Simulation of Rescue Force Communities in Mass Casualty Incident Situations

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Abstract: Mass Casualty Incident (MCI) situations require high flexibility from the involved rescue forces, including an increased need for efficient communication in sparse mobile ad-hoc networks. Simulations help to understand the performance of information flooding in these situations, to identify critical gaps in the infrastructure and to develop professional models. Based on resources, described as profiles, roles of community members can then be assigned more flexible. The presented approach and the thereupon aligned simulation provide a technological basis for developing a decision support system. This system can – before or during an MCI situation – provide support in mitigating risks. This will be achieved by executing (simulating) and comparing different alternatives to manage the situation at hand.

Keywords: Community simulation, self-organisation, professional model, agent-based communication, MANET.

1 Introduction

In case of a Mass Casualty Incident situation (MCI) emergency rescue services (fire brigades, medical service and police force) have to face several challenges. At the beginning there is often a discrepancy between the number of injured persons and the number of available emergency units at the place of action. So it is essential to coordinate all involved rescue forces and activities. Moreover, it is necessary to identify tasks and task sequences of all involved forces to support inter- and intra-organizational collaboration. In the light of MCI the *SpeedUp*[1] research project activities are focused on an IT framework to support communication and collaboration between mobile rescue forces [Spe12]. Starting with investigations of organizational structures and strategies for courses of action within various rescue forces, SpeedUp addresses the definition of an IT solution which is acceptable and utilizable for different organizational units in complex situations.

To support development, testing and evaluation of the SpeedUp IT solution we need regular MCI-like-situations. Based on the insight, that it is rather impossible to carry out real MCI exercises again and again, we aimed at finding a solution to replay such scenarios in a cost-efficient way. Therefore, we mapped these complex courses of events within inhomogeneous communities by using simulation techniques.

In this paper, we introduce a tool for simulating heterogeneous communities. Furthermore, we discuss our approach to develop a community simulation after collecting information in a prior analysis process. The approach is explained by using a MCI scenario with rescue worker communities.

The paper is structured as follows: Section 2 explains the scenario in more detail. Section 3 discusses the analysis process that is necessary to build an MCI-like-situation. In Section 4, we explain our agent-based discrete event-based simulation tool. Section 5 provides first results, whereas section 6 gives an outlook for future work.

2 Scenario

Typical examples for a MCI are bus, train or plane accidents. Insured people, rescue forces and equipment are spread over a large area. Structured and coordinated handling requires (1) data collection, (2) information forwarding and (3) hierarchical organization. Paper-based processes are reliable but slow and incomplete. Therefore, SpeedUp relies on electronic support for rescue forces using mobile communication devices (nodes). Known major risks of IT-based communication are inaccessibility as well as lost or broken down nodes. Its major strength is the autonomous and redundant replication of information within the entire ad-hoc network, if it is not partitioned.

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In order to act and collaborate in an appropriate way in MCI situations, rescue forces have to aggregate several types of information that form an *information building*. This information building is necessary to allow for fast information flow and filtering of relevant information [SKE+10]. Figure 1 provides an overview of the involved technological fields necessary to cover all information needs.

Instead of using paper to distribute the information to others, a mobile, self-organizing data platform is needed that supports the rescue forces [SSE10]. The information that has to be delivered differs for every organization and rescue worker and is task dependent.

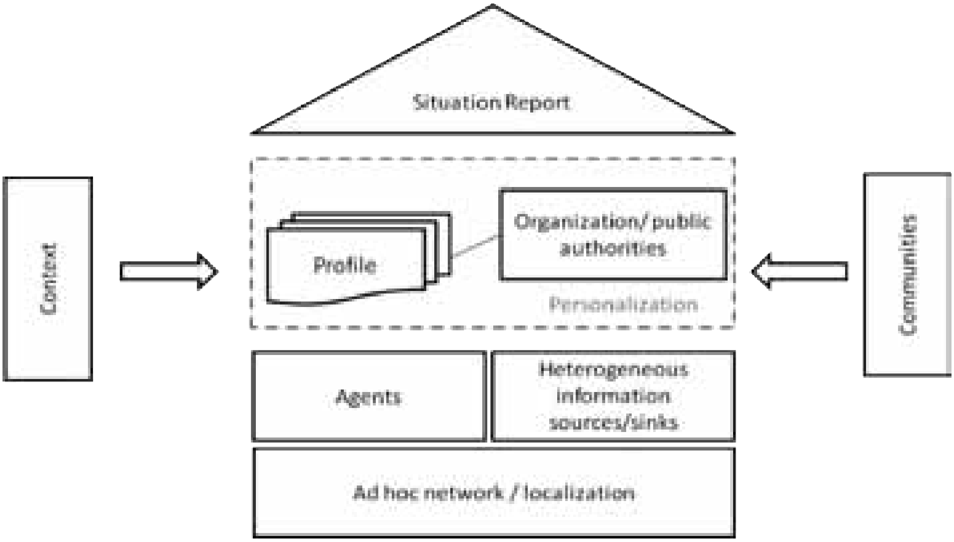

Figure 1: Information Building, adapted from [SKE+10]

At the technical level, ad hoc networks [BFS08] provide the infrastructure for information transmission. Therefore, the localization of rescue workers is important [SEE+11]. Mobile software agents [DCL11, BR05] can be used to integrate heterogeneous data resources and transport information. The share of personalized information for a rescue worker during a MCI in a certain role is restricted by policies [SKE+10] and depends on the context - the involved organization and the tasks to be solved. The context of a rescue worker can be described by his profile. A profile consists of the role the rescue worker plays in a certain mission and associated individual properties, like knowledge, expertise or physical state.

The knowledge about the MCI situation should be shared by the entire community of rescue workers, independent of the organization they belong to. The sharing of experiences helps to improve efficiency in future action situations. Thus, after an MCI situation it is necessary to discuss the event with all involved rescue forces and derive lessons learned. Moreover, the technical as well as the organizational support should be analyzed. For an analytic reflection, it is useful to simulate the entire situation again A simulation gives a cost efficient and a reproducible way to analyze the event. Event scenarios can be replayed several times with different parameters so that rescue workers can go deeper into concrete situations and can learn from the different perspectives.

Following this general goal we discuss in our paper the technological background of such a simulation tool. As a first step, our tool supports a simulation of prototypical action situations derived from real situations, as well as a what-if-analysis.

3 Simulation modeling approach

For the modeling of a simulation for rescue forces we propose an approach consisting of six phases: (1) data elicitation, (2) data processing, (3) structuring, (4) implementation, (5) simulation and (6) evaluation. The interplay of these 6 phases is shown in figure 2.

The first phase consists of the elicitation and collection of data originating from real action situations or interviews with rescue workers. The data will be processed in a second phase extracting the requirements of the environment and the involved rescue workers. In the third phase, the collected information will be structured for IT processing. In the implementation phase these structured data is transformed for being consistent with the simulation model. Hereby, the emphasis is on the modeling of single community members. The complex course of the action situation is simulated in the fifth phase by enacting the direct interplay of relatively simple entities (community members) and their ongoing interaction with the environment. The evaluation in the last phase helps to analyze the MCI event and may trigger another (simulation) perspective.

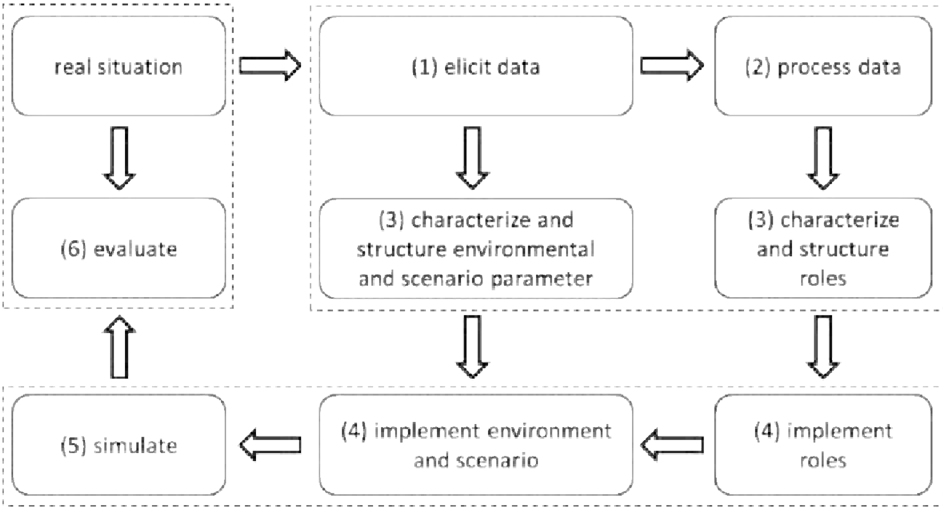

Figure 2: Schematic Procedure for the Development of a Community Simulation

(1) *Data elicitation*: Data collection depends on the given scenario and the available information. In our project, information was elicited from real action situations as well as practice exercises, interviews of rescue force members and from relevant legal regulations [WKM+10, Feu99, Feu06, Feu08, Thu08]. Legal regulations provide rules according to processes, organizational structures and competencies. More concrete

insights come from interviews. Such interviews provide information regarding typical procedures, used strategies, spatial distributions, but also quantitative data about necessary rescue forces, time efforts and problems in concrete situations. Furthermore, exceptions and weaknesses during events can be elicited. The collected data are a basis for future simulation runs and their evaluation.

(2) *Data processing*: The interviews are transcribed, generalized due to several criteria (code, main categories, sub categories, sources, sinks and segments), and extracted into a table [WKM+08]. For analyzing action situations, mind maps were used to look at aspects like location, forces, resources, weather, time and situation. Therefore, information is grouped to detect dependencies and gaps. Moreover, the whole sequence of events is transformed into a time line.

(3) *Structuring*: In every action situation, people are involved in different roles. These different roles are identified using the sequence of events (time line). Thereby, a role abstracts from a concrete person. Prior knowledge, expertise and the state of a person are allocated to a profile. Additionally, commands and activities are extracted from the time line for every role. A role is described by its tasks. Tasks can be divided into subtasks, so that a hierarchical structure is built. From the time line, pre and post conditions are allocated to a task. In table 1, roles are described by a hierarchical decomposition of their tasks to subtasks, combined with suitable pre and post conditions. From the mind map and the time line the necessary data for the environment are extracted.

Task	Action	Communication	Rescue force
Transport <patient> to patient positioning place	*[Patient not transportable]* ensure_transportability <patient> *[Patient transportable]*		
	[<Patient> transportable] organize_orderly <patient> <patient positioning place> *[enough <orderlies> available]*		
	[<Patient> transportable & enough <orderlies> available] *give_command <orderly> „transport <Patient> to <Patient positioning place>“* *[<orderly> and <Patient> arrived]*	Transfer command, transfer confirmation	paramedic, rescue aid man
escort <patient> to patient positioning place	*[patient can go alone] walk with <Patient> to patient positioning place* *[arrived]*		

Table 1: Decomposition of roles into tasks

(4) *Implementation*: The description of tasks is realized in the Belief-Desire-Intension (BDI) structure consisting of goals and plans (goal-plan-tree) [HSR12, GPP+99]. In the root of the tree is a goal that can be achieved by the successful execution of one of the subordinated plans (figure 3). Plans may consist of actions or other subgoals. Pre and

post conditions resulting from the structuring phase (3) are expressed by semantic queries to an individual data area (beliefs). Actions in the goal-plan-tree are atomic. They are characterized by their effects on the environment and by time costs.

For more information regarding implementation and simulation we refer to section 4. In the end the evaluation (phase 5) is discussed in section 5.

Figure 3: Example of a goal-plan-tree

4 Simulation

Rescue forces, e.g. medical personnel, have a lack formal training in mass causalities. Therefore, their education should be expanded [GJA05]. Simulation modeling is regarded as one of the leading techniques for improving the capabilities in case of incidents [JM06, JML07]. It was used e.g. in training of healthcare personnel [HYH+10] or terror medicine [HM09].

For our simulation, we use an agent-based, discrete event based approach [Gon09]. The simulation of the environment and all rescue workers involved in the scenario is done by agents. The simulated scenario is divided into active and passive entities. Passive entities only react to external influences, while active entities can carry out actions independently and therefore influence their environment. E.g. in our scenario, rescue workers are active entities, while injured people are regarded as passive entities [HSR12].

Figure 4 presents the agents which are necessary for a simulation. The environment agent manages the simulation time and the state of the environment that also includes the passive entities. The starting point for a simulation is a given scenario, which also describes the environment parameters for the scene as well as the number and position of injured people. Furthermore, the scenario includes a number of events that are defined to occur at a certain point in time during the simulation. This event set is managed by the

EnvironmentAgent. It checks in every time step, which events occur at this point in time. Additionally, it calculates how these events influence the state of the environment.

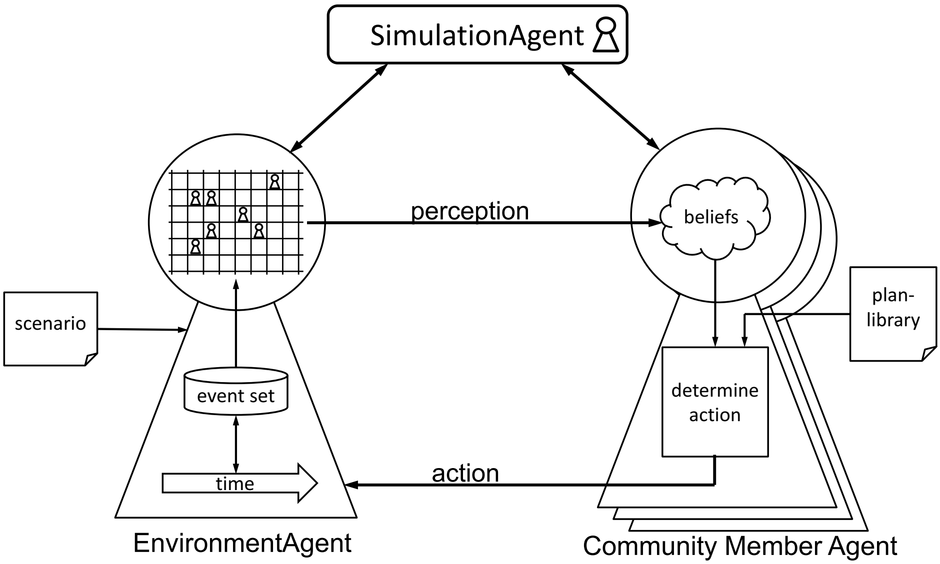

Figure 4: Simulation

An additional task of the EnvironmentAgent is to calculate the perception of every active entity which stands for a rescue worker. The perception is calculated in every time step based on the state of the environment. The results are transferred to an agent that simulates the respective rescue worker. The simulation of a certain rescue worker is thereby implemented by a Belief-Desire-Intention (BDI) agent [GPP+99], called *Community Member Agent* in figure 4. These agents manage their own view on the simulated environment by using their beliefs. The agent reacts to the new perception of the EnvironmentAgent by updating its beliefs, based on the perceptions. Afterwards, the BDI implementation helps to calculate the upcoming action of the rescue worker. This calculation of the next action is based on the current beliefs of the agent as well as on the plan library of the simulated rescue worker.

The processed action is transferred back to the EnvironmentAgent, which calculates the consequences of this action to the environmental state. So in the next time step it is possible to transfer the consequences of the previous action in form of a new perception back to the simulated rescue worker. A simulated time period ends, if all events taking place in this period have been handled, every active entity was sent a perception, and all active entities had the chance to perform their own actions.

For the management of the entire simulation there is another agent called *SimulationAgent*. This agent is able to start and to finish a simulation. Furthermore, it bridges the gap between the simulated system and the underlying agent system ellipsis

[ME11, Sch12]. In the case that more rescue workers are to be involved for a specific scene in a simulation, the SimulationAgent can start more Community Member Agents that can overtake the role of the newly involved rescue workers. In addition, it can link them with the simulated scenario.

5 Results

With our simulation tool, we can map a complex course of events with inhomogeneous communities. By mapping the rescue workers using BDI agents we are able to describe different rescue forces with their specific aims, procedural models and cultures. In a first evaluation, we simulated three different situations: a small, a medium and a large MCI event. We collected the typical information involved in such situations and modeled it.

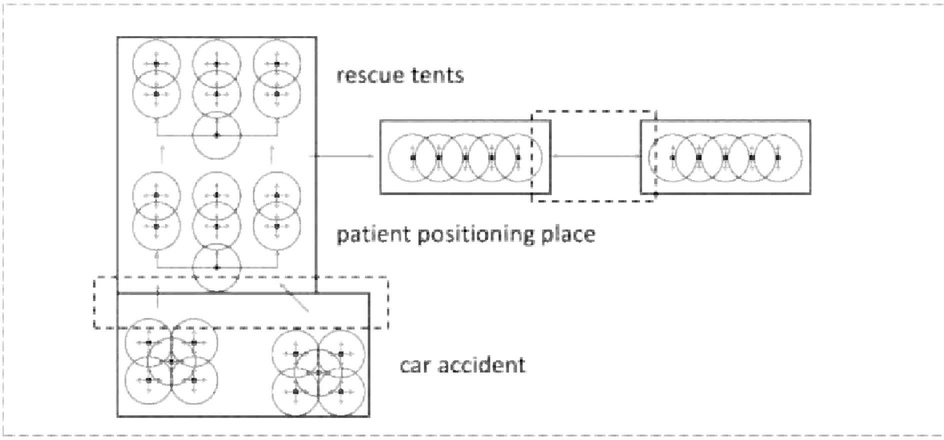

Figure 5: Evaluated small MCI scenario

Figure 5 shows the small MCI scenario that was simulated. Each of the circles defines a rescue force member. The arrows define possible moving directions of a rescue worker. At the bottom, a car accident occurred on the motorway which is the location of accident. Injured people are transported from the accident location to the patient positioning place in the upper left part. From there, patients can be transported in the rescue tents, where medical doctors can treat them. On the right site in figure 5, there are additional medical workers, policemen or fire workers that are waiting for action. All these involved rescue workers have to communicate with one another. If they are near to each other, like in the accident location or the rescue tents, communication is pretty easy using words. In case rescue workers are in different locations there might be interruptions in communication, displayed in figure 5 using squares with dashed lines. In our evaluation we could proof that the simulation approach works very well. For this evaluation we focused on prototypical scenarios with a fairly small number of roles. Therefore, our approach and our current version of the simulation tool need further improvement, refinement, and scaling. Nevertheless, we could show that the current tool implementation forms already a stable basis for a more detailed, professional simulation.

6 Conclusion and Outlook

Our proposed approach and the aligned simulation tool provide the technical basis to develop a simulation based, intelligent decision support system. This system can help to mitigate risks and dangers, as well as to weight different alternatives during preparation and in ongoing MCI situations.

A main objective of our future work will be to develop a complete training and decision support system based on our current, still relatively abstract technical tool. With such a system, real MCI situations will be re-enacted and decisions that were made in the MCI could be analyzed. In this way, experienced rescue workers will be able to reflect the consequences of their actions and simulate possibly better, alternative approaches. Using fictitious scenarios, it will also possible to evaluate new or unusual strategies during MCI events and see whether they are useful in real-life situations.

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SESSION 4

Infrastructure and Security