Design and competition strategy of KYUBIC for RoboSub 2022

Daiki Hamada, IRMIYA Inniyaka Reuben, Yusuke Mizoguchi, Riku Fukuda, Kaito Kuwata, Yoshiki Tanaka, SOLPICO Dominic Bautista, Rikuto Tanaka, Kazuki Harada, Akihiro sugino, Yusuke Yamamoto, Kota Mishima, Keisuke Nishimuta, Hiroaki Umezawa, Masahiro Nakamura, Shun Fukushima, Jiro Fukuda, Yuta Matsuoka, Ryo Miyakawa, Huang Bingqi, Yufuko Takahara, Kazuo Ishii, Shinsuke Yasukawa, Yuya Nishida

Graduate School of Life Science and Systems Engineering, Kyushu Institute of Technology
E-mail: kyutech.robosub@gmail.com

I. ABSTRACT

Kyutech Underwater Robotics is a student project team of Kyushu institute of technology (Kyutech). KYUBIC is a autonomous underwater vehicle (AUV) developed 2 years ago. For RoboSub2022, we developped hardware, cap and electrial circuit modification for payload and new dropper module. JETSON nano is installed for image recognition. About software, new system is installed based on ROS. In the experiment, we performed waypoint navigation, the most important navigation system for AUVs, and confirmed that position control was implemented.

Keywords—

Underwater robot, software development, Image processing, Waypoint tracking, ROS

II. COMPETITION STRATEGY

Kyutech Underwater Robotics is one of Kyutech's student project that aims to develop engineers with the task-solving, technical, and communication skills required by society. All team members are 18 students, 1 advisor and 1 staff, we had developed AUV "Darya bird" and "Yajiro Bay". In RoboSub 2022, new AUV "KYUBIC" developed 2 years ago will try competition.

KYUBIC has waypoint navigation, image processing system as buoy detection and path detection, and acoustic search system using hydrophone. Software for systems were developed by MATLAB/Simulink and ROS on Windows. By using current system, KYUBIC can try Coin Flip, Gate, Path and Buoys. About searching pingers, KYUBIC can't try from the viewpoint of sampling frequency. Current system's sampling frequency is 96 kHz for 4 channels but pingers frequency is 25-40 kHz, so current

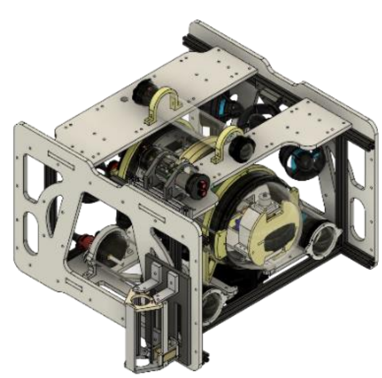


Fig. 1 AUV "KYUBIC"

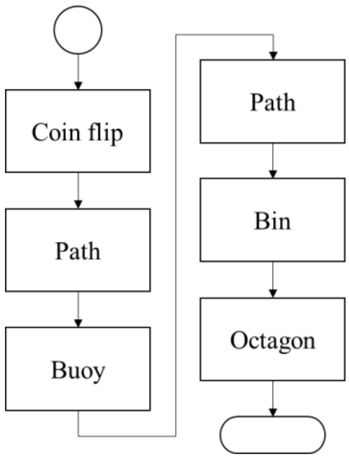


Fig. 2 Mission strategy

system can hear pingers but can't distinguish them. About Bins and Torpedoes, modules for Darya Bird and Yajiro Bay had developed, so KYUBIC can try by improved modules for KYUBIC. By time schedule, dropper module for Bin mission was developed.

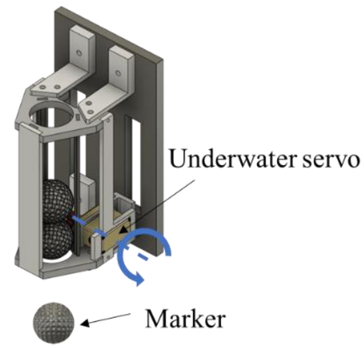
Based on the above, the mission strategy for this competition follows the procedure shown in the flowchart. All tasks are processed based on combining image processing and waypoint navigation. For bin, KYUBIC use developed dropper module.

Ⅲ.VEHICLE DESIGN

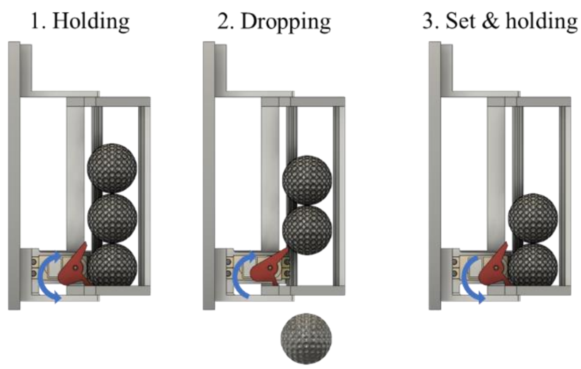
Image processing is most important function for our strategy. So, JETSON nano is installed for image recognition and reviewed the entire system and rebuilt the program operating environment.

A. Hardware

KYUBIC has six thrusters, pressure vessels, dropper actuator, and DVL (Doppler Velocity Log) and is used high density polyethylene board which specific density of 1.0 and aluminum frame for main frame. 3D model of KYUBIC is made by Fusion360 which can administrate CAD version by cloud. Thrusters are for four degree of freedom control, four thrusters are used for surge, sway, and yaw, two thrusters are used for heave. The pressure vessels include the main hull with main CPU, CPU for image processing, and two cameras, two battery hulls, the sensor hull with IMU and Wi-Fi, and the dropper hull.



(a) Overview



(b) Mechanism of dropping marker

Fig. 3 Dropper module

For payload like as dropper module, the cap hole of main hull and electrical system is renewal. New cap has 8 payload holes, upped from 6 holes, and a large connector for high battery ampere and can use 40A higher than old one using only 30A. In addition to that, the hole layout has been updated to make it easier to use, with payload, which is often changed, on the

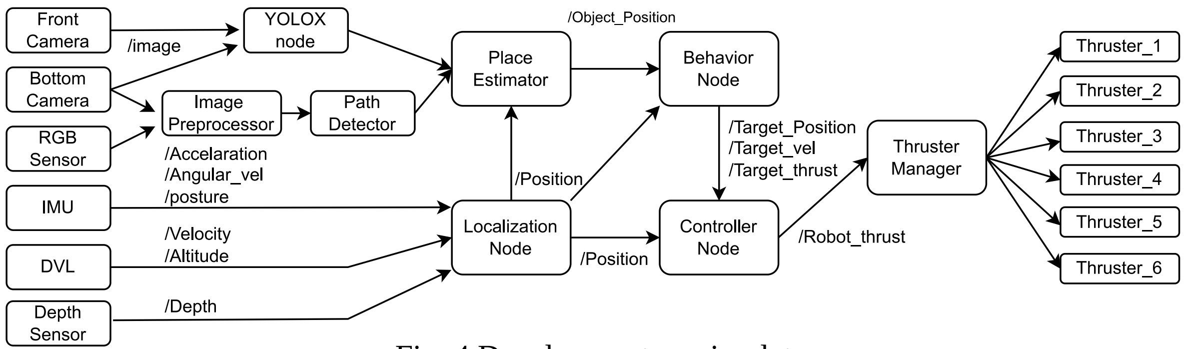


Fig. 4 Development on simulator

outside and thrusters and depth sensor, which are never changed, on the inside. The power supply system has also been reviewed and a new 5V power supply for JETSON nano and dropper has been added. This supply can use for additional payloads in future.

The dropper consists of actuator and module hull and developed by improving previous one. Figure 3 (a) shows developed dropper equipped underwater servo. Dropping marker mechanism is switching the marker stopper (Fig. 3(b)). The dropper can be equipped with three markers, and the stopper rotates to drop the markers one by Previous dropper actuator was used air actuation system, is for on air not for underwater so have some wrong for using. Instead of air actuation system, underwater servo is installed. Dropping marker mechanism is same with previous one only switching actuator changed underwater servo.

B. Software

The ROS node diagram of KYUBIC is shown in Figure 4. The Localization Node integrates information from Depth Sensor, DVL, and IMU and performs self-location estimation. Dead reckoning is used as the self-location estimation method.

Place Estimator is a node in KYUBIC that processes images from two cameras to recognize pictures on gate, buoy, and bin, and estimates the three-dimensional position of the picture in the world coordinate system.

The Behavior Node corresponds to the higher-level controller of the robot, which determines the robot's behavior based mainly on the information of Position and Object's Position and sends commands to the Control Node.

The Control Node calculates the thrust of the robot based on the current position received from Localization and the target value received from Behavior Node and sends it to the Thruster Manager Node.

Thruster Manager Node calculates the target thrust of each of the six thrusters from the thrust received from Control Node. And send them to the thrusters. Each node connected to the ROS network is written in C++.

This section describes the "Path Tracking" method. The Path is an orange structure placed at the bottom of the pool behind the Gate and Buoy. It is a visual cue that indicates the direction to the next task, and navigation by obtaining the angle of travel from this Path is called Path Tracking.

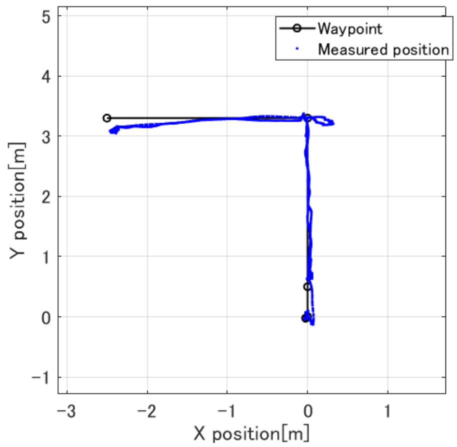


Fig. 7 Development on simulator

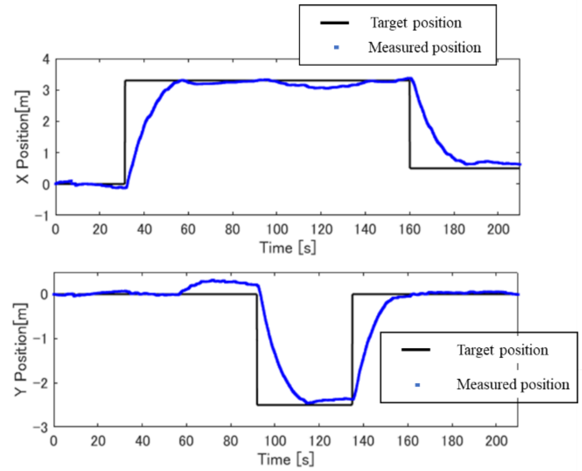


Fig. 8 Development on simulator

KYUBIC recognizes the Path by image processing a vertically mounted camera (bottom camera). First, the image acquired from the bottom camera is converted to grayscale. Next, this grayscale image is binarized using adaptive threshold. Next, the opening and closing processes are performed to reduce noise.

Next, labeling is performed to extract the rectangular regions (bounding boxes) of the path candidates. Each label is evaluated based on the validity of the pixel color, aspect ratio, and pointing direction, and the label with the highest evaluation is estimated to be the path region. The orientation of the path region and the location of the bounding box in the image are then published to the next node.

Pictures are placed on the Gate and Bin, which are used as landmarks for each task. To calculate these locations, we constructed a recognition system using YOLOX. Based on the recognition results, we further performed rule-based rectangle recognition, etc., and calculated the position of the pictures in the world coordinate system based on the world coordinates of KYUBIC.

The information about YOLOX was obtained through an exchange of information with OUXT Polaris[https://www.ouxt.jp/], a team participating in Maritime RobotX.

The cost of preparation for the pool experiment was high , and was not appropriate for a simple operation check. To reduce the preparation cost, a simulation environment was developed. The model could not be enhanced in this year's development, and it was not possible to simulate more practical experiments. We will continue to develop and improve this simulator. The simulator is based on a simulator called dave (https://github.com/Field-Robotics-Lab/dave).

IV.EXPERIMENTAL RESULTS

Navigation system is most important system for AUV. This time, KYUBIC has waypoint system and we conducted experiment for waypoint on sea. Figures 7 and 8 are experimental results. Figure 7 shows x-y position plot, black line and marker means waypoint, blue marker means AUV position given by dead reckoning. For dead reckoning, KYUBIC uses DVL velocity for surge and sway and IMU heading values. Figure 8 shows timeseries of x position and y position. About x position, some error during 100 to140 second, it's thought by effect of sea current, but error is only 0.2m and KYUBIC can return target x position.

V.ACKNOWLEDGEMENTS

We would like to thank professor Ishii, assistant professor Nishida, assistant professor Yasukawa. We especially would like to thank assistant professor Nishida, who gave us various advice, and supported by experiment in pool. This team supported by Kyutech・Meisenkai student project grant.

VI.REFERENCES

[1] W. Hori, R. Satoh, S. Nam, J. Ahn, N. Fujii, K. Matsuoka, Y. Soejima, Y. Takemura and K. Ishii, "An AUV Platform for Robot Behavior Development: Twin-Robot “DaryaBird ”and “OCTA ”, and Their' Mission Strategy," AUVSI&ONR' s 17th Annual RoboSub Competition, 2014.

[2] S. Hidaka, S. Kawashima, S. Nam, N. Fujii, R. Nakanishi, Y. Soejima and K. Ishii, "System Design and Hardware Development of Autonomous Underwater Robot “DaryaBird”," AUVSI&ONR' s 18th Annual RoboSub Competition, 2015.

[3] R. Nakanishi, J. Ahn, K. Suzuki, Y. Soejima, K. Masuda and Y. Nishida, "System Design and Hardware Development of Autonomous Underwater Robot “DaryaBird”," AUVSI&ONR' s 19th Annual RoboSub Competition Journal Paper, 2016.

[4] Ryuji Eguchi, Yoshiki Tanaka, Naoto Sohara, et. al, “Dual robot strategy for mission sharing and Processing distribution”, AUVDI&ONR's 22th Annual RoboSub Competition, 2019

[5] Toshimune Matsumura, Yuichiro Uemura, Kentaro Yanagise, Yoshiki Tanaka, Yuya Nishida, Kazuo Ishii,“Development of a Handy Autonomous Underwater Vehicle “Kyubic” ”, proceedings of the 2021 international conference on artificial life and robotics, 2021