Chapter 8

Rescue Robots

Field of expertise: Laboratory of Disaster Response Robotics

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Summary

In order to improve resilience, there is a need to utilize robot technologies such as drones. Research and development, as well as efforts for social implementation, are underway, based on the experiences of the earthquake and the nuclear power plant accident.

Keywords: disaster robotics, disaster prevention, emergency response, disaster recovery, remote technology, automation

Introduction

Rescue robotics is a new field of research that has been started worldwide after the Great Hanshin-Awaji Earthquake. Its representative examples include drones, underwater robots, ground-traveling survey robots, and teleoperated robotic construction equipment.

1: Problems Revealed by the Great East Japan Earthquake

What happened?

The purpose of using robots is mainly to carry out disaster rescue, emergency response, survey and repair work in dangerous and difficult places remotely and safely in place of humans; to achieve capabilities, performance, and accuracy that exceed those of humans and conventional equipment through sensors, actuators, and robot intelligence; and to dramatically improve the speed and efficiency of activities through automation.

In the aftermath of the Great East Japan Earthquake, a wide variety of robots were used to survey the damage caused by the tsunami and seismic motion, search for bodies, and measure radiation levels, etc. In addition, robots that were not originally intended for nuclear power plants were used for emergency response, cold shutdown, and preparation for decommissioning the nuclear power plants. This was the first time in human history that robots have been applied to disaster sites on such a large scale. The role played by robotics research and development after the Great Hanshin-Awaji Earthquake was not small.

At the same time, however, there was widespread public criticism about the lack of emergency response robots deployed in response organizations and facilities, which prevented a rapid initial response, especially at the Fukushima Daiichi Nuclear Power Plant, resulting in widespread damage. Most of the damage from the Great East Japan Earthquake was caused by the tsunami. Robots for the purpose of investigation, detection, and rescue at the site of structural destruction could not fulfill the requirements.

2: Paradigms Destroyed by the Earthquake

Conventional wisdom and necessary responses

The disaster has highlighted the technical challenges of robots. They did not have sufficient performance to replace human work, or even if they did, they could not be used. They did not meet safety standards such as being explosion-proof, and they could not perform well under difficult operating conditions due to the lack of technical toughness. A major problem was that the technology readiness level (TRL) of the robot technology had not reached a level sufficient for disaster sites.

At the same time, several social issues have become apparent. One of the major problems was that the use of robots was not specified in the government’s Basic Plan for Emergency Preparedness. As a result, there was no progress in deploying them to disaster response organizations, and no training was conducted. In the field, the lack of clear standards for the use of the robots made it impossible for the field commanders to make decisions on the use of the robots, and there was a lack of consistency in the field organization and activities. Robots are effective or indispensable for remote disaster information gathering and emergency work in nuclear power plant accidents and wide-area surveys, and it is important to prioritize them in preparation for infrequent disaster events and to determine how much to spend on them. The government should have thoroughly considered these issues, built a consensus in society, and proceeded step by step with the deployment of robots to improve the resilience of society through advanced technology. If the society focuses only on economic efficiency, the government will end up making decisions to reduce costs and minimize preparedness, then the same disaster damage will be repeated forever in the future.

The Council on Competitiveness-Nippon (COCN) took the social problems caused by the earthquake and the nuclear power plant accident seriously and made recommendations, by discussions held mainly with the industrial sector, on technical elements such as specifications of robots that should be prepared, standardization that should be implemented, and needed research and development, as well as on social elements such as measures to continue technological development and the establishment of a linkage with industry, the insurance system, and safety standards to let economic principles work. Many of the recommendations were implemented as priority measures in governmental policy.

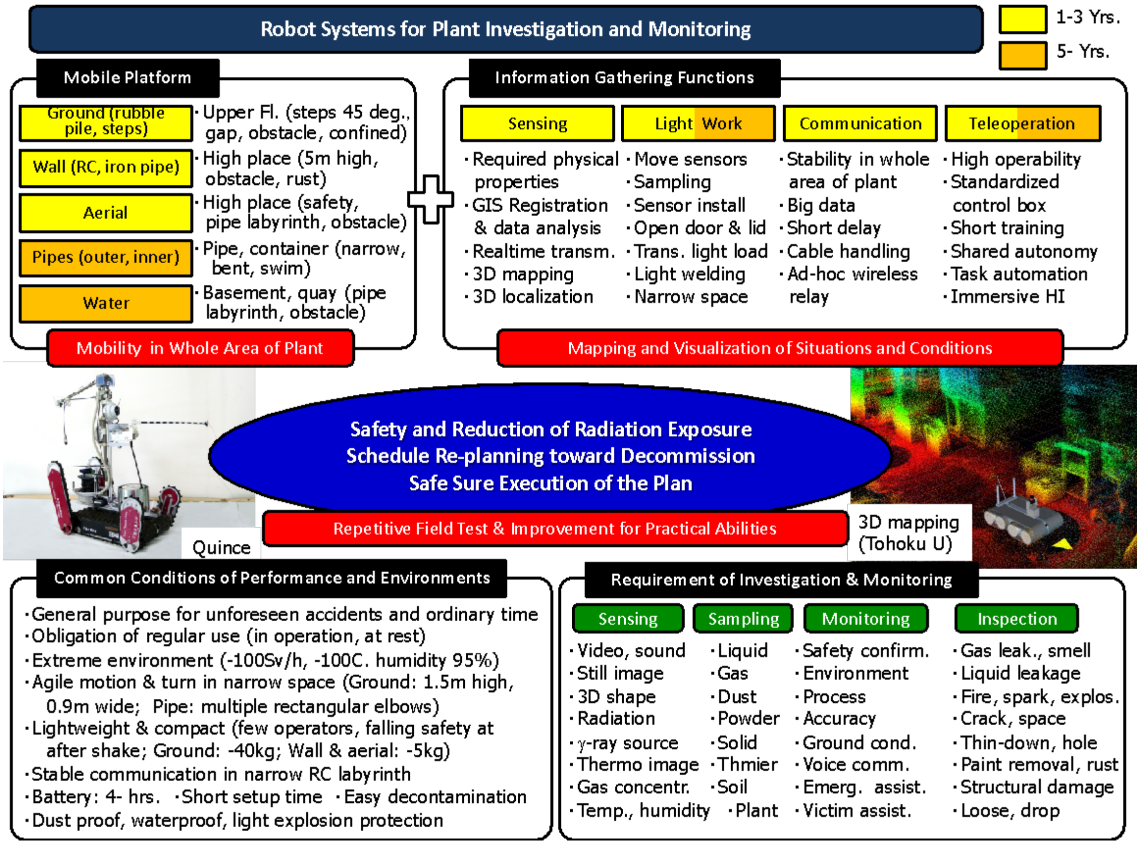

Figure 8-1. One of the recommendations of the Council on Competitiveness - Nippon (COCN)

3: A New Approach

A new approach to disaster science

The Cabinet Office launched a research project, “ImPACT Tough Robotics Challenge” (2014-18), to develop robotic technologies for disaster prevention, emergency response, and recovery. Aiming to create "tough" robotics technologies that are effective in the extreme environment of disasters, 62 groups from Japan and abroad developed five types of robotic platforms: flying robots (drones), construction robots (remote construction machines), cable-type robots (snakes), legged robots (quadrupeds), and Cyber Rescue Canine (digital suits). In addition to developing the platforms, they integrated audio-visual and tactile sensing, automatic recognition, autonomous intelligence, and extreme mechanisms that demonstrate capabilities in extreme environments and showed that they can function as a system in simulated fields.

The project invented technologies to continue flights under strong wind (20 m/s), heavy rain (300 mm/h) even if a propeller stops, and to hear human voices from under debris during flight.

In the Northern Kyushu Torrential Rain Disaster in 2017, the drone was dispatched to Toho Village in Fukuoka Prefecture to fly autonomously to take 2D ortho-images with a resolution of 2 centimeters and provided them to the responding organizations.

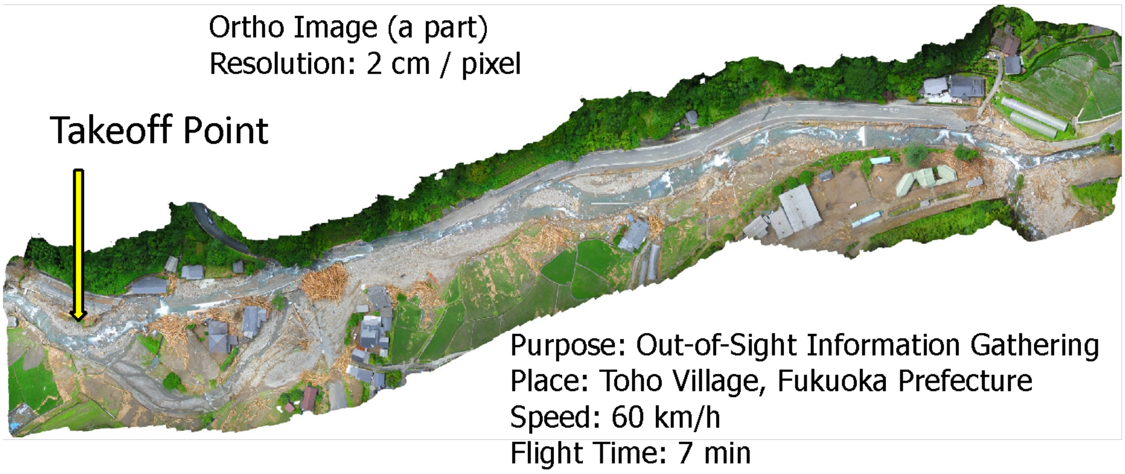

Figure 8-2. Ortho-image of the Northern Kyushu Torrential Rain Disaster (Toho Village, Fukuoka Prefecture)

Figure 8-3. "Dragon Firefighter", the flying fire hose

Figure 8-4. Cyber Rescue Canine suit

Figure 8-5. Dragon Hyper Firefighter Command Unit

A cable-type robot, “Active Scope Camera” was developed. It has a sense of touch to detect contact with debris, a sense of sight to create a 3D map in narrow rubbles and automatically recognize remaining belongings, and a sense of hearing to eliminate noise to hear human voices. Its prototype was used in narrow structures of the Fukushima Daiichi Nuclear Power Plant, which was difficult to survey by the other machines. In addition, the project developed a robot that can move and inspect pipes, ducts, vertical ladders, and stairs in industrial facilities, as well as a flying fire hose robot “Dragon Firefighter” and "Fireproof Gripper" that can grasp arbitrarily shaped objects in fires.

The Cyber Rescue Canine Suit can remotely monitor the rescue dog's location and behavior (walking, running, sniffing, or barking). This enables rescuers to remotely release many rescue dogs to carry out search activities. The system has been rented to the Japan Rescue Dog Association, and training in its use is ongoing. Research has also been conducted on estimating dog motivation and guiding dog behavior from a distance.

In addition to the ImPACT project, various other efforts were made. In the Cabinet Office SIP project, the "Spherical Shell Drone" was developed to inspect infrastructure. It flies freely between obstacles in the structure of bridges to map cracks in the concrete and automatically prepares an inspection report.

The National Research Institute of Fire and Disaster has developed the "Dragon Hyper Command Unit," a robot system to extinguish large fires in oil tanks. Based on the information gathered from a drone, a water cannon robot and hose-carrying robots move to extinguish the fires. The system has been deployed to the Ichihara Fire Department. The Fukushima Robot Test Field was established as a facility where robots can be tested.

4: Achievements and the Future

Immediately after a disaster strikes, drones will automatically take-off and fly over wide areas to gather information on dangerous areas and support the decision-making process of the disaster management headquarters. Remote construction machines will carry out work in dangerous areas and clear the roads. Rescue dogs can quickly find people in need of rescue and notify rescue teams. Active Scope Cameras can locate victims in the rubbles, examine their condition, and assist in rescue and emergency medical treatment. Robots will be dispatched to large fires and dangerous sites to calm them down safely and quickly. The cost of inspecting industrial facilities and infrastructures will be dramatically reduced. Hence, the resilience of society is drastically improved. With the advancement and spread of robot technology, such a scenario is becoming a reality.

Conclusion - From the authors

In order to overcome disasters, innovation through the active application of new technologies is essential because there is a limit to the capability of existing methodologies. Research and development, as well as practical application and deployment, must be pursued. The government must actively use them as an investment for the future and continue to tirelessly implement new approaches. We will realize a society where no lives are inexcusably lost.

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