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The Development of ROV (Remotely Operated Vehicle) by Applying PID (Proportional Integral Derivative) for Monitoring and Preservation of Coral Reefs at Pasir Putih Beach Situbondo

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Abstract

The necessity for the monitoring of coral reefs is becoming increasingly apparent, in order to facilitate the tracking of the health and development of these ecosystems. It is for this reason that underwater operating robots (ROVs) are being employed as an effective tool for the monitoring of coral reefs. ROVs are capable of diving to varying depths, accessing difficult-to-reach locations, and providing comprehensive visualisation through cameras and sensors. They are also equipped with an ROV depth system that, upon reaching a specified depth, enables the ROV to manoeuvre according to the user's instructions and to support its movements using the PID (Proportional Integral Derivative) Method. This research will investigate the potential of various ROV technologies for optimising the monitoring of coral reefs, including mapping, sampling, and environmental parameter measurement capabilities. The ability of ROVs to collect data in real-time without disturbing the ecosystem provides an advantage in long-term monitoring of changes in coral reefs. Furthermore, the potential challenges associated with the utilisation of ROVs for coral reef monitoring, including operational costs, technical maintenance, and the integration of complex data, are also addressed. Potential solutions to these challenges are also presented in order to facilitate the development and application of ROVs in coral reef monitoring. The combination of the advanced technology of ROVs with the urgent need for coral reef monitoring will facilitate a more comprehensive understanding of the health of these ecosystems, thereby enabling the implementation of proactive measures for the conservation and protection of coral reefs worldwide.

Keywords: ROV, Coral Reef, Technology, PID Method, Conservation.

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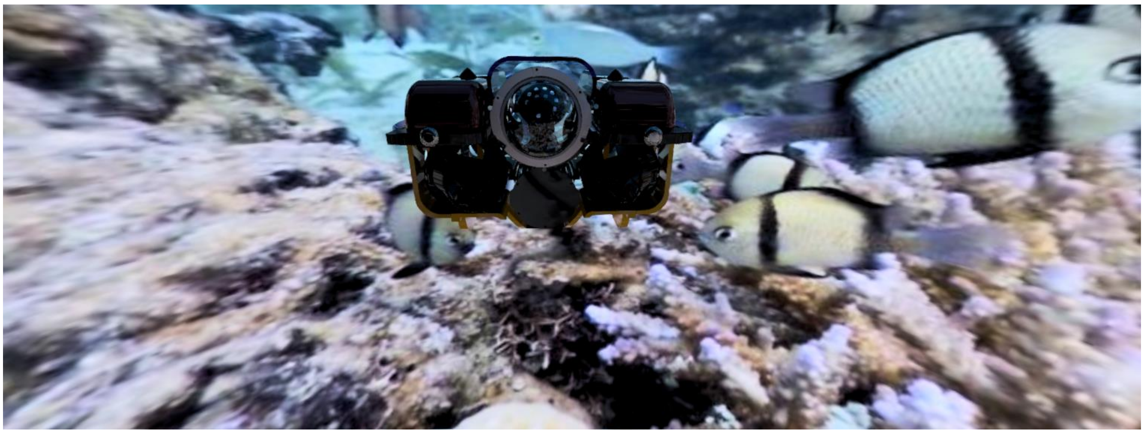
INTRODUCTION

Indonesia is characterised by a high proportion of coastal territory, amounting to 70% of the total land area. The country is endowed with a considerable underwater wealth, including extensive coral reef ecosystems. The government is engaged in the active cultivation of marine coral reefs with the objective of preserving these ecosystems. One of the locations is Situbondo White Sand Tourism Beach, which has been designated as a marine coral cultivation zone. The process of cultivating coral reefs is a complex one, comprising a number of distinct stages. These include the identification of an appropriate location, the selection of seeds, the planting of the seeds, and the subsequent monitoring of the seeds. One of the most popular tourist destinations in East Java is Situbondo White Sand Tourism Beach, situated approximately 23 km west of Situbondo. The beach is renowned for its gently sloping, white sandy beaches. The current status of the coral reefs at Pasir Putih Situbondo, which range from 23 to 49 per cent, represents a significant threat to fish species that rely heavily on these ecosystems. Pasir Putih Beach comprises four coral reef sites, two of which are in good condition and two in fair condition, with two reefs at each site. It is essential to conduct regular monitoring of the condition of the reefs in order to maintain their health and quality (Budianto & Suhardjito, 2017). Algae represents a significant impediment to successful transplantation, increasing the likelihood of disease development, including Black Band Disease, which was identified in the coral transplants at Situbondo's White Sand Beach. To date, divers have employed conventional monitoring techniques, namely direct observation on site, to assess the condition of coral reefs.

Figure 1 Design of ROV BIMA to Coral reefs monitoring



This method has a significant impact on divers' respiratory health, weather variability, and the risk of wild animal attacks. Furthermore, the duration of the dive is constrained, necessitating the allocation of several days or weeks to the monitoring of each reef site. It is therefore imperative that a solution to this problem is found. Politeknik Perkapalan Negeri Surabaya (PPNS) offers a technological solution. PPNS has developed an ROV system to address the issues encountered at Pasir Putih Situbondo Tourism Beach, particularly with regard to the monitoring of the coral reef ecosystem. To date, the utilisation of ROVs as a monitoring tool for coral reefs remains a relatively uncommon practice within the community, particularly among those engaged in coral reef farming. It can be reasonably deduced that this innovation may prove to be a more useful one in the future. In a previous study, a prototype ROV (Ship-RUV) was subjected to a series of tests to assess its suitability for hull inspection (Budianto, et al., 2023) (Budianto, et al., 2019). Furthermore, the Ship-RUV is capable of operating underwater and is the subject of a copyright. In the applied research phase, the Ship-RUV was transformed into the Ramona (ROV for Underwater Surveillance System), which successfully completed the function test stage. One of the next stages of ROV development is the creation of ROWAMBA, an underwater monitoring tool designed for use in tourist attractions in Bangsring Underwater Banyuwangi. The ROWAMBA ROV has demonstrated an exceptional capacity for capturing and recording real-time images and videos in authentic environmental contexts. Additionally, the research team developed and rectified any errors identified during the testing phase. One of the proposed innovations for the 2024 BIMA activities is the utilisation of remotely operated vehicles (ROVs) for the monitoring of coral reefs. This will supersede the practice of diving to track coral reefs on the seafloor (Rahmat, et al., 2020).

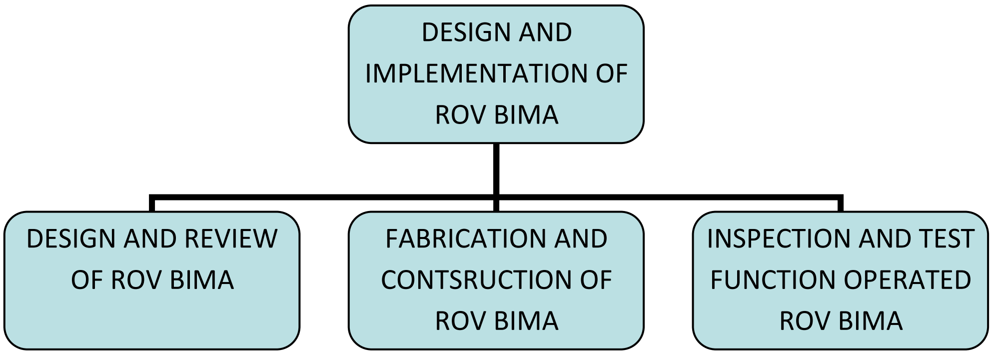
A remotely operated vehicle (ROV) is an underwater vehicle that is commonly used to monitor underwater conditions due to its ability to be controlled from a land-based location (Rahmat, et al., 2021). However, a limitation of previously developed ROVs is the monitoring process utilising permanently installed cameras, which results in less flexibility in image capture. One of the innovations produced is a system that tracks the condition of coral reefs using a monitoring camera that is capable of movement in four directions: right, left, up, and down (Karyono, 2018) (Sidi, 2018). The camera can be controlled via a joystick, thereby providing visual information about the condition of the coral reef, which is then relayed directly to the monitoring computer for further observation. Furthermore, as part of the development process, the ROV is equipped with a depth control system to prevent damage to the coral reefs due to the varying underwater depth contours of Pasir Putih. It is anticipated that the utilisation of ROVs for the monitoring of coral reefs in Pasir Putih, Situbondo, will prove an effective solution to the challenges currently faced by coral reef conservationists. The utilisation of remotely operated vehicles (ROVs) facilitates the monitoring of coral reefs in a more efficient and secure manner. This is due to the fact that the vehicles can be operated from a distance, either from the shore or from a vessel, if necessary to access areas that are otherwise inaccessible. Furthermore, the deployment of divers allows for the expeditious monitoring of coral reefs. Furthermore, the utilisation of ROVs enables the comprehensive processing of images obtained from underwater, facilitating the identification of objects and the classification of coral reef types for research and conservation purposes. However, a limitation of previously developed ROVs is that the surveillance process utilises permanently mounted cameras, which constrains the flexibility of image capture. One of the innovations produced is a system that tracks the condition of coral reefs using a monitoring camera that is capable of movement in four directions. The book is operated via a joystick, enabling the user to control the cameras and thereby obtain visual data regarding the condition of the reef. This information is then transmitted directly to the monitoring computer for further observation. Furthermore, as part of the development process, the ROV is equipped with a depth control mechanism. It is anticipated that the utilisation of an ROV to monitor the coral reefs in Pasir Putih Situbondo will facilitate the resolution of the challenges faced by those engaged in the conservation of coral reefs. The utilisation of ROVs facilitates the monitoring of coral reefs in a more straightforward and secure manner, as they can be operated from a distance and from land and sea, should access to inaccessible locations be required. Furthermore, the utilisation of divers permits a more prudent monitoring of coral reefs. Furthermore, the utilisation of ROVs enables comprehensive image processing of underwater environments, facilitating the identification and classification of coral objects for research and conservation purposes.

The PPNS research team engaged in a collaborative endeavour with Pokmaswas Karang Lestari of Situbondo District in the course of this research project. The objective of this collaboration was to identify novel solutions to the challenges associated with the coral reef monitoring system, which plays a pivotal role in the growth of the tourism and fisheries sectors in Situbondo District. The safety of divers is a concern for the partners, particularly in relation to the viewing of coral reefs. This area of Pasir Putih Beach represents one of the most significant threats to the existing coral reefs along the northern coast of Java, due to a range of underlying factors. Given the vital importance of coral reef ecosystems, it is imperative to implement measures to ensure their preservation, thereby facilitating an increase in fish population within these ecosystems. The research team and partners have agreed to develop ROV BIMA, an iteration of ROV ROWAMBA that prioritises the image and video quality of underwater objects. The designation "ROV BIMA" is derived from a combination of the names of the research team, comprising "Budi, Imam, Mbs, Arti," which were then consolidated into a single designation. Furthermore, the BIMA ROV is equipped with an ROV depth control system, which enables the ROV to manoeuvre according to the user's preferences when reaching a certain depth. Furthermore, the control system is designed to prevent the ROV from colliding with coral reefs during movement. This is achieved through the utilisation of the PID (Proportional Integral Derivative) Method, which plays a pivotal role in the development of ROV BIMA. Furthermore, the ROV BIMA represents an enhancement over the limitations observed in the preceding prototype testing. Previous ROVs have exhibited deficiencies, including the fixed camera's inability to rotate in accordance with the user's expectations due to its position. Furthermore, a depth control system was absent, thereby failing to prevent the ROV from colliding with submerged coral reefs during downward motion. Consequently, the BIMA ROV boasts a number of superior features, the first of which is a camera that can be rotated at the user's discretion, adjustable lighting when taking pictures and being manoeuvred.

METHOD

In this research project, the PPNS research team collaborated with Pokmaswas Karang Lestari Situbondo Regency with the objective of developing innovative solutions to the issue of monitoring coral reefs, which are of significant value in the advancement of the tourism and fisheries industries in the Situbondo area. The issue faced by the partner is the restricted scope of diver monitoring of coral reefs, coupled with the inherent risks to diver safety. ROV BIMA represents a consensus solution between the research team and partners. It is a development of ROV ROWAMBA, which focuses on the quality of underwater object images and videos. The creation of the research method must be in accordance with the planned flow chart (Wijaya, 2024) (Hasriati Nasution, 2023) (Wawan Wawan, 2023) (Susanto, 2023) (Riska Yanti, 2024) (Thathit Suprayogi, 2024). The ROV BIMA incorporates several enhancements from the ROV ROWAMBA, as illustrated in the research flow diagram below.

Figure 2 Flowchart design and implementation ROV BIMA



The research flowchart is explained as follows:

- Designing a simulation of the tool to be made, then buying tools and materials. If the simulation has been carried out, then the next is the manufacture of ROV. Making ROVs starts from making mechanical and then electrical programmes.
- Adding a depth control system to the ROV aims at reaching a certain depth when the ROV can manoeuvre according to the user's wishes. This control system also aims to prevent the ROV from crashing into coral reefs while moving. This addition uses the following PID (Proportional Integral Derivative). The PID controller is a widely utilised control method, largely due to its straightforward structure and reliable functionality (Li, 2006). A PID controller is a control system based on the principle of feedback control, which is used to regulate a system or process in order to achieve a desired

target or setpoint. a research will produce outputs that can be determined by each of its outputs (Salsabila Thifal Nabil Haq, 2024),(Caesar Adlu Hakim, 2024),(Moh Zainul Falah, 2024), (Rahimah Rahimah, 2021), (Erlinawati Erlinawati, 2021), (Heri Cahyono, 2021). The term PID, which stands for Proportional-Integral-Derivative, refers to the three main components used in this controller. The transfer function of the PID controller can be expressed as follows:

$$G_{PID}(s) = K \left(1 + \frac{1}{T_1}\right) + T_D \quad (1)$$

Where,

K	=	Proportional Gain
$T1$	=	Integral Time Constant
Td	=	Derivative Time Constant

In this context, Kp represents the proportional gain, Ki the integral gain, Kd the derivative gain, Ti the integral time constant and Td the derivative time constant.

1. Proportional control provides an overall control action that is proportional to the error signal through an all-pass gain factor.
2. Integral with low-frequency compensation by an integrator to reduce steady-state error.
3. The incorporation of a differentiator enhances the transient response through the implementation of high-frequency compensation.

PID control necessitates the presence of a constant multiplier, referred to as the gain. The significance of this constant in PID control is that it enables the system to respond in accordance with the specified control. Two methods are employed to ascertain the parameter values (Kp, Ki, and Kd) in PID, each with its own set of advantages and disadvantages. The first method is the manual tuning method, which involves initially raising the constant P in order to achieve a rapid response, followed by the addition of constants I and D to attain a stable system response. The second method is autotuning, which refers to a process of automatically identifying the optimal values for the proportional, integral, and derivative parameters for a given control system.

Depth testing was carried out using the method of measuring air pressure in a tube, which was measured in units of Pascal (Pa). If during this time the air pressure value does not decrease, the tube is considered watertight or waterproof. The formula commonly used to calculate the leakage rate in ROV tube impermeability testing is as follows:

$$\text{Leakage Rate } (Lr) = (P_f - P_l) : t \quad (2)$$

Where,

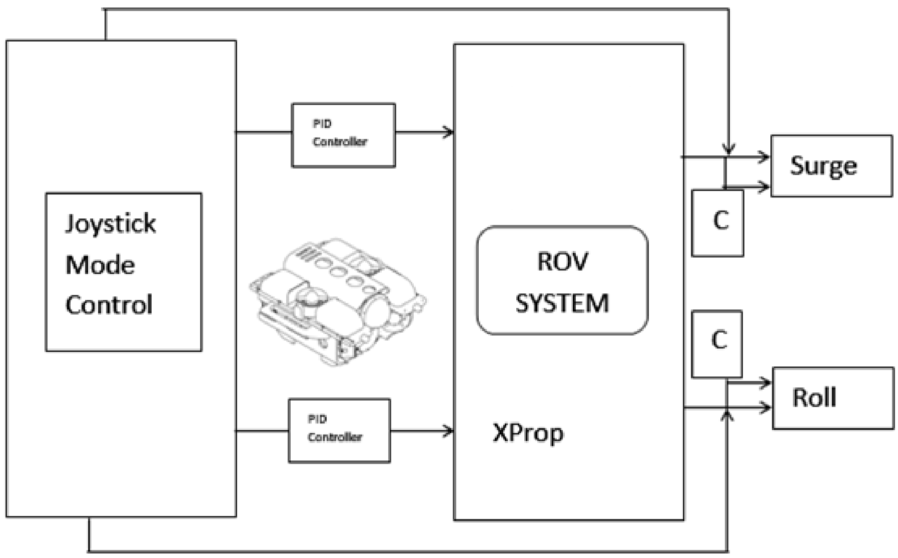
Lr	=	Leakage Rate	(inHg/s)
P_f	=	fisrt tube pressure	(inHg)
P_l	=	final tube pressure	(inHg)
t	=	test time	(s)

The objective of enhancing the camera and lighting on the ROV is to facilitate the rotation of the camera and light to the position desired by the user. In the ROV ROWAMBA, the camera remains fixed in one position; in contrast, the ROV BIMA is designed with the capability for the camera and light to move according to the user's desired orientation. Once the camera and lighting have been installed, a series of tests will be conducted to ascertain the extent to which the apparatus can be moved in accordance with the user's preferences. In the testing phase, the joystick is employed as an input device, with a cursor that can be controlled for the purpose of ROV movement (Budianto, et al., 2021). The testing of the joystick is based on two indicators: the performance of the individual features and the connection of the signal. This may be achieved by the creation of a program within the Arduino Integrated Development Environment (IDE) for the reading of input data from the joystick, followed by the uploading of the program to the Arduino board. Once the program has been uploaded, the serial monitor in the Arduino IDE can be utilised to view the input data from the joystick. Functional testing can then be conducted by attempting to move the joystick in a range of directions. The Arduino IDE facilitates the assurance that the joystick device is functioning correctly and providing precise input data through the implementation of joystick testing. The objective of the test data is to ascertain whether the tool is functioning correctly.

RESULT AND DISCUSSION

The PID (proportional-integral-derivative) control system on the BIMA ROV has been designed with the objective of ensuring reliable stability, position and speed control during deep-sea operations. The system employs thruster motors and actuators that are controlled in real time to maintain a stable orientation and to counteract the influence of ocean currents. The proportional component (P) generates a corrective response proportional to the ROV's position or orientation error in relation to the desired target, thereby enabling the ROV to respond expeditiously to positional alterations. The proportional value is set based on the constant Kp, which ensures that the ROV moves rapidly towards the target point without triggering excessive oscillations. This component is of significant importance in maintaining an immediate response to sudden shifts that may be caused by currents or unexpected movements, as well as in maintaining stability while manoeuvring underwater.

Figure 3 PID result of ROV BIMA



The integral component (I) is employed in the BIMA ROV PID system to address persistent errors and incorporate correction signals based on the accumulated errors over time. In the underwater environment, ocean currents are often slow but consistent, which means that minor positional discrepancies can accumulate and result in significant positional deviations if they are not addressed. The Ki factor, a constant in the integral component, serves to augment the correction of minor errors that persist over an extended duration. Consequently, the PID system facilitates the elimination of static errors (Budianto, 2022). This is particularly pertinent for ROVs operating at a depth of 500 metres, where alterations in current can influence position over an extended period. By establishing an appropriate integral value, the ROV is capable of maintaining a stable position without experiencing excessive deviation.The derivative component (D) in PID plays a crucial role in preventing oscillatory or sudden changes in motion by providing vital correction predictions. In the event of varying currents, the component is capable of detecting changes in position error velocity and accelerating the correction response by accounting for the trend of position or orientation shifts. The value of Kd is set so that the ROV is able to move smoothly and accurately without compromising positional precision. The use of this derivative component is crucial for maintaining the direction (yaw), depth, and orientation (pitch and roll) of the ROV in fluctuating marine conditions. The application of appropriate Kp, Ki, and Kd parameters through tuning methods such as Ziegler-Nichols enables the ROV BIMA to maintain responsive, stable, and energy-efficient control, which is essential for enhancing operational durability in deep-sea environments.

CONCLUSION

In conclusion, the implementation of a PID control system on ROV BIMA proved effective in improving stability, positioning precision, and control response in the challenging deep-sea environment. By employing proportional control to accommodate rapid positional shifts, integral control to eliminate static errors, and derivative control to prevent excessive oscillations, ROV BIMA is capable of maintaining a stable position and maneuvering in a responsive manner despite the presence of ocean currents and sudden changes in conditions. It is also essential to optimise the Kp, Ki, and Kd parameters through tuning methods in order to ensure a balanced performance between fast response and stability in underwater conditions. The PID system on the BIMA ROV makes a substantial contribution to the efficiency of the operation, assisting in the conservation of energy and the reduction of the load on the thruster motor. This is of particular importance for the durability and endurance of the tool at depths of up to 500 metres. Therefore, the implementation of a PID control system not only enhances the longevity and operational efficacy of the ROV in the deep-sea environment, but also optimises the overall reliability of the system, thereby contributing to the success of the underwater exploration mission.

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