Towards the design of respond action in disaster management using knowledge modeling

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Abstract. This position paper highlights current problems linked to the aspects of the multi-agency collaboration during disaster response. The coordination and cooperation depend on the information sharing and use which must face up to interoperability, access rights, and quality problems. The research project aims at providing an assessment of information impact on the disaster response in order to support the decision-making about what information shared or what quality of data used to improve the response efficiency. Our research approach propose to combine an information system able to integrate heterogeneous data and a simulation system to assess different strategies of information sharing, dissemination and use. A knowledge base is used as a bridge between information system and simulation system. This knowledge base allows for designing dynamically a simulation according to open data and for managing the own knowledge and information known by each agent.

Key words: multi-agent based simulation system, semantic, disaster response, information management

1 Introduction

The disaster response corresponds to the emergency crisis management and aims at acting to limit injuries, loss of life and damage to property and the environment [1]. This objective cannot be reached efficiently without the collaboration of multi-agency. This collaboration is the main issue of Disaster response. The collaboration has two aspects: the coordination and the cooperation [2]. The coordination is the act of managing interdependencies between activities performed to achieve a goal [3]. The three components of the coordination are activities which correspond to the goal decomposition, actors who are selected to be assigned to an activity, and interdependency which must be managed [3]. The cooperation is defined as joint pursuit of agreed-on goal(s) in a manner corresponding to a shared understanding about contributions and payoffs [2]. Here, the cooperation intervenes in the resource sharing to achieve response activities and in the information sharing to obtain a better view of the crisis situation.

Information and communication technologies play a key role to support the collaboration during disaster response by providing solutions of collaboration and cooperation. On the one hand, planning mechanisms allow for organizing actors, activities and resources by taking into account the different interdependencies. On the other hand, the use of semantic technologies through ontologies provides a support for a shared understanding. Several systems have been developed in order to facilitate the collaboration and assess different strategies of collaboration and communication between the different agencies. However, the problem of communication and information sharing intervenes at different levels: Community, Agency and Individual [4]. For the community, the problems concern mainly inter-organizational interdependencies and collaboration procedures where appears a lack of standardization and interoperability due to the need of collaboration between heterogeneous systems. For the level of agencies, the organizational procedures are focused on vertical sharing (means a sharing according to the hierarchical agency structure) of information whose access depends on responsibilities, privacy, security and authentication. For individual level, the execution of a task is influenced by the uncertainty and the time pressure related to the crisis situation. In this situation, each individual is confronted to information access limit, misinterpretation of information due to their quality and the difficulty in determining what information should be shared. [5] claims that Sharing and dissemination of information is both crucial and problematic. Among the different problems of information sharing, there is a lack of common vocabulary, and a lack of information about the scale of the disaster which conducts to an imprecise information. Moreover, another aspect of the importance of information for the victims is presented. A lack of updated information can increase fear, stress and other emotions of the victims. The sharing and dissemination of information is the heart of the response where the decision-making about the type, the quantity, and the quality of information is crucial. This decision-making during the response is difficult due to the time pressure of the situation. That is why, it is necessary to be prepared in order to make efficient decision about information sharing during the response. Consequently, this paper presents an approach based on a simulation system and a semantic geographic information system to support the preparation of decision-making about information sharing during a disaster situation. Through the combination of a simulation system and an information system, different strategies for the use, the dissemination and the sharing of information can be applied during a disaster response situation. The analysis of simulation results for different strategies aims at identifying the most suitable data to use, the most suitable information to share and disseminate. Section 2 presents works related to the problematic aspects of such a system.

2 Related work

The problematic to create a system which supports the decision-making preparation about information sharing during a disaster situation, has two problematic

aspects. The first aspect concerns the requirements in information sharing and the second corresponds to the evaluation of the different strategies on the disaster response. The two followings section deals with these aspects.

2.1 Information sharing

Several systems have been developed to facilitate the information sharing during the response. The project Disaster 2.0 offers a web platform where a description of situation needs can be deposed and stored thanks to the use of an ontology. This ontology aims at facilitating the research of specific needs for an agency to bring solutions to the needs corresponding to its capacity [6]. This type of information exchange provides an overview of situation needs and facilitate the management of these response needs. The paper [7] presents the ontology Einsim which aims at providing a simulation model allowing the combination with other response systems. The use of this ontology facilitates the reuse of information coming from response systems. Many common vocabularies have been developed to provide a common understanding and facilitate the cooperation. The management of a crisis (MOAC) vocabulary allows the description of humanitarian activities related to a crisis situation [8]. These activities can be specified by the three questions: Who? What? Where? Emergel ontology [9] has been developed during a European project to facilitate the collaboration between European country through a common language including a specification of pictograms. This ontology provides vocabulary to describe an emergency situation, mainly caused by natural disaster or by the collision of vehicles. Ontologies have been used to provide a common vocabulary allowing a common understanding for the cooperation and facilitating the information exchange. The advantage of ontology is to provide a structured storage of information which can be understood by humans and machines. Ontologies have also a flexibility advantage to combine them or merge them, thanks to matching techniques.

2.2 Strategy Evaluation

The preparation by assessing different strategies aims at determining the most suitable decision. This process is generally computed by a simulation system on different crisis situations using the strategy applications and result assesses for each strategy. The simulator Simgenis has been used to test two organizational strategies (centralized or distributed) and two communication modes (traditional paper or electronic forms) to evaluate their impact on the efficiency of the rescue process [11]. Thanks to this approach, they have identified that the electronic mode of communication reduces delays and victims losses. But the most interesting is that the most suitable organizational strategy depends on the relation between the number of victims and rescuers. Thus, the assessment of the response efficiency is computed according to the total number of victims, initial state of the victims and the total number of rescuers (e.g. doctors, firefighters, and nurses). The Drillsim platform [10] focuses on assessing the impact

of information technologies (IT) solution used during the disaster response to show that the use of appropriate IT solutions improve the response. IT solutions are mainly sensors and communication infrastructure including video and audio sensors, people counters, built-in RFID technology, power line, ethernet, and wireless communications. The assessment of the response efficiency depends on the evacuation speed and the number of injuries. The survey [12] presents a framework allowing to assess a response plan and the decision-making of agents by statistical results data according to the crisis incident and its executing plan. The assessment of the response plan can also compute through the use of an ontology and a reasoner to check the consistency of the response plan applied during the simulation [13]. The multi-agent based simulation is the main technology used to test different strategies and assess its impact. Among this related work, two main goals are identified. The first is the evaluation of response plans which are mainly applied in a situation of evacuation and only few of them are interested in the aspect of collaboration through organizational strategies or through the consistency of plans. The second is based on the aspect of information, one is focused on the use of information technologies which provide information about the situation and another is focused on communication ways. However, no simulation systems allow for assessing the impact of information sharing and dissemination.

3 Problem statement

Through the study of the related work, from our knowledge the use of ontologies for data interoperability and multi-agent based simulation appears as two technologies relevant for the creation of a system able to support decision-making about the information sharing and dissemination.

But we were not able to identify a system that supports the decision-making about information sharing and dissemination during the disaster response. This can be explained because of the information sharing is a first domain of research that is still facing up to problematic of interoperability and uncertainty of data. Regarding the second domain, the multi-agent simulation deals with problems of large scale simulation, realistic and generic model design, and intelligent agent for information processing. These two research problems must be addressed in the context of disaster response including the following aspects: The cooperation requires the management of information through a common vocabulary to facilitate the interoperability, the management of different data sources with different access rights, different quality and provenance. The coordination is influenced by the information, and requires the management of interdependencies between the different tasks, actors and resource in order to respond efficiently. The impact of information on the tasks execution and behavior of victims must be assessed. The information sharing intervenes in the cooperation and impacts the coordination. That is why, the assessment of information impact requires to take into account the cooperation and the coordination aspect, to show how the

information contributes to an efficient response. The simulation of disaster response can illustrate problems which have been solved thanks to the information sharing. According to [4], this information will reinforce peoples motivation for sharing information and thus, reduce the problem of reluctance to share information with other agencies. Moreover, [4] claims At the national level, authorities and laws can stimulate inter-organizational information sharing by implementing institutional mechanisms that dictate organizational policies and guidelines. Thanks to the proof of good practice in the information sharing providing by the simulation system, new laws can be created to improve and stimulate the information sharing during the disaster response. Thus, the creation of a system proving the importance of information sharing and identifying good practices in information sharing can generate new decision-making about that and improve the response efficiency. However, the creation of such a system requires to solve sub-problems. The heterogeneous data integration must be managed because of the need to integrate a diversity of systems for the cooperation between agencies. The simulation model must be designed to simulate the coordination during the disaster response according to the known information. The assessment of simulation results is required to determine the impact of information sharing on the response efficiency.

Heterogeneous data integration and management The heterogeneous data gather different types of information, different sources, and different format. The geographic information about the real world are required to build a realistic environment of simulation in the sense of a representation of the real world. The integration of this data type is generally done by the integration of geographical map [10], and the use of a geographic information system [14], [15]. The second type of data are the information data stored by all agencies which intervene in the response. This type of information can be information about resources (e.g. equipment, humanitarian resources), action plan, shelter plan, information about population, etc. Each agency has generally its own system to manage its data, which leads to a diversity of storage way and a difficulty for the interoperability. The ontology is generally used to facilitate the interoperability, but the different approaches to integrate data into ontology are generally specific to a format or a way of storage (e.g. GML2RDF [16], R2RML [17], specific connectors for each agency [18]). There is a lack in automatic integration of heterogeneous data in an ontological form. Filling in this lack can facilitate the integration of a new collaborator and its data into a collaborative system without the need to create a new connector or mediator to incorporate its data. The purpose of the information communication according to certain criteria to assess its impact on the response, implies also the integration of information about the data provenance and quality.

Simulation model The simulation model for disaster response must be able to manage large-scale simulation and requires the generation of crisis scenario [12]. Two main types of actor models are necessary: one for the victims and one for the responders [11] which have not the same behavior during the disaster

response. The simulation model must manage their interactions between them and with the environment and the potential problems that they could give rise. All these problems are limits for the simulation application.

Simulation assessment The assessment of the simulation aims at supporting the decision-making about the information sharing and dissemination during the response. That implies to allow the information communication according to certain criteria and observe the impact of this information on the response efficiency. The assessment requires to link the known information with their particularity to the actions or behavior resulting from the agent decision. A statistical study of the information communication impact would allow the different response agencies to decide what information is suitable to communicate and share.

4 Research approach

The approach to solve these issues of and its sub-problems previously presented, combines information management techniques and simulation techniques through the use of a knowledge base to provide flexibility for the simulation system, facilitating the integration and the management of data.

Heterogeneous data integration and management The integration of heterogeneous data has two main goals. The first goal is to allow a collaborative preparation by allowing the integration of information from different agencies with a right management to respect the information membership. The second goal is to use open data to create the simulation components dynamically. A majority of open data are available on csv and shapefile format or other schema-less format providing a table form which is problematic for a semantic integration. In order to integrate these types of file, we have developed an automatic process based on natural language processing, geographic tools and semantic web [19]. Thanks to this work, it is easy to integrate semantically information from all open data of a city as the different buildings, streets, quarters, fire station, hospitals, city alarm, etc. These types of file provide, first of all, the location, but sometimes also, information as the different services of a hospital and the number of beds for each service. Another example of information from this file is the location of the fire station, the number of professional firemen and the number of voluntary firemen or a building with the number of people inside. All of this information extracted semantically will be used to generate the environment of the simulation and its agent population. This approach is called knowledge-centric design because the simulation design is managed by the content of the knowledge base. This research problem is a part of the semantic geographic information system (SemGIS) project that manages data quality [20]. The simulation will be based on multi-agent because of the disaster response is a complex system where evolve entities with many interactions. In this case, the multi-agent based simulation is suitable because it consists in the entities and their interactions modeling to generate the emergence of the complex system. The modelling

of agents and their interactions will be managed by an ontology about disaster response which will describe the organizational structure of actors and their interactions. The representation of the two types of actors will be managed by two types of agents: behavior agents for the victims whose actions will be influenced by their emotions, and intelligent agents for responders who will make a decision of action according to their action plan and the situation information that they have access through the use of the knowledge base.

Plan of assessment A use case based on a flood situation in the city of Cologne in Germany is preparing to incorporate plan of the different responder and open data of the city into the knowledge base. Through this use case, a sufficient set of experiments will be led with different input parameters concerning the information sharing and communication. The result of each simulation through the follow-up of variables will be analysed according to the input parameter in order to identify the impact of information on the response efficiency.

5 Conclusion

The proposed approach aims at supporting the preparation for decision-making about the information sharing and dissemination during a disaster response to improve the response efficiency. The planned approach uses semantic technologies to integrate and manage information necessary for the simulation of disaster response. The management of agents with different knowledge and different information access can allow for assessing the impact of information or its quality on the response efficiency. This impact assessment allows for determining a certain data quality requirement to use during a disaster response or essential information which needs to be shared to obtain a best efficiency.

References

1. Copola, D. Introduction to International Disaster Management, Second Edition. Elsevier (2011)
2. Gulati, R., Wohlgezogen, F., Zhelyazkov, P. (2012). The two facets of collaboration: Cooperation and coordination in strategic alliances. Academy of Management Annals, 6(1), 531-583.
3. Malone, T. W., Crowston, K. (1990, September). What is coordination theory and how can it help design cooperative work systems?. In Proceedings of the 1990 ACM conference on Computer-supported cooperative work (pp. 357-370). ACM.
4. Bharosa, N., Lee, J., Janssen, M. (2010). Challenges and obstacles in sharing and coordinating information during multi-agency disaster response: Propositions from field exercises. Information Systems Frontiers, 12(1), 49-65.
5. Manoj, B. S., Baker, A. H. (2007). Communication challenges in emergency response. Communications of the ACM, 50(3), 51-53.

6. Beneito-Montagut, R., Shaw, D., Brewster, C. Web 2.0 and social media in disaster management: Using web 2.0 applications and semantic technologies to strengthen the public resilience to disasters (disaster 2.0 emergency management agencies use and adoption of web 2.0.). Technical report, Aston University, UK, 2013.
7. Poveda, G., Serrano, E., Garijo, M. (2015). Designing emergency management services by ontology driven social simulation. IT CoNvergence PRActice, 3(1), 17-32.
8. Management Of A Crisis (MOAC) vocabulary, http://observedchange.com/moac/ns/
9. Emergel, http://vocab.ctic.es/emergel/
10. Balasubramanian, V., Massaguer, D., Mehrotra, S., Venkatasubramanian, N. (2006, May). DrillSim: a simulation framework for emergency response drills. In International Conference on Intelligence and Security Informatics (pp. 237-248). Springer Berlin Heidelberg.
11. Saoud, N. B. B., Mena, T. B., Dugdale, J., Pavard, B., Ahmed, M. B. (2006). Assessing large scale emergency rescue plans: an agent based approach. The International Journal of Intelligent Control and Systems, 11(4), 260-271.
12. Praiwattana, P., El Rhalibi, A. (2016, April). Survey: Development and Analysis of a Games-Based Crisis Scenario Generation System. In International Conference on Technologies for E-Learning and Digital Entertainment (pp. 85-100). Springer International Publishing.
13. Serrano, E., Poveda, G., Garijo, M. (2014). Towards a holistic framework for the evaluation of emergency plans in indoor environments. Sensors, 14(3), 4513-4535.
14. Macatulad, E. G., Blanco, A. C. (2014). 3DGIS-Based Multi-Agent Geosimulation and Visualization of Building Evacuation Using GAMA Platform. The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 40(2), 87.
15. Chu, T. Q. (2011). Using agent-based models and machine learning to enhance spatial decision support systems: application to resource allocation in situations of urban catastrophes (Doctoral dissertation, Paris 6).
16. Casado, R., Rubiera, E., Sacristan, M., Schtte, F., Peters, R. (2015). Data interoperability software solution for emergency reaction in the Europe Union. Natural Hazards and Earth System Sciences, 15(7), 1563-1576.
17. Das, S., Sundara, S.,Cyganiak, R. (2012). R2RML: RDB to RDF mapping language.
18. Shafiq, B., Ae Chun, S., Atluri, V., Vaidya, J., Nabi, G. (2012). Resource sharing using UICDS framework for incident management. Transforming Government: People, Process and Policy, 6(1), 41-61.
19. Prudhomme, C., Homburg, T., Jean-Jacques, P., Boochs, F., Roxin, A., Cruz, C. (2017, April). Automatic Integration of Spatial Data into the Semantic Web. In WebIST 2017.
20. Institute i3mainz, SemGIS project, http://i3mainz.hs-mainz.de/de/projekte/semanticgis