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Application of Robotic System for Emergency Response in NPP

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1. Introduction

Increasing energy demand and concerns over climate change make increasing use of nuclear power plant in worldwide. Even though the probability of accident is greatly reduced, safety is the highest priority issue in the nuclear energy industry.

Applying highly reliable and conservative “defense in depth” concepts with the design and construction of NPP, there are very little possibilities with which accidents are occur and radioactive materials are released to environments in NPP. But NPP have prepared with the emergency response procedures and conduct exercises for post-accident circumstance according to the procedures.

The application of robots for emergency response task for post-accident in nuclear facilities is not a new concept. Robots have been sent to recover the damaged reactor at Chernobyl where human workers could receive a lifetime dose of radiation in minutes. Based on NRC’s TMI-2 Cleanup Program, several robots were built in the 1980s to help gather information and remove debris from a reactor at the Three Mile Island nuclear power plant that partially melted down in 1979. The first robot was lowered into the basement through a hatch and human operators monitoring in a control room drove it through mud, water and debris, capturing the initial post-accident images of the reactor’s basement. It was used for several years equipped with various tools allowing it to scour surfaces, scoop samples and vacuum sludge. A second version carried a core sampler to determine the intensity and depth of the radiation that had permeated into the walls. To perform cleanup tasks, they built Workhorse that featured system redundancy and had a boom extendable to reach high places, but it was never used because it had too many complexities and to clean and fix.

While remote robotics technology has proven to remove the human from the radioactive environment, it is also difficult to make it useful because it may requires skill about remote control and obtaining remote situation awareness regardless of the actual task. The efficiency of the human-robot interaction is very important to obtain the overall goal for the emergency response in timely manner. It would be a bottle-neck to apply the robotic technology for carrying the emergency response in NPP. Simple remote operation schemes are not adequate, more intelligent autonomous operation schemes are required to enhance the effectiveness of robots for the emergency response.

This paper presents recent trends in development of robotic technologies enhancing their autonomy for the emergency response in other countries. It also provides some basic research activities for the application of robotic system for emergency response in our institute.

2. Recent trends in robotic emergency response

In 1999, the Japan’s first nuclear criticality accident occurred at a nuclear fuel conversion plant. The accident caused six people to be exposed to radiation and triggered a national research and development program for the nuclear facility disaster countermeasure system. JAERI and Hitachi developed robotic systems for supporting nuclear disaster prevention which can gather information and carry various operations for the disaster mitigation. They can pass through narrow passages and stairways and cross over gaps to approach the concerned areas in nuclear facilities by remote control. They gather the environmental information with radiation sensors, infrared cameras and CCD cameras and transmit it to make timely decisions. To carry safe and speedy remote operation for the robots, sensor based autonomous control schemes were developed. A 3D viewing system has a stereoscopic camera and a multi-view system has several cameras can enhance the cognition of human operators and enable dexterous and precise operation in real time.

In 2007, Idaho National Laboratory has built a methodology to identify, develop and prove a semi-autonomous robot solution for search and characterization tasks with a hazardous environment. Primary issues of concern included obtaining of mapping, identification of safety zones, better situation awareness and dynamic human-robot interaction. With two experiments, they showed that robot autonomy can help mitigate some of the performance differences between operators who have different levels of training and robot experience, and can improve overall performance over tele-operated system.

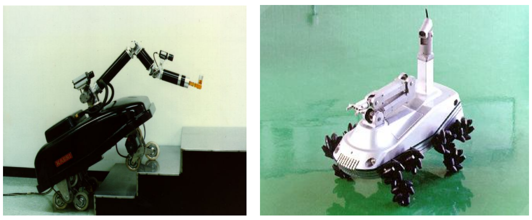
Above two research activities reveal that the first goal of application of robotic system is the information gathering and it should increase the situation awareness of human operators and possess some level of autonomy for its operation to ease the remote control action by human operators who have rare experience about the remote control.

3. Related research activities in KAERI

Fig. 1 shows several images of the internal of a containment vessel. There are stairways and narrow passages and the bottom is not even. Those complexities of the environments highly limit the application of mobile robots for such environments even during normal operation state of NPP.

Fig. 1. Internal images of a containment vessel

Fig. 2 shows two mobile robots developed for the first-aids during post-accidents. They can climb up stairs and pass through narrow spaces. But the controls of their operations are purely dependant on the skill of human operators. Even though they also have multi-view camera systems to enhance the situation awareness, such systems are not sufficient for real-time decision and control in cases when the robots are highly inclined and over uneven terrain.



(a) KAEROT-M (b) KAEROT-M1

Fig. 2. Remotely operated mobile robots

We have developed a new mobile robot with independently driven track mechanisms to obtain high mobility as shown in Fig.2. Because its width, length and height are 660mm, 800mm, 580mm respectively, it can pass through narrow region of containment building.

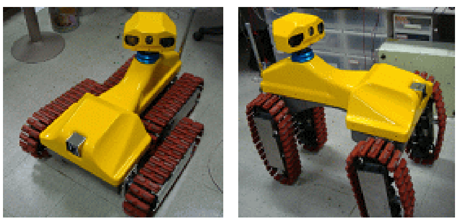
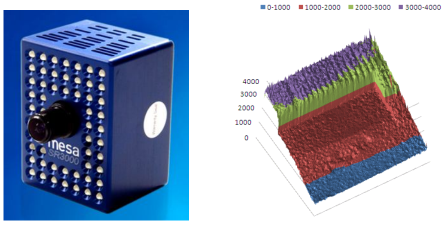


Fig. 3. KAEROT-QuadTrack

It has a stereoscopic camera system to provide 3 dimensional views for human operators and the images of an infrared camera helps detecting abnormally high temperature positions. A 3D laser scanner mounted in front of the body measures 3 dimensional distances up to 5 meters as shown in Fig.3.



(a) SR-3000 (b) 3D image

Fig. 3. 3D Laser scanner and its image

Fig.4 shows a sequence of climbing over a 400 mm vertical step obstacles. In order to control such motions, human operators should command the 8 joints revolution. We are developing a new control scheme for autonomously climbing over such obstacles.

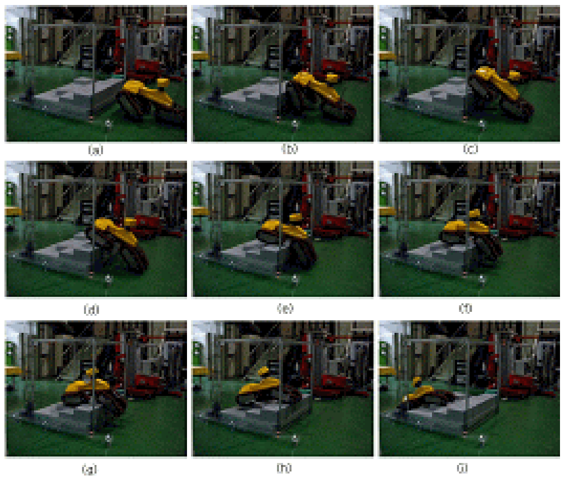


Fig. 4.Climbing sequence over a vertical step

4. Conclusions

We are developing a track-type mobile robot for the emergency response in NPP. We are developing a new control scheme for autonomously climbing over such obstacles and we convince that such autonomy improves its performance in application for the emergency response.

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