Robot Technology Utilized for the Great East Japan Earthquake and Accident at the Fukushima Daiichi Nuclear Power Plant

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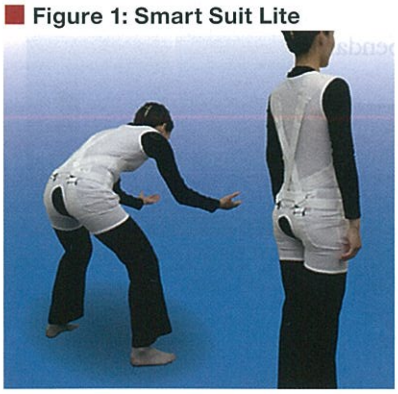
1. Introduction

On March 11, 2011, the Great East Japan Earthquake, of magnitude 9.0, and ensuing tsunami struck, causing loss of life far exceeding that of the Great Hanshin-Awaji Earthquake. Work to restore and rebuild the regions damaged by the tsunami has already begun, but even now, removal and processing of debris in the disaster-hit regions remains an issue. A large amount of contaminated material was also released by the accident at the Tokyo Electric Power Company (TEPCO) Fukushima Dai-ichi nuclear power plant, so the surrounding residents have been forced to evacuate the area for long periods of time. Decontamination of the contaminated areas is expected to consume enormous cost and time, and reports indicate that removal of the nuclear power plant itself, which caused the accident, will take 30 years or more [1].

For the Great East Japan Earthquake and nuclear power plant accident, work that was difficult for humans to do, and investigation or work in environments difficult for humans to enter required use of robots or other remotely operable devices. Various robotic technologies have already been used, but even more will be required in the future.

In this article, we introduce robotic technologies that have already been used in responding to the Great East Japan Earthquake and nuclear power plant incident, and discuss what issues need to be resolved for future disposal and rebuilding as well as in preparation for disasters and accidents that could occur in the future.

■ Figure 1: Smart Suit Lite



(Provided by Prof. Takayuki Tanaka, Hokkaido University)

2. Robotic Technology used in Responding to the Great East Japan Earthquake

Immediately after the Great East Japan Earthquake occurred, rescue robot researchers from NPO, the International Rescue System Institute, of their own accord and by request, brought robotic systems they had been developing to the disaster-hit areas and began support activity. In fact there were cases both where the robots were actually used, and where they were not used due to the severity of the environment or task.

The need for robotic technology spanned a wide range of situations, including search and rescue of victims, examining inside collapsed buildings, examination, diagnostics and repair of plants and facilities (industrial complexes, etc.), underwater investigation, recovery work, disaster area mapping, power-assist for heavy work, and victim mental-health care. For these needs, robotic technology was introduced and contributed to disaster response, including an active-scope camera, Quince, KOHGA3, Anchor Diver III, the ROV remotely operated vehicle, a two-armed hydraulic shovel robot, Smart Suit Lite (Figure 1), 3D measurement and mapping using a measurement vehicle with omnidirectional camera, and Paro (Figure 2). From overseas, the Center for Robot-Assisted Search and Rescue (CRASAR), lead by Prof. Robin R. Murphy of Texas A&M University in the USA, brought robots to the disaster site in Japan and cooperated extensively in examining the nuclear power station buildings from the air, as well as underwater examinations. Researchers and technologists engaged in development of robotic technology at universities, laboratories and in industry worked aggressively to contribute to disaster response, but there were cases when they were not necessarily able to contribute to addressing actual needs as effectively as was hoped.

■ Figure 2: "Paro" Paro Therapeutic Robot

(Provided by Dr. Takanori Shibata, AIST)

The effects of the disaster and accident are diverse, and the functionality required of robotic technology is accordingly diverse. For example, in the Great Hanshin-Awaji Earthquake, the search for disaster victims involved many fatalities due to being crushed under collapsed buildings, but in the Great East Japan Earthquake, more drowning fatalities occurred due to the tsunami. In the former, the search was conducted in the debris, while for the latter, it was more necessary to search in water. Thus, different technology is needed depending on the disaster conditions, and it is important to prepare for a variety of conditions and needs.

3. Robotic Technology used in Response to the Nuclear Power Plant Accident

For the accident at the TEPCO

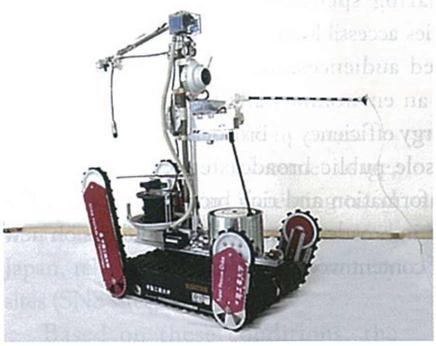
Fukushima Dai-ichi nuclear power plant, workers could not enter due to the high levels of radiation, so large amounts of remote-control technology such as robots and unmanned construction machines was brought in and continues to be used. The critical missions were to collect information and survey the accident sites, stabilize the cooling system and contain contaminants, but when these are done, equipment is being switched over to decontamination, decommissioning and dismantling the reactor. The most important objective, however, is to reduce the exposure of workers to radiation.

There have been many examples of remotely-operated devices introduced to deal with the Fukushima nuclear power station accident. Concrete-pump trucks were used to apply water (stabilizing the cooling system), unmanned equipment was used to clear debris, unmanned aerial vehicles (T-Hawk) were used for aerial surveys of the reactor buildings that exploded, and Packbots (Figure 3) and Quince (Figure 4) were used inside buildings (to obtain images for inspection and to monitor radiation, temperature, humidity, oxygen concentrations, etc.).

■ Figure 3: Examining inside reactor building with Packbots

(Provided by TEPCO)

■ Figure 4: Modified Quince



(Provided by: Prof. Eiji Koyanagi, Chiba Institute of Technology, and Prof. Satoshi Tadokoro, Tohoku University)

Contamination was monitored using a mobile robot mounted with a gamma-camera, decontamination was done with the vacuum-equipped Warrior mobile robot, and other mobile robots including Talon and Brokk contributed to clearing debris in the reactor buildings.

There will be even more difficult missions to accomplish in the future, such as removing the fuel and dismantling the reactors. Although examination inside the buildings using robots is continuing, there are still many areas such as the containment vessel and the pressure vessel that cannot be investigated. The environments are highly radioactive, making investigation more difficult. Identifying and stopping leaks in areas such as the pressure vessel, containment vessel, and suppression pool, is the extremely difficult, grand challenge; it is work that no one has ever done before, in a highly-radioactive environment that includes contaminated water. Medium and long-term measures such as removing the fuel are expected to take 30 years or more [1], and they will also require development of robotic technology. These are the unavoidable realities. To break through these difficult circumstances and solve these problems, we certainly must develop the required technology and contribute the technical achievements to society.

4. Issues with Robots used for Earthquake and Accident Response

In responding to the Great East Japan Earthquake and nuclear accident, except for the unmanned construction equipment, introduction of Japanese robotic technology did not necessarily go smoothly. This was mainly due to reasons other than problems with the robotic technology itself.

Most of the robots from the USA were robots for military use, but they were products with proven results. The US military not only supports R&D, but also procures large quantities, creating demand for the robots and enabling enterprises to enter the market as a business. This increases the sophistication of technology held by enterprise, increases innovation, strengthens industry competitiveness, and creates a flow cultivating the human resources required to develop the products. Countries in Europe have also designed a system in which it is mandatory to have robots capable of handling incidents or accidents in nuclear power plants, which has created demand for such robots in Europe. In contrast, the Japanese government has invested in research and development of robots for nuclear power plants but it, along with power companies, has denied the possibility of accidents and the need for robots to deal with them. Thus, no demand was created, and enterprises developing technology have not been able to maintain that technology. The same applies to disaster response, fire-fighting, defense and policing robots. As has happened with nuclear power robots, enterprises cannot engage in developing products if the users, which are the Japanese and local governments, do not procure and use them.

In Japan, the core strategy should be for disaster relief, safety and security rather than the military, and the nation takes a proactive lead with investment, creating demand and designing a system, so to ensure that robots and other machinery will be introduced smoothly when disasters or accidents occur, it will be important to establish the necessary operational systems and organizations.

5. Conclusion

Japan is not rich in resources and has achieved its economic development using technology and by nurturing the human resources to support that technology. However, systems built using technology are never perfect. It is very important to use technology with an awareness of both its usefulness and its limitations. On the other hand, it is also necessary to be aware of economic principles when implementing such technology in society.

The after-effects of the Great East Japan Earthquake and nuclear power plant accident were enormous. However, through them we gained valuable experience, and the ability to turn that experience into strength—to turn adversity into opportunity—is very important for the future of Japan.

References
[1] Japan Atomic Energy Commission, Tokyo Electric Power Corp., Fukushima Dai-ichi Nuclear Power Plant, Medium-to-Long-Term Measures Special Committee: "Robot Technologies Needed in Response to Accident and Disaster," (2011) (Japanese).