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# Modelling Interactions in Rescue Operations

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Samer Chehade, Nada Matta, Jean-Baptiste Pothin, and Remi Cograne

**Abstract**— In rescue operations, situation awareness is very critical to decision-makers and responders in order to reduce the bad consequences. Furthermore, a good collaboration between services and organizations is vital to achieve successful operations. Therefore, a good communication and information exchange between actors is crucial to meet these requirements. This work aims to enhance situation awareness in rescue operations by supporting communication and interaction between participating actors. To do that, we start by studying interactions, communication, and information flow. After that, we look forward to design and implement a communication system that will be used by rescuers and first responders. In this paper, we show our preliminary results in which we model the interactions.

**Keywords**— *Communication, Interactions, Modelling, Ontology, Rescue of people, Situation awareness*

## I. INTRODUCTION

Rescue of people consists in saving lives and property in case of specific situations by executing responsive operations. Rescuers from different organizations have to collaborate to achieve operations properly. In France, several public services are engaged in rescue operations. They have to achieve specific tasks in order to protect patients and victims of particular events by ensuring their safety, enabling them to escape from dangers, securing sites, applying first aid gestures, and finally ensuring the transportation and evacuation to a suitable place of reception [1]. They have to cooperate and each one must be aware of actions and situation's perception of others even if they are geographically dispersed. A common situation representation between different actors is hence required. The aim of sharing a unique situation representation between different involved actors is to support situation awareness and thus to achieve successful operations and decision-making. Moreover, these services must manage a huge flow of information coming from various sources. First responders have to act and responsibly have to make decisions based on these information. This information flow and complexity may lead to ineffective interaction and communication between stakeholders, which can influence collaboration and situation awareness. Authors in [2] mentioned that ineffective communication and interaction can lead to misunderstanding of the a situation, which can cause its misinterpretation and thus a lack of awareness toward it.

In order to support interactions between actors, we look forward to propose and design a system that will facilitate communication and information sharing in rescue operations in France. To design such a system, it is necessary to study and analyze the principles and actors' interactions. Thus, we will model these interactions and we will propose requirements to modelling them. An application ontology related to rescue

domain will serve us as a basis to complete the model and define requirements.

The paper is organized as follows. Section II describes in more details rescue operations, actors involved in France as well as situation awareness, interaction and communication problems. In section III, we discuss the literature review and related work. Section IV presents modelling requirements and elements, a structure model and the rescue interaction model, while section V concludes the paper.

## II. RESCUE OPERATIONS

### A. Definitions and participating actors

In most of the countries, rescue operations, also called Search and Rescue operations, are missions of medical units and firefighters. They consist in protecting lives and preventing losses through searching, locating and rescuing persons in distress situations. In France, two main organizations participate in rescue and emergency response operations: Firefighters know as Departmental Services for Fire and Rescue (SDIS) and Urgent Medical Assistance Services (SAMU) [3]. A detailed report [1] has been elaborated by the French state as a referential to delimit missions and make responsibilities clearer. SAMU are responsible of providing medical help to patients and victims by: (1) providing medical listening, (2) choosing adequate responses with respect to the nature of calls, (3) checking availability of hospitalization centers, (4) preparing the transportation and evacuation of victims using health transport organizations and, (5) ensuring victims' admission in hospitalization centers. Whereas, SDIS are responsible of protecting, securing and firefighting [1]. Add to that, some other centers and services participate in rescue operations. They make part of the two previous ones and their tasks are limited to logistics such as receiving calls, transferring calls to the adequate service, ensuring a good communication between SDIS and SAMU and managing resources. In addition to the description of services' missions, the common referential presents the organization of each service and its attached centers [1]. Each SDIS is connected to one or many Call Processing Center (CTA) that receives and processes alerts and calls. It is also responsible for choosing persons and materials to engage depending on the type of intervention. Add to that, a SDIS possesses one or several Fire and Rescue Center (CIS) responsible for engaging and sending resources chosen by the CTA to the intervention. Similarly, each SAMU has a Call Reception and Dispatch Center (CRRD) that receives calls and transfers them to a CTA of a SDIS when the participation of this latter in an operation is required. All these services and centers have to cooperate, collaborate and

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communicate in order to complete their tasks and missions appropriately.

### B. Situation awareness, interaction and communication problems

In rescue operations, being aware of the situation is very necessary for cooperation of rescue teams and decision-makers to reduce negative impacts such as loss of victim's life. Situation awareness serves as a basis of overall performance. It was defined as *"understanding the activities of others, which provides a context for your own activity"* [4]. A more recent definition was given by Endsley 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"* [5]. She also defined steps toward achieving human situational awareness and divided them into three levels. The first level is the perception of situation elements, their status, their dynamics, and their attributes. The second level involves the comprehension of these elements by understanding their meanings and relations. Finally, the third level consists in making predictions about the future status and attributes of situation elements based on the first two levels. From these definitions, we can say that situation awareness is the result of understanding of what is happening around and is the foundation for decision-making. Add to that, it has a crucial importance in collaborative environments such as rescuing since it can enhance team performance by enhancing the quality of decisions [5].

Ensuring a high level of situation awareness is one of the most difficult tasks in many jobs and one of the most challenging missions for rescue actors. It involves management and achievement of several activities such as communication, interaction and information exchange. Communication is a phenomenon to request and send knowledge and information. It can be in several forms such as: ordinary conversation, interpersonal communication, online communication, phone communication, written communication, and mass media [6]. It is very important to handle a good communication in rescue operations since it is the way to share critical information about locations of interventions and teams, victims' and patients' status and emergencies, hazardous conditions, and evolution of situations, which allows to handle the same situation awareness amongst all actors. However, handling this communication is still difficult due to many factors. First, a good communication requires a common understanding of the messages by the transmitter and the receiver in order to have a unique situation perception between them. In the domain of rescue where multiple actors coming from several different organizations participate in one operation, it is difficult to respond to this requirement since participators come from various backgrounds with distinct missions, experiences, and goals. The second important problematic is the dynamicity of situations and their continuous evolution. This imposes a non-stop exchange of information between actors as long as the situations evolve which can lead to a sheer volume of information to be transmitted, received and interpreted. Finally, exchanged information during rescue can take several forms and types. It can be medical, spatial, situational, and operational and it can be in forms of text, audio or video. This diversity and heterogeneity make it difficult to actors to interpret information in time-limited operations. Fig. 1

illustrates the multiplicity of engaged organizations and actors in rescue operations. We took the case of a medical rescue operation. In this example, we can see that different actors communicate and exchange a large volume of information like situational information and decisions.

According to these problems, we decided to work on enhancing communication and interaction in rescue operations in order to support situation awareness.

### III. RELATED WORK

Over the past decades, rescue operations and crisis management have merged technologies of information and communication, artificial intelligence, ubiquitous computing, sensors, robots, system engineering and other technologies. Many applications and systems were developed in order to support communication and information exchange in dynamic and critical domains such as crisis management and rescue operations. [7] proposed a communication system to be implemented in ambulance services in France. The aim of this solution was to facilitate exchanges between intervention crew/teams on sites and medical practitioners in hospitals during patients' or victims' evacuation and transportation. However, this system focus on medical information without taking into account other important information to be exchanged in rescue operations such as situational, operational and environmental information. Hence, its use is limited to medical emergency response. Moreover, several studies have been conducted to enhance situation awareness in rescue operations and crisis management. Some of them focused on supporting situation awareness in robot-assisted rescue operations [8], while others studied the consequences of using tabletops and mobile devices to support awareness in these operations [9]. Furthermore, many researchers worked on using ontologies to support situation awareness in such operations [10]. For instance, [11] proposed a system to enhance shared and team situation awareness in crisis and emergency management by using ontologies. For this aim, an application ontology was defined by extending the core ontology for situation awareness [12]. On the other hand, research on modeling interactions and communications in crisis management and rescuing has increased recently.

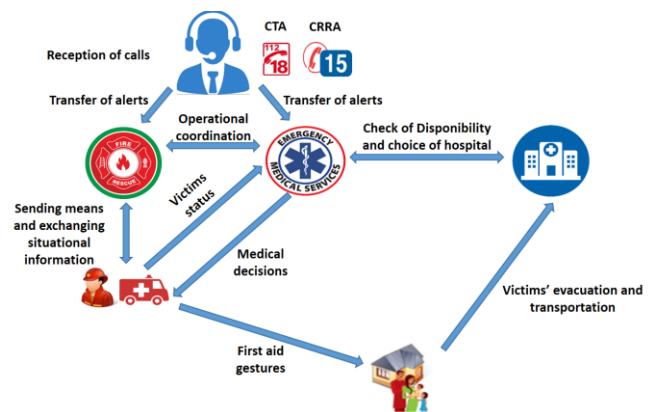


Figure 1. Involved organizations and actors in rescue operations. Some researchers chose to model human-robot interactions during rescue operations supported by robots as it has been done in [13]. Others focused on human-human interaction and communication in these operations. [2] modeled communication between involved actors in large-scale

emergency responses and crisis management. The aim of this study was to analyze the communication and the activity in inter-organizational emergency response and to extract problems related to information-sharing between actors. The proposed model included dependencies between actions, actors, and information but it does not take into consideration the information support, which is a main element in communication. Add to that, we cannot see the sources and destinations of information in this model.

However, in many countries, communication in rescue operations is still limited to oral communication by transmitting voices through radio devices. Statistics in France show that most of information exchange between rescuers on sites and operational centers are still oral [7]. Despite the fact that many systems were built, their use is still limited. This is because most of these systems do not achieve effects expected by involved actors in practical applications. They do not take into account the real needs of stakeholders. In our view, the main reason behind this is that the definition of interaction and communication flows in rescue operations is deficient. Subsequently, the information that an actor or a service is supposed to offer and receive are not clear, which obstructs the exchange of information. Thus, we analyzed communication and interaction and we modeled them based on information exchange and some other elements. An application ontology related to rescue is used to support the model as a source of main concepts. The model takes into consideration the source and destination of the information as well as its support. More details about these elements will be discussed in Section IV.

#### IV. MODELING INTERACTIONS

In rescue operations, difficulties of interactions and communication caused by multiplicity of actors and their backgrounds, lack of time, dynamicity of situations, and complexity of sheer volume of information coming from different sources, necessitate supporting information exchange and comprehension in order to enhance situation awareness. As cited above, our goal is to design and develop a communication and information sharing system. To do that, we started by analyzing communications, interactions and information flow in these operations through studying documents and laws related to the domain as well as conducting an interview with a domain expert. This study allowed us to analyze the activities and procedures and to link these activities with interactions. We defined required elements to be taken into consideration when modeling interactions in complex domains such as emergency response and rescue operations and we proposed a structure model based on a combination between several modeling diagrams. In this section, we give more details about interaction modeling requirements, the used ontology to define them, and finally the created interaction model related to rescue operations.

##### A. Requirements for modeling interactions

Before creating any model such as interaction or information models, defining modeling requirements and the

constitutes elements of the model is a must. The main objective of our model is to study and represent interactions and communication in rescue operations and then to develop a system aiming to support communication in order to enhance situation awareness. Related to awareness, which is the main interest of our work, ensuring a high level of situation awareness necessitates perceiving all elements in a situation within a volume of space and time as well as understanding their meanings and relations. Add to that, supporting communication and interaction requires identifying all the relevant information that inform on a situation. Consequently, defining situation elements and important information is the first step toward achieving awareness. These are the main elements to consider when modeling interactions and processes.

Ontologies can be very helpful in order to define and represent main situations' entities and existing relations between them [14]. They are defined as "*explicit specification of conceptualization*" [15]. Therefore, we took ResOnt ontology as a fundamental basis to define required elements [3] [10]. ResOnt ontology was defined to support communication and situation awareness in rescue operations by ensuring common situation representation and understanding between different actors. The reason we choose ResOnt ontology is that it covers all aspects, elements, and dimensions such as organizations, actors, materials and tasks in rescue operations. Fig. 2. shows the main concepts defined in ResOnt Ontology. Another reason behind choosing ResOnt is that it takes information flow, communication and situation related information (**information and situation related information ? Precise le premier information**) into consideration and those are important parameters for modeling interactions. Fig. 3. Illustrates a graph extracted of the ontology showing relations between main concepts and elements. For example, an Actor is an element from an Organization. S/he has characteristics such as role, skills, functions and availability, and s/he uses materials that have characteristics too. This actor can transmit Data that is communicated on time and informs on situation related information which is a main interest in our work. This SituationInfo contains information on Incident, Operation, Victims, Material, and Environment. This actor also executes other Actions and Tasks that are scheduled on Time during which an event can appear and affects SituationInfo. Based on these concepts and relations, we defined required elements to constitute an interaction model in rescue operations. The first element is *Actors* and their *Roles*. Rescue operations involve the engagement of several actors who can play different roles depending on their skills and functions, it is therefore important to distinguish between different actors when modeling. The second element is activities and actions carried by the actor. During rescuing, each actor has to carry different actions in order to fulfill his responsibilities. These activities and actions may require or generate a situation related information. Thus, taking them into consideration is also important since interactions depend on these activities. Actions and activities are represented as *Tasks* and *Operations* in our model. Another element is *Information* or *Data*. This is the basis for communication and situation

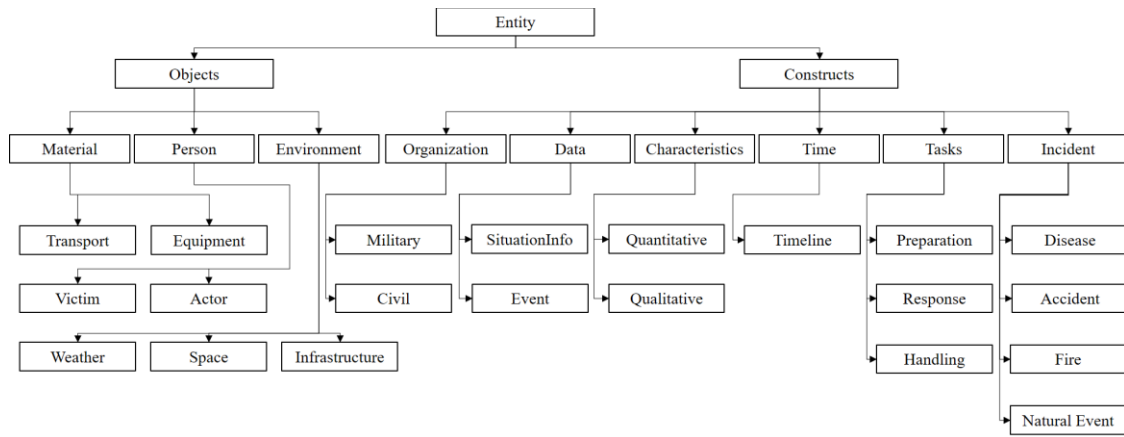


Figure 2. Main concepts of ResOnt ontology.

awareness. It informs on situation related information and all the elements perceived in an environment. When modeling interactions, it is vital to specify which information is being exchanged at each step. In addition, sharing this information demands using a communication tool. Thus, it is also essential to define the *Information Support* through which the communication is being carried as well as the type of communication. This definition can help specify where and when this support is required together with its type. Furthermore, actors participating in a single rescue operation are geographically separated. Some of them stay in rescue centers or call centers such as operators, while others are present in intervention sites such as rescuers. Therefore, tasks, operations and communications take place in different spaces. For this reason, it is required to make a differentiation between different *Spaces* when modeling. Moreover, since rescue operations are dynamic situations that evolve with the evolution of time, considering *Time* parameter is of high importance. This dynamicity affects the state of all the other elements such as situation information or tasks. However, modeling a complex process with respect to time is a challenging task. Authors in [16] declare that modeling dynamic and complex processes or interactions, such as emergency management or rescue necessitates dividing these processes into several phases and separating them with respect to time. Thus, we divided a rescue operation into separated main phases each composed of several sub-phases and we presented these phases on a timeline as shown in fig. 4. Add to that, the fact of dividing a complete operation into phases based on time, which is the main parameter in rescue

operations, facilitates modeling processes and activities and thus modeling interactions with respect to these phases. Furthermore, these phases are almost similar in all cases of rescue operations because they are generic and they are not limited to a specific type of incident so that they can be a basis for further modeling. Based on the evolution of time, a rescue operation can be divided into six main phases: Alert phase, Involvement / commitment of adapted means and persons, Departure of rescuers, On-site operations, Victims' evacuation and transportation, and finally, Return and end phase. From all of the above, we can summarize required elements to consider when modeling interactions as following: *Time, Space, Actors* and their *Roles, Tasks* and *Operations, Data* or *Information*, and finally, *Information support*.

### B. Rescue interactions model

Defining the fundamental required elements to be used in an interaction model for rescue operations allowed us to create a structure model. In this model, we include all the necessary defined parameters to take into consideration for modeling interactions. However, none of the existing models and diagrams allows representing interactions with taking into account all these parameters. Thus, we did a combination between Process Models [17], UML Activity Diagram and UML Collaboration Diagram [17] to represent our model graphically as shown in fig. 5. As we can see, we have two axis: The vertical axis represents the time. On this axis, we can see the sequence of events, procedures and activities with respect to time. Add to that, it allows the representation and separation between phases and sub-phases of an operation. While the horizontal axis represents space. On this axis, we can separate between different spaces and places in which an action is being executed or information is being used / displayed / shared (**more general**). Besides, this model includes actors represented by a person icon with the corresponding role. Since multiple actors are engaged having multiple roles, skills and functions, it is important to make this differentiation in the model. This person can execute an operation or a task represented by rectangles with rounded corners. To do that, he needs to access some information. Moreover, any task or operation can generate information and data to be communicated to other actors in other spaces. Information are represented in rectangles. Each rectangle contains the required or generated information. Concepts used

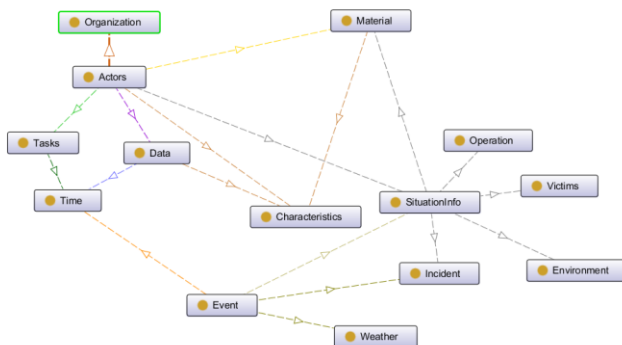


Figure 3. Graph extracted from ResOnt ontology

for information are the same concepts as defined in ResOnt ontology [3] [10].

Figure 4. Chronology of phases in rescue operations

Add to that, this model includes the information support. This support is used in order to send, receive, or visualize information. In fact, three types of data support are used in rescue operations in a way that information can be transmitted and received through three possible ways: Oral communication through Radio, mobile phones and fixed phones represented by red circle icon; Non-oral communication via Mobile phones and tablets represented by green mobile phone icon; And non-oral communication via desktops represented by desktop icon in blue.

After defining the required elements to constitute an interaction model in rescue operations, and creating a structure model, we moved to the last step, which is constructing an interaction model for rescue operations. To do that, we adopted an approach based on procedures derived from rescue operations in France. We took an example of an incident causing one or several victims and requiring the engagement of several actors from different organizations. Equipped with their vehicles and material, these actors have to access intervention sites, secure places, protect victims, retrieve information and exchange it with decision-makers, carry and execute suitable actions, and finally evacuate and transport victims to a hospitalization place. In fig. 6. we show only a part of the created interactions model illustrated on the structure model. **(je n'ai pas de figure 6 mais je ne suis pas sous word, des fois éléments sont supprimés)** It represents the interactions, communication and actions carried during On-site operations phase that starts at T3. However, due to a lack of space, we put just the first two sub-phases of On-site operations. At T3.0, and after leaving their CIS, rescuers access the intervention site and start with observation. First, they secure the site and search victims for protecting them. After that, they collect first information about the incident in order to evaluate the real situation and act appropriately. At the end of this step, rescuers got access to old information collected during the alert phase and new information collected by them using mobile phones or tablets. After gathering this information, the Commander of Rescue Operations (CRO) takes his first decisions. In case of any problem, need for reinforcements, or lack of relevant information, responsables in CTA and CIS need to be informed. Thus, the CRO completes a situation report and transmits it to CIS and CTA through mobiles. Operators in these two centers receive this

report, visualize sent information on desktops and act according to the CRA report. At T3.1, rescuers finish the first sub-phase consisting of accessibility, security, protection and information gathering, and a new sub-phase begins. The CRO in the intervention site makes new decisions and assigns tasks to others rescuers who start to execute actions and operations based on the situation. From the example above, we can see how actors involved in rescue operations interact with each other depending on the activity and action being carried as well as the situation. Add to that, we can see the required or generated information in each step and the support to transmit or receive this information. From this model, we can simply extract dependencies between Actor, Information, Action, Operation Phase, Time, Space, and Information support.

This work represents our work done toward modeling interactions in rescue operations. To do that, we analyzed interactions and communication related to activities based on a deep study of domain related documentation. Add to that, we identified required elements to consider when modeling interactions in rescue operations and we constructed a structure model. Finally, we applied the structure model to a rescue operation example in France and we created the rescue interaction model.

## V. CONCLUSION

Like several complex and dynamic domains, ensuring a good level of situation awareness in rescue of people is difficult. Many factors reside behind this difficulty such as dynamicity of situations, multiplicity of involved actors, difference in situations' comprehension and perception between persons and finally communication and interaction problems. These factors and many others can affect actors' decision-making and overall performance. This work aims to support interaction and communication between stakeholders and actors in order to enhance situation awareness. Consequently, we studied interactions and communication in rescue operations by studying procedures based on domain documentation. Then, we modeled these interactions and we defined the required elements to be used for modeling interactions in rescue operations based on a domain ontology. The elements are time, space, actors and their roles, tasks, information, and data support. Finally, we

Figure 5. Interactions during On-Site operations

validated our model by conducting an interview with a firefighter expert in Aube's Department in France. The approach to this modelling was based on procedures derived from rescue operations applied in France. However, this model can be used and applied in other countries since the main elements and parameters in our model are generic.

As a future work, we look forward to design and implement a communication and information exchange systems that suits

practical applications in rescue operations. This system will enable the exchange of different type and forms of information between rescuers on intervention sites and decision-makers in operational centers. To do that, we will study the integration and use of mobile devices such as smartphones and tablets in rescue environments as supports for communication in a way that is adapted to their operations without bothering them. This work will surely include a study

about the availability, integrity, confidentiality, and security of exchanged information.

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