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Design of Scout Robot as a robotic module for symbiotic multi-robot organisms

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Abstract:
Self-reconfigurable modular robots have been studied worldwide mainly for autonomous exploration in unstructured environments. In previous studies, robotic modules were designed to be functional only as a part of an assembled structure, and thus the exploration capability was limited. Symbiotic multi-robot organisms have been newly proposed to design robotic modules as large-scale swarms of robots that can physically dock with each other and symbiotically share energy and computational resources within a single "artificial-life-form". In this paper, a novel robotic module named Scout Robot, which is one of the three robotic platforms designed for the multi-robot organisms, is presented. The Scout robot is an autonomous miniature robot and equipped with many onboard sensors and a locomotion capability. It can move autonomously on rough terrains to explore the surroundings and interact with the other robots. The Scout robot is also equipped with 2 DoFs of actuation and shares the same docking design with the other robotic platforms, and thus can be a part of an assembled organism. In the experiments, the image-guided locomotion of a Scout robot and the multimodal locomotion of assembled robots were demonstrated.

1. INTRODUCTION

Self-reconfigurable modular robots have been studied worldwide mainly for autonomous exploration in unstructured environments, including applications for surveillance [1], rescue [2] and space [3]. In previous studies, robotic modules were designed to be functional only as a part of an assembled structure, and a single module didn't have its own function or role, which resulted in the limited exploration capability of the robotic systems. Symbiotic multi-robot organisms have been newly proposed in the framework of the Replicator project to design robotic modules as large-scale swarms of robots that can physically dock with each other and symbiotically share energy and computational resources within a single "artificial-life-form" [4]. In this paper, a novel robotic module named Scout Robot, which is one of the three robotic platforms designed for the multi-robot organisms (Fig. 1), is presented.

The Scout robot is equipped with many onboard sensors including laser-camera sensors for measuring distances and relative angles to surrounding objects. It has a locomotion capability using a caterpillar mechanism. The module is independent from the robotic system and can move autonomously to explore the surroundings and interact with the other robots (Fig. 2). The Scout robot shares the same docking design with the other robotic platforms and is also equipped with 2 DoFs of actuation for the reconfiguration of assembled structures. In this paper, five prototypes of the Scout robot modules were fabricated, and the laser-camera-sensor guided locomotion of a single module and the multimodal locomotion of assembled robots were demonstrated.

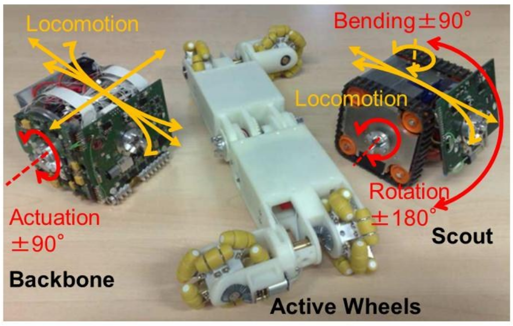

Fig.1. Three robotic platforms for multi-robot organisms (Backbone robot module, Active Wheels robot module, and Scout robot module).

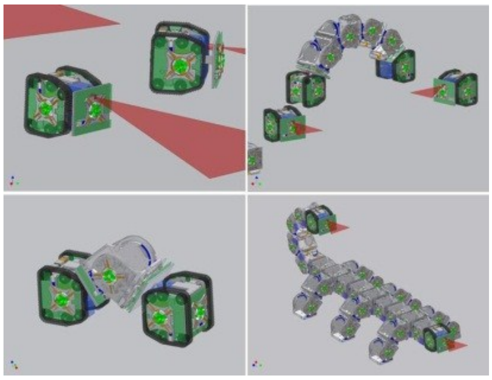

Fig.2. Scout Robots in the symbiotic robotic system

2. DESIGN OF THE SCOUT ROBOT

The Scout robot was designed as a fully-sensorized autonomous miniaturized robot as well as a module of the

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self-reconfigurable modular robotic system. The Scout robot has a quasi-cubic shape measuring 105 mm × 105 mm × 123.5 mm (Fig. 3). The chassis is composed of thin walls of 3 mm or 4 mm thick, which facilitates easy mass production. It has a locomotion capability using a caterpillar mechanism and is also equipped with 2-DoF actuation, namely lifting of the Rear wall and rotation of the Right docking unit, for reconfiguration after docking (Fig.4). The Scout robot was designed so that custom-made PCBs can be placed on each wall (as shown in green in Fig. 3). The PCBs accommodate many sensors [5] and are connected to each other and onboard electronic components. Among dozens of sensors mounted on the Scout robot, a triangulation-based laser-camera sensor composed of a laser-line generator and a miniaturized camera was investigated (Fig.5). We decided to implement two sets of laser-camera sensing units: On the Front wall, a camera is placed above a laser which is inclined upwards by 7 degrees, while a laser is inclined downwards by 7 degrees and placed above a camera on the Rear wall(Fig.6). The sensor configuration of the Front wall is good for far-range sensing and the detection of relatively high objects. On the other hand, the configuration of the Rear wall is good for short-range sensing and the detection of holes and small objects. As the robot can move both forward and backward and even in the upside down configuration thanks to the symmetric design, the robot can chose the sensor to use depending on the surrounding environment.

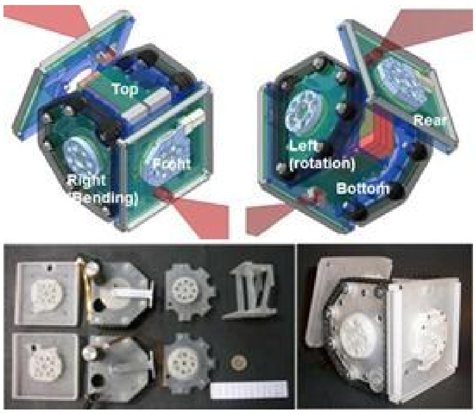

Fig.3. Design and fabrication of Scout Robot.

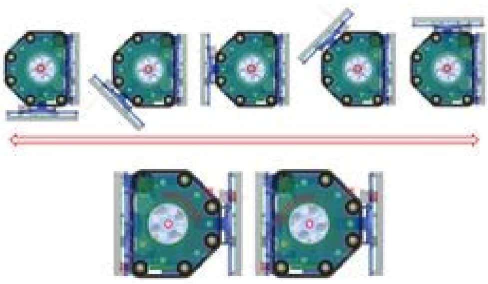
Fig.4. 2-DoF actuation of Scout Robot.

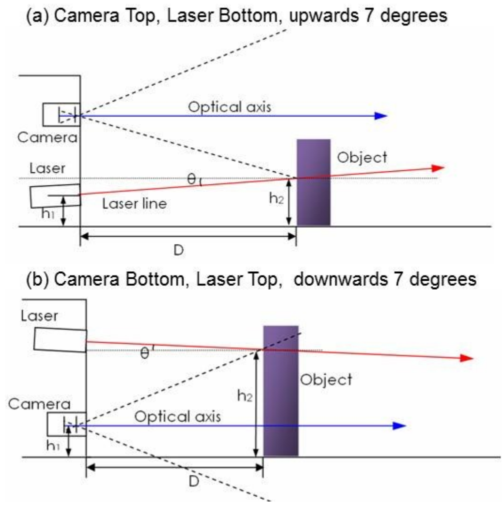

Fig.5. Laser-camera sensor configurations

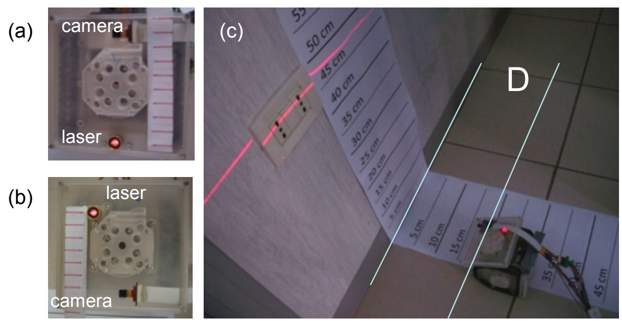

Fig.6. Implementation of laser-camera sensors: (a) Front wall, (b) Rear wall, (c) actuation of Rear wall.

3. EXPERIMENTAL RESULTS

2.1 Laser-camera sensors

Fig.7 shows captured images from the camera on the Front wall and the camera on the Rear wall when the robot was placed at 20 cm and 40 cm from the wall. The laser-camera sensor configuration implemented to the Front wall showed a good performance on far-range scanning as well detection of high objects. On the other hand, the configuration implemented to the Rear wall demonstrated the good detection of small objects or obstacles (e.g. holes) located close to the robot. High objects can be observed using the same sensor configuration by actuating the Rear wall as shown in Fig.7 (b-2). Owing to the symmetric design, this feature is effective even when the module is placed upside down. This highly symmetric design both of the robotic chassis and of component implementation is very advantageous for the self-reconfigurable modular robot.

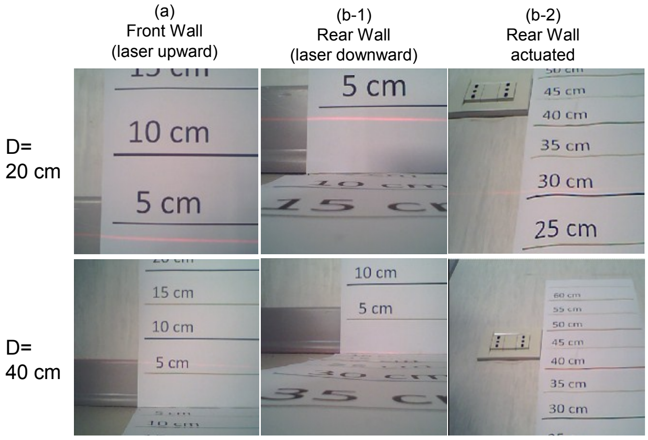

Fig.7: Captured images from the mounted cameras

2.2 Locomotion and actuation

The basic mechanical function of the Scout robot was validated by using a tethered control (Fig.8). The Scout robot can move at a speed of 105 mm/s, and is able to climb a slope of more than 40° inclination. Using the laser-camera sensors, the Scout robot can align itself to a wall with the predefined relative angle and distance. The actuation torque of 4 Nm was sufficient, and quadruped locomotion and inchworm locomotion were demonstrated.

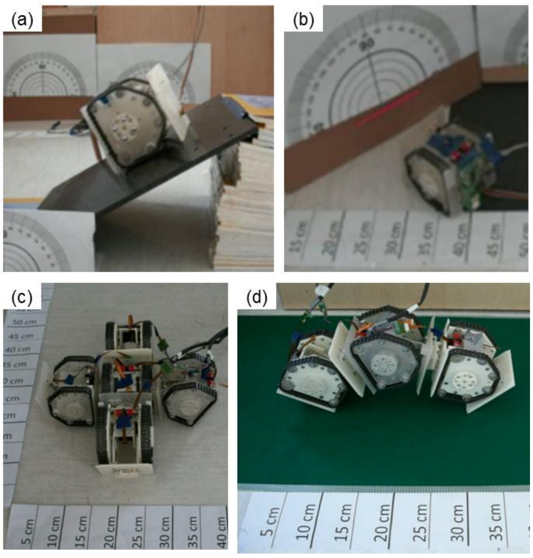

Fig.8: Experiments (a) locomotion on a slope, (b) sensor-guided locomotion, (c) Quadruped locomotion, (d) Inchworm locomotion.

4. Conclusion

We have developed a robotic module capable of automomous locomotion for exploration, and it can be a part of a self-reconfigurable modular robot as well. Basic mechanical performance was validated using prototypes. Future work includes implementation of electronic components and tetherless control of several Scout robots.

ACKNOWLEDGEMENTS

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