Semi-Autonoumous Modular Robot for Maintenance and Inspection

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***Abstract*—In this research, we developed a modular robot by improving our previous rescue robot. The previous robot has many serially connected crawlers to realize high mobility. However, the number of the crawler units was fixed and the operator could not customize the robot for the given task. In this research, we modularized our previous robot to solve this problem. We conducted experiments and demonstrated that the proposed robot can be applied to various search tasks by changing its formation.**

Keywords-snake-like robot; rescue robot; module; passive mechanism.

I. INTRODUCTION

Maintenance and inspection of buildings are among the important tasks for robots, and these robot can be diverted to search and rescue missions when disaster occurs [1]. The serially connected robot is a possible candidate for such robots [2-5]. It can overcome dents, bumps, steps, and rubble by utilizing its many crawlers. In addition, it can enter small spaces because its shape is long and thin.

However, these types of conventional robots have problems in operation [1-3]. Usually, these robots have many actuators and complex autonomous control or manual operation is required to operate in real complex environments such as rubble. In our conventional works [4, 5], to solve this problem, we proposed a serially connected crawler robot that has passive joints. Because the passive joints adapt to rubble without operation, the proposed robot can overcome rubble easily without complex control.

Unfortunately, the number of links of this previous robot was fixed, as was the search function of the robot. Thus, the operator could not customize the robot for the given task and given environment.

In this research, to solve this problem, we developed a modular robot by improving our previous serially connected crawler robot. Experiments were conducted and we demonstrated that the proposed robot can be applied to various search tasks by changing its formation.

II. PROPOSED ROBOT

We modularized each link of the previous robot. Figure 1 shows the basic structure of a module.

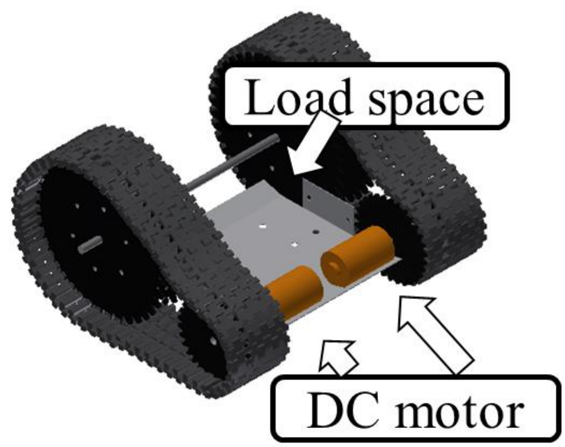


Figure 1. Basic structure.

As shown in figure 1. The basic module has a crawler on each of its two sides, and each crawler is rotated independently by its own DC motor. The basic module has load space, and we extend the function of the module by installing various devices as shown in Figure 2 and Table 1.

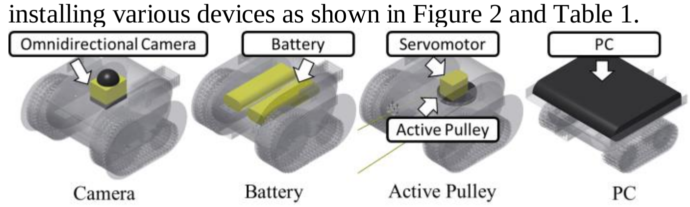


Figure 2. Various modules.

TABLE I. SPECIFICATIONS OF THE ROBOT

	Camera	Pulley	Battery	PC
Length [cm]	25	25	25	25
Height [cm]	15.5	15	15	12.5
Width [cm]	23	23	23	24.5
Weight [kg]	2.2	2.2	2.6	2.6

For example, by installing a battery, the basic module alone can be operated. It can turn to the desired direction by changing the rotating speed of the crawlers. These crawlers are operated by the user interface of a typical radio-controlled car.

By connecting various modules, some abilities of the robot can be enhanced. Figure 3 shows an example of three-module robot. Each module has a flexible link to connect another module.

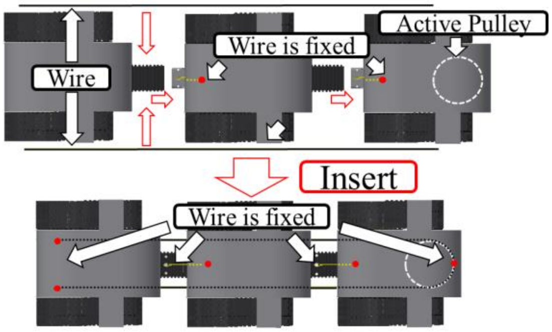


Figure 3. Muti-modules robot.

As shown in Figure 3. By connecting many modules, the mobility to overcome rubble can be enhanced. We can also install many functions on the robot. For example, by installing sensors and a PC, this robot can be controlled autonomously.

In case of many connected modules, the robot can be controlled by the mechanism proposed in [4, 5] as shown in Figure 4.

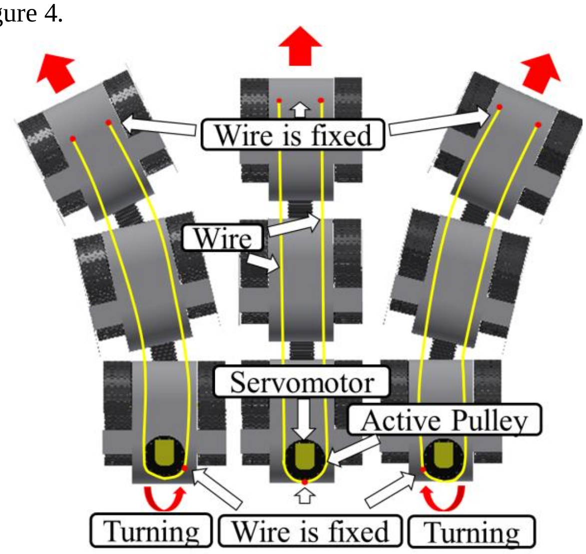
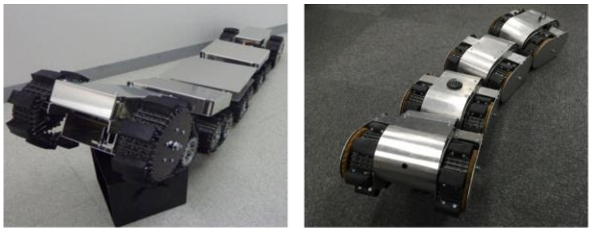


Figure 4. Turning mechanism.

We installed two wires on both sides of the robot as shown in Figure 3 and 4. These wires are pulled by an active pulley. Because all the joints are flexible, when the right (left) side of the wire is pulled, the body twists to the right (left), and the robot moves to the right (left). Because the joints move passively, the robot also adapts to complex environments and can avoid obstacles by utilizing the reactive force from contacting obstacles. Details of this mechanism are available in [4, 5].

Figure 5 shows the previous robot and proposed four-module robot.



Previous Robot Proposed Robot of four modules

Figure 5. Previous robot and Proposed robot (four modules)

As shown in Figure 5, a robot similar to the previous robot can be realized by connecting Battery module, Camera module, and Pully module.

III. EXPERIMENT

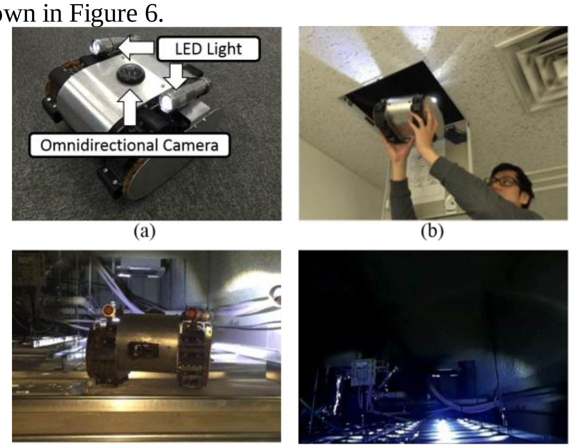
We conducted experiments to confirm its mobility. Table 2 lists best results for each configuration.

TABLE II. EXPERIMENTAL RESULTS

	One module	Two modules	Three modules	Four modules
Bump [cm]	5	15	20	25
Dent [cm]	15	20	25	25
Minimum turning radius [cm]	0	60	90	120

From Table 2, we confirmed that the small number of modules robots have higher turning abilities, and the large number of modules robots have higher mobility to overcome bump and dent.

Next, we conducted experiments to confirm performance of the proposed module mechanism. First, we applied a one-module robot to the task of inspection in a ceiling space as shown in Figure 6.



(a) (b)

(c) (d)

Figure 6. Inspection in a ceiling space : (a) One-module robot (b) Entrance of the celing space (c) Imagine from the entrance (d) image from the onborad camera

The module has two LED lights and one wireless omnidirectional camera. By exploiting its small size, the robot could enter the ceiling space.

Secondly, we applied four-modules robot to stairs with rubbles in order to confirm its mobility. Figure 7 shows experimental result.

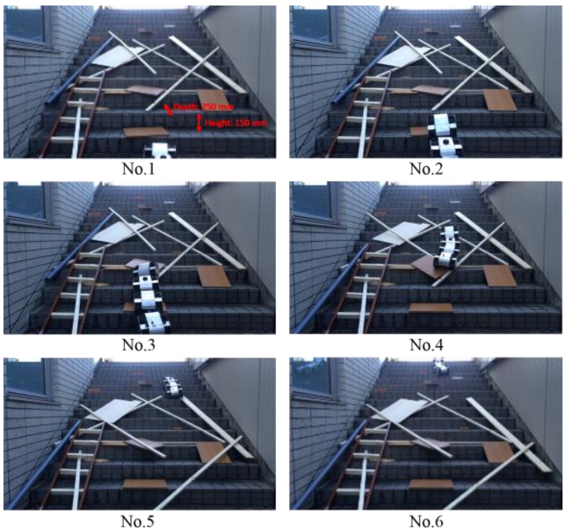


Figure 7. Experiment result of stairs

We can confirm that the robot has high mobility. In addition, as the flexible joints moves passively to adopt environment, operator did not have to control each joint. It means that proposed robot can be operated very easily and has high mobility.

Thirdly, we applied a four-modules autonomous robot to a rubble environment in order to confirm its autnomyy. This robot has a camera and a PC, and it chases a red target. Figure 8 shows the experimental result.

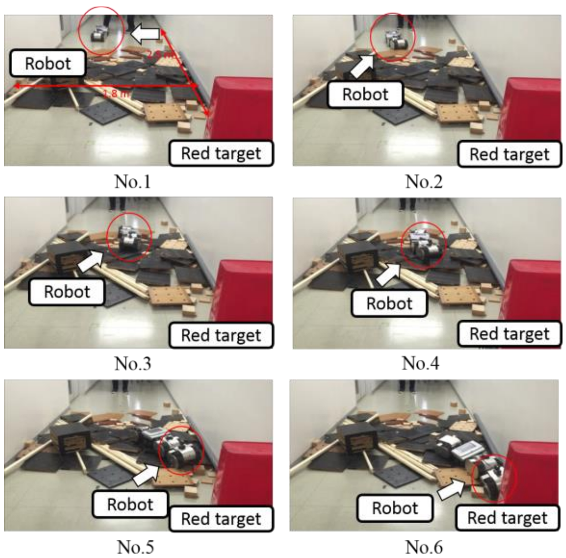


Figure 8. Experimental result of rubble

We confirmed that the robot can chase the red target autonoumously with overcoming the rubbles.

IV. CONCLUSION

In this research, we developed a modular robot by improving our previous serially connected crawler robot. With the proposed mechanism, the operator can customize the robot for a given task and given environment. Thus, the applicable tasks are drastically widened compared with the previous robot.

To demonstrate the effectiveness of the proposed robot, a prototype robot was developed. The results of experiments confirmed the advantages of both a small robot and a long-shaped robot can be realized by changing its formation.

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REFERENCES

[1] R. R. Murphy et al., “Search and rescue robotics,” in Springer Handbook of Robotics, B. Sciliannopp et al., Eds. 1151–1173, 2008.

[2] L. Shao, **B.** Guo, Y. Wang, “An overview on theory and implementation of snake-like robots,” IEEE International Conference on Mechatronics and Automation (ICMA 2015), Aug. 2015, pp. 70-75, ISSN: 2152-7431

[3] S. Murata, H. Kurosawa, “Self-Reconfigurable Robot,” IEEE Robotics & Automation Magazine Vol. 14 , Dec. 2007, pp. 71-78, ISSN: 1070-9932

[4] K. Ito and H. Maruyama, “Semi-autonomous serially connected multi-crawler robot for search and rescue,” [Online]. Available from: http:/www.trandfonline.com/doi/pdf/10.1080/01691864.2015.1122553/2016.01.08

[5] M. Mizutani, H. Maruyama, and K. Ito, “Development of autonomous snake-like robot for use in rubble,” Proc. IEEE Int. Conf. Safety, Security, and Rescue Robotics, IEEE Press, Nov. 2012, pp. 1-7, doi: 10.1109/SSRR.2012.652388

[6] Y. Yokokohji, “Interface design for rescue robot operation-introduction of research outcomes from the human-interface group of the DDT project,” J. Robot. Soc. Japan, vol. 22, no. 5, 2004, pp. 566–569. 2012, pp. 1–7, 2012.