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Technical note

Development of mobile robots for rescue operations

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Keywords: Rescue; snake-like robots; walking robots; group robots; hyper-tether.

1. INTRODUCTION

This paper presents several types of robots that have been developed by the authors that can be easily deployed and actively used in rescue operations. These robots can be classified in the following types: snake-like robots, walking robots and group robots.

2. MOBILE ROBOTS OPERATING IN DISASTER SCENES

2.1. Snake-like robots

This class of mobile robot is particularly suited for reconnaissance and rescuing tasks inside the rubble of a disaster scene.

Figure 1 shows ACM-R3 [1], a mechanical snake that moves using the same creeping propulsion movement principle that governs the motion of real snakes. Due to this propulsion method and their long, slender and smooth articulated body, real snakes have the skills to enter and move inside small cracks and crevices. The same performance can be expected from mechanical snakes that inherit these physical characteristics.

Figure 2 shows Souryu-I [2], which also presents good mobility characteristics peculiar to snake robots, although it has a reduced number of degrees of freedoms (d.o.f.). In this robot the number of d.o.f. has been intentionally limited to a minimum, in order to decrease the possibilities of mechanical failure and make it more robust for practical use. This robot is composed of front, center and rear bodies, which are connected by special two-dimensional joint mechanisms that change the front and rear bodies' postures symmetrically around the center body's pitch and yaw axes. Moreover, all the six crawler segments are actuated by a single electric motor, thus totaling only 3 d.o.f. for the entire robot. This robot includes a CCD camera and a microphone in the foremost part, and is suitable for finding victims buried under the rubble of a disaster scene.

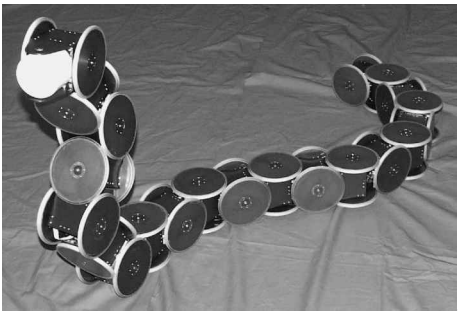

Figure 1. Snake-like robot 'ACM-R3' [1].

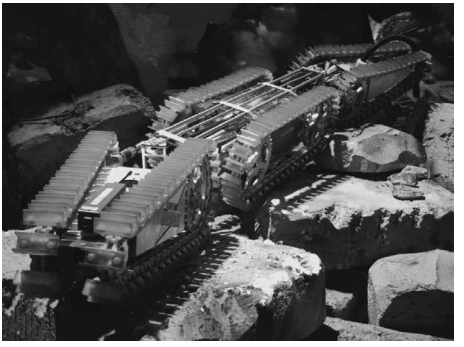

Figure 2. Connected crawler vehicle for inspection of disaster scenes 'Souryu I' [2].

Figure 3 shows Genbu [3], a fire-fighting robot. This robot has a unique and advantageous characteristic of using the fire hose's hydraulic energy as a source of energy for its actuation. Fire trucks supply water at a high pressure through the fires hoses, so that a robot properly actuated by this hydraulic energy could powerfully thrust its way through the debris inside a fire scene. In order to evaluate the mobility performance and to develop control algorithms for this type of robot, a first prototype equipped with DC motors was built. However, a new type of high torque hydraulic motor is under development to equip a practical fire-fighting robot Genbu.

2.2. Walking robots

Walking robots have the ability to freely walk around the disaster scene and are an important class of mobile robots to consider for rescuing tasks.

Figure 4 shows the quadruped walking robot TITAN VII [4] that has been developed in a joint project with a construction company. It can also walk on the ground, but its main role is to work on construction tasks on steep slopes. Such walking robots with multiple legs are especially suitable for rescue operations on uneven steep slopes and cliffs.

2.3. Group robots

It is advantageous to deploy as many robots as possible to a disaster scene, so that they can work independently and in parallel to finish the rescue operation in minimum time. However, some tasks such as removing heavy objects or overcoming high obstacles are difficult, if not impossible, to be performed by a single robot alone. In such cases, the cooperation among the robots can be an effective solution.

Figure 5 shows GUNRYU [5], a group robot that can work independently or in cooperation with each other. Each robot unit is equipped with manipulators that can be used for independent or cooperative working tasks, but also function as

Figure 3. Articulated multi-wheeled fire-fighting mobile robot 'Genbu' [3].

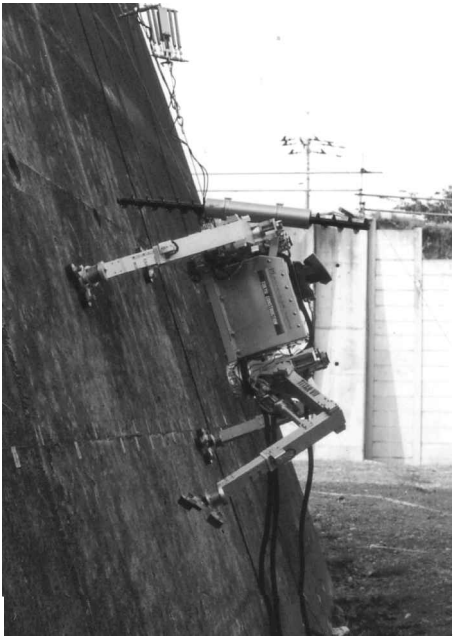

Figure 4. Quadruped walking robot for steep slopes 'TITAN VII' [4].

a connection means for connecting/disconnecting to/from the other robots in the group. Experiments demonstrate that much higher terrain adaptability and traveling performance are achieved for a group of mobile robots connected in series than compared to the performance of a single mobile robot.

2.4. Group robot using hyper-tether [6]

Mobile robots equipped with winches and tethers can also be useful in rescue operations. Hyper-tether research, in particular, explores the use of high-strength tethers with built-in electrical conductors and a tip interface that establish connection with other robots or tools. An example of an application is shown in Fig. 6 where two mobile platforms remotely manipulate a working tool suspended in the air. Moreover, the hyper-tether winch can be equipped with a launching device to throw the tether tip to distant places such as cliffs, the other bank of a river, an island or boat, or even on the upper stairs of a building, which are difficult to reach in other ways during an emergency. The anchoring tool connected in the tether tip then autonomously anchors itself to a firm place such as rocks or trees. This tether link itself works as a rescue rope, but it also helps the mobile robot to move towards the anchored point and continue the rescue operation.

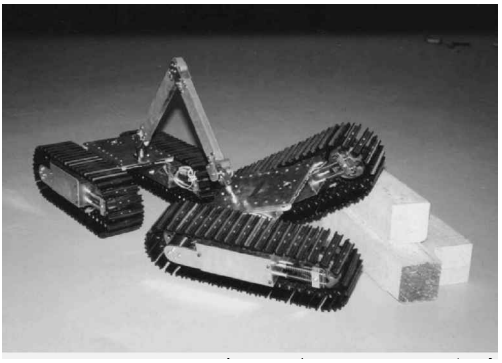

Figure 5. Cooperative robot composed of autonomous segments 'Gunryu' [5].

Figure 6. Wide field scanning task of hyper-tether [6]: versatile tether system mounted on a pair of 'HELIOS VI' robots.

3. CONCLUSIONS

This paper presented many actual robots developed by the authors that are expected to be useful in real rescue operations. Some of them have already been tested in the field and are ready for practical use, but the authors and their research group are continuously working on the improvement and development of new mechanisms and control algorithms in order to produce even more reliable and efficient rescue robots and equipment. A detailed explanation and new advancement reports concerning this research area and related technologies can be found on the authors' web page (http://www-robot.mes.titech.ac.jp).

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