Wearable system for the Disaster Mitigation Problem: Mission-Critical Man-Machine interface for the RoboCup-Rescue simulator

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Abstract

This paper proposes the development of the wearable system for the disaster mitigation problem. The RoboCup-Rescue project is a new research of disaster mitigation, search and rescue problems, and a RoboCup-Rescue competition is initiated in order to promote international research collaboration[3]. The RoboCup-Rescue simulator is a comprehensive urban disaster simulator. Wearable system is the mission-critical man-machine interface of this disaster simulator. It supports the communication between the simulator and rescuer. The conditions of the disaster and decision of rescuer are transmitted to the simulator in real-time, and results of simulation are indicates to rescuer in real-time. The objectives of it are to improve the rescuer ability of disaster mitigation and to transmit the information promptly.
Key words: Disaster Mitigation Problem, RoboCup-Rescue Project, Wearable System, Autonomous System, Mission-Critical Man-Machine Interface.

1. Introduction

The Hanshin-Awaji Earthquake killed more than 6,500 citizens on January, 1995. 80,000 wooden houses were collapsed. The damage of the basic infrastructures exceeded 100 billion US dollars. In 1999, Turkey Earthquake killed more than 15,000 citizens.
Several kinds of disaster simulators have already been constructed in many local governments in Japan. These analyze and estimate the past disasters, and sometimes are used effectively these simulation results in urban planning, disaster training and publications.
Because the main objective of these systems is basically analysis of past disaster and planning of disaster mitigation, most of these could not use in real-time. When the real disaster such as Hanshin-Awaji Earthquake in Kobe has far larger than the supposition, the planning is never useful.
The real-time disaster mitigation system contributed by high technologies such as intelligent robotics, virtual reality, and artificial intelligence is highly expected to mitigate such disaster damage.
The RoboCup-Rescue project is starting for the research of disaster mitigation, search and rescue problems. Its objectives are

(1) the robotics technology is applied to serious social problems to contribute human social welfare,
(2) new practical problems are proposed as challenges of robotics and AI to initiate a novel research field, and
(3) a new RoboCup competition is initiated in order to promote international research collaboration.

Based on these objectives, RoboCup-Rescue simulator, the initial project of it, was started, and will be demonstrated in 2000. The development of mission-critical man-machine interface, the real-world interface system of this simulator, was also begun at the same time.
This paper introduces the wearable system for the disaster mitigation that is the mission-critical man-machine interface for RoboCup-Rescue simulator.

2. RoboCup-Rescue project

2.1 Basic architecture of RoboCup-Rescue simulator

The concept of the RoboCup-Rescue simulation project is illustrated by Fig. 1.
The essence of this project is as follows[4].

(1) Simulation models of multiple urban disaster domains are integrated in distributed computers, as a comprehensive simulator.
(2) A large number of heterogeneous intelligent agents make actions of disaster prevention, mitigation, search and rescue in the simulation world.
(3) Instrumentation facilities and controller of the infrastructure in the real disaster field are connected

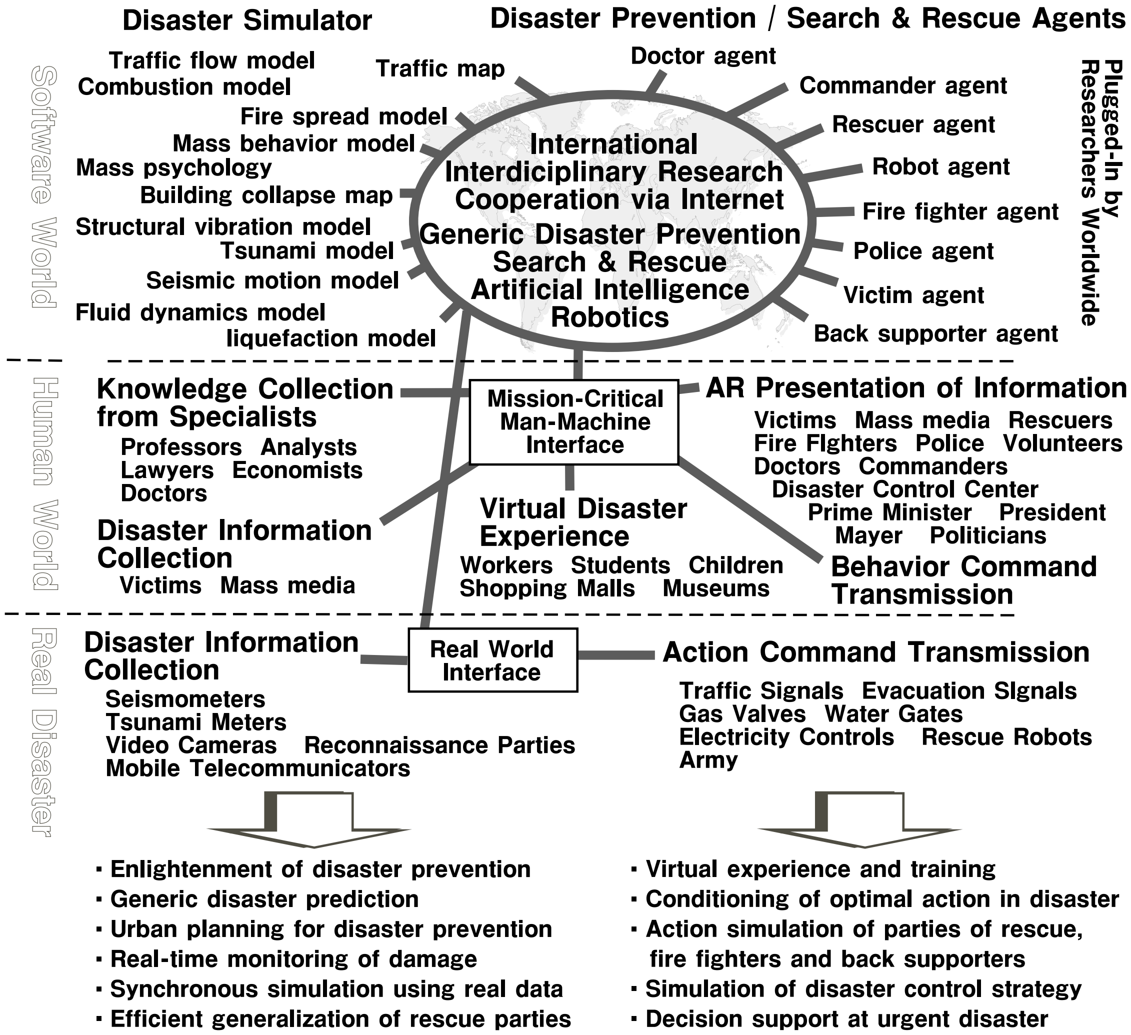

Fig. 1: Concept of the RoboCup-Rescue simulation project.

to the system by a real-world interface.

(4) Human activities of mitigation, search and rescue are supported by a mission-critical man-machine interface.

The overview of the architecture of RoboCup-Rescue simulator is illustrated by Fig. 2.

The simulator element includes the several kinds of disaster simulator such as traffic, spread of fire, collapse of building, etc. Each simulator periodically obtains necessary information from the kernels, and sends the results of it to distributed kernel. Each simulator also connects each other, and exchanges the quantity of state each other for synchronization.

The distributed kernel manage the all state of whole RoboCup-Rescue simulator as a god, and limits the providing information for each agents.

The distributed GIS (Geographical Information System) supply the several kinds of fundamental urban data, and manages the whole disaster states as a master database.

The agent element includes the several kinds of agent such as commander, rescuer, volunteer, transporter, fire fighter, police, and victims. Each agent separately communicates with distributed kernel, gets the surrounding visual and auditory information, and makes decision of their own behaviors according to diverse objectives. Their activities are transmitted to distributed kernel, and exchanged the states of disaster field. Each agents can communicates each other through the distributed kernel.

Fig. 3 shows the architecture of viewer system. Viewer system includes the three kinds of sub-viewer system. The first one is a main viewer system (Fig. 4 and Fig. 5[6]). The main viewer system shows the whole process and states of disaster with several kinds of three-dimensional view. This is for disaster mitigation center, and needs the multiple display and high-end graphical workstation. The second one is a plain viewer system. The plain viewer system shows the limited process and states of disaster in local area with wire-flamed three-dimensional view or two-dimensional view. This is for commander in disaster area with PDA or portable note style PC. The third

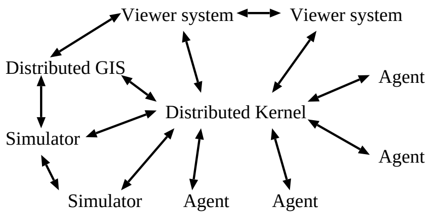

Fig. 2: Software architecture of RoboCup-Rescue simulator.

one is a wearable styled viewer system, wearable system. The purpose of it is not only the information support for rescuer, but also the grasp of disaster situation and the condition of the rescuer.

2.2 RoboCup-Rescue league

The final objective of the RoboCup-Rescue project is the robust social systems against large-scale several kinds of disaster that are composed by some elements such as distributed real-time simulator, autonomous rescue robot, wearable systems, etc[3]. Commander can verify planned strategies before real operations on their effectiveness, possibility of secondary disaster, etc on this systems.
These elements will be integrated by the simulator project, real machine project, etc.
To achieve this objective, The RoboCup-Rescue project is studied by an international research collaboration in the same way as the RoboCup. The RoboCup is a research and competition of intelligent behavior of soccer agents. Its final objective is that a humanoid robot team defeats the FIFA World CUP champion team in 2050[7]. It consists of a simulation league that software agents play in a virtual soccer field and a real robot league that autonomous robots plays in a small soccer coat[4]. Based on these activities, the RoboCup-Rescue project will be started at 1999, and a large number of researchers can participate in a research evaluation conference.
The real-time simulation of the large-scale and distributed systems that contains the several kinds of elements like RoboCup-Rescue simulator is a costly feature. This is one of the reason why statical disaster systems have been widely used. However, because the RoboCup-Rescue systems will be studied by an international research collaboration, the total costs of developments will be dynamically reduced like Linux.
The intelligence of agents such as rescuer, fire fighter, and police will be rapidly developed and evolves by the competition. Several kinds of disaster simulator, viewer system will be compared and developed. Through these activities, effective disaster mitigation system will be created and used as the best disaster mitigation system.

2.3 Information support for disaster mitigation

The importance of information support in rescuer activities has been recognized for a long time. Its objectives are to support prompt grasp of current condition and transmission of the planning. Unfortunately, most of recent large-scale disasters, most of exiting system for information support did not work correctly, because the damage of the disaster exceeded the supposition. As a result, the following situations were happened in Hanshin-Awaji Earthquake[1][2].

(1) The communication routes to outside of the disaster occurrence were cut for a few hours. It made the necessary supports from the outside too late.
(2) Several kinds of disaster mitigation centers were caught a grate damage, could not get the prompt grasp of disaster conditions. This situation made the effective planning of disaster mitigation too difficult.
(3) Because tele-communication network was troubled, the disaster mitigation center could not transmit and promote the plan of disaster mitigation immediately.

These happenings concluded that the following functions for information support system were necessary to disaster mitigation system for working it correctly.

(1) Prompt grasp of local disaster mitigation and distribution of disaster information to the disaster mitigation center that works correctly.
(2) Prompt support for action planning of disaster mitigation, search and rescue.
(3) Prompt support for collaborative rescuer activities between the rescuer, fire fighter, police, volunteer, victim and rescue robot.
(4) Reliability and robustness of the system.
(5) Continuity from ordinary times to emergency.

The wearable system that is presented in this paper will supports these functions as one of the viewer system of RoboCup-Rescue simulator.

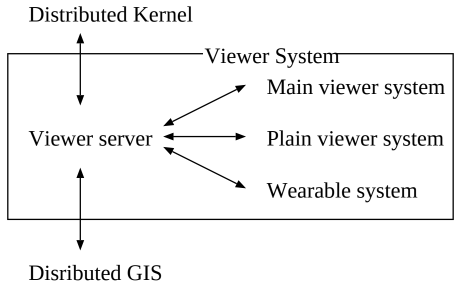

Fig. 3: Viewer system

3. Wearable system for Disaster Mitigation Problem

3.1 Wearable system

The wearable system was selected by following reasons as the mission-critical man-machine interface of RoboCup-Rescue simulator. There are two objectives in this sys-

Table 1: The specification of the prototype of sensor unit.

Specifications	
Dimension	60mm x 100m x 30mm
Weight	200 g
Function	GPS receiver
	Wireless communication unit
	8bit AD/IO

Fig. 4: Reference image of main viewer. No.1

tem. The first is to connect the RoboCup-Rescue simulator with rescue parties such as rescuers, fire-fighters, volunteers and victims. The second is to support their search and rescue activities by information augmentation and information processing.

(1) The system does not restrict the movement of arms and legs that are the important component for rescue activities.

(2) The system can customize depends on the mission or purpose.

(3) The system has the possibility that human can wear and use it at ordinary times.

The wearable system is completely different from the wearable computer. The wearable computer is only computer, and the user must operates it like standard personal computer. It never suit for the rescue system, because this kind of operate disturbs the rescue activities. The feature of wearable system is autonomous information providing and the autonomous sensing of disaster situations and rescue party's condition. It is composed by some small units connects with serial or wireless devices. Each unit independently works. The rescue parties equip with some of this unit, and can get the information such as detailed street map, location of victims, the condition of fire, etc in accordance with their mission.

The wearable system communicates with viewer server which is one of the component of RoboCup-Rescue simulator. Viewer server manages disaster situation and rescue party's condition, and sends it to distributed kernel periodically. The distributed kernel updates and simulates these data for the new plannings of rescue strategies. When the new rescue strategies are decided, this will

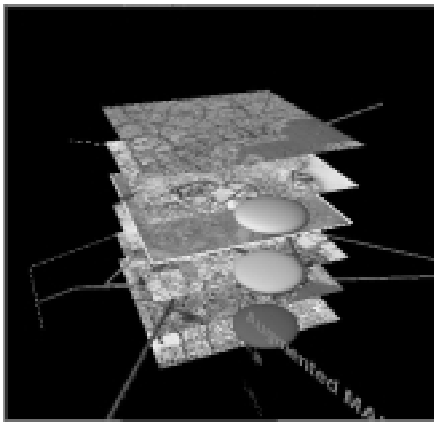

Fig. 5: Reference image of main viewer. No.2

be provided to rescuer party soon. This linkage between the disaster mitigation center and rescue party makes the rapid correspondence toward the various conditions possible.

There are following two kinds of control unit in this system.

(1) Device control unit
It manages the condition of each wearable unit and user, decides the method for information providing and condition grasping, and indicates the actions to each devices.

(2) Information management unit
It accumulates, relays, and summarizes the grasped condition data, selects and requests necessary condition data. It also accumulates, relays, and summarizes the planning or indication of disaster mitigation that is delivered from the viewer server. It studies and adapts the dynamics of the grasped condition data and the behavior of equipped person for better accumulation, relay and summarization.

Fig. 6 is one of the prototype of sensor unit. Table 1 shows the specification of it. The weight of the whole system is not fixed. It depends on the missions and objectives. It assumes that human selects and wears the most light system ordinarily, and adds the extra unit when some kinds of disaster happened. This is the same way that the human usually wears the clothes depends on its purposes or activities.

3.2 Reliability and robustness of the data exchange

The wearable system has following two kinds of autonomous condition mechanisms to cope with the some kinds of the trouble of the data connection between the wearable system and the viewer server.

3.2.1 Data transfer control mechanism

This mechanism is to cope with the changes of infrastructures and systems. The mechanism is composed by following two functions.

(1) Data transfer control
This function is to cope with the dynamics of data transfer rate between the wearable system and the viewer server or each wearable system. In most cases, the transfer rate of wireless communication is not so wide, and the dynamics of data transfer rate is not so stable. This function periodically investigates and calculates the data transfer rate between each connection using small ACK (Acknowledgement) packet, studies the patterns of changes and decides the maximum data transfer rate at each unit time[5].
When the capacity of data for transfer exceeds this maximum data transfer rate per unit time, this function deletes one of these data for reducing data transfer rate based on the evaluation of the importance of each data using the value of degree of importance. The value of degree of importance is always added by both of the distributed kernel and the information management unit. This valuation is based on the evaluation of each rescue party's mission, situation and requests.

(2) Load control
This function is to cope with the change of the condition of the wearable unit. There are several information presentation unit. The capability of each unit has no guarantee and is always changed by the running processes. Therefore, the most suitable method for smooth information providing depends on the capability of each unit. This function checks the load average of each unit, studies the dynamics of load average, decides the most suitable method and sends this information to the distributed kernel and information processing unit.

These functions make the wearable system can cope with the changes of network traffic and the condition of the wearable unit possible. The commander and rescue party does not need to mind these conditions, and can exchange the several kinds of data.

3.2.2 Multiple server architecture

In the large-scale disaster, some of the disaster mitigation centers may catch the great damage and be not able to work correctly. This kind of situation may happens by the secondary disaster or spread of fire. Multiple server architecture can cope with this kind of situations.

In the multiple server architecture, most of server does not have the whole functions. Each server has some reduced functions that can manages and achieves its purposes and missions. This distributed environment reduces a load average of each server.
If a large number of volunteer who equips the wearable system joins the rescuer activities, a large number of data connection will be happen. Because a large number of data exchange needs a numerous processing power and memory, the multiple viewer server is also suits for this kind of situation.
To cope with this problem, the multiple server have to exist and be distributed in many places.
Each wearable system must cope with following functions.

(1) The automatic server discovery function
The wearable system investigates the functions of each server and connects to one of these which is most suitable for the mission of this system.

(2) The server state observation function
The wearable system always observes the state of the current connected server (a supplied function, the current connection speed, etc.). When the connected server dies or more suitable server appears, the wearable system re-connects to the system using above function.

3.3 Training environment for rescuer

There are the following two ways of possibility of the training environment for rescuer.

(1) The training on the virtual reality environment.
Human who equips the wearable system can enter a virtual disaster field constructed on the large-scale virtual environment system like CAVE. This space works as the virtual training of search and rescue, or urgent planning place.

(2) The feasibility test and adaptation in an ordinal time.
It is clear that the tool that human uses in ordinal time is most effective one in emergent time. This is the way that human equips some of the basic unit of the wearable system like Fig. 6 at several places in the ordinal time as training. By this way, these wearable units studies the specific motion of each human, and adapts to each human separately. The human also be able to study an operation of the wearable system.

3.4 Collaboration between rescue robot and rescue party

One of the final objective of the RoboCup-Rescue project is the realization of the collaboration between autonomous rescue robot and rescue party. Each robot has a different ability for rescue. Therefore, smooth collaboration between the human and rescue robot makes the rescue activity more effectively. The necessity function such as local data exchange mechanism will be discussed and developed as one of the unit of the wearable system.

Fig. 6: The prototype of sensor unit.

4. Contribution toward the Disaster Mitigation Problem

The several kinds of resources and results of this project will basically published through the Internet without some kinds of data which contains the some personal code or secure data. The source code of application will be also published. This policy already gave the rapidly advancement of researches to the RoboCup simulation league. Because this project contains the numerous number of problems, this policy is necessary for succeeding this project.
The success of this project will gives the dramatically improvement of the several kinds of disaster mitigation problem. The open architecture of the system will provides the possibility of world-wide collaboration toward the extremely large-scale disaster. If the disaster mitigation center located on the disaster field suffers damage, other disaster mitigation center can support the disaster mitigation activities. The volunteers and the rescuers who wear the wearable system from other local governments or other countries can join and collaborate the rescuer activities smoothly.

5. Road-map of the development of wearable system with whole RoboCup-Rescue system

The final objective of this project is the creation of distributed large-scale social system for disaster mitigation. This grand challenge for AI, robotics, and virtual reality will be accomplished until 2050. This is a long term plan, and the following short term plan will be proceed.

(1) Phase 0 (1999 - March 2000)
Feasibility study of a disaster-agent simulator for a very simple agents and environments.

(2) Phase 1 (April 2000 - April 2001)
Development of simulator: limited disaster and limited agents. The 1st research evaluation conference.

(3) Phase 2 (May 2001 - April 2005)
Development of simulator: large-scale disaster simulator, heterogeneous agents.

The following short term plan is for the development of wearable system. There are some differences between these two plans.

(1) Phase 0 (1999 - June 2000)
The construction of some simple device units, the prototype systems of two control unit.

(2) Phase 1 (July 2000 - April 2001)
Feasibility test of prototype system in limited situations (indoor and fixed environment). The construction of the prototype of whole wearable system.

(3) Phase 2 (May 2001 - April 2005)
Function test of whole wearable system in real-world with RoboCup-Rescue simulator.

6. Conclusion

This paper introduces the basic architecture of wearable system which is the mission-critical interface of RoboCup-Rescue simulator. The wearable system is one of the client of viewer system for RoboCup-Rescue simulator. The objectives of it are to connect the virtual disaster simulation world with rescue parties such as rescuer, fire-fighter, volunteer, victim, etc. For keeping this connection, the system will mounts the data transfer control mechanism and the multiple server architecture. The prototype system will be presented at 2000.

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