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Underwater Robot Development for Manipulation Task and their Uses in Biwa Lake

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Abstract: In this paper, three different types of underwater robots for manipulation tasks are described. To improve the manipulation task performance of these robots, movable floating blocks were developed. The basic abilities of these robots were investigated in a test tank and Biwa Lake, the largest lake in Japan. Furthermore, we present the actual manipulation tasks performed by these underwater robots.

Keywords: underwater dual arm robot, gripper robot, core soil sampling robot

1. INTRODUCTION

Underwater manipulation tasks are highly required for ocean development, freshwater preservation, rescue activities, and maintenance of infrastructures such as dams because these tasks are too severe for divers.

We have been developing several underwater robots for manipulation tasks. This paper presents three types of the developed robots. Mainly, we focus on the use of these underwater robots in Biwa Lake, the largest lake in Japan. An urgent and crucial issue at Biwa Lake is to keep its water clean and drinkable. For this purpose, scientists engaged at Biwa Lake have been requesting us to develop underwater robots capable of lifting up objects or soil from the lake bottom. As of now, we have developed three types of underwater robots. The first robot has a dual-arm system controlled by an operator. To stabilize the robot body, movable floating blocks were developed; consequently, dexterous underwater tasks could be performed. The second robot is a gripper-type underwater robot with a newly designed controller using only one operator hand. The movable floating block system was used to widely change the pitch angle of the gripper. The third robot is specialized for soil core sampling from sea and lake beds. Initially, a core sampling robot that had to be released from a boat was developed. Subsequently, movable floating blocks were added to the robot in order to reduce the vertical height so that the robot could be released from shallow regions such as the lakeside of Lake Biwa. All three robots were tested in Biwa Lake. Motion performance during underwater manipulation tasks was demonstrated using experimental results.

2. DUAL-ARM ROBOT SYSTEM

2.1 Dual arm robot

We developed a remotely operated vehicle (ROV) having a dual-manipulator system and an attitude control system as shown in Fig.1 [1][2]. The robot weighs 56 [kg] (in air) and is 1.4 [m] long, 0.7 [m] wide, and 0.6 [m] tall when the manipulators are located in front of the vehicle. Six 80 [W] thrusters generate the propulsion for the ROV. This ROV has two manipulators and each manipulator weighs 5.5 [kg] in air and 3.6 [kg] in water. Each manipulator has four rotational joints (4 degrees of freedom (DOF)) and 1 DOF gripper hand. Harmonic drive motors inside waterproof cylindrical links actuate these joints and the grippers. The motor shaft is sealed with O-rings. Each motor has a gear head and an optical encoder for positioning the angle. The maximum velocity of the end-effector is about 1.0 [m/s].

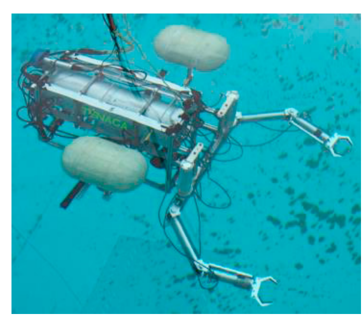

Fig. 1. Dual arm robot with movable floating block system

2.2 Movable floating block system

Since more than 20 percent of the total weight is attributable to the manipulators, it is difficult to keep the same attitude of the ROV when the arms move. To overcome this difficulty, we have developed an attitude control system. This system changes the center of buoyancy with respect to the center of gravity. The proposed system is called BG (buoyancy-gravity) system in this paper. Changing the center of buoyancy is accomplished by changing the position of the movable floating blocks. The BG system is depicted in Fig. 2. The float blocks are driven by the harmonic drive motor (30[W], gear ratio 100:1) through a reduction gearbox (40:1). The angular velocity of the float blocks is about 3[deg/s]. The performance of the BG system is shown in Fig.3. The motion needed from the top to the bottom is 8[sec].

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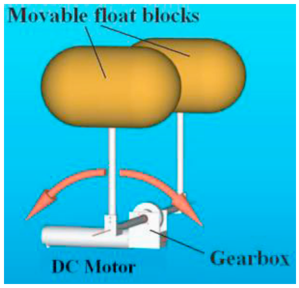

Fig. 2. Movable Floating Block System

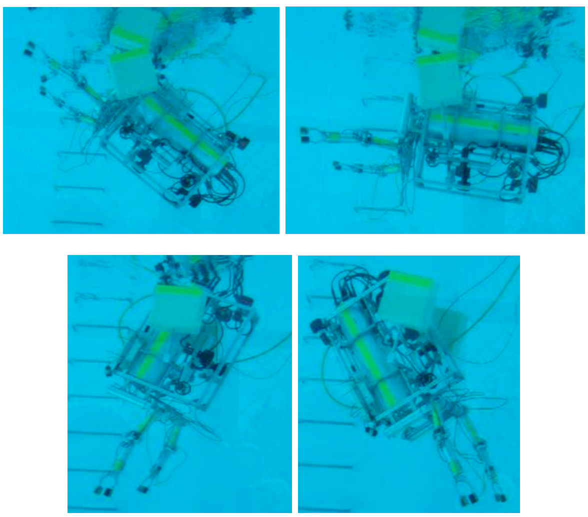

Fig. 3. Experimental result of BG system in test tank

2.3 Leader- follower type control device

This ROV has 17 actuators in total (6 thrusters, 8 manipulator's joints, 2 grippers and 1 attitude control). It is generally difficult for an operator to control an underwater robot with dual arms.

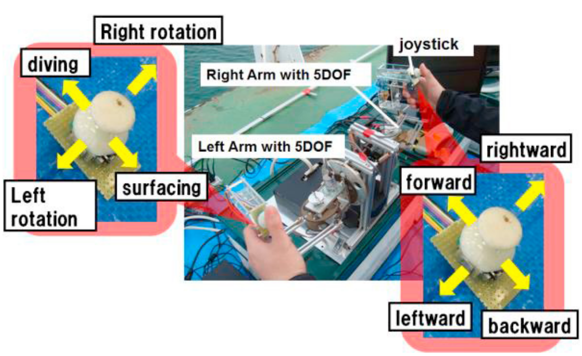

Fig. 4. Leader-follower type control device

To overcome this problem, we developed a new unilateral leader-follower type controller system for our ROV. The system comprises a leader-follower type controller, a monitor, and a PC. The developed controller has a multi DOF manipulator-like structure because an operator can intuitively control the multi-DOF manipulators. The details are presented in [3]. This controller has 10 DOF that is equal to the total number of DOF of the manipulators. Two small joysticks are mounted on each tip of the leader arms to control the vehicle motion as shown in Fig. 4. Each joystick has a push button to control the pitch angle of the ROV (the BG system). The entire controller system is compact size and is designed for set up and use in small boats.

2.4 Field work

A field trial in the Takeshima island area of Lake Biwa was conducted in 2010 to test the capabilities of the developed ROV. The ROV was launched from a small boat *YURICAMOME* (Biwako Kisen Steamship Co., Ltd.) as shown in Fig. 5. An operator controlled the ROV in the boat while observing a computer monitor as shown in Fig.6. Fig.7 demonstrates an experimental result where the dual arm robot lifted up an old tire.

Fig. 5. Experiment in Biwa Lake

Fig. 6. Controller in boat

Fig.7 Experimental result (Lifting up an old tire in Lake Biwa)

3. Gripper-type Robot System

3.1 Gripper-type robot

The developed gripper-type robot is shown in Fig.8. The robot is a human-portable ROV that weighs approximately 31 kg in air. This robot can grasp cylindrical objects and handle them in 6 DOF. To expand the pitch angle motion range, a