International Journal
of Applied Information Technology

http://journals.telkomuniversity.ac.id/ijait/

Implementation of Roll Control on Mini Remotely Operated Vehicle

Andi Sugandi [a], Simon Siregar [b, *], Lisda Meisaroh [c]

[a,b,c] *Dept. of Computer Engineering, Telkom University, Indonesia*

andisugandi@student.telkomuniversity.ac.id, simon.siregar@tass.telkomuniversity.ac.id, lisda@tass.telkomuniversity.ac.id

ARTICLE INFO

Received December 12th, 2020
Revised March 19th, 2021
Accepted April 6th, 2021
Available online June 29th, 2021

Keywords
Mini ROV, Control System, Pitch and roll, stabilization, wireless communication.

ABSTRACT

This paper describes the design and manufacture of an underwater explorer robot. The proposed Mini Remotely Operated Vehicle (ROV) is designed to be controlled remotely using a wireless communication module outside the water. ROV stability is needed to support the operation of ROV when do maneuvering in the water. The design of the ROV is aimed to maintain stability using a PID control system. Moreover, the gain PID values, kP gain, kI gain, and kD gain, must be set to perform roll stability. After performing a fine-tuning of the PID gain values, the experiment result shows that the system can maintain an average error of -1.70 degrees.

Acknowledgment

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

Corresponding author at Simon Siregar
School of Applied Science, Telkom University
Jl. Telekomunikasi No. 1, Terusan Buah Batu, Bandung, 40257
Indonesia.
simon.siregar@telkomuniversity.ac.id

ORCID ID:
Second Author: 0000-0003-1399-2670

https://doi.org/10.25124/ijait.v4i02.3437
Paper_reg_number IJAIT000040212 2020

1. Introduction

Most people want to explore the sea, but due to the lack of essential equipment needed to dive in the sea, most people have difficulty exploring. But there is another way that everyone can explore at sea, and even this tool can also be used to find shipwrecks in the depths of the sea, namely the ROV (remotely operated vehicle) robot. The first ROV was created in 1953 by Dimitri Rebikoff under the name POODLE [1]. In the 1990s, it was estimated that more than 100 companies making ROVs and more than 100 operators using 3,000 different ROVs of different sizes and capabilities.

Generally, the operator controls the ROV from a Ground Control Station (GCS) using a joystick or remote control. ROV with certain conditions can stabilize the roll and pitch positions if the ROV has a low enough center of gravity. However, this capability is highly dependent on the design of the ROV. Also, for certain missions, the ROV requires controlling the vehicle to pitch and roll. Several studies show several methods used to control pitch and roll. The methods used include using classical control systems such as proportional-integral-derivative controllers(PID) [2][3], as well as modern control systems such as sliding modes [4], linear quadratic regulators [5], linear quadratic gaussian [6], and fuzzy logic controllers [7]–[9].

In this study, the ROV robot was developed with a stability system of pitch and roll motion. An operator controls this ROV to carry out the assigned mission. To make it easier for operators to work, the ROV is assisted by a pitch and roll control system. With this system, the operator can control the ROV in the desired direction while maintaining the pitch and roll angles. The ROV requires an Inertial Measurement Unit (IMU) sensor and a Gyroscope sensor to maintain the pitch and roll angles. Then, a microcontroller will process the angle information using the PID method and produce pulse-width modulation (PWM) values for the four motors that control the pitch and roll direction.

Furthermore, the microcontroller will send pitch and roll angle information to the operator via a communication module. This research aims to make a mini ROV prototype with the ability to maintain stability in the pitch and roll directions. Moreover, the design can send pitch and roll information to operators. This paper consists of: Section 2 describes the proposed design of the mini ROV prototype. Moreover, Section 3 presents the experimental results of the ROV motion in roll and pitch directions. And the last section summarizes the conclusions of this paper.

2. Design

Figure 1 shows a block diagram of this mini ROV prototype. This design consists of two subsystems that communicate with two wireless communication modules. The first type of communication is using the 2.4 GHz frequency. The operator uses this frequency to send input to the vehicle's movement direction. Then, the other type of communication is using the 433 MHz frequency. We provide this frequency to send pitch and roll position information to the operator. The mini ROV subsystem consists of two sensors: an IMU and a Gyroscope, six motors, a remote-control receiver, an APC 220 transceiver, and an Arduino Nano-based microcontroller. These sensors produce velocity and position measurements of roll and pitch. With this information, this paper used an Arduino Nano to process the information from the sensor. This process yields a PWM value for each motor. The control system will control the PWM values for four vertical motor thrusters (pitch direction and roll direction). Also, the Arduino Nano manages to forward the pitch and roll position information to the operator via the APC220 transceiver. The Ground Control Station subsystem consists of an APC220, a monitor, and a remote control transmitter. The operator will provide direction through the Remote-Control transmitter and monitor the pitch and roll direction through the monitor connected to the APC220 transceiver.

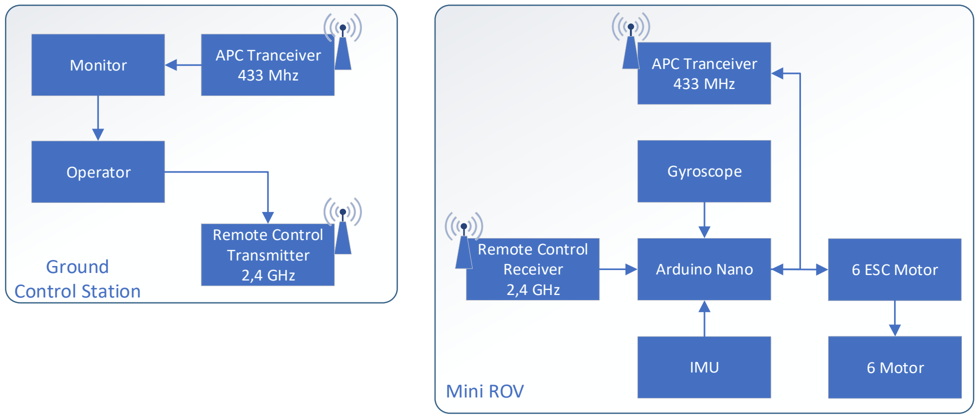

Figure 1 Proposed Block Diagram System

Figure 2 shows the design of the mini ROV prototype. This design shows four motor thruster are directed towards the vertical axis to control roll motion, pitch motion, and heave motion. The other two thrusters are positioned horizontally to control the mini ROV's surge and yaw movements. Thus, the total degrees of freedom of the mini ROV is five.

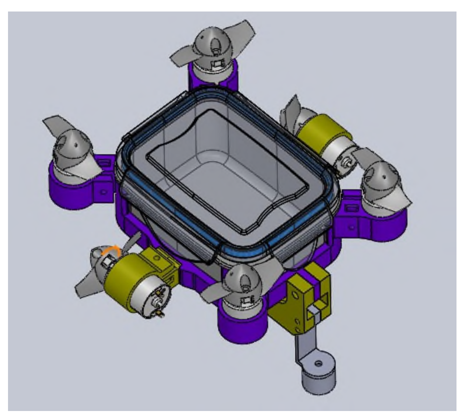

Figure 2 Rendered Result of The Proposed Mini ROV

2.1. Control system

A roll and pitch control system is a controller to determine the roll and pitch position with feedback on the system. One method of the controller is using proportional–integral–derivative (PID) controllers. PID controller is commonly used in the industrial world. Then the PID controller will act based on the error value obtained. Several PID controls must be known; namely, control P, control I, and control D.

The block diagram and the flowchart in

Figure 3 show the PID control system process, sensor input (gyroscope sensor and IMU sensor). The system receives data from the APC220 and gyroscope sensor then the Arduino nano will process the information from each component. For example, the APC 220 data will be set as the setpoint of roll and pitch position, while the gyroscope sensor data will provide the current position of roll and pitch position.

The PID control system operates to define the value of Pulse Width Modulation (PWM) of each motor and send it to the ESC (Electronic Speed Control). This process will be repeated until the system is relatively equal to the setpoints.

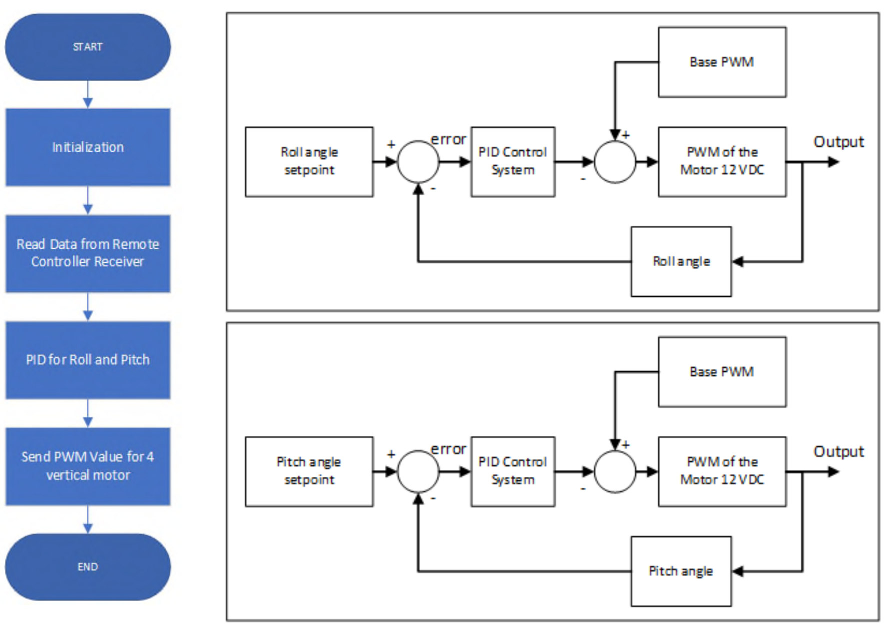

Figure 3 PID Control System Flowchart and Block Diagram

2.2. Telemetry Communication System

The telemetry communication system is a technology that is useful for remote control and monitoring to the operator. This system requires instructions or information sent from the operator to mini ROV and vice versa.

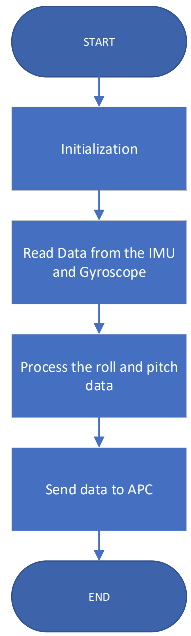

Figure 4 Telemetry Flowchart System

Figure 4 is a flow chart process for how the telemetry works with Arduino nano as a data sender to APC220. In this design, the APC220 communication module [10] is chosen as the telemetry communication to perform semi-duplex transceiver communication. Besides, this module can carry out laying data in the form of a digital serial as a carrier of a higher frequency to be emitted into the air. In the initialization process, the receiver receives telemetry data from APC220. Arduino Nano processes the data to check whether the received data is not corrupted and will be used as the setpoint. If the data is corrupted, the Arduino nano will discard the data and wait for more incoming data. The Arduino nano uses the setpoint and the sensor data from the IMU sensor and the Gyroscope sensor to give PWM value to the ESC (Electronic Speed Control) to operate the actuator (thruster motor). The PID process is used to produce PMW values. Moreover, the system will send roll dan pitch data to the APC220 module while sending the ESC value.

3. Experiment and Results

The experiment is conducted to test the ability of the system to control pitch and roll. The scenario of the experiment is limited only to measure the roll position of the vehicle. Figure 5 shows the experiment results for the proposed system to monitor the received and the transmitted data. The first line shows the data from the APC220 module, and the second line shows the PID process value for each actuator. The third line is used to give delay between the process.

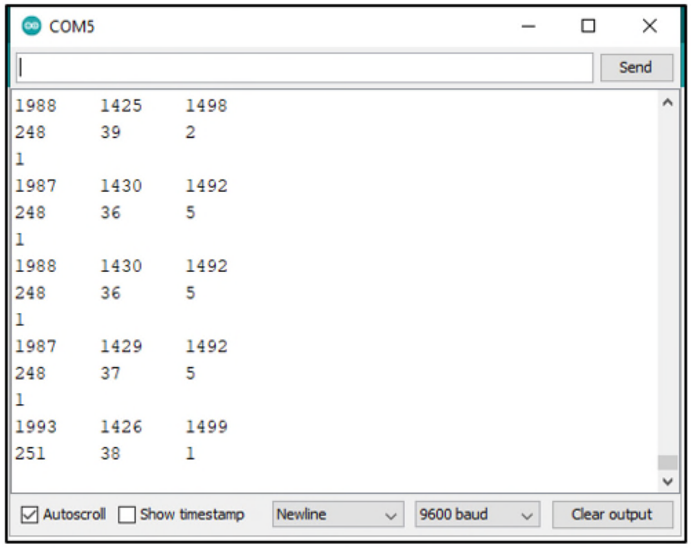

Figure 5 Received Data from APC 220

The values for each PID gain (proportional gain kP, integrative gain kI, and derivative gain kD) are shown in Table 1. These PID gains are obtained by using fine-tuning methods.

Table 1 Table of PID Controller Value

Motor	kP	kI	kD
1	3.055	0.003	2.05
2	3.055	0.003	2.05

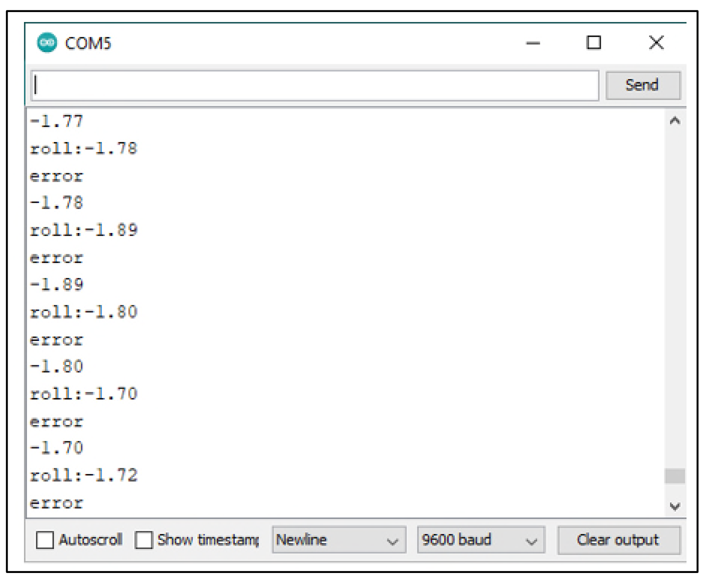

Figure 6 Error Measurement for Roll Angle

Figure 6 shows the error value generated from the PID system. The error value of the roll position is measured in degree. From Figure 7, the experiment shows the average error value for roll position is -1.70 degrees from the setpoint of 0 degrees. This information means that the system can stabilize in the roll direction of the proposed mini ROV.

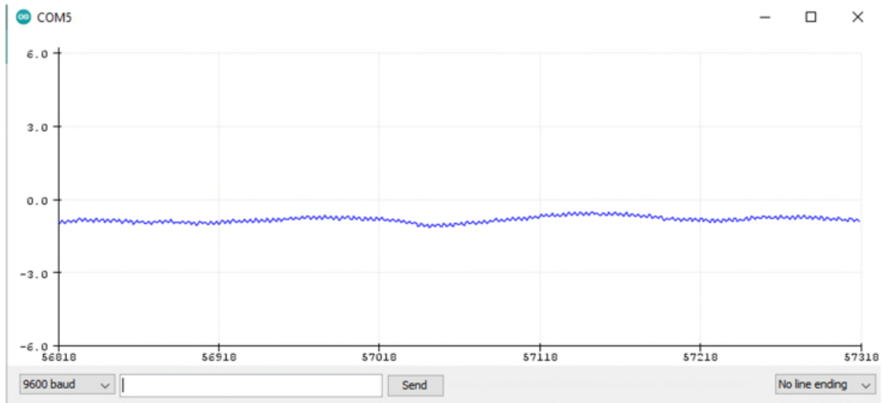

Figure 7 Experiment Result of The Average Roll Position Error

4. Conclusions

From the result of the experiments, this research shows a mini ROV prototype to maintain stability in roll and pitch. The system ability can maintain an average error of -1.70 degrees. Moreover, the average error and the system's response can be improved by adjusting and tuning the gain value of the PID control system.

Bibliography

[1] E. Ataner, B. Özdeş, G. Öztürk, T. Y. C. Çelik, A. Durdu, and H. Terzioğlu, “Design of Communication and Power Systems in Unmanned Underwater Vehicles,” *Eur. J. Sci. Technol.*, no. September, pp. 262–267, 2020.

[2] O. A. Aguirre-Castro *et al.*, "Design and construction of a rov for underwater exploration," *Sensors (Switzerland)*, vol. 19, no. 24, pp. 1–25, 2019.

[3] S. Siregar, M. I. Sani, S. T. P. Silalahi, and R. Febriansyah, "A Blue Robotic Sensor for Tech-SAS v1 ROV Depth Controller," *ICSECC 2019 - Int. Conf. Sustain. Eng. Creat. Comput. New Idea, New Innov. Proc.*, pp. 386–390, 2019.

[4] M. Chitre, "Depth control of an autonomous underwater vehicle, STARFISH," *Ocean. Ieee Sydney*, pp. 1–6, 2010.

[5] R. D. S. Tchilian, E. Rafikova, S. A. Gafurov, and M. Rafikov, "Optimal Control of an Underwater Glider Vehicle," in *Procedia Engineering*, 2017, vol. 176.

[6] M. W. S. Laua, E. Lowa, and G. G. L. Seeta, "Dynamic Modelling and Cascaded Controller Design Of A Low-Speed Maneuvering ROV Cheng Siong Chin," no. June 2014, pp. 1–36, 2006.

[7] A. Nag, S. S. Patel, and S. A. Akbar, "Fuzzy Logic Based Depth Control of an Autonomous Underwater Vehicle," *Int. Multi-Conference Autom. Comput. Commun. Control Compress. Sens. (iMac4s), 2013*, pp. 117–123, 2013.

[8] T. Wang, Q. Dang, and P. Pan, "A Predict-Fuzzy logic communication approach for multi robotic cooperation and competition," *J. Commun.*, vol. 6, no. 3, pp. 225–231, 2011.

[9] P. Saranguhewa, S. Lakmal, R. Lakmali, N. Gunawickrama, and S. Jayasundere, "Fuzzy Logic Based Motion Controller For Underwater Remotely Operated Vehicle," 2016.

[10] Appcon Technology, "APC Series Transparent Transceiver Module APC220-43," 2008.