RoboCup-Rescue Simulation: in case of Fire Fighting Planning

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Abstract. RoboCup-Rescue project was proposed, to examine disaster prevention and mitigation using technology from RoboCup. We have implemented a disaster simulator for RoboCup-Rescue, and use it to select the optimal distribution of fire brigades. We found the "Concentrate Strategy" is the best in this case.

1 Introduction

Disaster mitigation is attracting attention as a new domain for Multi-Agent System research, and RoboCup-Rescue[1] is proposed. We have been designed and implemented a simulator for the RoboCup-Rescue. SoccerServer[2] has been successful as a test-bed Multi-Agent environment with a few dozen agents. The RoboCup-Rescue Simulation System differs from SoccerServer in that it has to be able to handle much larger number of heterogeneous agents. These differences provide a lot of new research issues for Multi-Agent systems.

In this paper, we show an example of process to select the optimal agent distribution, in this simulation system.

2 RoboCup-Rescue Simulation System

2.1 Structure of the RoboCup-Rescue Simulation System

As shown in Figure 1, the RoboCup-Rescue Simulation System consists of a core module of the system called Kernel and a number of modules which are plugged into the Kernel. It can simulate many combinations of phenomena when we plug in the necessary disaster simulators. For the sake of modularity, these plug-in components communicate with each other only via the kernel using protocols based upon UDP/IP. These protocols are formed to make it possible to pass only the necessary properties of objects, where the simulation world consists of various kinds of objects, each of which has a certain properties. This protocol does not depend on any particular simulation model and algorithm; this design allows modules to be added or removed easily.

More details about the simulation system are shown in the "RoboCup-Rescue Simulator Manual"[4].

P. Stone, T. Balch, and G. Kraetzschmar (Eds.): RoboCup 2000, LNAI 2019, pp. 351-356, 2001.

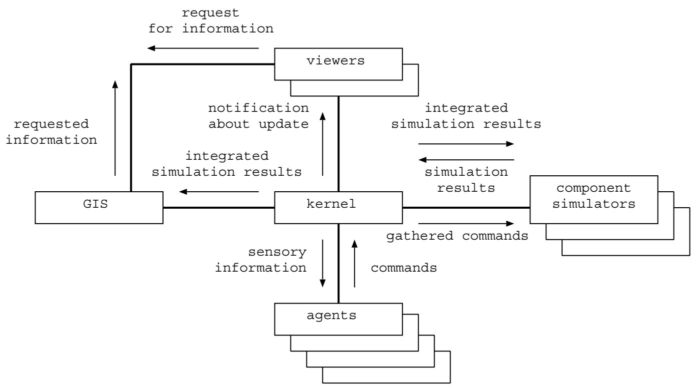

Fig. 1. Structure of RoboCup-Rescue Simulation System

2.2 RoboCup-Rescue Agent

One of the main tasks to consider in rescue activities is developing agents. Agent modules decide the action which intelligent individual is going to take. In every simulation cycle, agents receive sensory information and send back control commands. The perception information is extremely limited, and with this information, agents have to decide how they will act. Civilian, fire brigade, ambulance team and police force are now implemented.

2.3 Rescue vs. Soccer

The SoccerServer is a famous testbed for Multi-Agent research. Because of the features of the problem, rescue and soccer have many of differences as shown in Table 1. These differences provide new challenging problems.

– Agents may need to model other agents, because they can not assume their partners have the same abilities.
– Because sensory information is severely limited, agents need to look for necessary information actively.
– Because agents have to decrease the final damage of disaster, long term strategy must be considered.

3 Simulation Example

3.1 Simulation World

Using the RoboCup-Rescue Simulation System, we simulated a part of the fire fighting activities after the Hanshin-Awaji Earthquake [4] on January 17th 1995. In this experiment we use the following components.

[4] More than 6,500 people were killed and about 80,000 houses were collapsed by this earthquake.

Table 1. Difference between RoboCup-Rescue Simulation System and SoccerServer

	Rescue	Soccer
Number of Agents	More than 100	11
Agents in the team	Heterogeneous	Homogeneous
Information	Severely Limited	Partial
Strategy	Long Term	Short or Middle Term
Goal	Many	Only one

– RoboCup-Rescue Kernel version 0.21
– The real-world GIS data of Kobe-city (about 500m square)
– Fire simulator using "Kobe City Fire Bureau - Applied Technology - Takai's Model" [5]
– Sample Traffic Simulator
– Sample Viewer (2D)
– Fire Brigade Agents

The simulation treats the case that, there is a big earthquake and fires have ignited at three locations (X:right, Y:left, Z:center). In the initial state, fires spread according to the fire simulator. There are nine fire brigade agents in this area. They go to the fire sites and start fire fighting. The simulation will continue until all the fires are extinguished.

The purpose of this simulation is to find the optimal distribution of fire brigade agents to fire sites. The optimal distribution minimizes the damage of the disaster. We define the number of buildings, which are damaged by fire more than 1%, as the amount of damage.

3.2 Fire Brigade Agents

In this simulation, fire brigade agents have the following features.

– It can see fire from any place in the map.
– It can see other objects (like other agents) within 30m.
– It can send a control command either "move" or "extinguish".
– It cannot communicate with other fire brigades directly.

In this simulation, a fire brigade agent goes to the nearest burning building for which no other fire brigade is extinguishing the fire, and continues fire fighting until the fire is extinguished or the building is burned out. The agent which is assigned to an ignition point gives priority to extinguishing fires near the ignition point.

3.3 Find the Optimal Distribution of Rescue Agents

To minimize the damage of the disaster, the efficiency of the rescue agent needs to be maximized. We investigate agents' efficiency with different distributions by simulation. In this experiment, the optimal distribution is decided with the following three steps.

Acquire the "assigned number and damage" function
First, we investigate the function of "assigned number and damage" for each fire site around the ignition point, by simulation. To check each point separately, only one ignition point is activated in each simulation. We simulated the fire spread with one to nine fire brigade agents and captured the damage data.

Calculate the function of "assigned number and efficiency"
In this step, the function of "assigned number and damage" is converted into the function of "assigned number and efficiency". We use the following equation to calculate the efficiency of agents assigned to the fire site i : E_{i,N_i}

$$E_{(i,N_i)} = \frac{Const}{D_i * N_i} \tag{1}$$

where $Const$ is the constant value, D_i is the amount of damage caused by fire site j and N_i is the number of agent engaged in the work at the fire site i. This means that D_i and N_i are inversely proportional to E_i.

Select the Best Strategy
The optimal distribution (x,y,z) is decided as the distribution that maximizes the total efficiency E_T calculated by the following equation:

$$E_T = E_{(X,N_x)} * N_x + E_{(Y,N_y)} * N_y + E_{(Z,N_z)} * N_z \tag{2}$$

3.4 Results

First, we simulated with only one ignition point to acquire the "assigned number and damage" function. Figure 2 shows the damage for each number of agents for the ignition point Z. The higher line indicates the total damage, and lower line indicates the extinguished number out of this damage.

Then, the function of "assigned number and efficiency" is calculated using equation(1) as shown in Figure 3. The constant value for the equation is 1,000,000. This curve means that, with five or six fire brigades, they can give full play to their ability, but four fire brigades are not enough to prevent the spread of fire. The graph shows that, this domain has a feature that cooperation can make the efficiency per agent be much improved[3]. So this result gives meaning to the distribution of rescue agents.

The function of "assigned number and efficiency" for the ignition point X and Y can be calculated by the same simulation. Considering these functions, "Concentrate Strategy" X:7, Y:1, Z:1 maximizes E_T in equation(2), when the total number of agent is 9. We compare the following two strategies to confirm the result.

– "Balancing Strategy" : The same number of fire brigade agents are dispatched for each fire site. (X:3, Y:3, Z:3)
– "Concentrate Strategy" : The calculated optimal strategy. (X:7, Y:1, Z:1)

Figure 4 shows the result with "Balancing Strategy" and Figure 5 shows the result with "Concentrate Strategy". "Balancing Strategy" could prevent the fire spread around Y, but enlarged the damage around X and Z. Final damage with each distribution was 501:405. "Concentrate Strategy" reduces the damage by about 20% compared to the "Balancing Strategy".

4 Conclution

The RoboCup-Rescue Simulation System provides a Multi-Agent environment to test cooperative behaviors of agents. In case of simulation of fire fighting activities on this system, cooperation can make the efficiency per agent be much improved. We presented a simulation example to select the optimal distribution of agents, and found that "Concentrate Strategy" is the best in this case.

This paper treated only the fire brigade agent. We may have different results, when using the road blockade simulator, building collapse simulator, and other kinds of agents. These topics will be addressed in future work.

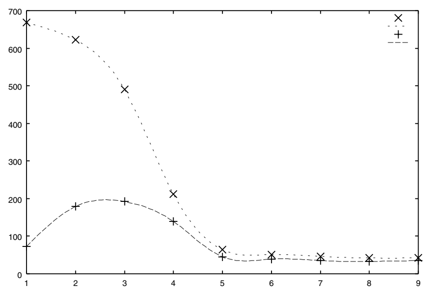

Fig. 2. Change of the Damage

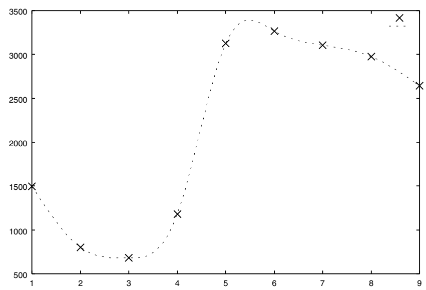

Fig. 3. Efficiency per an Agent

References

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Fig. 4. Simulation Result with Balancing Strategy (X:3, Y:3, Z:3)

Fig. 5. Simulation Result with Concentrate Strategy (X:7, Y:1, Z:1)

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