**TELKOMNIKA Telecommunication, Computing, Electronics and Control**
Vol. 18, No. 3, June 2020, pp. 1546~1552
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v18i3.14885 

# Single camera depth control in micro class ROV

**Simon Siregar, Muhammad Ikhsan Sani, Sintong Tua Parlindungan Silalahi**
Computer Engineering Department, Faculty of Applied Science, Telkom University, Indonesia

**Article Info**

***Article history:***

Received Sep 1, 2019
Revised Feb 4, 2020
Accepted Feb 23, 2020

***Keywords:***

Ardusub
Camera-based depth control
distance measure
ROV
Triangle similarity

**ABSTRACT**

Navigation is one of the main challenges in an underwater vehicle. To measure and sustain the depth in the micro class remotely operated vehicle (ROV) robot is one of the main demands in the underwater robot competition. There are many sensors that can be used to measure the depth; one of the sensors is using a single camera sensor. In this works, camera-based depth control is developed and evaluated for micro class ROV, namely as fitoplankton SAS ROV. Fitoplankton SAS ROV is a micro ROV prototype with six thrusters. To maintain the depth position, a PID control system with a camera-based depth sensor as the input of the setpoint is used. Moreover, the method for the camera to measure the distance is using the triangle similarity method. In this paper, the experimental scenario is using the rectangular marker to measure the distance, and the value of the depth is processing in the ground control station (GCS). The GCS will send the thruster value to control the depth, which depends on the PID control system. The experiment results show an average of depth accuracy of 95.74% to the depth setpoint.



***Corresponding Author:***

Simon Siregar,
Computer Engineering Department, Faculty of Applied Science,
Telkom University, Telekomunikasi St, Indonesia.
Email: simon.siregar@tass.telkomuniversity.ac.id

## 1. INTRODUCTION

A vehicle that can maintain its position in running an underwater mission in the Singaporean Robotic Games competition is a necessity. Singapore Robotic Games (SRG) [1] 2019 have eleven events are planned for the games. One of the categories played in this event is the Underwater Robot Competition. In this category, the arena is in an L-shaped aquarium tank with obstacle and goal post [2]. The water tank depth will be around 40 cm. The robot design in this competition should be fit in a cube of 30 cm of width, 30 cm of length, and 30 cm of height. The goals in this competition involve picking up objects/cargoes from the middle area of the aquarium, obstacle avoidance from the accessories in the aquarium, and dropping the cargoes in baskets at both ends of the tank. The challenge in this competionis to direct the robot to the tank middle section while maintaining the depth to avoid other obstacles in the tank. In this paper, Figure 1 shows the proposed design of fitoplankton SAS remotely operated vehicle (ROV). In previous research, the development of underwater ROV starts from a navigation system based on a smartphone camera [3]. After that, the research continues with researching preferable wireless data communication for small underwater water ROV [4, 5] and continues with tethered wired data communication [6]. Moreover, powerdistribution and consumption on ROV is one of the main research in previous research [7]

The studies on maintaining depth is accomplished in several method based on the actuator, such as using thruster [8], using elevator [9] and using a bouyancy engine [10]. Each methods have superiority and weakness. The main gains using thruster [11] then elevator and buoyancy engine is better control response and better pression in maintain depth but consume the highest energy. The bouyancy engine [12] have better response then elevator but consume more energy then the elevator [13]. There are several control system such as proportional, derivative, and integral schemes [14], LQR schemes [15], fuzzy logic [16], sliding mode schemes [9, 17]. Most of these methods are used commonly used to regulate in ROV. These depth control has several input feedback. Most common sensor to measure the depth is using pressure sensor, but other studies are using sonar sensor and camera. In this paper, a camera is choosen as the main sensor for depth control as the lowest cost sensor for shallow water with sufficient ambience light.

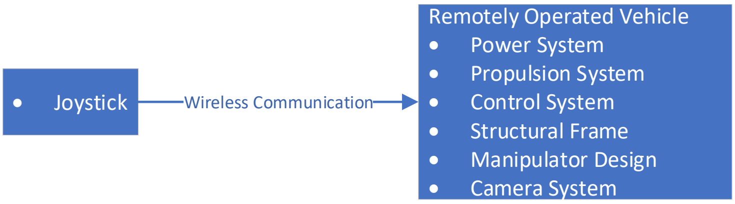


Figure 1. General design of ROV system in SRG competition

## 2. PROPOSED MICRO ROV SYSTEM

The design of Fitoplankton SAS ROV is based on 3 degree of freedom (DOF) control: surge control, heave control, and yaw control. In this study, fitoplankton SAS ROV is designed based on 5 DOF control: surge control, heave control, pitch control, yaw control dan roll control, using six motor thruster. To control yaw and surge motion, motor thruster numbers 5 and 6 are placed parallel to the horizontal axis. Meanwhile, to control heave, pitch, and roll motion, motor number 1, 2, 3, and 4 are placed parallel to the vertical axis. The detail of the position thruster motor can be seen in Figure 2. The dimensions of the design vehicle are 25 cm in length, 20 cm in width and 15 cm in height. The camera position on the vehicle is placed in the center of the vehicle. It is intended that the marker image to be captured by the camera can always be captured by the camera.

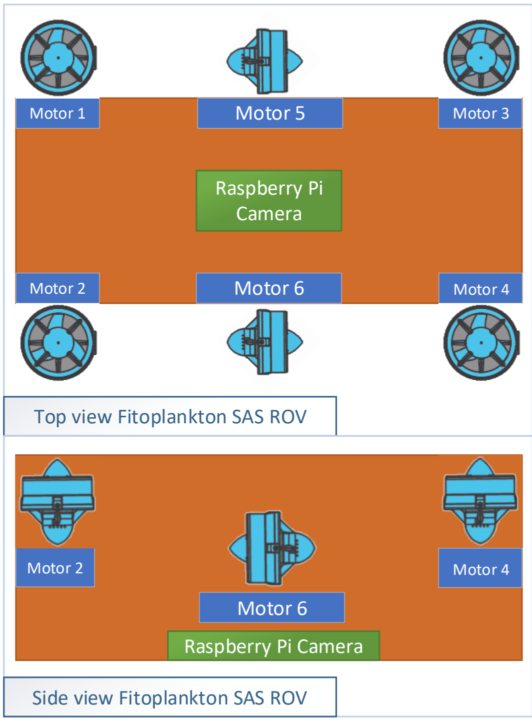


Figure 2. Proposed design of fitoplankton SAS ROV mechanical

The fitoplankton SAS ROV system is using a Raspberry Pi type B+, a PIXHAWK, and a Personal Computer. Raspberry Pi is a single-board computer (SBC) used as a companion computer. This companion computer is based on ARDUSUB companion computer, which functions as a communication bridge between PIXHAWK and Topside Computer for transmitting the telemetry information and the command. To measure the depth of the vehicle, a camera that is connected to a raspberry Pi (companion computer). Meanwhile, PIXHAWK is a flight controller which is used to acquire data from internal embedded sensors (IMU and Compass), and execute action by sending pulse width modulation (PWM) values to every DC motor. The PIXHAWK is also used to control five DOF rotational and translational motion. The description of the entire system block is shown in Figure 3.

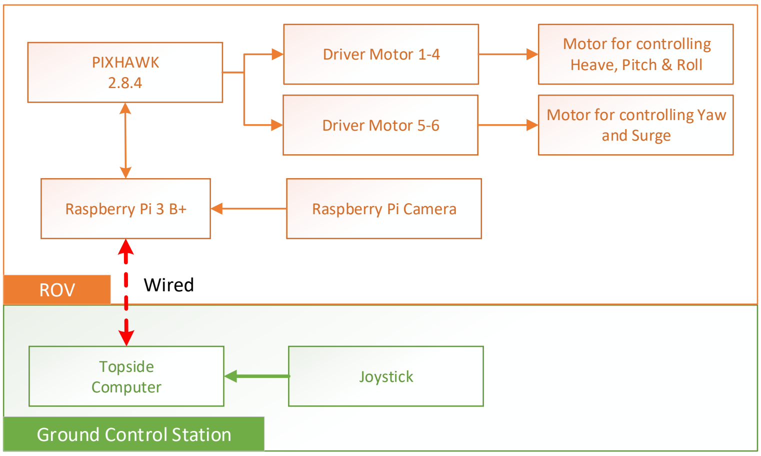


Figure 3. Proposed design of fitoplankton SAS ROV system

## 3. RESEARCH METHOD

### 3.1. Distance measurement system

Several studies on the use of cameras as sensors to detect distance have been carried out. The number of cameras used in some of these studies varies. One study uses a single camera called the triangle similarity for object [18]/marker to distance camera method [19-22]. Other studies have shown the use of more than one camera, known as a stereo camera [23, 24]. Several other studies have shown the use of lasers to triangulate distances using a single camera [25]. The research that has been carried out according to the method carried out in this paper is to use an image marker such as a car plate to measure the distance of a car [26, 27]. Using the triangulate distance principle, the parameter f, which is a focal length of the camera lens, the parameter r, the radius of the marker in the image plane, and the parameter R, the radius of the marker in the object plane and parameter d, which is the distance from the camera to the object. The distance measurement from the camera and the object can be evaluated using in (1-3). Figure 4 shows how the working principle of this method;

$$\frac{f}{d} = \frac{r}{R} \tag{1}$$

$$f = d \times \frac{r}{R} \; pixels \tag{2}$$

$$d = f \times \frac{R}{r} \; cm \tag{3}$$

Moreover, Figure 5 shows the flowchart of this method. This flowchart is running in ground control station (GCS) to measure the depth and used image streaming from the raspberry pi camera in companion computer to send images from the ROV to GCS. The distance detection application to measure the distance between the object to the vehicle is described as follows:

– The live image from Raspberry Pi camera is captured in companion computer in ROV is streaming to Ground Control Station via Gstreamer application.
– Initialize is the first process to start the system and all library information.

- After initialize, a calibration method is used to calibrate the currently known parameter with the environment parameter. In this experiment, the known image picture, distance, and dimension are inserted and processed to know the focal length.
- Find Image marker is the next step in this algorithm. The finding of the image marker process consists of convert the image to grayscale and apply edge detection. With this process, the contour (outline) of the image will reveal.
- After the contour is revealed, the next process is determining the largest area. Contour approximation can be applied to the algorithm. Some other research is utilized color marker, keypoint detection, local invariant descriptor, and keypoint matching to make the system robust.
- Then this algorithm will measure the position in x-y coordinates and the width and height of the largest area.
- Next process is execute a function which uses the triangle similarity in (1-3) that computes the distance to an object.
- The Last process is to send the value of thruster based on the calculation of the PID control system to the companion computer in ROV and executed by PIXHAWK.

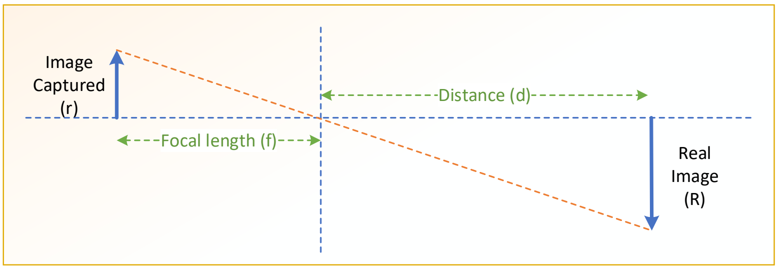


Figure 4. Proposed distance measurement method for fitoplankton SAS ROV

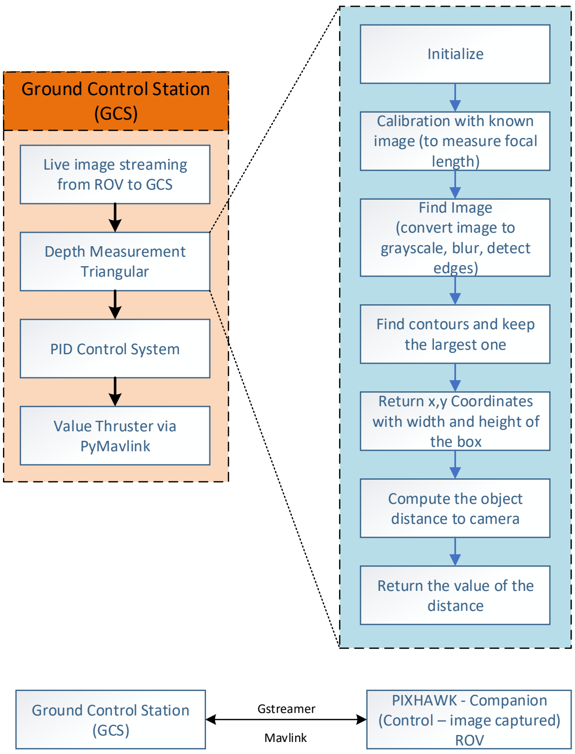


Figure 5. Proposed distance measurement method for fitoplankton SAS ROV

### 3.2. Depth control system

After assembling the design of the fitoplank ROV, the vehicle tested its ability to control heave to maintain the depth. The application of PID control system is running in ground control station computer.

The values of each parameter Kp, Kd, and Ki is using the values in our previous research [3], which are set to 15, 6, and 6, consecutively. The proposed control system in this research is shown in Figure 6.

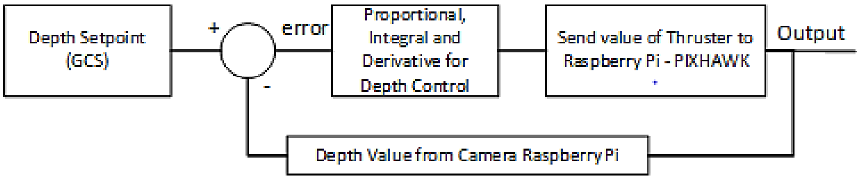


Figure 6. Proposed distance measurement fitoplankton SAS ROV

## 4. RESULTS AND ANALYSIS

### 4.1. Assembly proposed design

After designing the hull, Figure 7 shows the results of the assembly of the SAS ROV Phytoplankton design. The hull material used in the SAS ROV Phytoplankton is a waterproof plastic container, while the frame of the motor and propeller thruster holder is printed using a 3D printer. Figure 8 on the left shows the vehicle's view from the side, the center shows the ROV's view from the top, and the right shows the ROV's view from the bottom side. At the bottom of the vehicle, there is a transparent part that is used to place the camera.

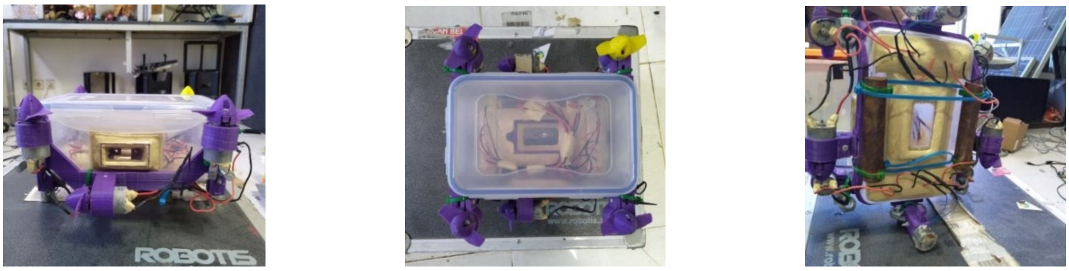

Figure 7. Mechanical assembly of fitoplankton SAS ROV

### 4.2. Experiment scenario

In this study, the vehicle was tested by placing a vehicle in an aquarium with a depth of 40 cm. Testing is done by programming the depth set point on the companion computer. The PIXHAWK flight mode will set to STABILIZE MODE. In this mode, the PIXHAWK will maintain the pitch and control of the ROV to level. The value of the setpoint used is 5 cm difference from 35 to 10 cm, and the time interval between setpoint depths is 10 seconds, with the size of the image marker in this scenario is 5 cm. Figure 8 shows an overview of the depth level testing from the side (left) and from the upper side (right).

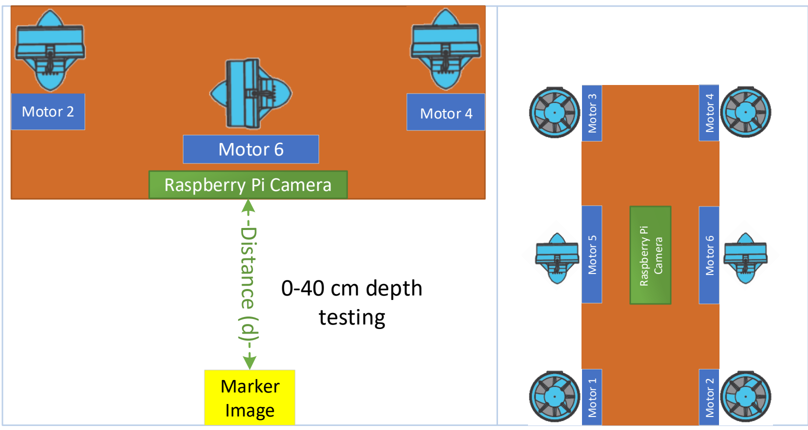


Figure 8. Mechanical assembly of fitoplankton SAS ROV

### 4.3. Experiment result and analysis

After set the values of the control system parameters (Kp, Kd, and Ki) in the PID control system, the ROV tested into the designated scenario. The depth is set by using a program for 60 seconds. In one loop programme, every 10 seconds, it will change the setpoint value to the specified depth. The ROV response in the experiment to the given setpoint are shown in Figure 9. The graph shows the ROV's ability to response on the given setpoint. Due to the sensor sensitivity of the Raspberry pi camera to environment lighting and the error of dimension measurement due to roll and pitch effect of the ROV, the ROV mode is set to STABILIZE Mode, and the experiment is conducted only in daylight time. Moreover, the distance measurement value is generated on average in 100 samples of an image to reduce the spike of distance measurement error. The value of 100 samples is set based on the response time and accuracy of distance measured. The average error after image processing and control system on the specified setpoint is 95.74%.

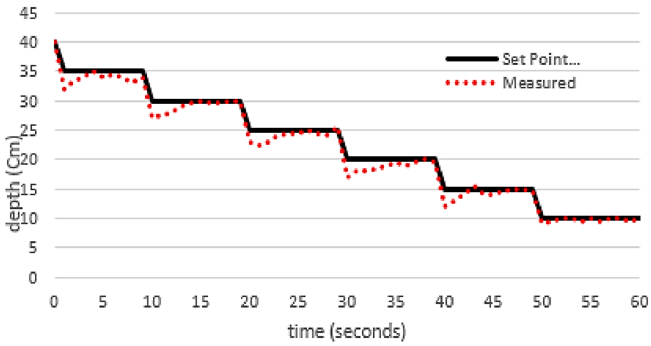


Figure 9. Experiment result of distance measurement Fitoplankton SAS ROV

## 5. CONCLUSION

This paper presented a micro class ROV with the ability to maintain depth with a single camera using the triangle similarity algorithm. The level of accuracy of depth by using this sensor is better than in our previous studies using proximity sensors. For further development, several other sensors can be explored to be used to measure the depth and altitude of the vehicle, such as: using a sonar-based sensor.

## ACKNOWLEDGEMENTS

This research and experiment were sponsorship by Riset Desentralisasi-Penelitian Terapan Unggulan Perguruan Tinggi (PTUPT) from The Ministry of Research, Technology, and Higher Education, Indonesia. Moreover, this work was also assistance and conducted in ENS Research Laboratory and backed by Robotic SAS member, Faculty of Applied Science, Telkom University.

## REFERENCES

[1] Wang D., "Report on robotics and automation activities in Singapore: Regional," *IEEE Robot Autom Mag,* vol. 17, no. 1, pp. 118–119, 2010.
[2] 2018 SRG. *Underwater Robot Competition,* pp. 37–41, 2018.
[3] Sani M. I., et al., "Navigation system for smartphone-based autonomous underwater vehicle," *Int. Conf Smart Cities, Autom Intell Comput Syst ICON-SONICS,* pp. 24–29, 2018.
[4] Sani M. I., et al., "2.4 GHz wireless data acquisition system for FIToplankton ROV," *6th Int. Conf. Inf. Commun. Technol.,* pp. 189-193, 2018.
[5] Sani M. I., et al., "FIToplankton: Wireless controlled remotely-operated underwater vehicle (ROV) for shallow water exploration," *Int J Electr Comput Eng,* vol. 8, no. 5, pp. 3325-3332, 2018.
[6] Siregar S., et al., "Low-cost communication system for explorer-class underwater remotely operated vehicle," *TELKOMNIKA Telecommunication, Computing, Electronics and Control,* vol. 17, no. 2, pp. 593-600, 2019.
[7] Sani M. I., et al., "An electrical power control system for explorer-class remotely operated underwater vehicle (ROV)," *TELKOMNIKA Telecommunication, Computing, Electronics and Control,* vol. 17, no. 2, pp. 928-936, 2019.
[8] Christ R. D., and Wernli R. L., "The ROV manual: A user guide for remotely operated vehicles," *Butterworth-Heineman,* 2013.
[9] Hong E. Y., Soon H. G., and Chitre M., "Depth control of an autonomous underwater vehicle," *STARFISH,* pp. 1-6, 2010.
[10] Ullah B., et al., "Underwater gliders control strategies: A review," *Asian Control Conference,* pp. 1-6, 2015.

[11] Cruz N. A., "Autonomous underwater vehicles," *IntechOpen,* 2011.
[12] Sanap M., et al., "HYDROBOT: An underwater surveillance swimming robot," *Int. Conf. Commun. Inf. Comput. Technol,* pp. 1-7, 2018.
[13] Jenkins S. A., and D'Spain G., "Autonomous underwater gliders," *Springer Handb Ocean Eng,* pp. 301-321, 2016.
[14] Noh M. M., Arshad M. R., and Mokhtar R. M., "Depth and pitch control of USM underwater glider: Performance comparison PID vs LQR," *Indian J Mar Sci,* vol. 40, no. 2, pp. 200-206, 2011.
[15] Upadhyay V., et al., "Design and motion control of autonomous underwater vehicle, amogh," I*EEE Underw Technol,* pp. 1-9, 2015.
[16] Nag A., Patel S. S., and Akbar S. A., "Fuzzy logic based depth control of an autonomous underwater vehicle," *Int Mutli-Conference Autom Comput Commun Control Compress Sens,* pp. 117-123, 2013.
[17] Isa K., Arshad M. R., and Ishak S., "A hybrid-driven underwater glider model, hydrodynamics estimation, and an analysis of the motion control," *Ocean Eng,* vol. 81, pp. 111-129, 2014.
[18] Cao Y. T., et al., "Circle marker based distance measurement using a single camera," *Lect Notes Softw Eng,* vol. 1, no. 4. pp. 376-380, 2013.
[19] P. Alizadeh, "Object distance measurement using a single camera for robotic applications," PhD Thesis. Laurentian University of Sudbury, vol. 126, 2015.
[20] Jawad H. M., and Husain T. A., "Measuring object dimensions and its distances based on image processing technique by analysis the image using sony camera," *Eurasian J Sci Eng,* vol. 3, no. 2, 2018.
[21] Hartmann J., et al., "Target detection using image processing techniques," *AIAA Infotech@ Aerospace*, 2015.
[22] Rahman A., "An image based approach to compute object distance," *International Journal of Computational Intelligence Systems,* vol. 1, pp. 304-312, 2008.
[23] Gökçe F., et al., "Vision-based detection and distance estimation of micro unmanned aerial vehicles," *Sensors,* vol. 15, no. 9, pp. 23805–23846, 2015.
[24] Kollmitzer C., "Multimedia communications, services and security," *Springer International Publishing,* 2107.
[25] Barreto S. V. F., Sant'Anna R. E., and Feitosa M. A. F., "A method for image processing and distance measuring based on laser distance triangulation," *Proc IEEE Int Conf Electron Circuits, Syst,* pp. 695–698, 2013.
[26] Phelawan J, Kittisut P., and Pornsuwancharoen N., "A new technique for distance measurement of between vehicles to vehicles by plate car using image processing," *Procedia Eng,* vol. 32, pp. 348-353, 2012.
[27] Deshmukh P. D., "Analysis of distance measurement system of leading vehicle," *Int J Instrum Control Syst,* vol. 2, no. 1, pp. 11–23, 2012.