Chapter 4
Information Infrastructure for Rescue Systems

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Abstract In a disaster situation, it is important to quickly collect global information on the disaster area and victims buried in the debris awaiting rescue. In the DDT project (Special Project for Earthquake Disaster Mitigation in Urban Areas, III-4 Development of Advanced Robots and Information Systems for Disaster Response), research and development activities on rescue infrastructure for global information collection have been carried out. In infrastructure-related activities carried out by the mission unit, ubiquitous handy terminal devices and technology for forming ad-hoc wireless communication networks were developed. In addition, technology was developed to integrate the information collected, including communication protocol

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design, on a GIS system. In this paper, the current R&D activities of the mission unit with regard to infrastructure in the DDT project are overviewed, and some technologies developed thus far are introduced.

4.1 Introduction

In the disaster situation presented by an earthquake, it is important to collect various types of information on the disaster as soon as possible and provide it to the right people. Quick acquisition of information on the locations of the damaged area, nature of the damage, and locations of debris under which victims are possibly trapped is necessary for rescue strategy planning. At the same time, people affected by the disaster seek information on the locations of refuge and family. For collecting and providing such information, the infrastructure of information plays quite an important role. In a disaster situation, conventional information infrastructure such as the Internet and cellular phones could possibly be damaged and rendered useless. Therefore, it would be indispensable to develop an ad-hoc information infrastructure. In this paper, the recent R&D activities of the mission unit related to infrastructure for the DDT project [13] are overviewed, and some technologies developed thus far are introduced.

4.2 Rescue Infrastructure

4.2.1 Information Collection and Sharing in the DDT Project

In the Japanese project for the Development of Advanced Robots and Information Systems for Disaster Response in DDT (Special Project for Earthquake Disaster Mitigation in Urban Areas, III-4 Development of Advanced Robots and Information Systems for Disaster Response) [13], the infrastructure mission unit has been developing ubiquitous devices for collecting information on the disaster area with the construction of an ad-hoc network, and a system to integrate the information collected into a GIS (Geographic Information System). In the DDT project, various types of robots (on-rubble robots, in-rubble robots, and aerial robots) have been developed to search for victims, collecting information on the disaster area, etc. It is expected that the information infrastructure would collaborate with these robots. The information collected by the robots is transmitted by ubiquitous devices in the information infrastructure and integrated with a GIS. The robots can also utilize this information (e.g., map information and victim information) stored in a GIS to operate intelligently and effectively.

4.2.2 R&D Activity Overview in Infra-MU

This mission unit [1, 2] has conducted research and development in technology to integrate the information obtained from a large number of intelligent sensors distributed over a disaster-stricken area. Operating effectively as a system in real time, network household electric appliances, PDAs, and robots provide information, and an action plan can be developed for an area stricken by disaster. We have implemented trial production based on the research and development work carried out thus far, with emphasis on the following two developments:

1. developing a ubiquitous handy terminal device and technology for forming an ad-hoc wireless communication network; and
2. designing communication protocols and developing a technology to integrate the information collected in a GIS system.

Figure 4.1 depicts the final stage of the R&D activities of the mission unit with regard to rescue information infrastructure.

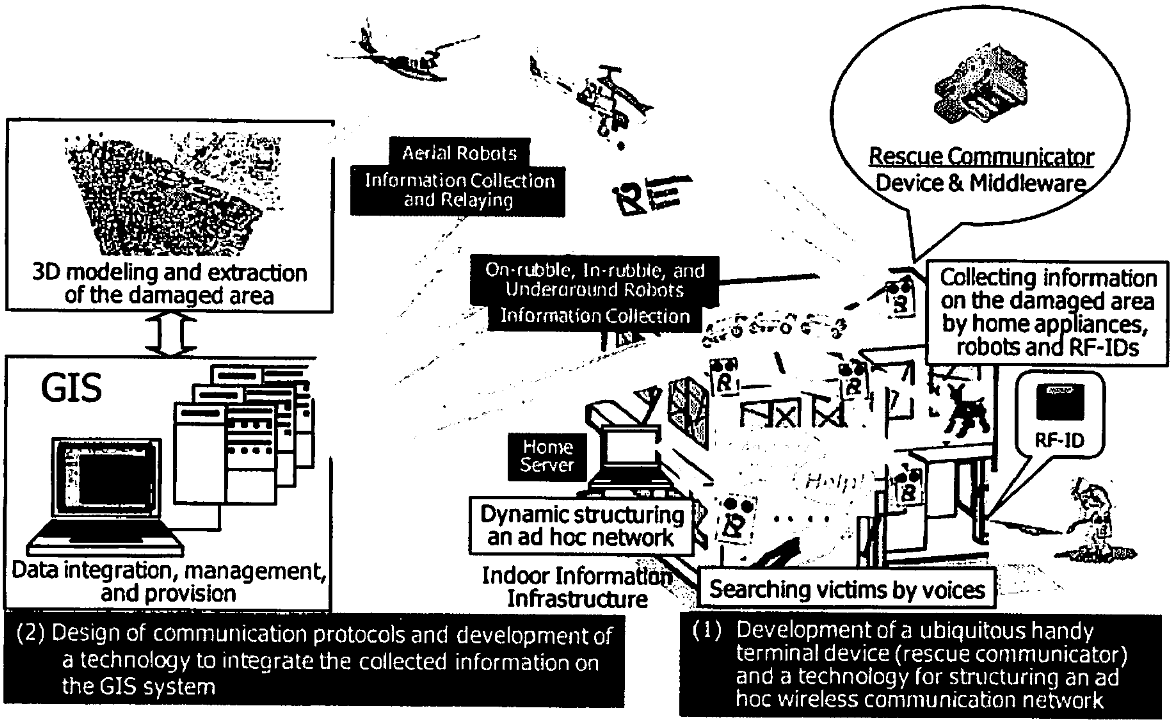


Fig. 4.1 Task force in rescue infrastructure

4.3 Development of Ubiquitous Devices for Collecting and Providing Information

4.3.1 Development of Rescue Communicator

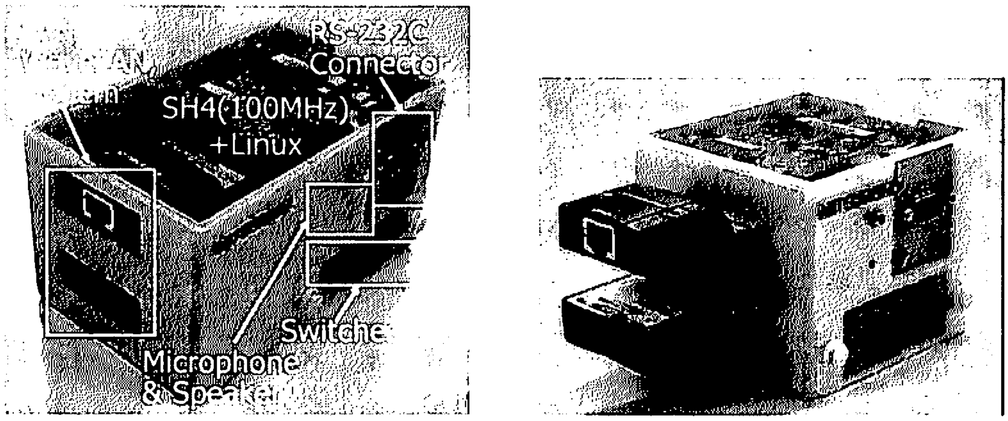
A new intelligent sensor node called the Rescue Communicator (R-Comm) has been developed for collecting and providing information as a ubiquitous device for a rescue information infrastructure platform. The main specifications of the R-Comm are listed in Table 4.1. The R-Comm comprises a microprocessor, a memory, three compact flash slots, a voice playback module including a speaker, a voice recording module including a microphone, a battery including a power control module, and two serial interfaces. One of the compact flash slots is equipped with a wireless or wired LAN model for wireless/wired communication. Linux is installed and used as the OS for the R-Comm. An RF-ID reader/writer and other peripheral devices can be connected to the serial interface. When the power plug is connected, the power control system charges the battery, and if the power supply is cut, the power control system switches the power source automatically to the battery. For intermittent use, the system can operate for 72 h, which is the critical time for humans to survive.

Two types of R-Comm were developed "long type and short type" depending on the inclusion or exclusion of the compact flash cards. Figure 4.2 shows the images of the two types of R-Comm.

A function to form an ad-hoc network among multiple R-Comms was developed. Any data collected by the R-Comms can be sent not only by a one-to-one wired/wireless communication link, but also by hopping among multiple devices using the common protocol MISP via the ad-hoc network, which was also developed in this project. The details of the protocol are presented later.

Table 4.1 Specifications of R-Comm

Item	Specification
CPU	Renesas SH4 (100 MHz)
Memory	32 MB
Extension slot	Compact flash x3, RS-232C x2
Communication	Wireless LAN, InfraRed, RS-232C
Other interfaces	AD/DA/voice
Size	985 / 635 cc, 500g
Acting time	4 h (continuous), 72 h (intermittent)



a b

Fig. 4.2 Images of R-Comm. **a** Long type. **b** Short type

4.3.2 Verbal Victim Search by R-Comms

A verbal victim search system was developed at RIKEN (The Institute of Physical and Chemical Research) and the University of Tokyo by utilizing the voice playback and recording function of the device [3, 7]. In an emergency situation, the device set in the living environment can be activated by signals sent from external systems or earthquakes detected by internal sensors (occurrence of vibration or voltage drop). The devices can then be operated automatically to call for victims by playing voice messages and by recording sounds for several seconds after a message, in which any voice reply by the victims must be included.

The device is supposed to set off fire alarms in houses/buildings, or serve as a wireless LAN router/access point for homes in advance. Figure 4.3 (a), (b), and (c) show the victim search procedure in the latter case.

In the normal situation, the R-Comm functions as a network router, as an access point, or as a bridge, and can provide home network services including information for home appliances, for nursing elderly people, or for security, as shown in Fig. 4.3 (a). However, if the R-Comm detects earthquakes, it changes its mode, broadcasts emergency information, calls for victims, collects information on victims, and sends the information to a disaster management center, as shown in Fig. 4.3 (b). If the global network is down, the R-Comm forms the ad-hoc network automatically with neighboring devices to send information, as shown in Fig. 4.3 (c).

A new version of the R-Comm is under development by the IRS (International Rescue System Institute); the new version has a TITech Wire I/F giving high expandability to add functions to control robots, such as A/D converters, D/A converters, counters, and motor drivers. PCMCIA card I/F and IEEE 1394 I/F modules are also under development for the new version.

To realize a distributed search environment, a miniature type R-Comm with reduced function is also under development. By using the miniature R-Comm, we can construct a hierarchical local network by one parent R-Comm and several miniature R-Comms, which can be deployed in each room. Figure 4.4 shows an experimen-

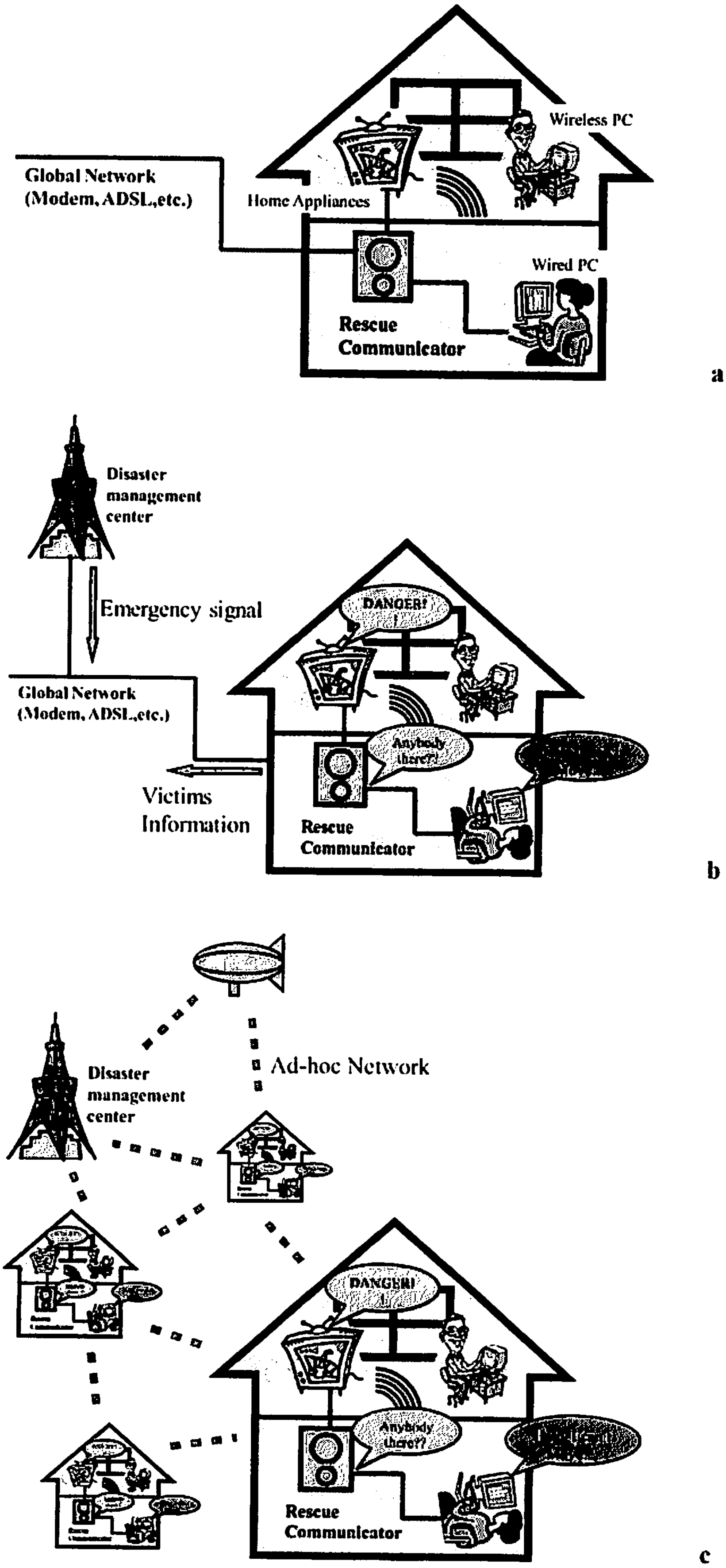


Fig. 4.3 Procedure of victim search depending on situation. a Normal situation. b Emergency situation (global network is alive). c Emergency situation (global network is down)

tal setup to construct such a local network using one parent R-Comm and three IDR-Rs (Intelligent Data Carriers for Rescue) representing the miniature R-Comm terminals.

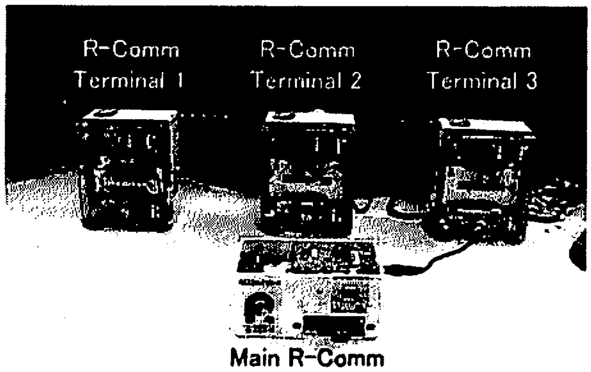


Fig. 4.4 Local network setup

UAV (unmanned aerial vehicle) is an effective means to collect sensory data stored in R-Comms using an ad-hoc network and to link them to record videos from the air. Field tests using an unmanned blimp developed by RIKEN [4, 5], a cable-driven balloon developed by the IRS [14], and an autonomous helicopter developed by Kyoto University [10] were carried out as shown in Figs. 4.5, 4.6, and 4.7, respectively. The communication between the R-Comm and UAVs was found to be reliable within 5 m, 40 m, and 20 m in the case of the blimp, balloon, and helicopter, respectively, while the stable communication range on ground without occlusion was 300 m.

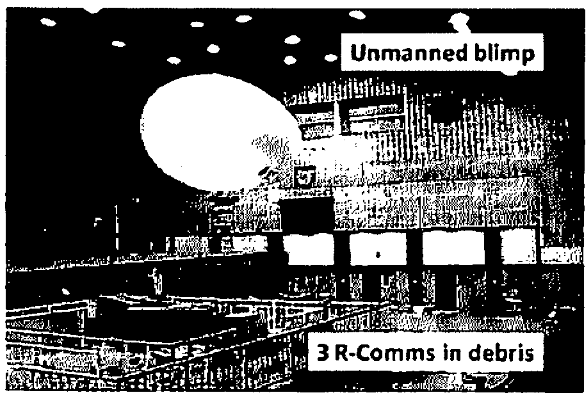


Fig. 4.5 Communication test between blimp and R-Comm in indoor environment

4.3.3 RF-ID-Based Emergency Information Collection and Delivery System

A disaster information collection system using an RF-ID transceiver and ad-hoc network was developed at the NICT (National Institute of Information and Commu-

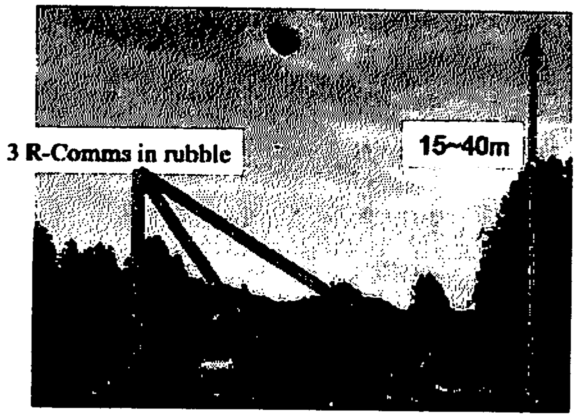


Fig. 4.6 Communication test between balloon and R-Comm

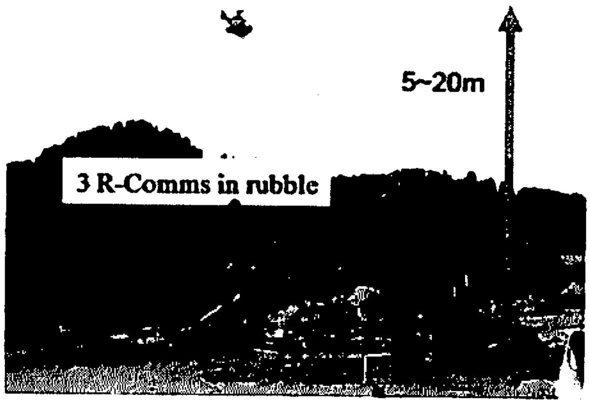


Fig. 4.7 Communication test between helicopter and R-Comm

nications Technology) [15, 16]. RF-ID is useful as a means to collect information on damage and the state of people with the help of intelligent devices and networks to determine strategies for rescue in disasters. A victim evacuated from a damaged house to a point of refuge can place an RF-ID tag at the entrance gate of his/her house and write into the tag a message indicating his/her safety and the place of refuge to any family member that may visit the house; here, the RF-ID tag works as an electrical signboard.

Another use of RF-ID tags is information storage on logs for victim search using rescue surveyors and corps. Any fire fighters, rescue surveyors, or corps searching the house can store the results of the search in the tag set at the entrance gate. This information can be shared by any other rescue surveyors or corps who visit the location with a reader device. The information can also be transmitted to a disaster information management center where all the information is collected, integrated, and utilized.

Figure 4.8 shows the handy terminal and RF-ID tag developed. A GPS antenna is equipped with the handy terminal. The rescue corps carrying the terminal can see a map of the damaged area with symbols over locations for which rescue information is stored; the information can be displayed using a GIS.

The rescue corps visiting a location where a tag is placed can read the message in the tag using a reader device, and can store the information together with the location information obtained by the GPS antenna in the GIS system. Alternatively,

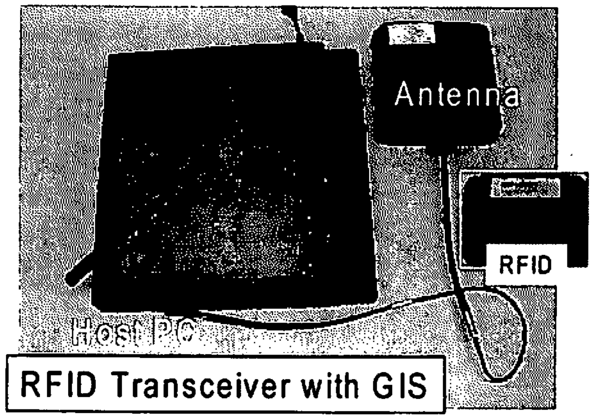


Fig. 4.8 Handy terminal and RF-ID tag

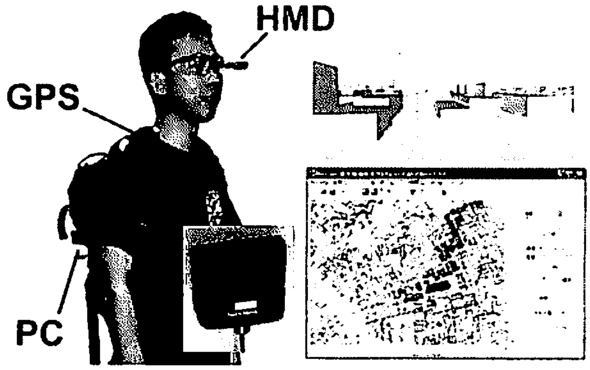


Fig. 4.9 Wearable system for rescue surveyor

they can send the information to a center by wireless communication. Figure 4.9 shows a wearable terminal prototype with which the rescue corps can see a 2D or 3D map with rescue information through an HMD (head-mounted display).

Field test experiments were carried out on the system, and it was verified that the information obtained by multiple rescue corps carrying the terminal device can be transmitted to a center by ad-hoc and multi-hop wireless networks, and that all the information collected can be integrated in the GIS database at the center.

4.4 Disaster Information Collection and Data Integration Using Dynamic Communication Networks

4.4.1 Protocols for Rescue Information Collection and Common-Use Database for Data Integration

In order to effectively utilize all the information collected by various agents, such as rescue surveyors, rescue corps, rescue robots, and sensor nodes (Rescue Communicators), a common protocol called the MISP (Mitigation Information Sharing Protocol) for rescue information exchange and sharing was designed by the AIST (National Institute of Advanced Industrial Science and Technology) [11]. All the data collected should be integrated in a database, referred to efficiently, and enable quick decision making on rescue team deployment to the right locations. A new common-use rescue information integrated database for unifying information using the MISP protocol and API, called RaRuMa (DAtabase for RescUe MAnagement), was developed by the AIST [11]. This integrated database accumulates the information that the rescue infrastructure and rescue robot collect in real time, and offers it in a reusable form. There are plans to combine this rescue-integrated database with integrated earthquake disaster simulation GIS systems called DiMSIS/DyLUPAs, which are currently being developed by the National Research Institute for Earth Science and Disaster Prevention (NIED) [6].

DaRuMa and MISP offer convenient functions for rescue information integration since they are extendable, fast, scalable, network-based, and compatible with various standards; in other words, they are platform independent. Some standard templates are provided for sensor data and coverage.

The details of MISP and DaRuMa are described in another chapter of this volume [12].

4.4.2 Experiments on Rescue Information Collection and Integration

Information sharing, based on spatial temporal GIS, between rescue robot systems and the disaster management system has been discussed at Kyoto University, University of Electro-Communications, and Waseda University [8, 9].

An autonomous mobile vehicle and an imaging system to extract objects different from the normal scene were also developed. The system employs omni-directional vision. It can be utilized for detecting objects that appear in a disaster, or damaged objects and buildings in the disaster area, by extracting the difference between the captured scene and the normal scene. The detected objects can be registered in the GIS in KIWI+ format.

The information exchange software was developed based on MISP, and it was applied to information sharing experiments in the Yomakoshi area, which was destroyed by a powerful earthquake in 2004. Figure 4.10 shows the system configuration of the experimental system for ground and aerial information collection with spatial temporal GIS. The system allows various ways of data collection, such as manual camera work by rescue surveyors using a PDA equipped with a GPS, image capture from the air by an unmanned aerial vehicle (UAV), and image capture by a ground vehicle equipped with a GPS gyro consisting of an RTK-GPS, a D-GPS and an inertia sensor, a high-resolution camera, and a laser range finder. All the data obtained by these means are sent to the DaRuMa database based on MISP, and they are also sent to the spatial temporal GIS (DiMSIS/DyLUPAs).

Figure 4.11 shows the result of the experiment. Each picture is saved on a DiMSIS/DyLUPAs synchronized with the position and time, and the data are indicated by a symbol on a map using a viewer system. The data contents, such as images, can be displayed by clicking the symbols. The integration of the data collected by various types of information sources on a GIS database was successfully executed, and easy lookup of all the collected data on the map was verified.

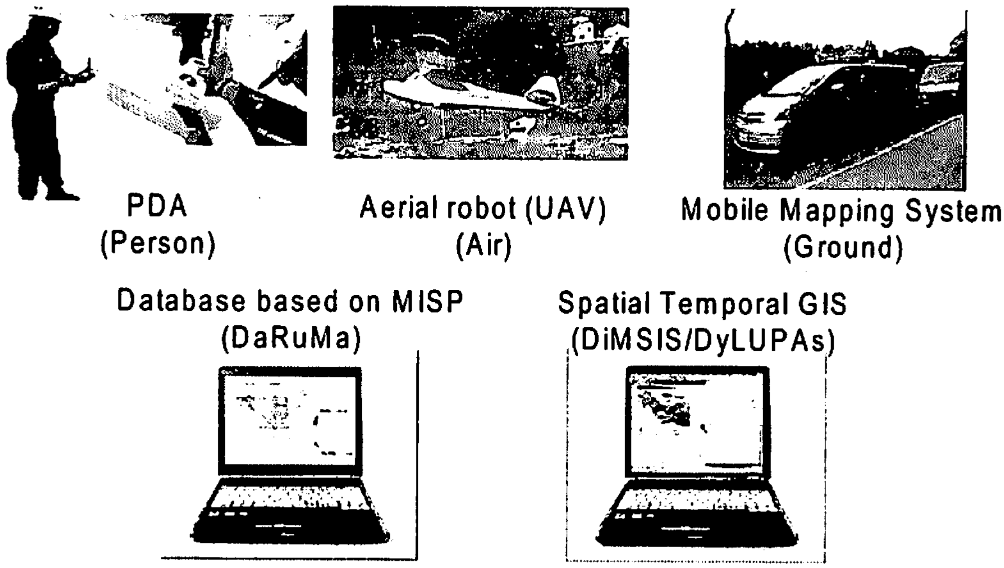


Fig. 4.10 Ground and aerial information collection system

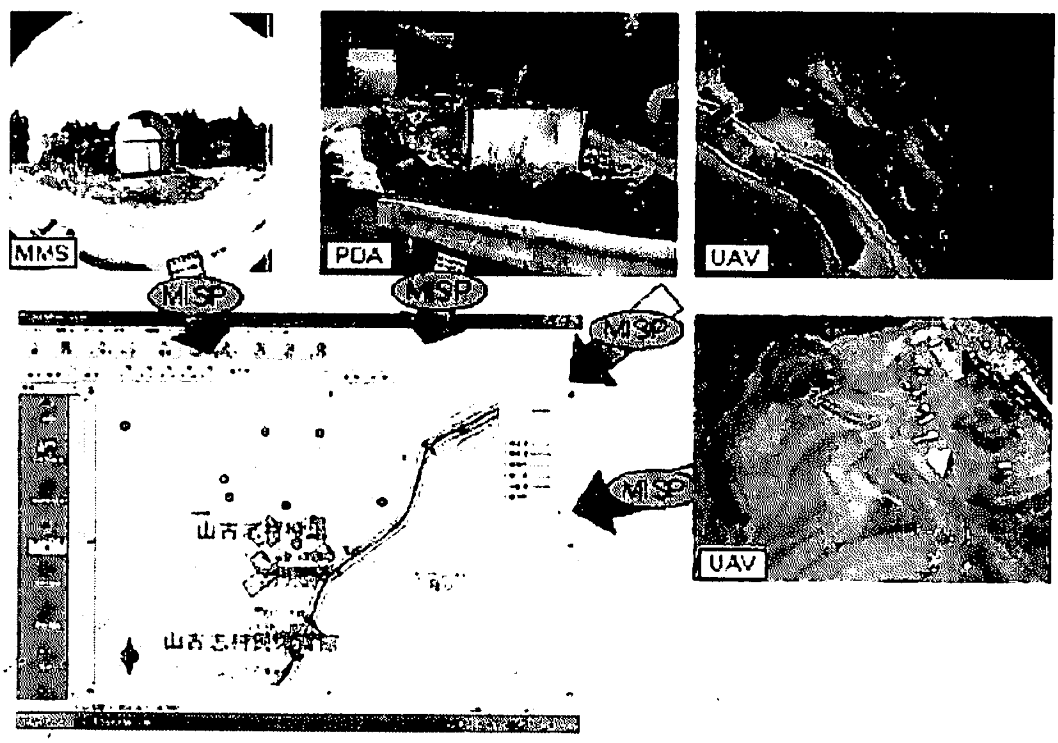


Fig. 4.11 Experimental result for the disaster area

4.5 Conclusions

In this chapter, an overview of the R&D activities of the information infrastructure mission unit of the DDT project was provided. A ubiquitous device, called the Rescue Communicator (R-Comm), developed as part of the rescue infrastructure to collect, transmit, and provide information on the disaster situation was introduced and its application to victim search together with the utilization of RF-ID tags was discussed. The designed protocol, MISP, for communication between various types of data collection devices, including rescue robots, was introduced along with the GIS database, called DaRuMa, for disaster and rescue data integration. Some results of an experiment conducted in a real disaster area were also shown, in which a UAV, a ground vehicle, and rescue surveyors were used for data collection; the collected information was sent to and integrated in a GIS database.

The information infrastructure mission unit carried out some more tests together with other mission units on the transmission and integration of data collected by on-rubble robots, in-rubble robots, and aerial robots in test fields and in a real disaster area.

Acknowledgements The authors thank Mr Hiroshi Nakakomi and Mr Jun'ichi Takiguchi (Mitsubishi Electric Corp.) for the implementation of devices and the GIS registration system.

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