Development of Remotely Operated Vehicle for Small-size Jellyfish Extermination and its Evaluation of Extermination Motion Control

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Abstract

In recent years, increase in the number of jellyfish has caused damage in the fishery and tourism industries. Therefore, the extermination work of jellyfish is being carried out by human hands. However, conventional methods for extermination are required a lot of time and manpower. In this paper, we propose a method for extermination work of jellyfish using underwater robot. Also, we introduce developed ROV type underwater robot, which is called J.E.N.O.S.(Jellyfish Extermination Nifty-robot for Ocean Sustentation), and its extermination motion control. The ROV is developed in consideration of the attitude control during the extermination operation. Because, the attitude, such as surge and pitch angle, of ROV becomes unstable when performing jellyfish extermination. Therefore, we equipped 8 thrusters to improve attitude stability during the jellyfish extermination. As a result, surge acceleration is reduced to about 30.0%, and pitch angle velocity is reduced to about 25.8%.

Keywords: robot design, ocean engineering, remotely operated vehicle, jellyfish extermination

1. Introduction

In recent years, the massive increase in the number of jellyfish is damaging to ocean environments such as decrease in biodiversity. Also, the number of jellyfish is increasing across Asia, damaging the fisheries, power generation and tourism industries [1][2]. It is supposed that these causes are overfishing of fishery resources, changes in coastal topography due to global warming, and eutrophication [3]. In Japan, the aurelia, which is small and poisonous jellyfish, is damaging to human activities such as fisheries and tourism industries. furthermore, they gather at the water intakes of power plants, and clog the intakes [4][5]. Therefore, jellyfish extermination work is carried out to reduce such damage.

Conventionally, jellyfish extermination work is used fishing nets. The workers catch jellyfish using fishing nets, and then caught jellyfish is cut up by the workers. However, this method is required a lot of cost such as financial cost, time, and manpower. Furthermore, the number of fishery workers in Japan has been declining in recent years due to the decreasing birthrate and aging population [6]. Underwater robot can be mentioned as a solution to this situation. The advantage of underwater robot is that, unlike humans, they do not have to bear any physical burden and can work for a long time. In this paper, we design and develop a ROV (Remotely Operated Vehicle) for jellyfish extermination work, which is called J.E.N.O.S.(Jellyfish Extermination Nifty-robot for Ocean Sustentation) and evaluate ROV motion to jellyfish extermination.

2. Development of Jellyfish Extermination ROV

2.1. *Operation of developed to ROV*

The jellyfish extermination ROV is operated on the small size fishing boat. The detail of proposed jellyfish extermination ROV operation is illustrated in Fig.1.

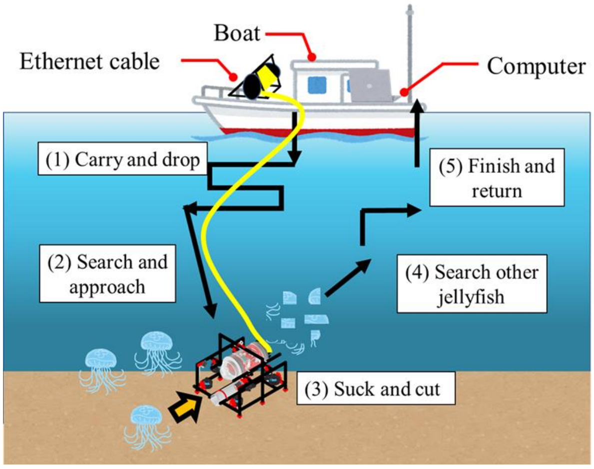

Fig. 1 Overview of the proposed jellyfish extermination ROV operation method

In the proposed operation, the ROV has 5 steps to exterminate jellyfish.

(1) The ROV and operator are carried using a boat to the field where is number of jellyfish is increasing. Then, the ROV is dropped to the sea area.
(2) The ROV is controlled by operator to search jellyfish. If a jellyfish is found, the ROV approaches to the jellyfish.
(3) A jellyfish extermination device, which is mounted to ROV, sucks the jellyfish with water. Then the jellyfish is cut by the blade.
(4) The ROV is controlled to search other jellyfish in the same sea area.
(5) After the work in the sea area is finished, the ROV is returned on the boat. Then, operator try to same works in the other sea area.

We develop a ROV which can operate these steps.

2.2. *Design concept and specifications of ROV*

The ROV is necessary several condition to operate the proposed jellyfish extermination work on the boat. The design concept of ROV, which is considered to develop, is described below.

(i) Small size and light weight
(ii) High maintainability
(iii) Wide viewing angle and high recognition rate
(iv) High positional stability

We proposed a ROV operation method, which can be done with a few workers compared to conventional method, such Fig.1. Therefore, the design concept of ROV, which satisfies (1) ~ (5), is necessary. For the design concept (i), size and weight must be designed easy enough to be drop and return on the boat by 2 people. Because the minimum number of people required to work on a boat is 2 for the safety.

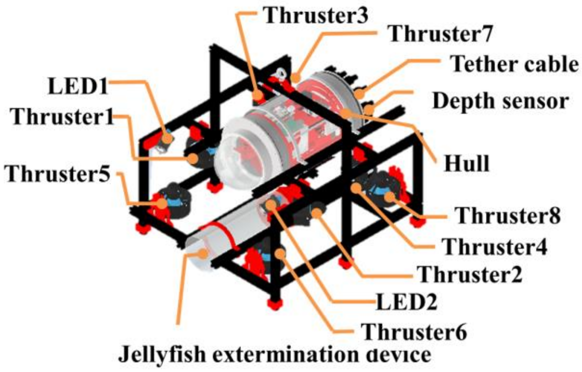

Fig. 2 Overhead view of designed the ROV for jellyfish extermination

Table 1 Specifications of developed to ROV

Dimensions	0.65 x 0.52 x 0.47 [m] (L x W x H)
Dry weight	17[kg]
Maximum depth	10[m]
Actuator	Thruster x 8, Micro servo motor x 2
Battery	Lithium-ion battery x 1
Sensors	USB camera x 1, IMU x 1, Depth sensor x 1
Umbilical Cable	100[m] length, 7.6 [mm] diameter
Equipment	LED x 2, Jellyfish extermination device x 1 Voltmeter x 1
Angle of view	Pan110[deg], Tilt120[deg]

The purpose of the design concept (ii) is to ensure that if a problem occurs during the operation, such as a poor connection or dead battery related to the internal system of ROV, it can be recovered and repaired quickly.

Underwater environment is dark and makes it difficult to recognize objects. Therefore, like the design concept (iii), the ROV is necessary to light source and wide viewing angle.

In the Fig.1, we proposed an operation method, which is sucked the jellyfish and cutting them. However, in this way, the posture of the ROV tends to be unstable because of the suction device applies the force to ROV. Therefore, the ROV is necessary to high positional stability for jellyfish extermination in the design concept (iv).

The designed ROV, which is considered the design concept (i) ~ (iv), is shown in Fig.2 and the ROV specifications is shown in Table 1.

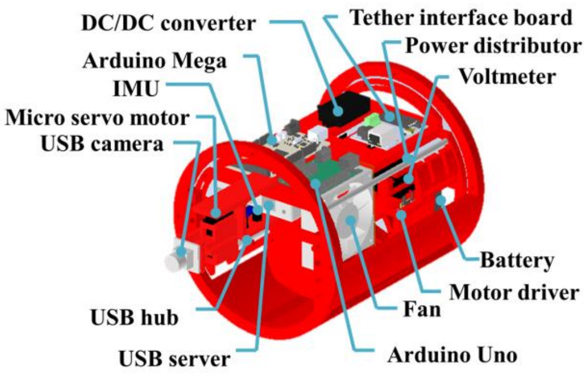

Fig. 3 Inside design of the hull of developed ROV

As shown in Fig.2, the ROV includes a hull, which is composed camera dome and acrylic cylinder, thrusters, LEDs and jellyfish extermination device. Each device is equipped using aluminum frames to ROV.

The ROV is designed 0.65 x 0.52 x 0.47[m] and 17[kg] because of design concept (i) for the drop and return work. This size and weight are made possible the extermination operation using the ROV by 2 grown mans on the boat.

The ROV hull inside is designed as a module for design concept (ii). The inside design of hull is shown Fig.3.

As shown in Fig.3, the control units such as Arduino, battery, motor drivers, sensors are placed one hull inside.

This is a single module, designed to be easily inserted into and removed from the hull by slide mechanism.

The camera system is composed by a camera, 2 LEDs and 2 micro servo motors to satisfy design concept (iii). The camera system can move to pan and tilt angle. Also, the LEDs, which has a maximum brightness of 1,500 lumens [7], are equipped.

The ROV has low positional stability during jellyfish extermination work because the center of rotation of ROV and jellyfish extermination device are mounted at a distance as shown in Fig.2. Therefore, the force from jellyfish extermination device occurs to surge direction and pitch angle. This force makes the ROV posture unstable, and it is made difficult to jellyfish extermination work. The ROV is mounted 8 thrusters which are maximum output of 5.25 [kgf] at 16 [V] [8] to satisfy design concept (iv). We placed 4 thrusters in the surge and sway directions, and other 4 thrusters are placed in the heave direction as shown in Fig.2 for high positional stability of the ROV.

2.3. *Design of power and communication system*

Power source of the ROV is employed a lithium-ion battery which is 14.8[V], 18[Ah]. The designed power system is shown in Fig.4.

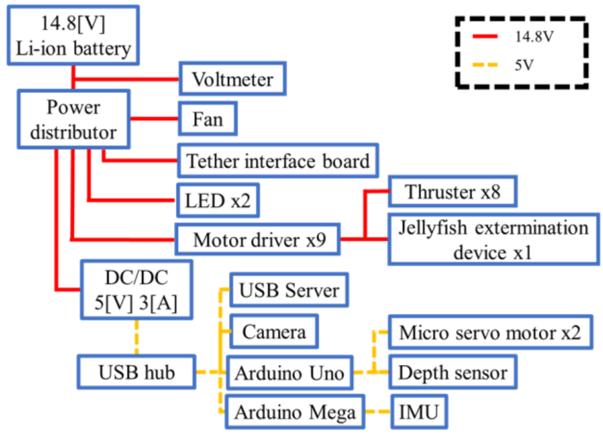

Fig. 4 Overview of power supply system

The battery is supplied DC 14.8 [V] to electronic parts as shown in Fig.4. DC 14.8[V] are employed to supply power to fan, voltmeter, LEDs, motor drivers and tether interface board. Also, DC 5[V], which are employed to sensors and processing units, are converted by DC/DC converter, and those are employed to supply power to USB server, camera, Arduino Uno and Mega.

The communication system is illustrated in Fig.5.

As shown in Fig.4, the ROV communication system is employed various communication formats. The computer on the boat is connected to ROV by ethernet cable via tether interface and then the ethernet signal is converted to USB serial by USB server. The USB hub, which connected to Arduino Mega and Uno, is connected to USB server. Arduino Mega controls thrusters, jellyfish extermination device, LEDs and get the IMU data. The PWM signal is employed for the thruster and LED control. The PWM signal, which outputted to Arduino Mega, has 1100 to 1900 [micro sec.] range. Arduino Uno controls micro servo motors for camera movement and get the depth sensor data.

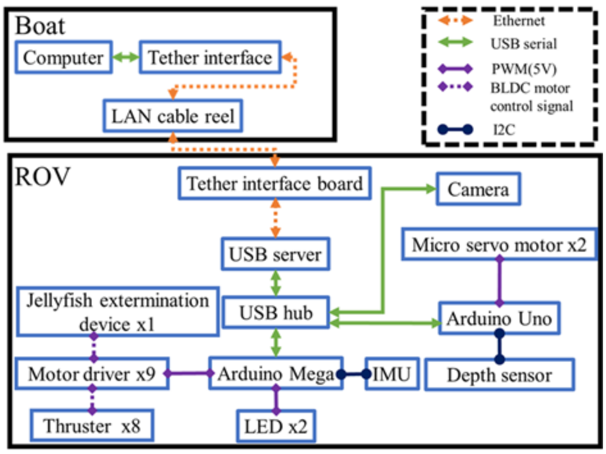

Fig. 5 Overview of communication system

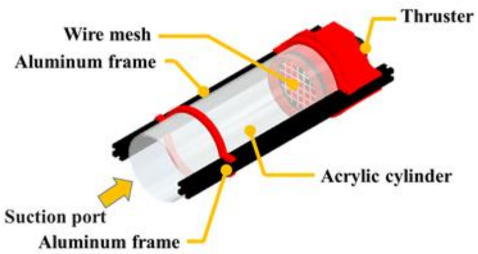

Fig. 6 Overview of jellyfish extermination device

Table 2 Specification of jellyfish extermination device

Dimensions	0.46 x 0.15 [m] (L x W)
Dry weight	2[kg]
Actuator	Thruster(T200)
Suction port diameter	100[mm]
Filter size	15 x 15[mm]
Thrust	Up to 4.07 [kgf] at 16 [V]

2.4. *Jellyfish extermination device*

We proposed jellyfish extermination method using suction device in Fig. 1. The jellyfish extermination device, which can be possible the proposed jellyfish extermination ROV operation method, is illustrated in Fig.6 and the Specifications is shown in Table2.

The jellyfish extermination device is a thruster, wire mesh, acrylic cylinder, and frames as shown in Fig.5. When the thruster rotates, the jellyfish is sucked in and cut off by the wire mesh and blade of thruster. In the proposed jellyfish extermination ROV operation method, we do not collect cut jellyfish because the cut jellyfish are used as food for marine organisms in marine ecosystem.

The wire mesh is made of stainless steel and the mesh size is 15 [mm] x 15 [mm]. It also serves to crush jellyfish and to protect hard objects other than jellyfish, such as large rocks and shells, from the thruster.

3. Evaluation experiment of developed ROV

We evaluate stability of the ROV motion and jellyfish extermination device is performance by 2 experiments.

For the motion stability, the jellyfish extermination motion of ROV is evaluated with acceleration and angular velocity. For jellyfish extermination device, the device is evaluated with jellyfish sample extermination time.

3.1. *Evaluation of extermination motion control*

The extermination motion of ROV is performed using jellyfish extermination device which mounted downside of the ROV. Therefore, when using the jellyfish extermination device, the pitch angle rotates as the robot moves forward. To solve this problem, we stabilized the posture by using other thrusters mounted on the ROV. In this experiment, the thrust of the extermination device was set to 1.44 [kgf]. The control results are shown in Fig.7, and the scene of experiment illustrated in Fig.8.

The Fig.7 (a) ~ (b) represents acceleration of surge, sway, and heave direction. And the Fig.7 (d) ~ (f) are shown angular velocity of roll, pitch, yaw angle. The dashed lines represent acceleration and angular velocity during extermination motion without control of other

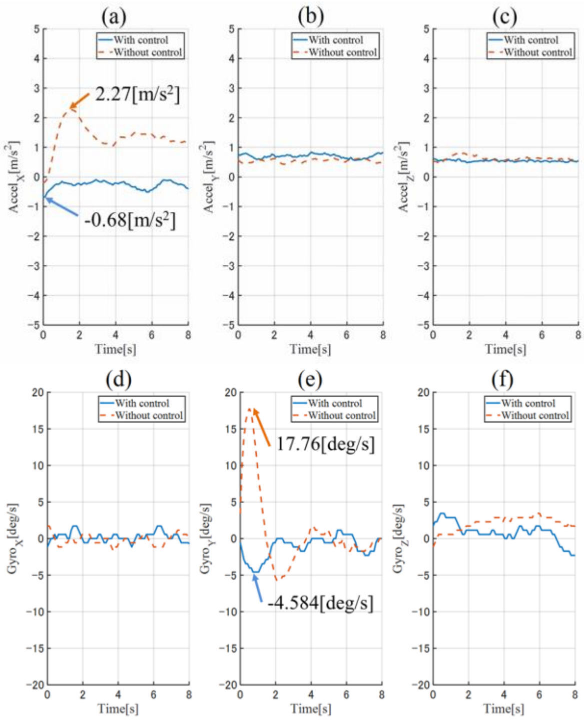

Fig. 7 Experimental results

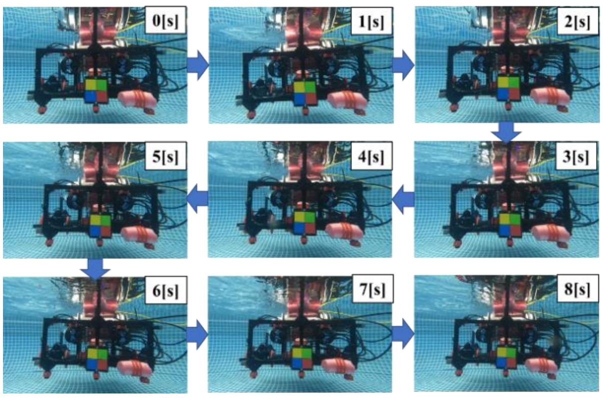

Fig. 8 Scene of the extermination motion control

thrusters, and the solid lines represent acceleration and angular velocity during extermination motion with control of other thrusters. Also, each data is measured by IMU which is mounted the ROV.

Fig.7 (a) in the dashed line, the ROV can confirm that the acceleration is applied in the surge direction during extermination motion and its maximum acceleration of the surge direction was 2.27[m/s^2]. Fig.7 (a) in the solid line represents the surge acceleration which is reduced by mounted thrusters on ROV. As a control result, the acceleration of surge direction is about 30.0% reduced. Fig.7 (b) and (c) are shown acceleration of sway and heave direction, and there was little acceleration in those direction.

Fig.7 (d) and (f) are shown angular velocity of roll, yaw angle, and there was little angular velocity in those direction. However, Fig.7 (e) in the dashed line is shown high angular velocity and its maximum angular velocity of the pitch angle was 17.76[deg/s]. Fig.7 (e) in the solid line represents the angular velocity which is reduced by mounted thrusters on ROV. As a control result, the angular velocity of pitch angle is about 25.8% reduced.

We can see in Fig. 8 that the acceleration and angular velocity are highly reduced. In Fig. 8, a marker is attached to the lower center of the ROV, and the movement of the marker was observed during the extermination motion. As a result of observation, it was confirmed that the robot hardly moved.

3.2. *Evaluation of jellyfish extermination device*

We experiment to evaluate the flow velocity of jellyfish extermination device. In this experiment, the 3 types of cylindrical jellyfish samples, which composed of water and gelatin, was employed. Each jellyfish sample was made using 200, 300, 400 [ml] of water, 5, 10, 15[g] of gelatin, 1, 2, 3[g] of red food coloring, and each size (radius x height) was about 28[mm] x 80[mm], 35[mm] x 105[mm] and 40[mm] x 130[mm].

In the experiment, the sample is dropped in front of the jellyfish extermination device and then sucked to measure the flow velocity. Using an underwater camera, the jellyfish samples were recorded at 120 frames and the flow velocity was measured. The force output by the thruster which is mounted jellyfish extermination device is 1.44 [kgf]. The scene of device evaluation is shown in Fig.9.

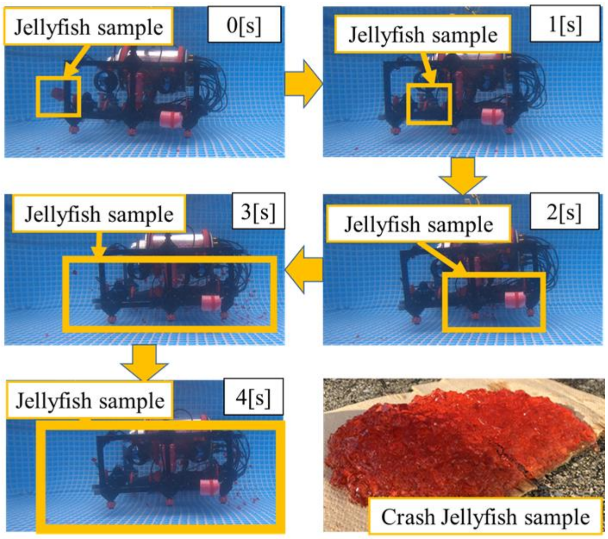

Fig. 9 Scene of jellyfish extermination device experiment

As shown in Fig.9, each jellyfish sample was chopped by jellyfish extermination device. The measured flow velocity employed the samples, which is made using 200, 300, 400 [ml] of water, was 0.60[m/s], 0.56[m/s] and 0.53[m/s]. As a result, it was confirmed that the larger the volume, the lower the flow rate.

4. Conclusion

In this paper, we design and develop a ROV for jellyfish extermination work and evaluate ROV motion to jellyfish extermination. The design concept of ROV was shown in (i) ~ (iv), and a ROV was developed that satisfies it.

In the evaluation of extermination motion control, maximum acceleration of surge direction was 2.27[m/s^2], and maximum angular velocity of pitch angle was 17.76[deg/s] by thruster which is mounted jellyfish extermination device without other thruster control. The acceleration of surge direction was reduced about 30.0[%], and angular velocity of pitch angle was reduced about 25.8[%].

There are many issues to be solved for the operation in the oceans, such as automatic recognition of jellyfish and improvement of attitude control capability such as hovering control of the ROV.

In the future, we will solve these problems and try to make practical use of the ROV for small jellyfish extermination operations.

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Authors Introduction

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