TOWARDS PLANNING FOR EMERGENCY ACTIVITIES IN LARGE-SCALE ACCIDENTS

An Interactive and Generic Agent-Based simulator

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Abstract: In this paper we describe the design and development of an interactive and generic agent based simulator, providing valuable support for organizing the emergency rescue plans of a large-scale accident. Analysis of real rescue activities has been conducted in collaboration with medical experts in order to understand the collaborative process and the involved actors and features. Based on the emergency analysis, an agent-based model and simulator was constructed including (1) the autonomous **A**gents – representing victims with evolving illness and rescuers (doctors, nurses, fireman) collaborating to rescue the first ones; (2) the **E**nvironment –representing the accident site having obstacles and dangerous areas and where the victims are initially spread and the doctors move to explore –perceive - treat and helpers evacuate; (3) the **I**nteractions between rescuers – exploring collectively, evacuating by pairs, communicating directly or via artefacts- (4) the **O**rganization of actors as distributed "independent" sub-teams in various site sub-zones or as a centralized whole team conducted by the rescue chief; and (5) the **U**ser interfaces allowing mainly initial configuration of the simulations (e.g. number of victims and states, followed strategies, rescuers behaviours), continuous visual control of the process of rescuing (e.g. site overview with acting-interacting agents, graphics, text descriptions), dynamic changes of parameters of an on-going simulation (e.g. adding new victims, adding new rescuers, or adding dangerous zones or new obstacles on sites) as well as step-by-step simulation. This simulation shows that it is possible to create a virtual environment with cooperating agents interacting in a dynamic environment. On-line and off-line analysis of simulation traces and results enable us first understanding complex situations in rescuing activities in large-scale accidents, and than planning for responding to crisis situation. This simulation approach is useful for identifying the best scenarios and eliminating potential catastrophic combinations of parameters and values, where rescue performance could be significantly impacted.

1 INTRODUCTION

Understanding complex situations has always been a great challenge particularly when it involves human life in crisis situations. Understanding how technology can aid cooperation in such situations has posed further challenges. In fact, studies of collaborative work in a naturalistic settings have been used to understand the characteristics, interactions and activities of the actors involved in cooperative work within their shared environment. Understanding this type of "real-world" cooperation is fundamental for designing innovative solutions to support cooperative work. Such solutions are not limited to the development of collaborative information systems and groupware tools, but also to the development of new cooperation configurations and communication devices. The deeper our understanding of the collaborative process, the better we will be able to provide a more appropriate and supportive plan for responding to crisis situations.

It is recognized that computer simulation, especially agent-based simulation, is a valuable tool for studying complex systems. Several agent-based simulation applications have been developed in many domains (e.g. (Kreft, 1998), (Strader, 1998), (Terano, 2000)). Despite this growing interest in applying computer simulation to study complex systems, there are few simulation studies that have been conducted in order to understand and to model various configurations of computer supported work (c.f. (Dugdale, 2000), (Pavard, 2000)).
Our primary research motivations are to understand the rescue activity, the cooperation between rescuers, the mode of control, and the use of artefacts, etc. so that they may be modelled and simulated with the aim of providing better emergency rescue plans.
In this paper we describe the design and development of an interactive and generic agent based simulator which can provide valuable support for organizing the emergency rescue plans of a large scale accident.
We have developed a virtual collaboration environment where we can evaluate (run and compare) different cooperative rescue scenarios (both real and hypothetical). This allows us to study the activities of the group (mainly cooperation between rescuers using traditional or electronic communication artefacts); to assess the best configuration (number of doctors, resources, etc) for better rescue results; to assess the use of different communication devices.
This paper is organized as follows. In section 2, we describe our analysis results of emergency activities in large-scale accidents. In section 3, we explain the main collaboration aspects we modelled and we describe the simulation model and validation. In section 4, are our conclusions and description of future work.

2 OVERVIEW OF THE CASE STUDY: ON SITE RESCUE AND EVACUATION

An accident is an unfortunate, harmful event, caused unintentionally where one or many persons become victims and need rescuing interventions. Disaster rescue is one of the most serious social issues. Rescue and evacuation is a complex situation where various agents (victims, doctors, fireman, policeman) with heterogeneous competences and having various roles, organize themselves dynamically on teams, adapt their behaviour (individual, collaborative, walking, searching, hearing, treating…), process continuously all received information (e.g. a doctor receives information from victims, rescue Chief, other rescuers) and react in an unpredictable way to their environment. Their main objectives are rescuing victims, performing better evacuation results and mainly reducing delays and minimizing number of dead victims.
According to the type of the accident, various emergency plans are provided.
Our analysis of real rescue activities has been based on medical sources (Ecollan, 1989), (PR, 2000) and has been undertaken in collaboration with SAMU[i] teams in order to understand the collaborative process. Our goal is to model certain elements of this collaboration in order to understand the particular role played by each element.
To ensure good medical care in exceptional emergency situations, which adapts to the evolution of the emergency event, the SAMU have to perform many operations without delay. The main objective of these operations is to provide the victims with the necessary care depending on their state, as soon as they are reachable, even though the victims cannot yet be evacuated.
The emergency medical care consists of the main following steps: 1. Assessment of the medical needs of the victims. 2. Participation in victims identification, movement of victims if necessary and provision of essential medical care. 3. Categorisation of the victims according to the seriousness of their injuries and situations (prioritize according to needs), orientate victims 4. Evacuation and transportation of victims. 5. Elaboration of retrospective medical summary reports.
As a first step, we modelled an accident site where sets of victims are randomly spread on an area and where a group of rescuers (medical team, fire brigade team) arrive on the site to rescue the injured. According to rescuing strategy (distributed or central) various communications and coordination activities between the heterogeneous agents are performed.

3 MODEL AND SIMULATOR

The main objectives of this computational modelling approach are to understand, answer, and solve different questions and problems concerning emergency rescue in large-scale accidents. The first and immediate questions aim at understanding rescuers collaboration on site and design optimal – efficient and adequate rescuing plans: how do the initial state of victims affects the performance of rescuing? How do the number of each type of rescuers affects the rescue activities and how is related to the number of victims? How does the communication mode affect rescue performance? How the rescuers behaviour (treating first or evacuating first) influences performance? How does the kind of accident affect rescuing? More broadly, we are interested in how an agent-based simulator can help design new collaboration technology solutions.

3.1 Model overview

We are using an Agent-Based approach to design and develop our model and simulator in an iterative way. The main components of our model are (1) the autonomous **A**gents – representing victims with evolving illness and rescuers (doctors, nurses, fireman) collaborating to rescue the first ones; (2) the **E**nvironment –representing the accident site having obstacles and dangerous areas and where the victims are initially spread and the doctors move to explore –perceive - treat and helpers evacuate; (3) the **I**nteractions between rescuers – exploring collectively, evacuating by pairs, communicating directly or via artefacts- (4) the **O**rganization of actors as distributed "independent" sub-teams in various site sub-zones or as a centralized whole team conducted by the rescue chief; and (5) the **U**ser interfaces allowing mainly initial configuration of the simulations (e.g. number of victims and states, followed strategies, rescuers behaviours), continuous visual control of the process of rescuing (e.g. site overview with acting-interacting agents, graphics, text descriptions), dynamic changes of parameters of an on-going simulation (e.g. adding new victims, adding new rescuers, or adding dangerous zones or new obstacles on sites) as well as step-by-step simulation.

The main classes of our object class model are *environment* and a hierarchy of *actors.* We considered two categories of actors: victims and rescuers. The latter roles are specialized as doctors who have the responsibility of treating victims and deciding about their evacuation off-site and their "helpers" who enable reaching victims and lifting them off site. Figure 1 shows an overview of our model.

3.2 Main modelling details

Our model first focuses on what happens when we have victims, doctors and their "helpers" and other resources at the site of the emergency.

3.2.1 Modelling environment

The environment is representing the disaster site where the victims are spread and rescuers move in it to perceive each other and victims. In order to model all accident kinds, we defined two concepts of dangerous zones and/or obstacles characterizing any point of the grid; where no agent can move through an obstacle, they can only turn around it ; and where only firemen can go into dangerous zones to pull the injured clear of the wreckage. These obstacles and dangerous areas can be initialized at the beginning of the simulation or can be added interactively later.

3.2.2 Modelling victims

Two main concepts are modelled to represent victims as autonomous agents:

Victim's gravity for which a scale has been adopted according to White Plan as follows: 1 = Extremely serious; 2 = Very Serious; 3 = Serious; 4 = Not Serious; By extension, 0 = dead .

Victim's gravity evolution has been modelled as a function of time by using probabilities of transition from one state to the other. A 5 by 5 transition Matrix G, has been defined where each cell G(i,j) equals the probability of evolving from gravity i to gravity j.

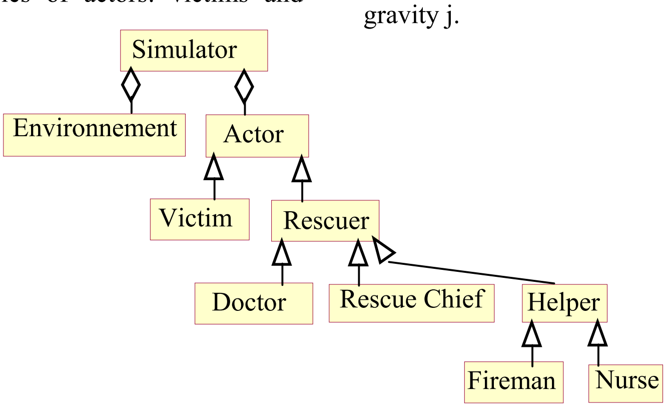

Figure 1 : overview of the simulator architecture

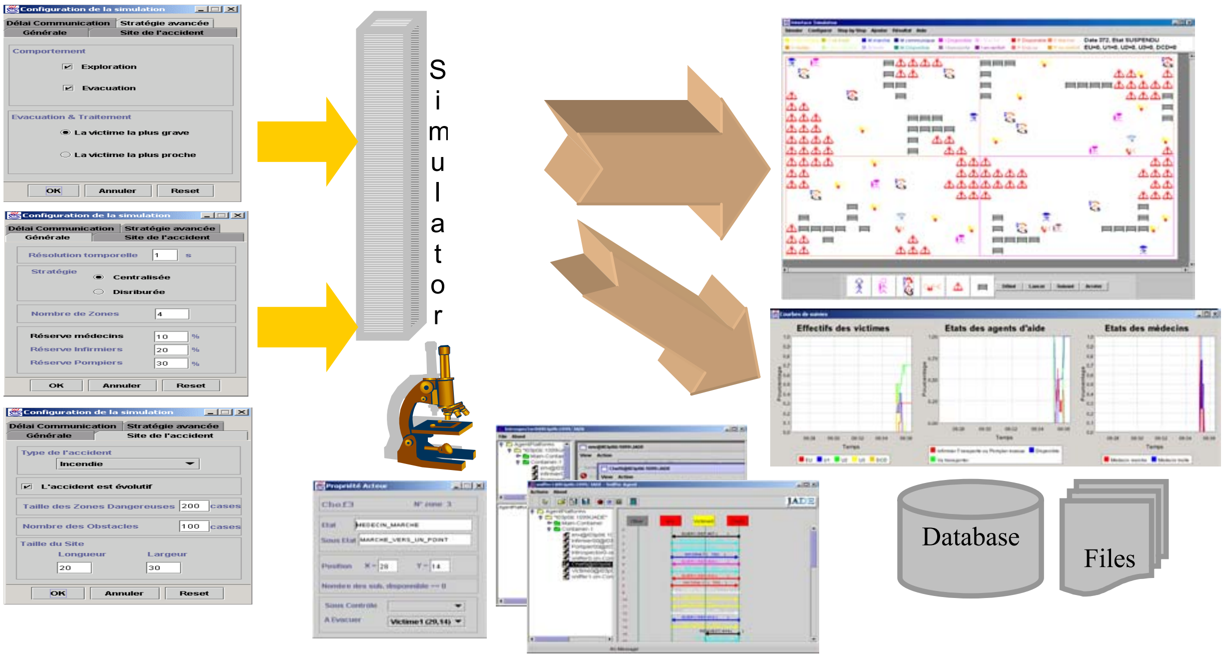

Figure 2: Overview of the simulator: input, output and control interface

This gravity evolution is affected by rescuing activities.

3.2.3 Modelling rescuers

The main actors in our model are the victims and rescuers (doctors, nurses and fireman). The model focuses on the rescuers behaviours and strategies, with all of actors interacting dynamically in the environment representing the site of accident. All of the actors are implemented as autonomous cognitive agents.

3.2.4 Genericity and interactivity for more realism

The simulator is generic so that we may: run and test different rescue strategies (e.g. centralized or distributed); choose and prioritize the rescuers behaviours (e.g. explore, treat, evacuate); select different communication modes (e.g. direct or mediated communication); choose between different communication artefacts (e.g. paper or an electronic evacuation form: Medicard microchip storing the victims data with transmission via LAN); specify environment properties in terms of obstacles and/or dangerous sectors (this allows us to represent many different kinds of accidents).
The simulator is also interactive allowing step by step simulation. This means that at any time step we can run an follow closely and gradually the on-going simulation. Also we can change the configuration of the site (e.g. adding new obstacles and/or damage), or add new agents (e.g. victims, rescuers) where we can cope with realistic scenarios where new victims are discovered after the first exploration and/or where the environment features change, such as after a seism or a fire.

3.3 The developed simulator

The simulator, which has been developed using the agent-based platform JADE. JADE (Java Agent DEvelopment Framework) (Jade, 2004) is a software framework fully implemented in Java language. It simplifies the implementation of multi-agent systems through a middle-ware that complies with the FIPA specifications (Fipa, 2004) and through a set of graphical tools that supports the debugging and deployment phases. Our simulator interface provides Input, Output and Control widgets and displays as shown in figure 2. In fact, the simulator, as shown in figure 2, provides various output representations. A control panel enables the user to run a simulation step by step or continuously, and to stop it. A display is given of the site, showing the spatial position of victims as well as the location and the status of cooperating rescuers. Adequate coding colors, changing according of the state of each agent, enable the user to follow the evolution of the rescue process. Graphics show the number of victims per gravity degree, and also the state of each kind of rescuers over time. A textual trace of execution shows where various comments are written to report on the occurring simulation events and evolution. Added to these real-time on-simulation displayed output results, all the simulation events and each agent status evolving on each step are traced in an event database and files which are generated for further analysis by statistical tools (such as SPSS).

4 CONCLUSION

By this modelling and simulation activity we have shown that we can create a virtual environment with cooperating agents interacting in a dynamic environment.

Our simulator is under exhaustive validation and testing. Many questions are being studied by this simulator. The first issues we are investigating by our simulator are how rescue performance (as a first approximation, it is measured by the ratio of the global number of alive victims evacuated from site over the initial number of victims) is affected by the number of rescuers, their behaviour (exploring first, or evacuating first) as well as the whole strategy adopted (centralized control by a rescue chief or a distributed rescue in separate zones with inter-teams collaborations) and the communicating artefacts used.

With the modelling activities we begin to understand in depth the cooperation processes, and we can uncover the parameters, variables, and strategies hidden in this social work. By simulating various scenarios, we can understand and plan for efficient rescuing.

Our ultimate aim is to get this simulator assist rescuing decision making both: «off-line» by supporting design new /adapted/ adequate organization rescue plans; and on real time by managing resources and supporting real time decisions.

Also we are using this approach to design new collaborative situations (e.g. assess the use of an electronic medical card and decide on its contents)

Finally, we are improving this virtual environment to provide realistic software training tools.

Consequently, three new extensions to this model are currently being studied and performed: (1) First extension: the rescue is being considered on the scale of a town or city including target hospitals where victims would be sent via various kinds of ambulances and taking on consideration the routes and their accessibility. (2) Second extension: the simulator is being modified to become distributed over several platforms to be able to simulate a very large number of agents (like in very large-scale accidents) and where we keep interactivity. (3) Third extension: an integration of virtual reality and this multi-agent simulator.

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