N3-AUV (Nusantara 3-Autonomous Underwater Vehicle): design and implementation for underwater exploration

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Abstract. Autonomous Underwater Vehicle (AUV) is a type of underwater robot that can move and perform pre-assigned the missions based on a program which is installed in the microprocessor in the body of the vehicle. AUV uses thrusters to maneuver underwater and may be supported by a compass, various sensors, and a camera that are attached to the vehicle. In this paper, we present the development of N3-AUV and a pool test of this performance. N3-AUV uses 8 thrusters, 2 webcam cameras, Raspberry Pi, a depth sensor, and a compass. The vehicle has a torpedo-like shape so that it is easier to move underwater relatively faster. With 2 webcam cameras, where the first one is placed under the frame to record images of the conditions beneath the vehicle and the second one is placed in front of the frame to record the conditions in front of the vehicle. A pool test was conducted by means of pre-assigning missions, such as navigating pass the goal post, and finding and knocking down an underwater object. N3-AUV can complete three mission out of four. Missions that have been carried out successfully are navigation, acquisition, and localization. N3-AUV has a maximum speed of about 1 m/s.

1. Introduction

Indonesia is the largest maritime country in the world with a water area of about 5.8 km² or about 1.3 % of the total water area in the world. Indonesia is an archipelago that is spread from Sabang to Merauke. As a maritime country, Indonesia should have the independence of science and technology in order to become the world maritime axis. The Marine technology that is being developed is an Autonomous Underwater Vehicle (AUV) that operates underwater. AUV is an unmanned underwater vehicle that has many uses [1][2]. The development of AUV is done to demonstrate the ability of Indonesian people for the innovation of marine robotics. AUV moved according to the program and then use array from marine acoustic flare [3], or combination from acoustic information like acoustic Ultra Short Base Line, GPS positioning, and inertial navigation [4].

Generally, AUV has a torpedo-like shape, moving with a propulsion system in water, where it is controlled and maneuvered with a motion of six Degrees of Freedom (DOF) by the computer on board [5][6]. AUV can be added by several sensors like ADCP (Acoustic Doppler Current Profiler), CTD, Echo sounder, side-scan sonar, and cameras. AUV has been used for underwater exploration. The first AUV that used for underwater exploration is IFREMER L’Epaulard AUV that mapped deep-sea Mangan (Mn) compounds [7]. But, one of publication about underwater exploration firstly use the AUV is WHOI AUV ABE in Juan de Fuca Ridge (1995-1996). Some of AUV is used to detect underwater volcanic mount, it is MARUM Seal 5000 AUV [8], and JAMSTEC Urashima AUV uses for map the
hydrothermal vent Iheya-North Okinawa [9]. And then, REMUS AUV is used for map seagrass in Juan de Fuca, North America [10]. Until now, there were several AUVs used in underwater exploration, for example, is NERC Autosub6000, MBARI D. Allan B., WHOI Autonomous Benthic Explorer ABE, MARUM Seal 5000, IFM-GEOMAR ABYSS, Ifremer AsterX, JAMSTEC AUV Urashima, and ACFR AUV Sirius.

Autonomous Underwater Vehicle (AUV), named N3-AUV, is a robot that is able to observe an object or any process underwater. N3-AUV is operated wirelessly and its movement is powered by a battery. AUV is one type of underwater robot that can be used in underwater exploration and the military system [6]. Like any other autonomous vehicle, N3-AUV can be programmed and have a sensor and manipulator that is placed on the N3-AUV, so it can do the assigned mission. N3-AUV is a development from N2-AUV with various changes from the latter. The vehicle has a torpedo-like shape, so that it is easier to move underwater relatively faster, at 1 m/s. Development and innovation of underwater robotics necessary for technological independent especially marine technology. And make underwater exploration easier.

2. Methods
Designing and manufacturing has been carried out from August 2018 until March 2019, in the Marine Instrumentation Laboratory, Faculty of Fisheries and Marine Science, IPB University. Table 1 show material of this research.

| No. | Item's name             | Type                        | Total |
|-----|-------------------------|-----------------------------|-------|
| 1.  | Micro PC                | Raspberry Pi 3              | 1     |
| 2.  | Microcontroller         | Arduino Mega 2560           | 1     |
| 3.  | Camera USB              | Logitech 729p               | 2     |
| 4.  | LCD +Driver I2C         | 16X2                        | 1     |
| 5.  | Depth Sensor            | Bar 50 sensor – R1          | 1     |
| 6.  | Servo Motor Underwater  | Tower pro                   | 3     |
| 7.  | Thruster                 | T200 Blue Robotics          | 8     |
| 8.  | ESC                      | Blue Robotics               | 8     |
| 9.  | Battery Lithium Polymer | 4 Sed 5200 mAh              | 2     |
| 10. | 16 DOF                  | Gy-88                       | 1     |
| 11. | UBEC                    | 3A 5V                       | 2     |
| 12. | Acrylic                 |                             |       |
| 13. | Polyethylene            |                             |       |
| 14. | Switch                  |                             |       |
| 15. | Other supporting tools  |                             |       |

Figure 1. Front-view of the gate.
2.1. Design of N3-AUV
N3-AUV is (57x51x30) cm in size and has a torpedo-like shape. The frame is made of polyethylene and the pressure hull, shaped like a tube, is made of acrylic. The pressure hull functions as a place for electronic components. Eight thrusters are used, where the two thrusters placed in the middle are used to move forward, and four thrusters placed in every corner are used to move up and down, while two thrusters placed in the front and back are used to turn left and right. When designing the AUV it must be considered that there is no leak in the pressure hull of AUV. Design of N3-AUV follows the concept of hydrodynamic in order to make sure the AUV could move easier [1].
2.2. Electronic system design
The electronic device mainly consists of a power supply from the battery, raspberry Pi 3 as micro PC, Arduino Mega 2560 as a microcontroller, LCD 16x2 in size for display, GY-88 to retrieve data of the compass, a depth sensor to stabilize the AUV underwater, and two webcam cameras, where the first is placed under the frame to record images of the condition beneath the vehicle and the second one is placed in front of the frame to record the condition in front of the vehicle.

2.3. Software design
Software design includes making the program flows using Arduino and Python. The program that is made must be corresponding with the mission. The program for object detection uses color detection from the CV2 module.

3. Results and discussion
Navigation system firstly used for the military in America to carry the Polaris nuclear missile [11]. Now, the navigation system has become widely used, like for map-making, land survey, scientific, hobbies, and many more [12]. Land navigation cannot be applied for underwater navigation, because underwater cannot transmit the compass modules signal to surface. The AUV needs navigation system so its location could be known [12]. Navigation and localization are challenging for AUV because of the rapid attenuation from the higher frequency signal and
unstructured of the underwater environment [13].

![N3-AUV](image1)

**Figure 7.** N3-AUV.

### 3.1. Navigation
The goal of this mission is to swim through a specific place at the bottom of the pool. N3-AUV has to swim through the 150 cm high gate without touching the gate. The gate was used to make sure the AUV has accurate navigation system that was placed parallel to the side of the swimming pool, approximately 12 m away from the starting point. See figure 8.

![N3-AUV](image2)

**Figure 8.** N3-AUV has successfully swim through the gate.

### 3.2. Target acquisition
The goal of this mission is to detect and acquire a target among the series of drums at the bottom of the pool in the target zone. The target zone is defined by a green-colored mat laid out on the floor of the pool. There are 3 colored drums in the arena, where all of them are placed on the mat. One of the drums, chosen at random, will be blue in color. While the rest are red in color. The AUV needs to drop a ball in one of the drums to successfully complete the task. N3-AUV has successfully drop the ball into one of the red drums, because red is easier to be detected underwater. While blue drum is harder to be detected since its color are similar with water environment. See figure 9.
Figure 9. N3-AUV has successfully dropped a ball in the red drum.

3.3. Localization
The goal of this mission is to locate a yellow flare. This flare could be located anywhere within the pool. The AUV should locate and bump into a flare causing the ball on the flare to drop out. The flare is yellow in color. See figure 10.

Figure 10. N3-AUV successfully located and bumped into a flare.

If N3-AUV is compared with previous series ~N2-AUV~, N3-AUV better than N2-AUV in underwater movement. N3-AUV’s movement is faster than N2-AUV. Because, N3-AUV has a torpedo-like shape so that it is easier to move underwater relatively faster. N3-AUV can move based on Six Degrees of Freedom (DOF), that means the AUV can change position with three translation movement, namely: forward/backward (surge- X axis), left/right (sway-Y axis), and up/down (heave- Z axis). And can change position with three rotation: Yaw, pitch, and roll.

4. Conclusion
The N3-AUV has average speed of about 0.5 m/s and a maximum speed of about 1 m/s. Pressure hull of N3-AUV has a torpedo-like shape in order to move easier underwater. Missions that have been carried out successfully are navigation, target acquisition, and localization. N3-AUV can move based on Six Degrees of Freedom (DOF) that means the AUV can change position with three translation: forward/backward, left/right, and up/down. And can change position with three rotation: Yaw, pitch, and roll.
5. References

[1] Izhar M I 2012 *Development of autonomous underwater vehicle* (Malaysia: Faculty of Electrical Engineering University Malaysia Pahang)

[2] Herlambang T, Nurhadi A and Tjadmioko E B 2016 Optimasi model linear6-DOF pada sistem Autonomous Underwater Vehicle *Seminar Nasional Maritim, Sains, dan Teknologi terapan* 1 69-74

[3] Jakuba M V, Roman C N, Singh H, Murphy C, Kunz C, Willis C, Sato T and Sohn R A 2008 Long- baseline acoustic navigation for under-ice autonomous underwater vehicle operations *Journal of Field Robotics* 25 861-879

[4] McPhail S 2009 AutoSub6000: a deep diving long range AUV *Journal of Bionic Engineering* 6 55-62

[5] Manik H M, Syakti A D, Jaya J V, Apdillah D, Solikin S, Dwinovantyo A, Fajaryanti R, Siahaan BO and Sanubari M 2017 Autonomous underwater vehicle untuk survei dan pemantauan laut *Jurnal Rekayasa Elekrika* 13 27-34

[6] Herlambang T 2017 Desain system kendali gerak surge, sway dan yaw pada autonomous underwater vehicle dengan metode sliding mode control (SMC) *J. Maths.* 14 53-60

[7] Galerne E 1983 Epaulard ROV used in NOAA polymetallic sulfide research *Sea Technology* 24 40-42

[8] Marcon Y, Sahling H, Borowski C, Ferreira C, Thal J and Bohrmann G 2013 Megafaunal distribution and assessment of total methane and sulfide consumption by mussel beds at Menez Gwen hydrothermal vent, based on geo-referenced photo-mosaics *Deep-Sea Research Part I* 75 93-109

[9] Kumagai H, Tsukioka S, Yamamoto H, Tsuji T, Shitashima K, Asada M, Yamamoto F and Kinoshita M 2010 Hydrothermal plumes imaged by high-resolution side scan sonar on a cruising AUV, Urashima *Geochemistry, Geophysics, Geosystems* 11 1-8

[10] Moline M A, Woodruff D L and Evans N R 2007 Optical delineation of benthic habitat using an autonomous underwater vehicle *Journal of Field Robotics* 24 461-471

[11] Neitz M and Neitz J 2000 Molecular genetics of color vision and color vision defects *Achieves of Ophthalmology* 63 232-237

[12] Harun M H, Aras M S H, Basar M F M, Abdullah S S and Annuar K A M 2015 Synchronization of compass module with pressure and temperature sensor system for autonomous underwater vehicle (AUV) *J. Teknologi* 74 161-167

[13] Paull L, Saeedi S, Seto M and Li H 2014 AUV navigation and localization: a review. *Journal of Oceanic Engineering* 39 131-149