RoboCup-Rescue Disaster Simulator Architecture

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Abstract. *RoboCup-Rescue* project aims to simulate large urban disasters and rescue agents' activities. The simulator must support both simulation of heterogeneous agents such as fire fighters, victims' behaviors and interface to disaster's environments in the real world. *RoboCup-Rescue* simulator is a comprehensive urban disaster simulator into which a new disaster simulator or rescue agents can be easily plugged. In this paper, the simulator's specification, based on the Hanshin-Awaji Earthquake, and the simulator's architecture are described.

1 Introduction

RoboCup-Rescue addresses the problem of the simulation of a large-scale urban disaster and the rescue operation that ensues [1]. The initial stages of the *RoboCup-Rescue* initiative are concerned with building a simulation environment chiefly for research and competition, while the eventual goal is to support disaster management before and after a major catastrophe.

The characteristics of the RoboCup disaster simulation are a comprehensive disaster simulator by distributed computation, and a large-scale heterogeneous agent system. In this paper, the simulator's specification, based on the Hanshin-Awaji Earthquake, and the simulator's architecture are described.

2 Design from Nagata Ward Case Study

The *RoboCup-Rescue* project will support the functions for the disaster and rescue simulations. Our scenario of rescue operations and requirements for the simulator are as follows:

1. A large urban disaster is composed of various kinds of disasters such as fire, building blockage, road blockade, etc. The simulators for these disasters have been developed independently in each field. *RoboCup-Rescue* simulator can be plugged into these component disaster simulators.

P. Stone, T. Balch, and G. Kraetzschmar (Eds.): RoboCup 2000, LNAI 2019, pp. 379-384, 2001.

2. At a large disaster, fires break out at the same time. Traffic jams caused by civilian's behavior may have an effect on rescue operations [2]. *RoboCup-Rescue* simulator must simulate the rescue operations at the civilians' action level.
3. Large earthquakes take place all over the world every few years on average. In the last five years, Kobe-Awaji, Los Angeles, Turkey and Taiwan suffered from large earthquakes. *RoboCup-Rescue* simulator will simulate each disaster by replacing geographic data and disaster models.

Necessary conditions for *RoboCup-Rescue* project are considered by investigating disasters in Nagata Ward. The area was 11.47 km^2 and one of most damaged areas of the Hanshin-Awaji Earthquake. On October 1, 1994, 130,466 people (53,284 households) lived there.

simulation period : Rescue activities start when earthquakes occur, and are to be continued for years. The purposes of the activities change as time passes. The purpose of rescue activities at the first stage is saving victims without any aid from outside. The period to be simulated is set to the first 72 hours, considering that after that period the survival rate decreases rapidly.

rescue agents : When earthquakes occur, only local rescue agents will perform the first rescue actions. There were 7 rescue agents at Nagata fire offices. The order of rescue agents is set in this order.

space resolution : Representing disaster situations or rescue activities requires the display of items the size of cars. In order to do that, GIS (Geographic Information System) data is maintained with a resolution of 5 m mesh. The area of 1.5 km^2 centered on JR Nagata railway station is selected to be the target for the prototype system from the amount of GIS data.

3 Prototype system

3.1 Architecture of prototype system

Fig. 1 shows the overview of the *RoboCup-Rescue* prototype simulator. It is composed of a number of modules which communicate with each other using a protocol based upon UDP/IP. The modules are one kernel, one GIS, agents, component simulators, and 2D/3D (dimensional) viewers.

Kernel controls the simulation by receiving and sending messages between other modules. At the beginning of the simulation, the kernel receives the initial configuration of the simulated world from the GIS module. At every simulation step, the kernel sends to agents sensory information, and receives their action commands. The kernel checks the validity of actions. For example, when a fire brigade agent extinguishes a fire, it cannot use water beyond the amount provided by fireplugs. To disaster simulators, the kernel sends changes in the world, and receives from them the result of simulations.

Agent module controls an intelligent agent that decides its own actions according to situations. Civilians, fire fighters, ambulance teams and so on are agents. The agents are virtual entities in the simulated world.

Component simulators simulate the effect of disasters by their own methodologies. Building and road blockage simulators calculate how the buildings are broken, and the roads are covered with the broken buildings. A fire simulator calculates how the fire spreads, and how fires are extinguished by fire fighting.

GIS module provides the configuration of the world, where roads run and where buildings and individuals are located at the beginning of the simulation [5]. The other role is to manage the spatial temporal data representing transition of the disaster and the rescue operations during simulation steps.

Viewers visualize the result of simulation. Global information is displayed in a form of 2D scenes, and local scenes are displayed as 3D images.

3.2 World Model

The world model of prototype system is consisted of the following objects:

Building : a building which may collapse, obstruct a road, or bury persons.
Civilian : a family or a person which has encountered the disaster.
Car : a car which a civilian agent drives.
Fire brigade : a team that extinguishes fires.
Fire station : a station that can order fire brigade agents.
Ambulance team : a team that rescues persons buried alive and carries injured persons to hospitals.
Ambulance center : a center of ambulance teams that controls the team.
Police force : a team that opens roads obstructed by collapsed buildings.
Police office : a center of police forces that orders the police.

3.3 Protocols between modules

Table 1 shows protocols that specify communications among modules. In the prototype system, one simulation cycle is one second of computer time and it corresponds to one minute in the real world time. The simulation cycle follows the following steps:

1. At each cycle, the kernel sends `sensory information` to each agent module. This information consists of objects that the agent can see at that time. They are within a certain radius around the agent.
2. Each agent module decides what actions the individual should take, and send it to the kernel as `command`.

[5] The prototype system uses a GIS data format based on KIWI format that is discussed in Intelligent Transport Systems Working Group of ISO as a standard format for car navigation systems.

3. The kernel gathers all messages sent from agent modules, and broadcasts them to the component simulators.
4. The component simulators individually compute how the world changes its internal status. These results are sent back to the kernel.
5. The kernel receives the simulation results of the component simulators within a certain time, and integrates them. The kernel broadcasts the integrated result and forward simulation clock.
6. The viewers request the GIS to send updated information of the world, and display visually the information with statistical data.
7. The GIS keeps track of the simulation results, and the changes in the simulated world.

At step 2, the agent modules decide the agent's behavior according to their objectives, such as to search for the victims, to rescue them, to evacuate them to safe places, to provide them with some food, etc. A local language is defined for the agent-agent communication. Agent `act` command includes the followings: `extinguish` *Target*, `rescue` *Target*, `load` *Target*, `unload`, `open` *Target*.

Table 1. commands in agent's protocol.

Command	Information Transfer	Function
Initialization		
init	agent → kernel	Initialization of agents
Action Commands		
move	agent → kernel	Motion of agent body
act	agent → kernel	General term for disaster mitigation action, implemented ones are extinguish, rescue, load, unload, open.
say	agent → kernel (agent)	Auditory information transmission
tell	agent → kernel (agent)	Via transmission line
Sensory information		
see	agent ← kernel	Visual information acquisition
hear	agent ← kernel (agent)	Auditory information acquisition
listen	agent ← kernel (agent)	Via transmission line

4 Evaluation of prototype system

The prototype system is tested under the following environments.

machine environments : Modules in prototype system are distributed throughout seven computers. Their processing power is at the Pentium III 700 Mhz level, and they are connected within a 100 M sub-network.

GIS test worlds : Four different sizes - 1/1000, 1/100, 1/10 and 1/1 scale - are tested. 1/1 scale model is a square area 2,217 *m* on a side. There are 9,357 houses and the road network consists of 9,776 links and 9,143 nodes.

Fig. 2 shows a snapshot of a 2D viewer at the 1/10 scale and the 1/1 scale model. The spots are buildings and the lines are roads. The color of buildings is green, and buildings turn red when they burn. The points on the lines represent agents. The number of civilians is 934 at 1/10 scale. The real number, which is 100 times this number, is too large to use at this time.

The prototype shows our formulation manages a comprehensive disasters simulation. However, it becomes clear that there are following problems:

agent How much of the world should an agent know ? A civilian agent knows his/her neighborhood better than the area far away, while a fire brigade agent knows the simulated area equally with a rough resolution.

component simulator How does the component simulator finish its simulation within a simulation step for large cities ? Especially, a newly plugged simulator does not know how much area it should calculate or how much time it takes to calculate.

kernel All data is communicated among modules via kernel The amount of data that the kernel must handle increases as the number of modules or the size of area becomes larger. One kernel becomes inevitably unable to handle the data as the size becomes larger or the simulation level becomes finer.

5 Discussion concerning a new *RoboCup-Rescue* simulator

RoboCup-Rescue simulator provides not only a multi-agent system but also a challenge problem for distributed interactive simulations. Taking into account other simulator systems [3] or standardizations [4], topics such as data distribution for a large city, evaluation standard for rescue competition. are being discussed for the next simulation system.

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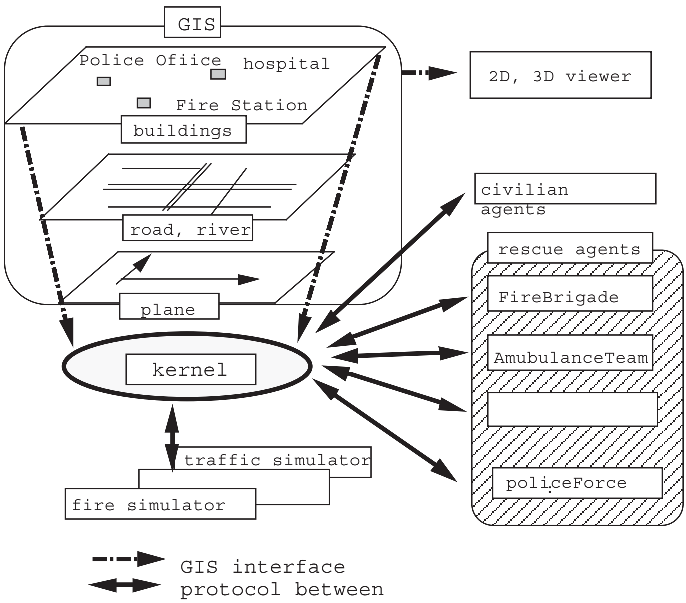

Fig. 1. Overview of prototype rescue simulator

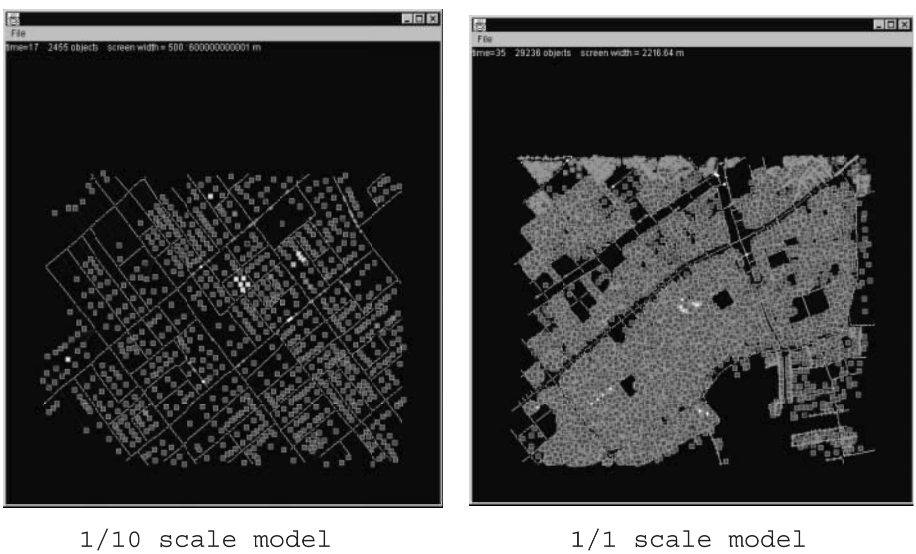

Fig. 2. 2D viewer of 1/10 scale and 1/1 scale.