Development of a Handy Autonomous Underwater Vehicle “Kyubic”

Toshimune Matsumura
Dept. of Human Intelligent System, Kyushu Institute of Technology
2-4 Hibikino, Wakamatsu, Kitakyushu, Fukuoka 808-0196, Japan
E-mail: matsumura.toshimune399@mail.kyutech.jp

Yuichiro Uemura
Dept. of Human Intelligent System, Kyushu Institute of Technology
2-4 Hibikino, Wakamatsu, Kitakyushu, Fukuoka 808-0196, Japan

Kentaro Yanagise
Dept. of Human Intelligent System, Kyushu Institute of Technology
2-4 Hibikino, Wakamatsu, Kitakyushu, Fukuoka 808-0196, Japan

Yoshiki Tanaka
Graduate School of Life Science Systems Engineering, Kyushu Institute of Technology
2-4 Hibikino, Wakamatsu, Kitakyushu, Fukuoka 808-0196, Japan

Yuya Nishida
Kyushu Institute of Technology, 2-4 Hibikino, Wakamatsu, Kitakyushu, Fukuoka 808-0196, Japan

Kazuo Ishii
Kyushu Institute of Technology, 2-4 Hibikino, Wakamatsu, Kitakyushu, Fukuoka 808-0196, Japan

Abstract

Ocean is one of big challenging and extreme environments, and hard for human to access directly. As the tool for ocean survey, Autonomous Underwater Vehicles: AUVs are expected and developed from ‘80s. The recent rapid progress of computer and information technologies makes the development of AUVs easier and more practical. We had developed a handy AUV “Kyubic” for the observation of shallow water and artificial structures. In this paper, we describe the system architecture of Kyubic and the experimental results in Underwater Robotics Competition in Okinawa 2020.

Keywords: Autonomous Underwater Vehicle, System design, Robot competition.

1. Introduction

The ocean is one of the most difficult environments for humans to access directly. Autonomous Underwater Vehicle (AUV) are expected to be a tool for marine research [1]. Currently, there is a growing need for underwater robots for surveys and work in shallow water, as well as for surveys and work on artificial structures such as coastal areas, dams, and bridge piers. However, AUV used for marine research require a large support vessel equipped with a crane, which makes it difficult for a few people to operate. In addition, works at shallow water are still often performed by divers or small Remotely Operated Vehicles (ROV). Working at a depth of several tens of meters is a heavy workload for divers. In addition, ROV are limited by their tethers. Therefore, there is a need for a compact and lightweight AUV that can be operated by a few people. Since it is easy to develop a small and lightweight AUV, underwater robot competitions are being held with the aim of activating research and education in the underwater field. In particular, since the Underwater Robotics Competition in Okinawa is a competition held in the actual sea area, it is required to operate an AUV suitable for the actual

© The 2021 International Conference on Artificial Life and Robotics (ICAROB2021), January 21 to 24, 2021

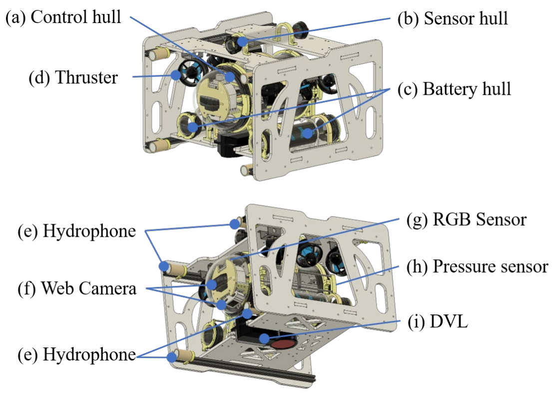

Fig.1 The 3D design of Kyubic

Table 1 Specifications of Kyubic

Structures	Acrylic Pressure Hulls × 4 H : 400[mm] W : 550[mm] L : 570 [mm] Weight : 32 [kg] 15[m] depth pressure resistant
Actuators	Thrusters (Blue Robotics T200) × 6
Batteries	Li-ion 14.8[V], 18 [Ah] ×2
Computer system	PC：NUC 817BEH CPU：Intel Core i7-8559U RAM：32 [GB] SSD：2 [TB]
Communications	Ethernet Wireless LAN Optical LAN
Sensors	USB Camera × 2 IMU(CSM-MG100) DVL(Pathfinder) Hydrophone (SPU0414HR5H-SB) ×4
Software	MATLAB & SIMULINK ROS

environment. The paper explains the configuration of the newly developed AUV "Kyubic" as one of the small underwater robots and reports on its operation in Underwater Robotics Competition in Okinawa 2020.

2. The hovering type AUV Kyubic

2.1. *Kyubic specifications*

In our laboratory have developed "AquaBox" and "DaryaBird" as small and light AUV systems [2][3]. The AUV "Kyubic" aims to be smaller and lighter than conventional robots, and its development concept is as follows.

(i) Small size and lightweight, enabling operation by a few people
(ii) Boxed structure with additional options depending on the mission

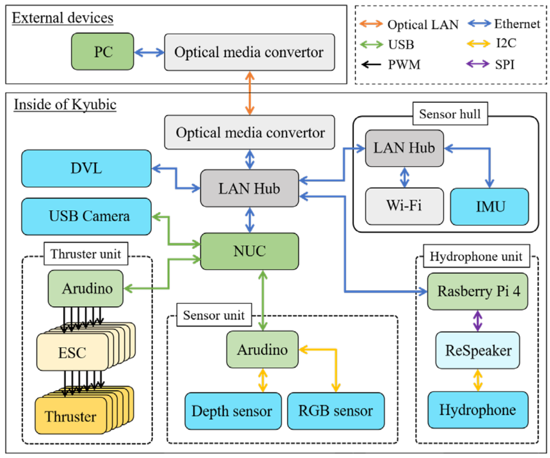

Fig.2 System architecture of Kyubic

(iii) Modular structure for easy maintenance
(iv) AUV and ROV modes can be selected depending on the mission

Table 1 shows the specifications of the AUV "Kyubic". The AUV has a boxed structure and is compact and lightweight.

2.2. *Hardware*

Fig. 1 shows the layout of Kyubic. The AUV is framed of four pressure vessels. The power circuit, motor driver, microcomputer, and control PC are installed in an 8 inch pressure vessel (a). Wi-Fi and IMU are installed in the 2 inch pressure vessel (b). The control and drive batteries are installed in a 3 inch pressure vessel (c). In addition, this AUV is installed with six thrusters (d), four hydrophones (e), two Web cameras (f), an RGB sensor (g), a pressure sensor (h), and a DVL (i). Fig. 2 shows the system architecture of Kyubic. This AUV is intended to be a versatile testbed and software development. For this purpose, a small computer NUC with high processing capacity is installed in a pressure vessel. The AUV uses information from sensors such as the DVL, IMU, and pressure sensors to control the autonomous mode. The depth sensor, RGB sensor, and ESC are controlled by Arduino, and the hydrophone is controlled by Rasberry Pi4. These systems are modularized, and modules can be easily added or removed. In the previous DaryaBird, it was not possible to turn off the power of the sensor by itself. Therefore, it was necessary to turn off all the systems when a problem occurred. To solve this problem, Kyubic has a system configuration that allows the power supply of the sensor to be controlled by itself. In addition, DaryaBird control with control PC directly the motor driver. Therefore, the user could not control the robot if the control PC system terminated improperly. On the other hand, Kyubic has an Arudino between the control PC and the motor driver. Therefore, when the command value from the control PC is not received for a certain period of time, the power supply of the motor is stopped. The thruster control unit is modularized, and the modules can be easily used individually or installed on a robot, resulting in a highly versatile system configuration. The same applies to the sensor unit and hydrophone unit.

2.3. *Software*

Kyubic's control system uses Mathworks' MATLAB / Simulink and ROS control methods [4]. In particular, the Robotics System Toolbox supports ROS, which enables highly functional and fast development using MATLAB and ROS programs. The Parallel Computing Toolbox is a script-based and Simulink model-based program which can build multiprocess and parallel computations. Stateflow is a tool for computing state transition control methods. Fig. 3 shows a architecture of the software. Simulink is divided into 1-5 models (Sim1-Sim5), each of which exchanges data through a ROS network. Sim1A gets the attitude data of the AUV from IMU and the positioning data from GNSS. Sim1B gets the ground speed from the DVL and the depth data from the depth sensor. Sim2 handles the PID control of the thrusters, and Sim3 handles the image processing. Sim4 records data and does action strategies. Stateflow is used for the action strategy, making it easy to visually understand the values and transitions of the process being executed. Kyubic uses positional control to perform waypoint tracking. Waypoint tracking is a method in which a specific position on a defined path is specified and the robot moves to pass through that position. For the path, the CSV data includes the waypoint number, target position (x, y, z), target attitude of the AUV (roll, pitch, yaw), arrival judgment threshold, timeout, and mission number. Hence, load the CSV as external data. The previous DaryaBird needed to write the target value directly to stateflow. However, Kyubic only updates the csv data and does not need to change the stateflow. In addition, this AUV can control the operation values of Sim4 by GUI. Fig.4 shows the

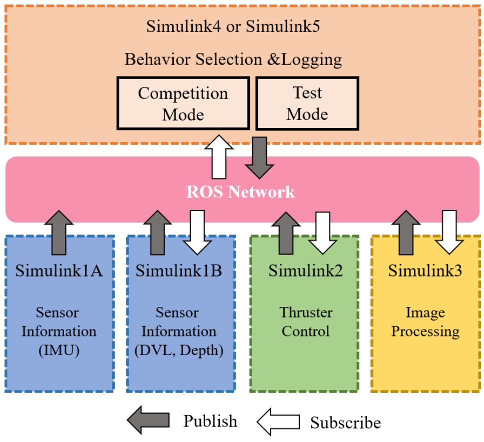

Fig.3 Software architecture of Kyubic

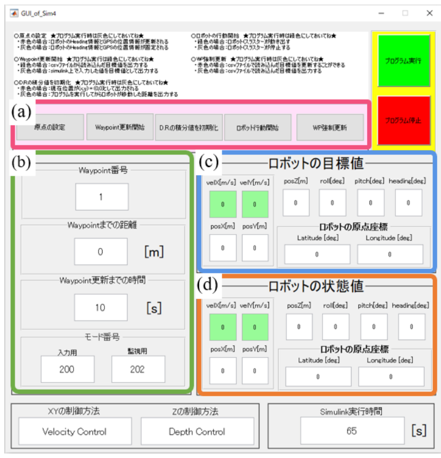

Fig.4 Sim4 operation GUI

GUI of Kyubic. (a) in the GUI is an item that the user inputs before the robot starts its action, such as the origin setting and the command to start the robot's action. (b) shows the set waypoint number, distance to the waypoint, and mode number. (c) shows the target value of the robot, and (d) shows the state value of the robot. This GUI can be used to avoid human errors during robot operation and to monitor the robot status for efficient operation.

3. Sea trial in shallow water

3.1. *Underwater Robotics Competition in Okinawa*

Kyubic was operated at the Underwater Robotics Competition in Okinawa , and the results are described. The Underwater Robotics Competition in Okinawa is the only competition in Japan that is held in actual marine

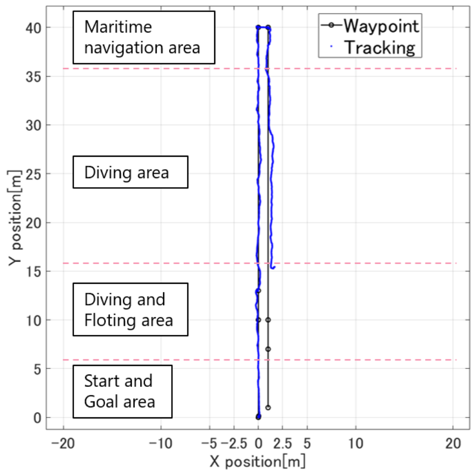

Fig.5 Waypoint and Tracking

environments. The rule of the AUV department is that it navigates there and back in a straight line of about 40 meters in shallow water in five minutes. In the middle section, there is a diving area, and the AUV needs to dive and navigate 20 meters. For details of the rules, please refer to [5].

3.2. *Navigation results of the competition*

Kyubic navigated in the surge direction throughout the entire area. This AUV dived to a target depth of 0.5 m in the diving area and turned for the turnaround in the maritime navigation area. At the turnaround point, the AUV navigated 1[m] in the x direction to prevent the AUV from involving the safety rope. Fig.5 shows the waypoints and the trajectory of Kyubic. In this competition, Kyubic was able to navigate to the turnaround dive area in five minutes. For the trajectory, this AUV achieved path following with a maximum error of 1.5 [m] in the y direction. The cause of the error in the trajectory is considered to effect of tidal currents and cumulative error due to dead reckoning. Fig. 6 shows the control performance of velocity of surge direction, depth, and heading. The graph of the velocity in the surge direction show an estimated value of about 0.2 [m/s] against the target velocity of 0.6 [m/s]. It is assumed that this result was due to inadequate adjustment of PID and inferior to control performance. In the depth direction, the tracking is slow and overshoots the target value, show that convergence is taking time. It is assumed that the PID was not adjusted sufficiently for depth. In the heading, there is a slight overshoot, however, it is generally in correspond with the target value.

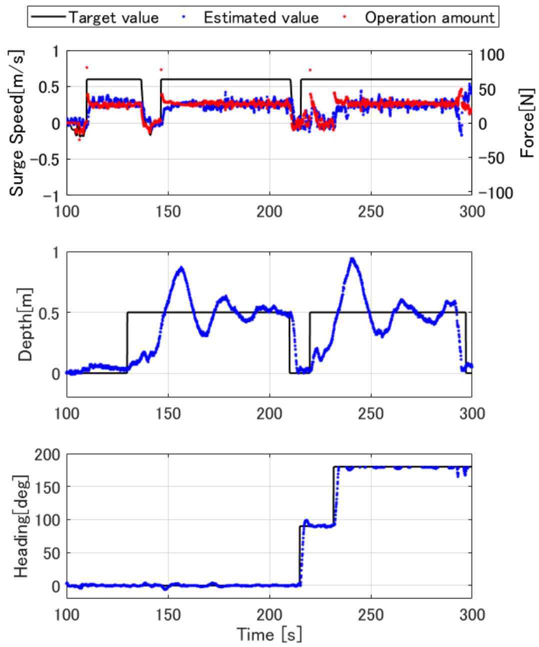

Fig.6 Target value and Estimated value

4. Conclusion

We developed a small underwater robot system "Kyubic" for observation in shallow water. In addition, we were able to confirm its basic performance in a competition in shallow water. In the future, we will improve the control performance and implement acoustic communication and image processing using Kyubic.

References

1. Yuya Nishida, et al., Underwater Platform for Intelligent Robotics and Its Application into Two Visual Tracking Systems, Journal of Robotics and Mechatronics, Vol.30, No.2, pp. 238-247, 2018.
2. Satomi Ohata, et al., Small Underwater Robot Systems "AquaBox" for Shallow Water Observation, The Japan Society of Naval Architects and Ocean Engineers, Vol.4, pp.513-516, 2007.
3. Wataru Hori, et al., An AUV Platform for Robot Behavior Development: Twin-Robot "DaryaBird" and "OCTA", and Their' Mission Strategy, AUV&ONR's 17th Annual RoboSub Competition Journal Paper, 2014.
4. Takashi Sonoda, et al., System Development of AUV's Sampling Device Controller Employing MATLAB/Simulink Toolboxes, ICAROB, 2019.
5. Underwater Robotics Competition in Okinawa, http://www.robo-underwater.jp/2020/rchp/JPN/index.php , (2020.12.25).

© The 2021 International Conference on Artificial Life and Robotics (ICAROB2021), January 21 to 24, 2021