule markup language (unary/binary datalog). SWRL has the full power of OWL DL (description logics).

Rules are of the form of an implication between an antecedent (body) and consequent (head). The intended meaning can be read as: whenever the conditions specified in the antecedent hold, then the conditions specified in the consequent must also hold.

Information providers like sensors, agents in the field, or other scientists provide the information required by the destination users according to their context ontology. This information instantiates the domain ontology and is stored in the situation ontology. Context ontology also provides the background and supporting information using reasoning and inference to make logical recommendations for users. Information in the situation ontology can be queried by the user as required and it can also trigger action recommendations automatically using rules.

1. http://www.w3.org/Submission/SWRL

User queries are converted into queries written in SPARQL[2].SPARQL is a recursive acronym that stands for SPARQL Protocol and RDF Query Language. It was standardized by the RDF (Resource Description Framework) Data Access Working Group (DAWG) of the World Wide Web Consortium. SPARQL allows a query to consist of triple patterns, conjunctions, disjunctions, and optional patterns. We have added context ontology so that if situation cues are supported by the different types of context information, most of the ambiguity from the information used for SA can be removed (Javed et al., 2011).

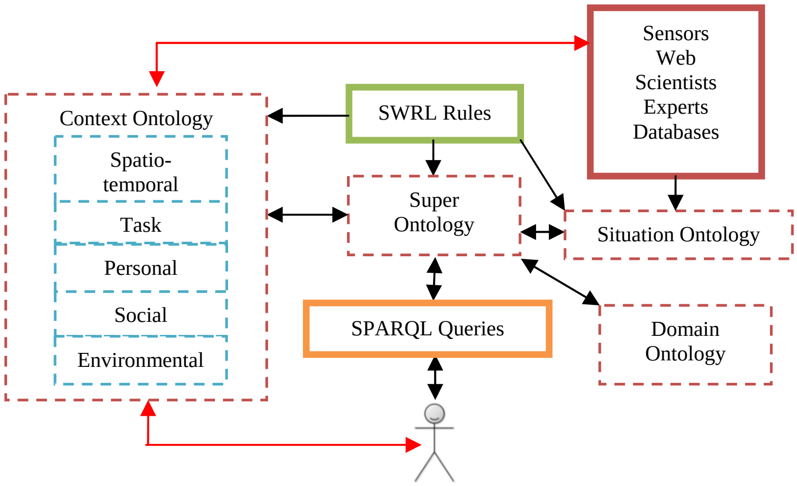


Figure 4. System architecture

CASE STUDY: ONTOLOGY APPLICATION FOR TSA IN EMERGENCY MANAGEMENT

With the proposed ontologies for emergency management (context, domain, and situation) and the corresponding inference mechanisms, we can demonstrate how ontology can be used to support TSA and SSA by means of a case study of exemplar tsunami situations and their assessment. The exemplar tsunami situation is motivated by a scenario created for a national level tsunami exercise in New Zealand. The scenario presented below serves as a test bed for our approach.

Emergency Management in New Zealand

In New Zealand, the National Crisis Management Centre (NCMC) looks after a crisis at national level and coordinates with the regional emergency offices known as Group Emergency Operation Centers (GEOCs). GEOCs in turn coordinate with local Emergency Operation Centers (LEOCs) within that region. Coordination between NCMC and GEOCs and LEOCs is critical for SA and decision making as most of the major decisions are made by NCMC and implemented by LEOCs and supporting organizations such as Fire Service, Police etc (Javed et al., 2011).

A Coordinated Incident Management System (CIMS) is used for managing the response to an incident involving multiple responding agencies. CIMS has five basic functions: Controller, Planning & Intelligence (P & I), Operations, Logistics and Welfare. The P & I function is responsible for forecasting the incident development, anticipating likely needs, and drafting the Incident Action Plan. This role of the GEOC has a strategic scope. The Operations function enacts the Incident Action Plan, which makes sure that responders are as focused and aware as possible so that they can fulfill the objectives set by the Controller. The Operations Manager is generally responsible for the operational command of resources. This means allocating specific functions to agencies in their areas of expertise, monitoring their performance, and providing a communication link between the responders and the other elements of the GEOC, especially Logistics. The Logistics function or Manager ensures the continuity of operations by making sure that there are sufficient resources on-site and within GEOCs. The Welfare function is responsible for the wellbeing of affected people during or after the emergency situation especially in the case of evacuees. They set up temporary welfare camps and provide accommodation, food and basic medical facilities until required. The Controller is responsible for the overall incident progression and has overall accountability for the incident. The Controller's responsibilities include:

2. http://www.w3.org/TR/rdf-sparql-query

- Safety of staff and public
- Overall operation of GEOC
- Approval of Situation Reports issued by the GEOC
- Incident management, i.e. the strategy that will be most effective at resolving the incident with economical use of resources. This strategy is issued through the use of Incident Action Plans (IAPs)
- Approval of IAP
- Property conservation, which relates to the overall damage limitation

Situation awareness required for mass evacuation

To explain our approach, we consider a tsunami scenario. First, individual / team members use seismic and related data to register an underwater event (e.g. earthquake or volcanic explosion) that could cause a tsunami. Deep-Ocean Assessment and Reporting Tsunami (DART) data are then analyzed to confirm whether a tsunami has been generated or not. Once it is confirmed that a tsunami has been generated, areas of possible devastation are marked and planning for possible evacuation is started. Although priority zones are designated, decision makers must remain aware of other areas at risk. Similarly, decisions to evacuate, and the time and extent of evacuation, should take into account schools, hospitals, and other buildings that may need special attention. Planning for the safe evacuation of people, which includes transport, food and shelter, and medical facilities are critical considerations since wrong decisions can lead either to unnecessary disruption or increased casualties and economic loss. The safe return of evacuees, once water levels have returned to normal, is also a major factor dependent on damage, access and services. While evacuees are away from their property, proper security should be provided for their properties and possessions.

These planning steps have many considerations for individual and team situation awareness. And of course, the situation is continuously evolving so that monitoring wave height, direction, and rise in sea level provides the necessary information cues to update situation awareness and its possible evolution.

An ontology for mass evacuation

For demonstration purposes, we have used Protégé' 4.02 to develop a simple OWL-based ontology for mass evacuation. Figure4 shows a part of the highest-level description or Super Ontology that imports other ontologies. The ontology concepts perform the same roles as described above in system architecture whilst the relations between them yield the understanding needed for SA. Projections are then made from rules and axiom-based inference and reasoning. This ontology extends the concepts of the upper level Situation Awareness Core Ontology due to Matheus et al. (2003).

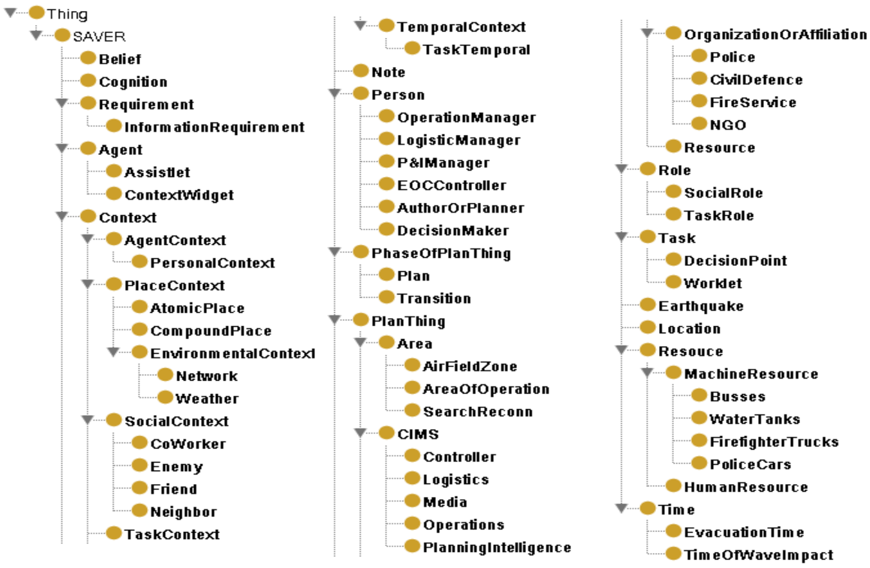


Figure 4. Part of example Super Ontology

Figure 5 illustrates the partial OWL / XML rendering which is required for (a) SSA and (b) TSA. Situation analysis is obtained from situation ontology and assessment is assigned to the 'SA' concept in the Super Ontology. This is the SA of the situation agent. The SA of every team member is either identical with that of the situation agent or similar with some variation suggested by a team member. The agent updates the SA accordingly so that the SSA remains accurate and shared among all the team members. As shown in Figure 5 (a), Person's SA is described by domain and range concepts. Similarly, Figure 5 (b) models the relationship of task and information requirement so that inferences can be made that assist individuals and their team members to complete their tasks.

```
<ObjectPropertyDomain>
    <ObjectProperty URI="&SSA;hasSA"/>
    <Class URI="&SSA;Person"/>
</ObjectPropertyDomain>
<ObjectPropertyRange>
    <ObjectProperty URI="&SSA;hasSA"/>
    <Class URI="&SSA;SA"/>
</ObjectPropertyRange>
```

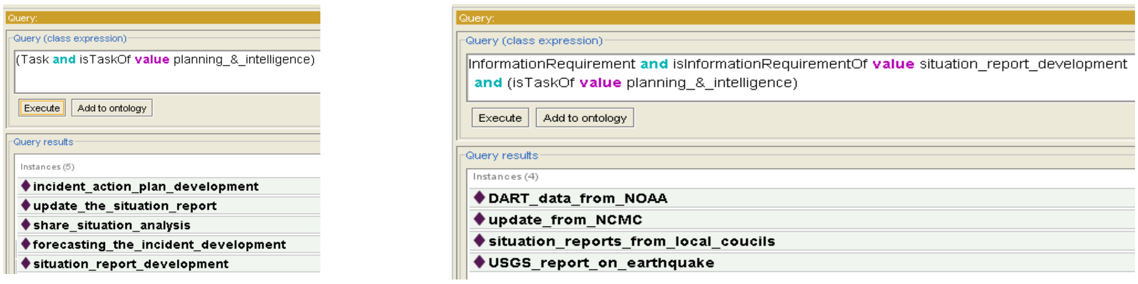
(a)

```
<ObjectPropertyDomain>
    <ObjectProperty URI="&SSA;hasInformationRequirement"/>
    <Class URI="&SSA;Task"/>
</ObjectPropertyDomain>
<ObjectPropertyRange>
    <ObjectProperty URI="&SSA;hasInformationRequirement"/>
    <Class URI="&SSA;InformationRequirement"/>
</ObjectPropertyRange>
```

(b)

Figure 5. Partial OWL / XML rendering of ontology for SSA and TSA

Using the above relationships we can query tasks related to specific roles, e.g. planning and intelligence as shown in Figure 6 (a). Simillarly, we can use the task information to inquire about the information requirements of a specific role and task, e.g. "situation report development" as shown in Figure 6 (b). In this way, emergency mangers can be prompted about various tasks according to their roles at different phases of the disaster and provided with the information required to complete these tasks. Or this information can be routed to the team member if any input or collaboration is required from him / her.



(a) (b)

Figure 6. Query result for tasks of a specific role (a) and information requirements of specific task (b)

CONCLUSION AND FUTURE WORK

In this paper, we have proposed a new way of looking at SSA and TSA from a team decision perspective. Our approach leads to a conceptual framework for a computerized emergency management system that is scalable and adaptive to dynamic situations and the changing dimensions of shared and team situation awareness. The ontology-based approach for SA inference is implemented with a case study of mass evacuation following a tsunami. Both approaches seem promising though more work is needed to infer belief of other team members. We are working on modeling a very detailed real scenario of emergency decision making using ontology for team situation awareness. During this work we will use a wide range of context information and various roles of emergency managers to show how coordination and collaboration can be improved in a larger extent. We are considering using the number of correct inferences and situation assessments as criteria to validate the concepts.

REFERENCES

1. Baumgartner, N., Gottesheim, W., Mitsch, S., Retschitzegger, W., & Schwinger, W. (2010). Editorial: BeAware!-Situation Awareness, the Ontology-Driven Way. *Data Knowl. Eng.*, *69*(11), 1181-1193.
2. Bolstad, C. A. & Endsley, M. R. (2000) The Effect of Task Load and Shared Displays on Team Situation Awareness. In: *14th Triennial Congress of the International Ergonomics Association and the 44th Annual Meeting of the Human Factors and Ergonomics Society*, pp., Santa Monica.

3. Boury-Brisset, A.-C. (2003) Ontology based Approach for Information Fusion. In: *Sixth International Conference on Information Fusion*, pp. 522-529.
4. Endsley, M. (1995) Toward a Theory of Situation Awareness in Dynamic Systems: Situation awareness. In: *Human Factors*, Vol. 37, pp. 32-64. Human Factors and Ergonomics Society.
5. Endsley, M. R. & Robertson, M. M. (1996) Team Situation Awareness in aviation maintenance. In: *40th Annual Meeting of the Human Factors and Ergonomics Society* pp. 1077-1081. Human Factors and Ergonomics Society, Santa Monica.
6. Fracker, M. L. (1991) Measures of Situation Awareness: Review and Future Directions. pp. Armstrong Laboratories, Crew Systems Directorate, Ohio.
7. Gadomski, A. M., Bologna, S., Costanzo, G. D., Perini, A. & Schaerf, M. (2001) Towards Intelligent Decision Support Systems for Emergency Managers: the IDA approach. In: *International Journal of Risk Assessment and Management* Vol. 2, pp. 224-242.
8. Graham, S.E. & Matthews, M.D. (2000). Modeling and Measuring Situation Awareness. In J.H. Hiller & R.L. Wampler (Eds.), *Workshop on assessing and measuring training performance effectiveness (Tech. Rep. 1116)* (pp. 14–24). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.
9. Haddow, G. D., Bullock, J. A. & Coppola, D. P. (2007) *Introduction to Emergency Management*, Elsevier.
10. Horney, T., Jungert, E. & Folkesson, M. (2003) An Ontology Controlled Data Fusion Process for a Query Language. In: *Sixth International Conference of Information Fusion*, pp. 530-537.
11. Javed, Y., Norris, T., Johnston, D. & Doyle, E. H. (2011) Towards a Framework for Crisis Decision Support Systems: Information Requirements for Contextual Team Situation Awareness In: *(accepted)CutterIT Journal: Special Issue on IT and Crisis Management*, pp.
12. Matheus, C. J., Baclawski, K., Kokar, M. M. & Letkowski, J. J. (2005) Using SWRL and OWL to Capture Domain Knowledge for a Situation Awareness Application Applied to a Supply Logistics Scenario. In: *Rules and Rule Markup Languages for the Semantic Web First International Conference*, pp. 130-144.
13. Matheus, C. J., Kokar, M. M. & Baclawski, K. (2003) A Core Ontology for Situation Awareness. In: *Sixth International Conference on Information Fusion*, pp. 545-552.
14. McGuinness, D. L. (2003) Ontologies for Information fusion. In: *Sixth International Conference on Information Fusion*, pp. 650-656.
15. Nofi, A. A. (2000) Defining and Measuring Shared Situational Awareness. pp. Center for Naval Analysis, Alexandria
16. Robbins, H. & Finley, M. (2000) The New Why Teams Don't Work: What Goes Wrong and How to Make It Right, Berrett-Koehler Publishers.
17. Roosen, J. T. (1997) Factors Affecting Crisis Management. In: International Oil Spill Conference, Improving Environmental Protection, Progress, Challenges Responsibilities, pp., Florida, USA.
18. Salas, E. & Prince, C. (1995) Situation awareness in team performance. In: *Human Factors*, Vol. 37, pp. 123-136.
19. Salmon, P. M., Stanton, N. A., Jenkins, D. P., Walker, G. H., Young, M. S. & Aujla, A. (2007) What Really is going on? Review, Critique and Extension of Situation Awareness Theory. In: *Proceedings of the 7th International Conference on Engineering Psychology and Cognitive Ergonomics*, pp. Springer-Verlag, Beijing, China.
20. Shu, Y. & Furuta, K. (2005) An Inference Method of Team Situation Awareness Based on Mutual Awareness. In: *Cognition, Technology & Work*, Vol. 7, pp. 272-287. Springer London.
21. Smith, K. & Hancock, P. A. (1995) Situation Awareness is adaptive, externally directed consciousness. In: *Human Factors*, Vol. 37, pp. 137-148.
22. Steinberg, A. N., Bowman, C. L. & White, F. E. (1999) Revision to JDL Data Fusion Model. In: *SPIE, Architectures, Algorithms and Applications*, pp. 430-441.
23. Stout, R. J., Cannon-Bowers, J. A., Salas, E. & Milanovich, D. M. (1999) Planning, Shared Mental Models, and Coordinated Performance: An Empirical Link Is Established. In: *Human Factors: The Journal of the Human Factors and Ergonomics Society*, Vol. 41, pp. 61-71.
24. Tufekci, S. (1995) An integrated Emergency Management Decision Support System for Hurricane Emergencies. In: *Safety Science*, Vol. 20, pp. 39-48.
25. Wellens, A. R. (1993) Group Situation Awareness and Distributed Decision Making: From Military to Civilian Applications. In: *Current Issues in Individual and group decision making*, pp. 267-291.
26. Ye, X., Wang, Y., Li, H. & Dai, Z. (2008) An Emergency Decision Support System Based on the General Decision Process. In: *2008 IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology*, Vol. 3, pp. 215-218. wi-iat.
27. Yoon, S. W., Velasquez, J. D., Partridge, B. K. & Nof, S. Y. (2008) Transportation Security Decision Support System for Emergency Response: A Training Prototype. In: *Decision Support Systems*, Vol. 46, pp. 139-148.