# Design of Disassembly-reassembly Type USV for Coral Reef Research

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**Abstract**

Researchers are conducting physical surveys by diving and swimming to study the effects of microplastics and global warming on coral reefs. The area, time, and water depth that can be investigated by diving are extremely limited. In addition, to collect microplastics, it is necessary to tow the nets, but chartering a ship is expensive. Therefore, the authors are developing a system that simultaneously operates a USV and a UUV to simultaneously observe the sea surface and underwater. In this paper, we conducted a conceptual design, carried out fluid force measurements, trajectory tracking experiments, and image recognition using AI, with the aim of realizing a lightweight USV that can be divided during transportation to coral reef areas and reassembled on site for operation.

*Keywords*: USV/UUV combined, Disassembly-reassembly type USV, Coral reef monitoring, AI image processing

## 1. Introduction

In recent years, marine plastic waste has been widely recognized as a global environmental problem. Because most plastics undergo very slow chemical or biological degradation in the environment, debris can remain in the ocean for years, decades, or even longer [1]. The term microplastic refers to very small and ubiquitous plastic particles less than 5 mm in diameter. They have been separated into different fractions: large (1–5 mm) or small (1 µm–1 mm) microplastics and the fraction below 20 µm (20 µm–1 µm) [2], [3]. Microplastics can adsorb and carry hydrophobic chemicals that can have biological and toxicological effects on the environment [4]. Therefore, a clear understanding of the interactions of small microplastics with the environment, especially living organisms, is essential to assess potential health hazards. To this end, it is important to have accurate methods to quantify the mount of such particles in natural environments. By monitoring the amount and characteristics of particles over time, along with the coordinates from which they were collected, it will be possible to define the extent of the effects they cause.

Additionally, by collecting small microplastics and identifying them at the single particle level, it will be possible to create some indicators regarding the potential impact of microplastics on marine biodiversity and their distribution in the ocean. Currently, there are two methods for collecting microplastics in coral reef waters: chartering a ship and towing the nets, or having people swim and tow the nets. The former requires the ship to be routed from the port to the collection site, and costs such as chartering fees are incurred. While the latter can be accessed directly from the beach, the area in which it can be retrieved is very limited.

With the goal of improving these shortcomings and efficiently collecting more microplastics in coral reef waters, we are developing a disassembly-reassembly type USV, which we will introduce in this paper. The USV under development will tow the net while automatically following a set trajectory by a biologist to collect microplastics. The time and trajectory of microplastic collection will be recorded by GNSS data. Since the work is intended to be carried out even on remote islands, we designed a structure that could be disassembled, transported by aircraft, etc., and reassembled on-site.

## 2. USV System Development

### 2.1. *System architecture*

An external view of the developing USV is shown in Fig.1. The dimensions of the USV is shown in Fig.2. As shown in Fig.1, this USV consists of four hulls. The size of the hull was determined to fit within the typical packaging size used in typical Japanese delivery services. As shown in Fig.2, the thruster, computer, and GNSS antenna are attached to the aluminum frame. The center of the hull has a large opening so that the USV can collect microplastics while navigating, and a net for collecting microplastics is attached to the rear of the USV. The hardware components of control system is shown in Fig.3. This USV is equipped with two microcomputers. One computer is for motion control, and the other is for image acquisition and processing. Image processing is supposed to be used for collision avoidance when the tide is low and the reef is exposed above the sea surface. As for the algorithm of trajectory tracking, we hire optimal control based 1-type servo [5].

### 2.2. *Drag force measurement of a hull*

In order to estimate the maximum speed of the USV and construct a nominal model for designing the optimal control system, it is necessary to estimate the drag force coefficient. Therefore, as shown in Fig. 4, the hull was set in a circulating water tank and the drag force was measured by varying the flow velocity and angle of attack. The flow velocity was increased every 0.2 m/s and was measured from 0.4m/s up to 1.0 m/s. The measurement results are shown in Fig.5. As the graph shows, it is almost parabolic, confirming that the drag force is proportional to the square of the flow velocity. The drag force coefficient when moving forward is estimated using the equation, where $D$ is drag force, $\rho$ is water density, $A$ is representative area of the hull, $u$ is velocity.

$$C_d = \frac{D}{\frac{1}{2}\rho A u^2} \qquad (1)$$

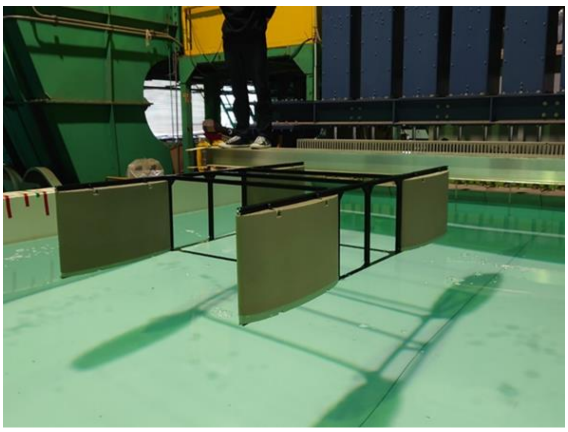

Fig. 1. External view of the USV

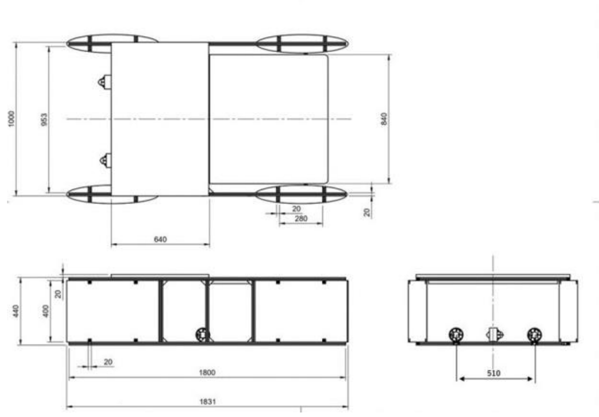


Fig. 2. Dimensions of the USV

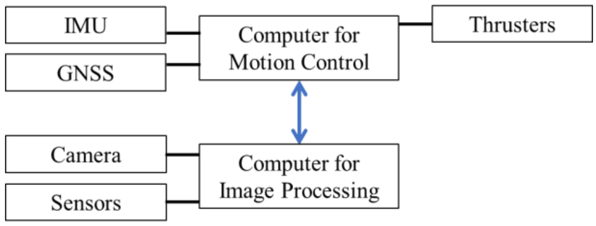


Fig. 3. Control system architecture

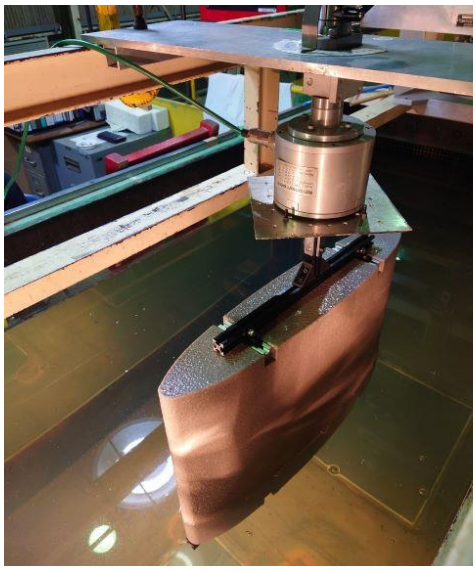

Fig. 4. Hull drag force measurement.

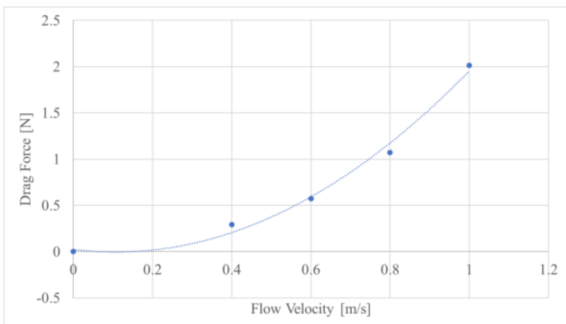


Fig.5 Drag force result

The drag force coefficient became 0.18 in average.

## 3. Image Recognition Experiment Using AI

Since it is necessary to avoid obstacles during automatic navigation, we are considering an image object recognition function. We conducted an experiment using YOLOv5 using our university's pier column as an example. Fig.6 is an example of an image of the "pillar" labeling that YOLO is trained to learn. About 100 photos were taken to show the different shapes of the pillars on the quay and the changes in the exposed parts of the pillars due to the ebb and flow of the tide, and were used as training data. Fig.7 shows the results of image recognition based on the above learning. It can be seen that the pillars at the bottom of the quay could be recognized, but the probability of recognition was only about 60%, and when sailing from an angle, it was often not possible to recognize them. Fig.8 shows the results of learning by adding additional training data, including images from diagonal directions. The recognition rate was over 80%, and the pillars could now be recognized even in images viewed from an angle. Image recognition using AI is extremely important as a function of USV, and in addition to detecting obstacles, it may also be applied to recognizing coral reefs using underwater cameras in coral reef surveys. YOLO is a very powerful tool, but it is necessary to prepare various images as training data, and how to obtain images for learning at the first site is a future issue. One possible solution would be to fly a UAV (Unmanned Aerial Vehicle) in the research area and use the images captured by the UAV as learning data. Floating debris such as large pieces of wood or plastic bottles can break the microplastic mesh if the USV swims over them, so it must have a function to find them ahead and avoid them.


Fig.6 An image example for pillar labeling

Fig.7 An example of image recognition results

Fig.8 Improved recognition result after more learning

## 4. Trajectory Tracking Experiment

In order to confirm the resolution of GNSS and confirm the trajectory tracking performance, we conducted a trajectory tracking experiment using a catamaran-type USV that has been developed in our laboratory, rather than the USV currently under development. The results are shown from Fig. 9 to Fig.11. Fig.9 is a map of the trajectory in the actual ocean area. Fig.10 shows the results of thrust forces. Fig.11 shows converting the latitude and longitude to the XY coordinate system with the starting point as the origin. It was set to sail to the (-10,10) point and then return to the origin. On the day of the experiment, the wind was strong and there was some deviation from the straight trajectory, but we were able to confirm that it had sufficient performance to collect microplastics.


Fig.9 Trajectory result

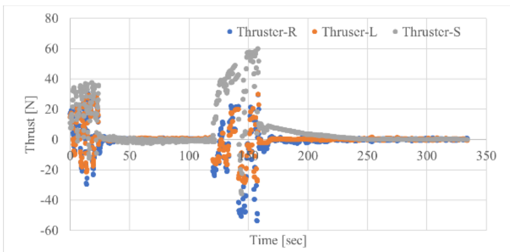

Fig.10 Thruster forces

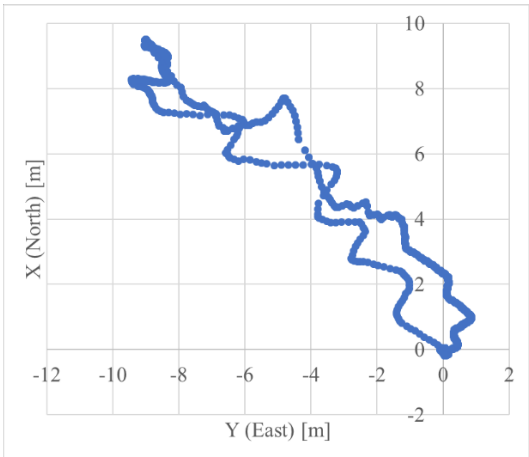


Fig.11 XY coordinate of the trajectory

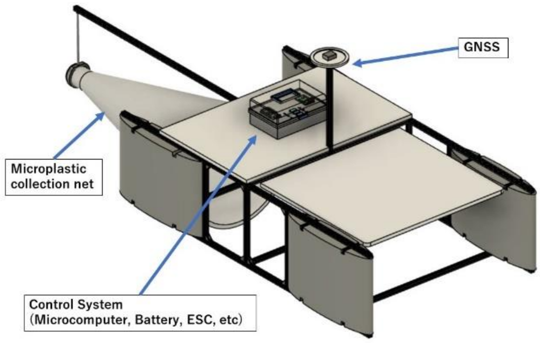


Fig.12 The total image of the USV

## 5. Summary

In this study, we designed a USV with the goal of automating and reducing the cost of microplastic collection in coral reef waters, which is currently done manually. A split-assembly type USV was designed to facilitate transportation to remote islands. The conceptual design drawing is shown in Fig.12. In order to realize the obstacle avoidance function through image processing, we implemented an object detection system using AI. In order to construct a nominal model for control system design, the hull's fluid force coefficient was identified through experiments using a circulating water tank. Through trajectory tracking experiments using existing USV, we have confirmed that trajectory tracking is possible within an error range of approximately 1m. We plan to conduct microplastic collection experiments.

## References

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