Situation Representation and Awareness for Rescue Operations

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ABSTRACT

During rescue operations, being aware of the situation is very critical for rescuers and decision-makers to reduce the impacts. This work aims to support situation awareness amongst actors participating in rescue operations by adopting an ontology-based approach. An application ontology is proposed based on existing related ontologies and operational expertise collection. It will help to ensure common situation representation and understanding between different actors. After that, a knowledge-based system will be developed and integrated in actors' environment to support decision-making. Our preliminary results are shown in this paper.

Keywords

Application Ontology, Common situation representation, Rescue of people, Situation awareness.

INTRODUCTION

Rescue of people consists in saving their life in case of particular situations by applying responsive operations. In France, it is described as precise duties to be achieved by several public services in order to ensure the protection of people by allowing them to escape from dangers, securing intervention sites, providing medical help, and finally, making sure the evacuation to an appropriate place of reception (Diederichs et al., 2006). These services have to deal with several flows of information coming from many sources. They have to make decisions based mainly on these information. They also have to cooperate and each one should be aware of actions and environment's perception ensured by the other even if they are not in the same place. A shared situation representation between different involved actors is thus required. The aim of sharing a common situation representation between actors is to ensure situation awareness.

Semantic representation techniques (Sowa, 2000; Studer et al., 1998) and ontologies (Gruber, 1993) can be very helpful in order firstly to represent main situations entities and then to guide situation's perception sharing between actors (Nunavath et al., 2016). In this paper, we present our work done toward the definition of an application ontology to represent rescue operations in France as well as information and data flow between actors. This ontology will help to share common situation representations between different actors. It responds to situation awareness requirements, which necessitate having a global vision of main elements, aspects and dimensions in a given situation. This paper is divided in three sections:

1. Definition of rescue operations and actors involved in France
2. Situation awareness and rescue operations
3. Ontology for situation representation, a methodology to build it and related existing ontologies

RESCUE OF PEOPLE

Also called emergency rescue, *rescue of people* is one mission of medical services and firefighters. It consists in ensuring the safety of victims and patients by making them able to escape from a danger, sending adapted means and securing interventions sites, applying first aid gestures, and, finally, ensuring the evacuation and transportation to a suitable place of reception. In France, two main services are engaged in rescue operations and emergency care to the population: Emergency Medical Assistance Services (SAMU) and Departmental Fire and Rescue Services (SDIS) (Diederichs et al., 2006). A common referential has been elaborated in order to make responsibilities clearer and delimit missions (Comité quadripartite DDSC et DHOS, 2008). The mission of SDIS is to ensure protection, prevention and firefighting. They are also responsible of the rescue of patients or victims of disasters and accidents as well as their evacuation (Chehade et al., 2018; Comité quadripartite DDSC et DHOS, 2008). Whereas, the mission of SAMU is limited to providing medical assistance in emergency situations. This task can be divided into five subtasks: 1) Provide permanent medical listening, 2) choose and trigger responses according to the nature of the calls, 3) make sure the disponibility of the means of hospitalization adapted to the patient's or victim’s condition, 4) prepare victims transportation using a private transport company or another public service and, 5) make certain the victim's admission. Other centers and services also participate in rescue operations. They are attached to the two previous ones and are responsible of receiving alerts and calls, transferring received calls to the good actor as well as ensuring a good information exchange and communication between SDIS and SAMU. Each SDIS possesses Health and Medical Rescue Service (SSSM) that assists, in particular, in emergency relief missions. Moreover, it has a Fire and Rescue Departmental Operational Center (CODIS) responsible for coordinating the activity of fire and rescue services. Add to that, it has one or several Alert Processing Centers (CTA), responsible for receiving, reorienting and processing requests and alerts. On the other hand, each SAMU has a Center of Receiving and Regulating Calls (CRRA) responsible of receiving alerts and calls and transferring them to a SDIS when there is a need of participation of this latter in a rescue operation. They are also connected to Mobile Service of Emergency and Reanimation (SMUR), which provides care for victims or patients whose conditions require, urgently, special medical care.

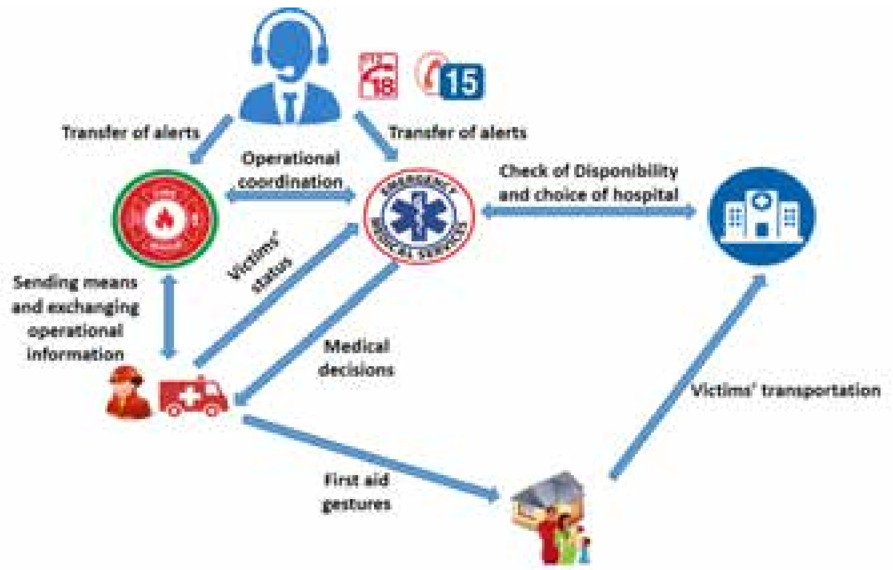

Figure 1. Involved actors and flow of information during rescue of people

An example illustrating the multiplicity of engaged actors during an operation is shown in Figure 1. In this example, we took the case of a medical rescue operation. As we can see, participating actors exchange a sheer volume of information such as operational information or victim’s status. This plurality of sources and the important volume of exchanged information during an operation can lead to overcharge and make it challenging for actors to understand provider’s intentions. Sharing situations’ perception between actors can be important in order to solve this problem and ensure situation awareness. Ontologies can help in order to ensure sharing same perception of situations.

SITUATION AWARENESS

Nowadays, the term of situation awareness is widely used; it serves as a foundation of overall performance throughout many different domains, such as education, military operations, air traffic control, driving, search and rescue, and crisis management (Endsley, 2006). Endsley in (Endsley, 1995) defined it as *“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"*. In addition, she defined steps to achieve human situational awareness and divided them into three levels. The first level of situation awareness is the perception of the situation elements, their status, their attributes, and their dynamics. After that, level two consists in the comprehension of the elements and the current situation. This comprehension depends on understanding the meaning of elements perceived in the first level as well as the relation between these elements and the objectives. Finally, the third level involves making predictions about the future status and actions of the situation elements based on the first two levels. From the above definition, we can say that situation awareness is the result of understanding of what is happening around us and is the basis for decision-making. Researchers in different areas have determined that expert decision-makers start with classifying and understanding a situation, and proceed then to decision making (Endsley, 2006; Kulyk et al., 2008). Furthermore, situation awareness has a vital importance in vital collaborative environments since it can improve team performance by improving the quality of made decisions (Endsley et al., 1995). Rescue domain is one of these environments.

Problems of Situation Awareness in Rescue Operations

In rescue operations, being aware of the situation is very important for cooperation of participating teams and decision makers in order to reduce negative impacts such as loss of a victim's life. However, ensuring a high degree of situation awareness is one of most difficult components of many jobs and one of the most vital and challenging duties for many rescue actors (Endsley, 2006). In fact, multiple actors coming from various organizations participate in a single operation as it was shown in Figure 1. These actors are from various backgrounds with distinct missions, experiences, expertises and goals. Thus, it is difficult for decision-makers to understand the situation perception of actors and other-decision makers. During a rescue operation, a large number of information is exchanged between actors during an operation. These actors have to interpret these information in order to develop an overall picture of the situation since their decisions are based on understanding the situation first. This interpretation can differ from an actor to another since they are from different backgrounds and are presents in different places. For example, a decision-maker has to make his/her decisions based on the received information from another actor and his understanding of the situation. S/he has to be aware of the exact situation because any misunderstanding of the situation can lead to its misinterpretation and thus to bad decisions and actions (Nunavath et al. 2016). Moreover, the dynamicity of situations and the continuous evolution of their status is another problematic in face of enhancing situation awareness. According to these problems, we decided to work on sharing a common situation representation and environment perception between different actors, which can lead to ameliorate awareness of the situations.

Related Work

In recent years, rescue operations and emergency responses have merged technologies of computer, communication, artificial intelligence, system engineering and knowledge engineering. These technologies aim to support the coordination, cooperation, communication and decision making of actors. Several systems and applications were developed recently in order to support information sharing and enhance situation awareness in critical and dynamic domains such as rescue operations and crisis management. Some researchers focused on studying situation awareness in robot-assisted rescue operations (Larochelle et al., 2011; Riley and Endsley, 2004) while others studied the effect of using mobile devices and tabletops in these operations (Bergstrand and Landgren, 2009; Engelbrecht et al., 2011).

On the other hand, research on ontology-based situation awareness has enormously increased during the past and current decades. Several ontology-based situation aware systems were successfully developed such as "AKTiveSA" (Smart et al., 2003) and "BeAware" (Baumgartner at al., 2010). An important number of studies confirm the importance of using ontologies in order to ensure this awareness (Kokar et al., 2009; Kokar and Endsley, 2012; Matheus et al., 2003). They also afford high-level ontologies to capture situation descriptions. These ontologies can be specified and contextualized in order to define more domain specific ones. Javed el al, (Javed et al., 2011) developed a system for enhancing shared and team situation awareness in emergency management domain by using ontologies. They created an ontology by extending the Core Ontology for Situation Awareness (Matheus et al., 2003). Authors in (Nunavath et al., 2016) proposed representing and sharing domain knowledge through domain model in order to support situation awareness. To do that, they developed an ontology in order to unify concepts between actors. However, their work was restricted to a specific kind of emergencies that is the fire building. Ashish et al, (Ashish et al., 2009) worked on situation representation in crisis management domain. The aim of this representation was to support situation awareness through the support of multiple applications such as monitoring, analyzing and planning. They based their work on event-based approach to represent the state and the evolution of crisis, the progress of response process, and the state of crisis site. To do that, they constructed an ontology and they proposed an *event management system* as a framework for representing situations. However, it is limited since the representation depends on the occurrence of events and makes it difficult to represent all the required information such as the availability of resources or hospitals.

As discussed previously, we found that several ontologies have been defined in order to support situation awareness in crisis and emergency response domain. However, none of these ontologies covers all aspects, dimensions and elements in emergency management, which is necessary to ensure situation awareness and representation. Add to that, we did not find any ontology that aim to ensure situation awareness in traditional rescue operations. Based on this problematic, we propose to construct an ontology for representing situations during rescue operations. The principle objective of this ontology is to respond to situations awareness requirements. The first requirement of situation awareness is to have a global vision of a situation. In other words, this ontology take into consideration all aspects, elements and tasks in order to promote situations perception between different actors and to support situation awareness.

ONTOLOGY FOR COMMON SITUATION REPRESENTATION

As cited above, our aim is to build an application ontology related to rescue operations in France and to be more specific, to the organization, communications, responsibilities, flow of information and processes during a rescue operation. This ontology will be used for representing situations and sharing these representations between different actors. In this section, we give details about ontologies, their categories and the methodology we followed in order to construct the proposed ontology. This ontology will help to emphasize main elements to share between actors especially when operating and solving a problem. It will be used in communication and problem's perception support systems.

Definitions

Ontology is defined as *"an explicit specification of conceptualization"* (Gruber, 1993). Ontologies can serve on two levels: (1) as a vocabulary that makes use of appropriate terms to describe entities and agents of a domain, as well as interactions and relationships between them and (2) as a knowledge base for a particular domain. In rescue operations domain, ontology can grant a shared perception of a situation by actors. This reduces the chances of misunderstanding and the rescuers as well as decision-makers can fully understand the evolution of situations. Generally, there are three categories of ontologies. This classification depends on the level of generality of the ontology, and are separated into *application ontologies*, *domain ontologies*, or *generic ontologies*, also called *top-level ontologies*. Generic ontologies are domain independent. They contain general concepts such as action, space, time, object, event and many others that can be used in different domains. Examples of these ontologies are DOLCE defined by its authors as an ontology of particulars (Gangemi et al., 2003), the Suggested Upper Merged Ontology (SUMO) (Pease et al., 2002) and OpenCyc ontology (Matuszek et al., 2006). Domain ontologies are related to a specific domain such as rescue operations. They are specification of generic ontologies. A specification of domain ontologies can be done in order to construct application ontologies that describe specific concepts in a specific domain and specific associated tasks. Good examples of domain ontologies are that related to emergency response and crisis management domain (Li et al., 2008; Yu et al., 2008). Moreover, a huge number of application ontologies have been constructed from which we cite EDXL-RECUER (Barros et al., 2015), SHARE-ODS (Konstantopoulos et al., 2006), and EMERGEL ontology (Azcona, 2013) developed to support RESCUER (Villela et al., 2014), SHARE (Konstantopoulos et al., 2006; Velde et al., 2005), and DISASTER (Azcona, 2013; Schütte et al., 2013) projects respectively.

Methodology

To construct ontology, we adopted the methodology proposed by (Bachimont et al., 2002). This methodology consists of three main steps: Normalization, Formalization, and Operationalization. The advantage of this methodology is that it details steps to build the ontology starting from identifying units until having a complete ontology with rules and relations passing by structuring taxonomies.

Normalization

This step consists in identifying terms and units in a domain, extracting their meanings, giving complete definitions to these terms, and then expressing differences and similarities of each term or unit with respect to its parents and siblings. The result of this step is a first taxonomy of notions, which can be modified during the definition of properties and relations with other notions. This modification can occur in the Formalization step. In order to identify terms, a deep study of the domain is required. This study includes studying and analyzing the domain related documentation and conducting interviews with domain experts. Another key component in this step is to reuse other existing ontologies as much as possible since they may contain common concepts with their definitions and relationships (Bouaud et al., 1995). To do that, we started by studying domain related documentation. In addition, we conducted an interview with a firefighter expert in France. The aim of this interview was to understand the organization and role of different actors and organizations. Questions turned on the different hierarchies of organizations, their roles and relations between them. We explored also the literature review about existing ontologies related to situation awareness and rescue operations domain.

During our literature review, we found and studied many ontologies defined in the domain of rescue operations. Some of these ontologies and not directly applicable in our case such as SHARE-ODS that does not cover all aspects in rescue operations (Konstantopoulos et al., 2006), while others are not publicly accessible. In addition, we found an ontology related to situation awareness that is the main interest of our work (Matheus et al., 2003). We also found several application and domain ontologies constructed in emergencies and crisis management domain. These ontologies cannot be used completely in our case because there is a difference between an ordinary rescue response and an emergency or crisis response. However, we used these ontologies as supports to borrow ideas and some defined concepts in order to build our ontology specific for rescue operations in France. In addition, many important concepts related to our particular context are not defined in previous ontologies. For instance, structures and actors organization, roles, dataflow, and many other concepts. From the ontologies that we found, we based our study on five ontologies that are the most applicable to our context. These ontologies are the emergency response ontology (Li et al., 2008), the emergency ontology (Yu et al., 2008), EMERGEL (Azcona, 2013), EXDL-RESCUER (Barros et al., 2015), and the situation awareness core ontology (SAW) (Matheus et al., 2003).

The first ontology we studied is the EMERGEL ontology (Azcona, 2013) defined in the context of the project "DISASTER" focusing on information exchange on a semantic level (Azcona, 2013; Schütte et al., 2013). It is an application ontology built to temporally describe a crisis or disaster situation. In order to construct this ontology, authors specified some generic classes defined in the top-level ontology DOLCE particulars (Gangemi et al., 2003). This ontology takes into consideration, **SPACE**, **TIME**, **OBJECTS** representing physical objects, **CONSTRUCTS** representing non-physical objects, and **ACTIVITIES** representing duties and missions to be achieved. Examples of concepts of this ontology are *Person*, *Equipment*, *Vehicle*, *Communication*, *SpatialPoint* and *Infrastructure*. The advantage of this ontology is that it covers different subjects in emergency response.

The second ontology we chose is the EXDL-RESCUER ontology (Barros et al., 2015) developed to support the project "RESCUER" designed to assist actors in emergencies by using crowdsourcing information (Villela et al., 2014). The aim of this application ontology is to construct a conceptual model corresponding to coordination and information exchange with other systems. It defines a group of message contexts and focuses on the type of exchanged data during an emergency. In this ontology, authors defined concepts correspondent to the type of exchanged messages such as Alert, MsgType, ResponseType, Info, etc.

The third ontology we consider is the emergency ontology constructed to enhance the reorganization of knowledge in decision-support systems (Yu et al., 2008). Authors developed this domain ontology by adopting the Activity First Methodology (Mizoguchi et al., 1995). This ontology contains four main classes: **EVENT** that can be a *disaster* or a *disease*, **SUBJECT** divided into *personal* and *actor***,** **TASKS** consisting of *detection*, *prevention*, *rescue*, *evaluation* and *communication*, and **RESOURCE** that can be *artificial* and *inartificial*. Each class is also divided into several subclasses, each having many instances. We used this ontology since it gives the many general concepts that are in common between rescue operations and crisis management. This ontology has the advantage of covering multiple contexts in disaster response, ranging from events to tasks, passing by resources and subjects.

Moreover, we studied the 'Task Ontology' constructed in the aim of supporting the deployment of the evacuation planning system during emergencies (Li et al., 2008). This ontology defines a unique vocabulary usable by different actors and organizations regardless of the emergency nature. It defines four generic concepts that are Preparation, Response, Rescue, and Handling, divided each into several sub concepts. This ontology is restricted to the steps and tasks to achieve during an emergency. From this ontology, we reused some concepts that are in common with rescue operations such as communication, medical aid, and victim assistance.

Finally, we studied the core ontology for situation awareness (Matheus et al., 2003). Authors constructed this ontology as a reference for building ontologies for arbitrary situations. The generic concept defined in this ontology is **SITUATION** that is a collection of **SITUATIONOBJECTS**, **GOALS** and **RELATIONS**. SituationObjects represent entities in the world and they have attributes. One kind of SituationObjects is PhysicalObject. The main advantage of this ontology is that is takes into consideration the evolution of situations with respect to time and space. From this ontology, we reused several main concepts used for situation representation such as Situation, Time. However, we did not extend this ontology since it is a little bit specified to situation awareness and when we tried to extend it we were not able to cover all concepts and aspects in rescue operations. Another reason that prevented us from extending it is that there is a mix between Attributes, Relations and Properties and we cannot follow this mixing since we decided to use semantic networks for representations. Semantic Networks are one type of formalisms used for knowledge representation in which there is a difference and separation between an Is-a relation and other relations that are in general properties which makes inferences simpler (Sowa, 2008).

After studying the existing ontologies, the domain related documentation and conducting an interview with a firefighter expert, we identified notions. We gave then definitions and we classified these notions into a first taxonomy. We moved then to the next step: the ontology formalization.

Formalization

The second step is Formalization and consists in defining properties and relations between notions classified into the taxonomy obtained in the first step (Bachimont et al., 2002) and reorganizing this taxonomy in a way that it enables the addition of new concepts. At the end of this step, the taxonomy will become a true ontological tree and notions will become concepts with relations between them. To do that, we defined relations between concepts. However, we stayed with our relations at a high level without making relations between low-level concepts. The part related to relations and properties will be detailed in the Operationalization subsection.

Let us talk first about the main concepts and the final taxonomy of our ontology. First, we considered a rescue operation as an entity and we divided it into two generic concepts **OBJECTS** and **CONSTRUCTS** in order to make a first classification between different categories as it has been done in EMERGEL ontology (Azcona, 2013). These two categories represent physical and abstract defined in SUMO (Pease et al., 2002). We chose to follow the classification of SUMO since it is a top-level ontology that can ensure interoperability between lower level ontologies. **OBJECTS** are defined as a representation of physical objects in the real world. As shown in figure 2, the main category **OBJECTS** include three main concepts: *Environment, Persons and Material.* Each main concept contains several sub-concepts. *Environment* represents the context of operations. It contains Infrastructure that includes Ways, Ports and Buildings, Space that could be a Decision Space or an Intervention Site and Weather that is divided into Temperature, Wind and Humidity. *Person* represents people involved in a rescue operation. A person can be an Actor who is participating in an operation or a Victim who is being rescued. While in *Material*, we consider concepts concerning inartificial resources used during a rescue operation including Transport, Medical, Safety, Catering, Communication equipment and Technical equipment.

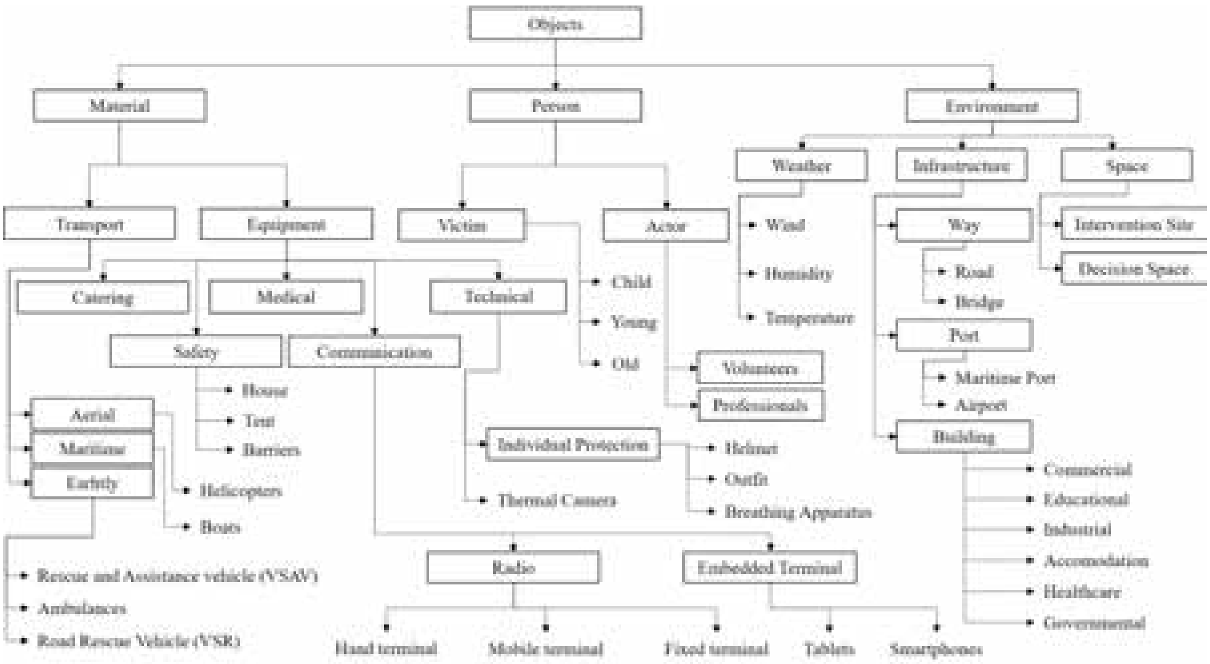

Figure 2. Hierarchy of Objects

On the other hand, **CONSTRUCTS** contain concepts related to non-physical objects. This category includes six main concepts that are *Tasks, Organization, Time, Characteristics, Data* and *Incident,* divided each into several sub-concepts as shown in Figure 3. *Organization* represents the organism involved in an operation. It can be a Military organization such as Army and Firefighters (SDIS) or a Civil organization such as medical services (SAMU) connected each to different centers. *Time* is used for sure since we talk about dynamic operations and situations and it contains Timeline. *Characteristics* are used to describe some objects and constructs. They are divided into main categories: Qualitative and Quantitative Characteristics. For example, Type and Form can characterize the exchanged Data. It can be a report in form of text. *Data* represents the exchanged information before, during and after an operation. It informs on situations and their evolution as well as occurring events during a situation. *Incident* represents the type of situation behind the intervention. It can be a disease, an accident, a fire or a natural event causing victims. Finally, *Tasks* represent the required missions and duties to ensure effective operations. These tasks covers three main phases: 1) Preparation phase including tasks to be taken before an operation such as personal training and resources maintenance, 2) Response phase including tasks to be achieved during the operation such as Communication, Coordination, Cooperation and, 3) tasks to be taken at the end of the operation such as investigation, reporting and supplying social assistance to the victims. Due to a lack of space, we decided to represent the concepts related to Tasks in a separated figure of constructs as shown in Figure 4.

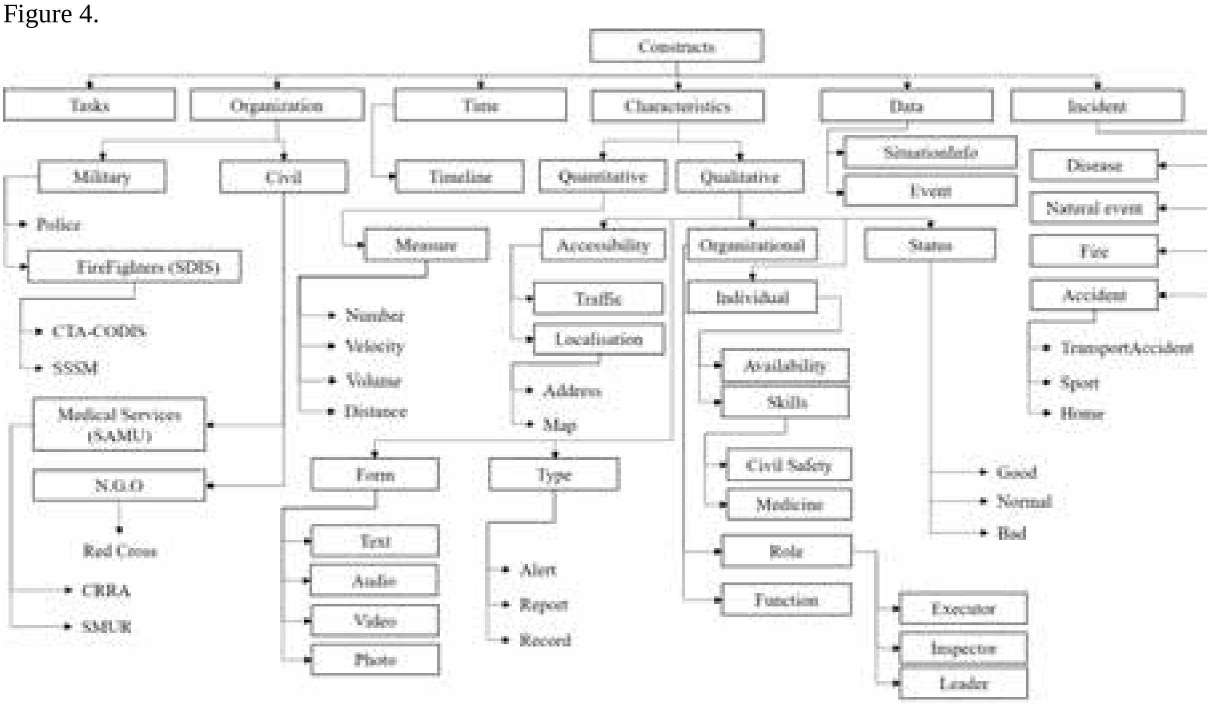

Figure 3. Hierarchy of Constructs

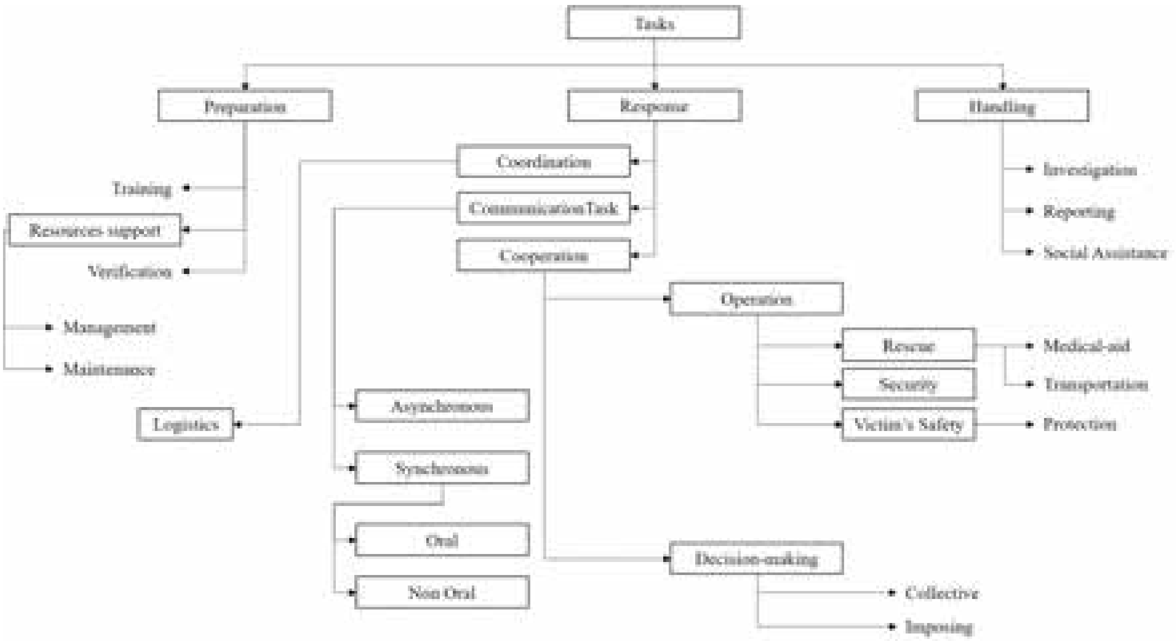

Figure 4. Tasks to be achieved

Finally, we moved to the last step: the Operationalization.

Operationalization

The last step consists in implementing the ontology in a system using a formal representation language. The result is called computational ontology (Bachimont et al., 2002). To do that, we used Protégé 5.2 (https://protege.stanford.edu/products.php#desktop-protege), which enables building OWL-based ontologies (Musen, 2015). The advantage of using Protégé is that it enables building ontologies, defining rules and doing required inferences. In this step, we defined our concepts and sub-concepts as classes and sub-classes. Figures 5 and 6 show the classes defined under **OBJECTS** and **CONSTRUCTS** respectively.

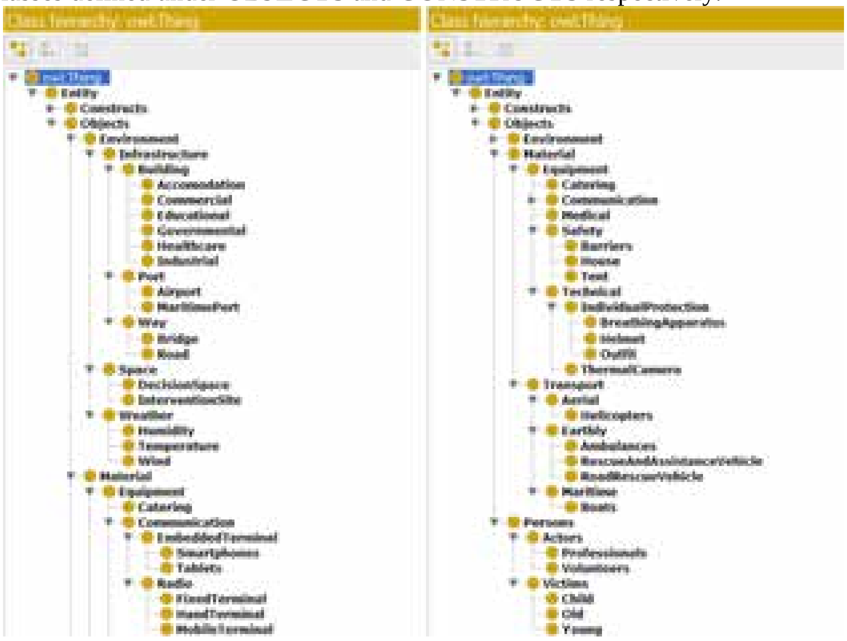

Figure 5. Classes of Objects

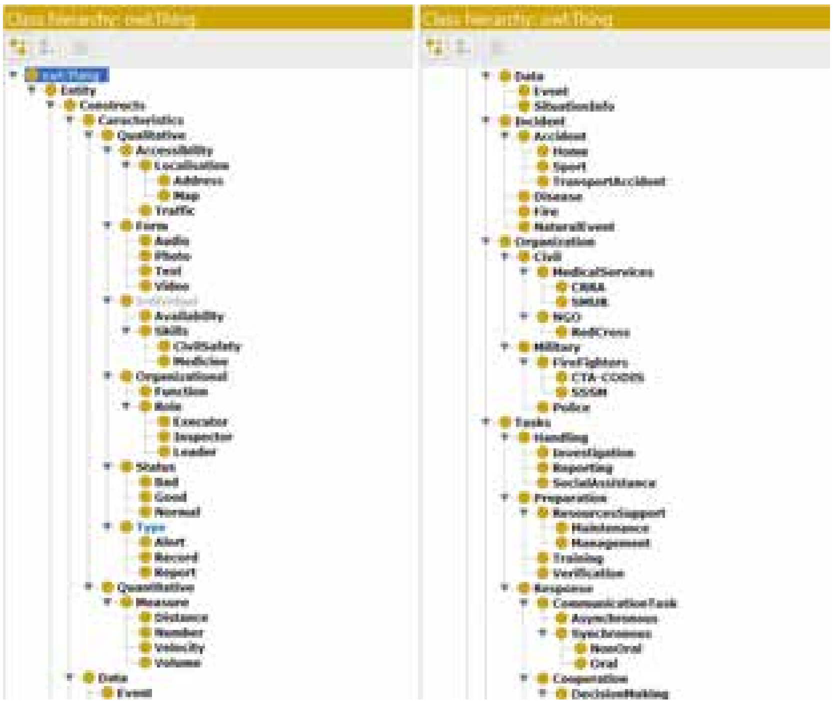

Figure 6. Classes of Constructs

After that, we identified properties of concepts. These properties are the relations between concepts. Figure 7 shows an example of properties defined for the concept Actors.

Figure 7. Example of Properties

After finishing the taxonomy and identifying relations between concepts, we represented the obtained ontology using graphs. These graphs show different concepts and relations between them based on the defined properties. Figure 8 presents an extract of a graph showing different relationships that exist between some concepts of the ontology.

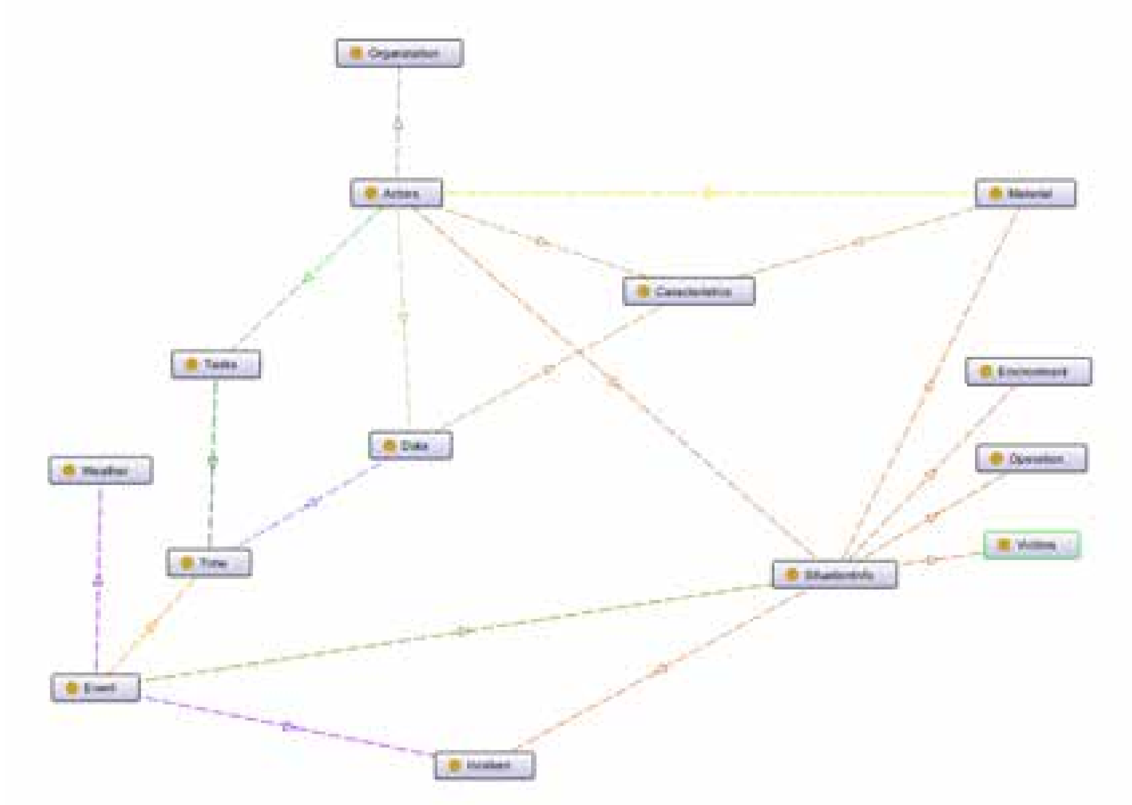

Figure 8. One graph of the implemented Ontology

In this example, we can see that an Actor is a part of an Organization. S/he has Characteristics that can be Individual such as Availability or Organizational such as Function. This actor uses Materials having characteristics too such as the state of the material. S/he transmits Data that is communicated on Time and informs on SituationInfo, which contains information on Operation, Material, Victim, Environment and Incident. An actor does also other Tasks that are scheduled on Time. On a certain Time, an event can occur and affects SituationInfo. This event can be a change in Weather or a sudden Incident.

The work done represents the methodology we adopted and different steps to construct the proposed Ontology. To do that, we identified notions. We gave then definitions and we classified these notions into a taxonomy. After that, we identified properties and relations between concepts and we reorganized our taxonomy. Finally, we implemented this ontology in a computational language OWL using Protégé 5.2 and we represented it using conceptual graphs. As a future step, we look forward to evaluate the developed ontology and submit it to an ontology catalog. The aim of building this ontology is to support situation awareness in rescue operations. It will be used not only for communication and situation's representation but also to help actors to build the relations between elements by using an inference system.

CONCLUSION

Like several dynamic and complex domains, ensuring a high level of situation awareness in rescue operations is difficult. This difficulty is caused by many factors such as multiplicity of actors, dynamicity of situations and difference in situations' perception between a person and another. All these factors and many others can affect actors' performance and decision-making. To respond to this problematic, we constructed an application ontology related to rescue operations in France. It will be used for ensuring common situation representation between actors. This representation helps to unify situations perceptions and understanding between different actors involved in rescue operations and then to enhance situation awareness. It helps also to display important elements in a situation, their evolution and the occurrence of events, which is the basis of situation awareness. To construct the ontology, we adopted a methodology consisting of three steps: Normalization, Formalization and Operationalization. We also studied domain related documentation and several domain existing ontology. After that, we implemented this ontology in OWL language using Protégé 5.2. However, our ontology is not evaluated yet since it is our first study in this aim.

As a future work, we will detail this ontology and instantiate it based on expertise collection and modeling. Thus, we will conduct more interviews with actors from different organizations involved in rescue operations. After that, we will test it in real cases, evaluate it and submit it to an ontology catalog. Finally, we will study the design and implementation of a knowledge based system that will support decision-making and situations understanding in rescue operations environments by exploiting the constructed ontology. This work will include naturally a study about the confidentiality and security of exchanged information.

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