Multi-agent Systems in Modeling and Simulation of Fire Spread

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Abstract

This paper presents a conceptual study for the phenomenon of fire spread. The proposed study is based on simulations using the RoboCup Rescue environment. Using a socio-cognitive approach, it can be used in three dimensions: (i) assist in proposing new structures or alternatives to situations of collective panic, checking the viability of their existence and operation; (ii) obtain a better understanding of the reasons social, anthropological, psychological, etc. that subsidize and direct the type of collective behavior in crowd panic; (iii) assist in decision making aimed at minimizing the loss of life in a situation of spreading fire. One of the challenges to be overcome in this research is the integration of the different theories and computational environments in order to open paths for future researches. Making possible a further study on phenomenon of panic in crowds in danger situation.

1 Introduction

The area of Multi-agents Simulation (MAS) is formed by the intersection of the areas from Distributed Artificial Intelligence (DAI) and Computational Simulation. This area provides an adequate infrastructure to model and understand processes related to social interactions such as coordination, cooperation, training and coalition of groups, evolution of conventions and standards, free will, resolutions of conflict, among others. Multi-agents simulation models are based on the idea of the relationship of an individual with a program it is possible to simulate an artificial world formed by interactive computing entities where an agent represents an entity of the target system, or a group of them. As the infrastructure of technical and theoretical areas of Simulation allows to capture the essential elements of a target system without working directly with it, it is appropriate to deal with a phenomenon such as the spread of fire without putting at risk the integrity of living beings and the environment [1].

This paper proposes a study between the fire propagation, using the ResQFire Simulator (RoboCup Rescue fire simulator), and a MAS. In order to understand how different agents collaborate one which other to reach a common goal (rescue civilians and extinguish fire in this paper) a scenario for study is proposed and simulated, aiming to obtain an accurate approximation of the real world.

The remaining of this paper is structured as follows. Section 2 has a picture of the RoboCup Rescue environment for simulation. In Section 3 a simulation is presented followed by its analysis in Section 4. The Section 5 contains the conclusions of this work.

2 RoboCup Rescue in Modeling of the Multi-agent Environment

The RoboCup Rescue project [2] aims to simulate disaster situations involving the use of digital resources. The project promotes research on physical robots and virtual environments for simulated search and rescue, coordination of team work and strategies for redemption in several occasions, in an interconnected way. Such simulations introduce advanced and interdisciplinary research among various areas, such as: Multi-agents Systems (MAS), Artificial Intelligence (AI), robotics, logic programming, among others [3, 4].

The RoboCup Rescue environment can be divided in two different units: rescue robots and rescue simulation. This last one can be separated in other two sub-units: virtual robots and agent simulation. This paper aims to present a study using the components of the unit Agent Simulation. The design of the unit Agent Simulation starts with the definition of its architecture, ie, their blocks (or modules) and the main structural interaction between these blocks. The initially proposed architecture considers the following main blocks: number of agents with different capabilities, a set of simulators for specific aspects of the field, a process that connects the Agents and the simulators (kernel), a process for maintenance of geographic information called GIS (Geographic Information System) and a predefined set of messages for inter-agent communication and perception of each agent on the state of the world.

The types of agents used in this work are: `Civilian`, `Fire Brigade`, `Ambulance`, `Fire Station`, `Ambulance Center` and are divided into two groups: `humanoid` and `non-humanoid`. The humanoid agents have the capacity to act directly on the environment, and can be of type: `Civilian`, `Fire Brigade` and `Ambulance`. Any humanoid has the ability to communicate and move in the geographic area of the simulation, each agent has specific capabilities. The Agent `Civilian` (individual or family) is a victim of the disaster, which may need to be helped (by the agent `Ambulance`). The agent `Fire Brigade` has the ability to extinguish fires in buildings, manipulating the hose to set the angle of departure and the quantity of water. The agent `Ambulance` has the ability to rescue the humanoid agents (including other ambulances). Only the agent `Ambulance` has the ability to help any humanoid directly.

A non humanoid agent represents an organization of humanoid agents. These organizations are the `Fire Station` and the `Ambulance Center`. The `Fire Station` collects and integrates all the information sent by the agents `Fire Brigade` and allocates according to a simple policy. The `Ambulance Center` collects and integrates all the information sent by the agents `Ambulance Center` and allocates according to a simple policy as all the non humanoid agents.

In the architecture of the Unit Agent Simulation there are some simulators trying to make the simulation as real as possible. Each simulator of a specific aspect of the domain updates the properties of geographic objects and calculates the effect of actions performed by each agent. The simulators used in this work are: Traffic Simulator (TFS), Fire Spread Simulator (FSS) and Visualization Simulator (VS). The others simulators take care of various aspects not treated by the described above, for example the evolution of the vitality of buried or injured humanoid agents [5].

The TFS covers aspects of the movement (handling) of the agents by geographic area. The movement of agents is interrupted by blockades on roads (Blockage Simulator) and the conflicting movement (e.g. in opposite directions on the same track) of agents that can trigger gridlock traffic [5].

The FSS addresses the issues of fires in buildings, as well as its evolution and spread to neighboring buildings. The evolution depends on such factors as the material of construction, area of the building and the amount of water already sent (by `Fire Brigade`) to extinguish the fire. The spread depends on the distance of neighboring buildings and the number of neighbors. The fire is the only destructive effect that continues to spread after the end of the earthquake. The FSS was designed not only in order to be applied in cases of earthquakes, but also in cases of common fire [6].

The VS constructs a view to virtual reality and displays to the spectators (human). This simulator do not simulate a particular aspect of the field (as the other simulators), but helps to understand that the conduct of a simulation.

3 Experiment Conducted

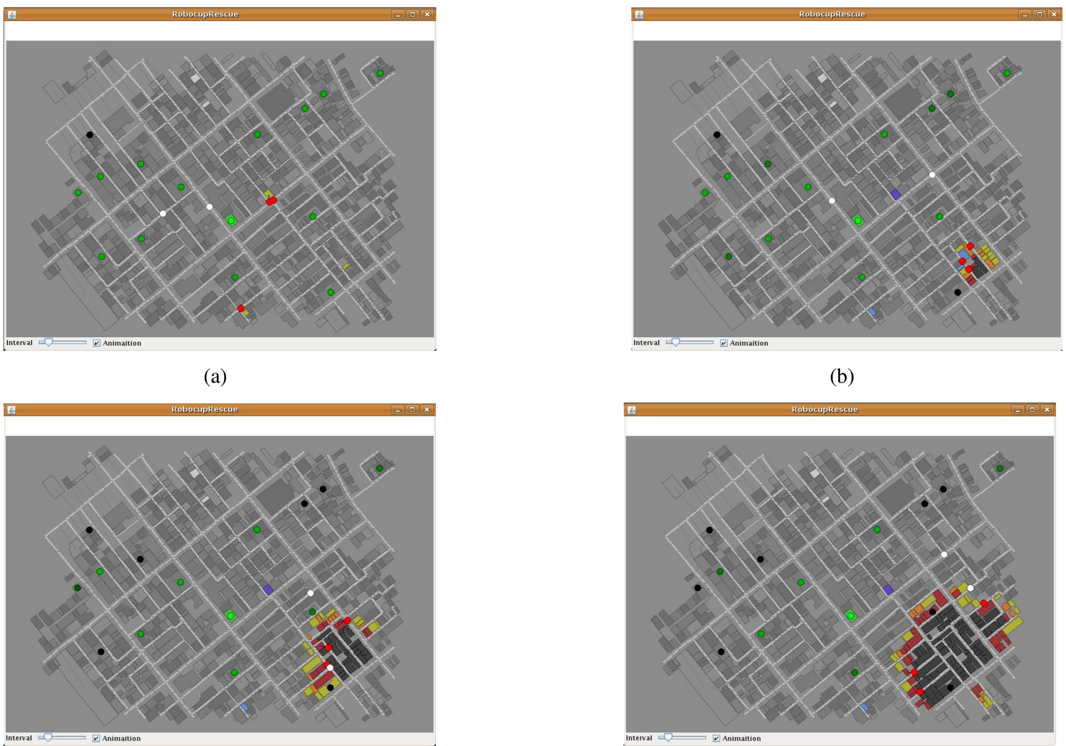
From the study of the RoboCup Rescue environment a simulation was performed in order to better understand the spread of fire in cities and the cooperative actions among agents to achieve a common goal. For this study one scenario were created using as main map the city of Kobe (Japan).

This simulation intends to show the inefficiency of a society (agents) against the fire spread when there is are no good resources available or communication. Based on [7, 8] this experiment also hopes to help future studies on the collective behavior in situations of disaster, and show how the spread of fire occurs in a real scenario (as in buildings of a city).

In the conducted experiment, were chosen three initial outbreaks of fire, a point of refuge (green building), three Agents `Fire Brigade` (red spots), twenty (20) Agents `Civilian` (green spots), two Agents `Ambulance` (white spots), a non humanoid Agent `Fire Station` and a non humanoid Agent `Ambulance Center` (light gray edifications). In this scenario the Agents `Fire Brigade` had a low capacity to contain the fire. For this, variables responsible for the ability of water allowed for each agent, the radius of vision in relation to notification of fire, distance needed to combat the fire, number of messages allowed, quantity of water available in shelters (replenishment of water), and others were assigned in order to undermine the fight against fire. That is, in this simulation the Agents `Fire Brigade` did not have a good amount of water available, the amount of water returned to the agents at the shelter was not fast enough, it was necessary to be very close to the target during the fight and their messages beyond to have a small scope were restricted on quantity. Figure 1 shows the development of simulation realized.

4 Analysis of the Model

All the simulation takes 300 cycles, in this section a deeper analysis is made to explain the experiment. According to Figure 1 is evident the low efficiency in combating the spread of fire during the time. Even with a reasonable amount of cycles and a few ignition points (initial point of the fire spread) the agents `Fire Brigade` did not manage to contain the fire which spread rapidly.



(a) (b) (c) (d)

Figure 1: The cycles of the simulation: (a) 10^{th} cycle; (b) 80^{th} cycle; (c) $150^{th}0$ cycle; (d) 210^{th} cycle.

Figure 1(a) shows the initial configuration of the fire propagation (10th cycle). The agents `Fire Brigade` even with a poor configuration try to stop the progress of fire through the city. Since there are only three initial fire outbreaks the agents are capable, with a great effort, to extinguish it in some isolated buildings. However, there are some points that cannot be reached quickly due to delay in fulfilling the tasks in other parts of the map, giving space to the fire start to have major dimensions (Figure 1(b)). As there is a minimum distance set as a negative factor to fight the fire, if one agent is trying to contain the fire and others come through the same path to help him these new agents will be stucked (due to poor communication) and useless (since the distance between the fire and the agents is greater then the permitted distance to fight the fire) behind the existing agent, until this agent makes a move clearing the path.

With the deadlock caused by poor cooperation between the agents the fire is able to propagate faster, as shown in Figure 1(c). Due to the new fire proportion, even with the separation of agents to stop the fire spread is almost impossible to reverse the scenario since that each agent hasn't the power of water needed to contain it. At the end of the simulation, as shown in Figure 1(d), a considerable part of the city is burned out. Showing that even with considerable time simulation the agents were unable to contain the fire spread. Therefore, it is possible to establish a direct relationship between lack of resources (e.g. water) and poor communication among agents for failure of the operation.

5 Final Considerations

The RoboCup Rescue environment due to its complexity and size allows to use one of its tools for a more specific and detailed research. The fire simulator opens doors to direct applications in the study of collective behavior (e.g panic in crowds [9]). Through the simulation performed the inefficiency of the agents, forward the spread of fire, confirms the experiments expectations, showing that the agents do not have the necessary conditions to control the fire spread. Once the fire started the experiment shows different speeds in its propagation, that because the specific characteristics of each building are different one each other (e.g. material, heat coefficient etc).

A contribution of this paper is related to the use of the theory of MAS in a model construction, allowing to establish the relationship between an individual with a program and thus simulate an artificial world composed by computational interactive entities. This has been an appropriate infrastructure for model and understand complex social processes such as formation of coalitions and groups, development of standards and conventions, to link micro-macro, among others. Thus it can also assist in the construction of public works, looking for more efficient and safe buildings.

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