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Design and Fabrication of 3D Printed Remotely Operated Vehicles (ROVs) for Shallow Underwater Environmental Monitoring

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Abstract

The vitality of aquatic ecosystems is essential for biodiversity, water quality, and comprehensive environmental sustainability. However, exploring underwater environment poses many challenges due limited accessibility, and the high expense of monitoring equipment. Nowadays, ROVs has emerged as a viable solution that provides a cost-efficient and customizable method, facilitating the swift creation and deployment of lightweight, high-performance vehicles designed for specific monitoring purposes. Nevertheless, designing ROVS involves optimizing hydrodynamic efficiency through streamlined shapes and propeller designs. The design, material selection, and thruster system of ROVs are crucial for their performance, durability, and operational effectiveness in underwater environments. This work integrates the ROV control module with custom 3D printing design which is name as '3DSeaProbe'. The ABS Glass Fiber filament is used in 3D printing which enhances the material's properties, making it more rigid and robust. Six-thruster configuration is employed for the ROV manoeuvrability capability. The 3DSeaProbe can reach depth and manoeuvre up to 50 meters and is able to be used in a range of underwater applications, surveillance, operations, maintenance, and measurement.

1. Introduction

Remotely operated vehicles (ROVs) are unmanned, tethered underwater vehicles with a neutrally buoyant umbilical cable that is controlled from the surface. Generally, the depth of operation ranges from 200 to 11,000 m and is typically used in the exploration and mapping of underwater environments. In this work, designing the 3DseaProbe ROV involves optimizing hydrodynamic efficiency through streamlined shapes and propeller designs custom for underwater environmental monitoring, such as lakes and ponds. The environment selected is a shallow freshwater environment, which is crucial for providing safe drinking water, supporting agriculture, industry, and ecosystem conservation. The process includes selecting materials with high yield strength to maintain structural reliability in challenging underwater environments [1].

For portability and lightweight 3DSeaProbe, the power systems need to be efficient, considering factors such as propulsion, instrumentation, and communication [2]. Sensor integration and arrangement are crucial, necessitating the application of sensor fusion techniques to combine data from multiple sources.

Buoyancy and motion control need to be aligned to ensure 3DSeaProbe stability and efficient navigation. Tether management is a key consideration for minimizing drag, preventing entanglements, and enhancing the overall durability of the design ROV [3-4]. Designing for varying operational depths involves considering hydrostatic pressure, where the design must accommodate changing pressure conditions [5].

This work integrates the ROV control module with a custom 3D design. However, when designing an ROV, it must be hydrodynamically efficient [6]. The ROV should have a smooth, streamlined shape and utilize thrusters that are powerful enough to propel the ROV through the water at the desired speed. It is essential to note that modifying the ROV's design or construction may impact other aspects of its performance, such as speed, payload capacity, or range. It is important to carefully consider all the factors involved before designing 3DSeaProbe [7]-[8]. Thus, calibration of the navigation control module and sensors is necessary to improve the performance of ROVs [9]. Finding a fine balance between weight and power is certainly not an easy task. The underwater thruster and navigation control module are crucial for achieving the desired navigation performance [10]-[11].

2. Methodology

This new ROV design takes into account the portability and shallow underwater constraints of lakes and ponds. The overall design of the proposed ROVs has been based on study consideration in terms of structure designs, materials, and maneuverability performance [12].

The design consists of six thrusters that enable the desired motion control of five degrees of Freedom, such as translational motion (surge, sway, heave) and rotational motion (yaw & pitch). Additionally, the theoretical underpinnings applied in the design and structures of the ROV 6 thruster represent effectiveness in energy use and versatility in a variety of operational. Leverages existing developments in autonomy to allow ROVs to adapt nimbly to instantaneous environmental changes. This consideration is complemented by the way remotely operated vehicles (ROVs) achieve an integrated combination of multi-directional forces to move through currents and barriers, as discussed in [13]. Figure 1 illustrates the 3DSeaProbe, a 3D Design Created using Fusion 360 software.

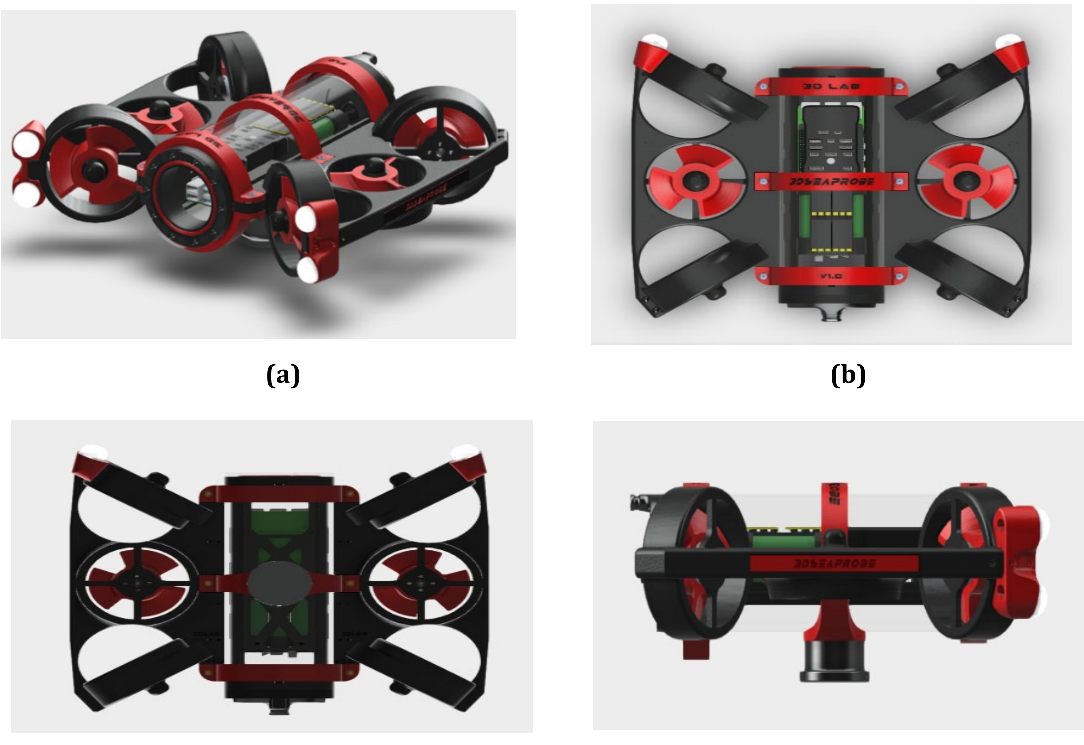


Fig. 1 *3DSeaProbe: 3D Design using Fusion 360 software (a) Isometric view; (b) Top; (c) Back; (d) Side*

The buoyant force (Fb) acting on the ROV is essential for maintaining neutral buoyancy underwater. This force is determined by the formula

$$Fb=\rho_{water} \cdot g \cdot V_{displaced} \tag{1}$$

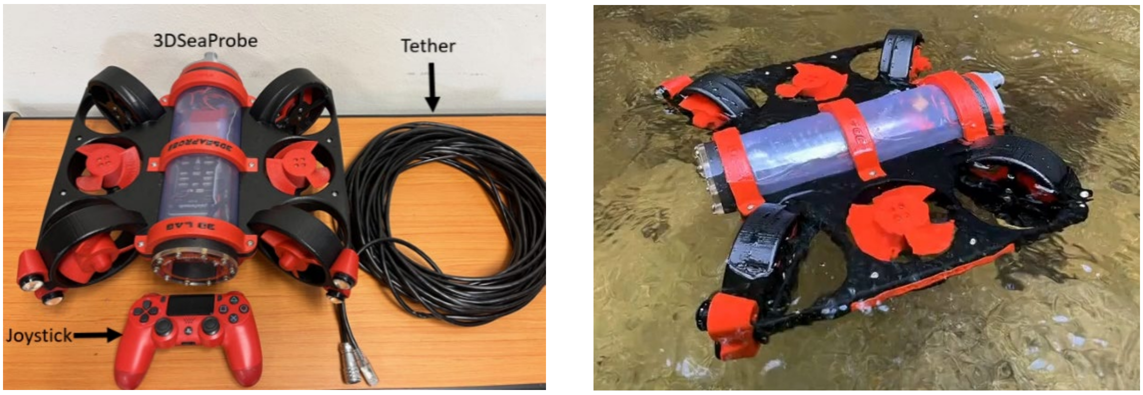
where is the density of water, is the acceleration due to gravity, and is the volume of water displaced by the ROV. Achieving neutral buoyancy ensures that the ROV hovers at a specific depth, remaining stable and controlled without sinking or rising, thereby facilitating stable and controlled operations. The tension in the tether (T) connecting the ROV to the surface is determined by

$$T = \sqrt{T_t^2 + W^2} \tag{2}$$

This equation considers the tension in the tether (Tt) and the weight of the ROV (W). Maintaining optimal tension is critical for stable communication, power transmission, and overall control of the ROV during underwater operations.

The ROVs consist of an electronic part inside the acrylic cylinder that will secure all the electronic components inside it from any possibility of danger that could happen during the operation of the ROVs. The use of ABS Glass Fiber filament for the fabrication of the ROV body is a strategic choice due to its strength and durability [11]. The specified printing temperature and speed parameters are crucial for achieving optimal results in terms of both structural integrity and printing quality.

This is particularly important for applications such as ROVs, where the vehicle must withstand the pressures and conditions of underwater environments. The recommended printing temperature of 250 °C, which is based on the type of filament and printer conditions [14]. In our work, we used the Elegoo Neptune 3 Max FDM 3D printer. The speed of printing, ranging from 50 mm/s to 80 mm/s, is another critical parameter. The printing speed affects the quality of the printed object. Higher speeds may lead to decreased layer adhesion and compromise the structural integrity of the printed part, while lower speeds might result in better detail and adhesion. The fully assembled ROV is shown in Figure 2, featuring an integrated sensor module, control system, battery, and tether.



(a) **(b)**

Fig. 2 *Prototype of 3DSeaProbe (a) Full design; (b) Buoyancy level*

Table 1 shows the specifications for the 3DSeaProbe ROV. The 3DSeaProbe is with dimensions of 310 mm x 340 mm x 100 mm (expanding to 130 mm in height with sonar module) and a weight of 3.3 kg, features a six-thruster configuration for precise maneuverability, powered by 12V Lithium Ion batteries, and equipped with advanced navigation and sensory systems, including a Pix Hawk 4 control system, Pi 4 companion computer, an 8-megapixel Pi Cam V2, multiple IMUs, depth/pressure sensors, and a Bluerobotic Ping Sonar for altimeter and echosounder functionalities, ensuring optimal performance at speeds up to 2 m/s with a 0.5-hour endurance at 1 m/s.

Table 1 *Overall ROV specification (3DSeaProbe)*

Features	Specification
Dimension	310 mm (L) x 340 mm (W) x 100 mm (H): 130mm (H) with sonar
Weight (air)	3.3 Kg
Speed	0 -2 m/s
Endurance	0.5 hours @ 1 m/s
Watertight enclosure Diameter	Outer 90 mm Inner 80 mm
Watertight Enclosure Inner Length	230mm
Battery Connector	XT30
Memory	SD Card 8 GB
Power Supply	12V Lithium-Ion Batteries (3S 2P) / 6000mAH
Main Control System	Pix Hawk 4
Companion computer	Pi 4 (Laptop communication module)
Camera	Pi Cam V2 8-megapixel resolution, CSI, Serial Interface Horizontal FOV: 62.2 degrees Vertical FOV: 48.8 degrees
Inertial Navigation System Module	MPU6000 (6-axis IMU) L3GD20H (3-axis gyroscope) LSM303D (6-axis IMU) Honeywell HMC5883L Three Axis Compass IC IST8310- 3-axis digital magnetometer
Depth/Pressure/Temperature Sensor	MS5611 Barometer – Pressure sensor/temperature sensor for altitude measurements Bar30 High-Resolution 300m Depth/Pressure Sensor Current and voltage sensing
Thruster	Brushless 970 KV (6 unit) Trust 1.4 kgf/unit
Electronic Speed Controller	Bluerobotic Basic 30A ESC
Echo Sounder	Bluerobotic Ping Sonar Altimeter and Echosounder
Lights	4-unit x 23 mm diameter x 90 lumens, 12 v Light beam angle 130 degrees LED controller 20 A
Tether	5 mm Diameter 50-meter Length

Figure 3 shows a block diagram of 3DSeaProbe. The integration and placement of all devices, including the vent hole and power module, must be well-balanced to ensure buoyancy capability, stability, and freedom from water leakage [15-17]. Not only that, but the calibration of all readings and sensor placement must be carefully decided to ensure the reliability of the recorded data, which may be affected by vibration from thrusters, electromagnetic interference, and acoustic noise.

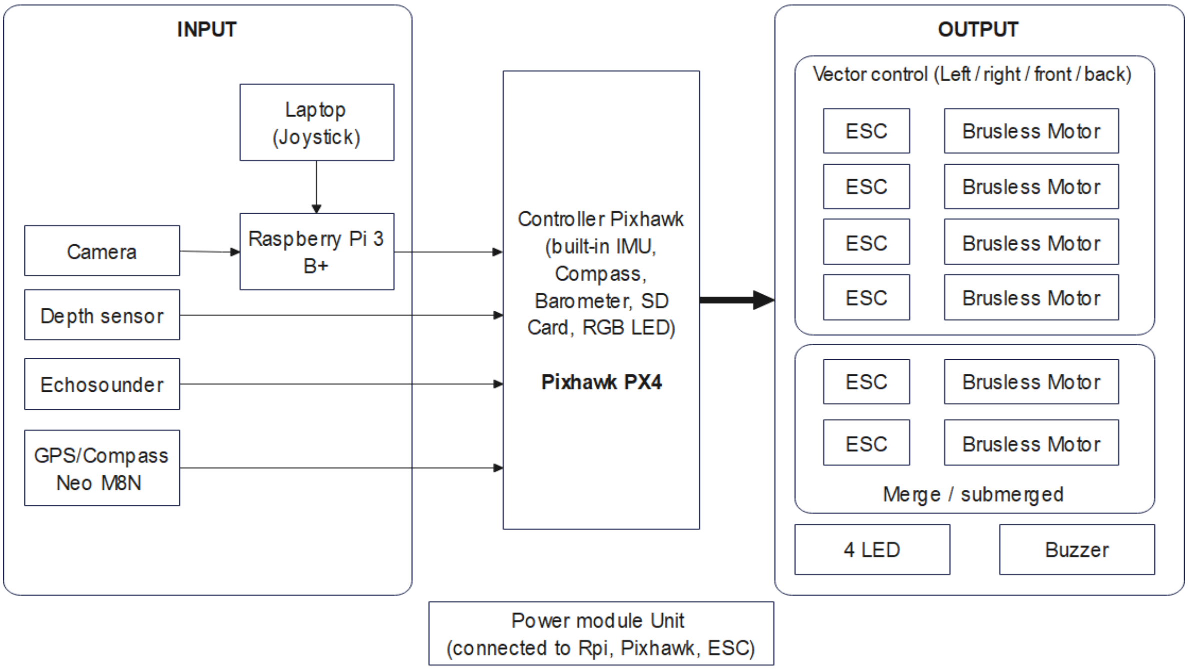


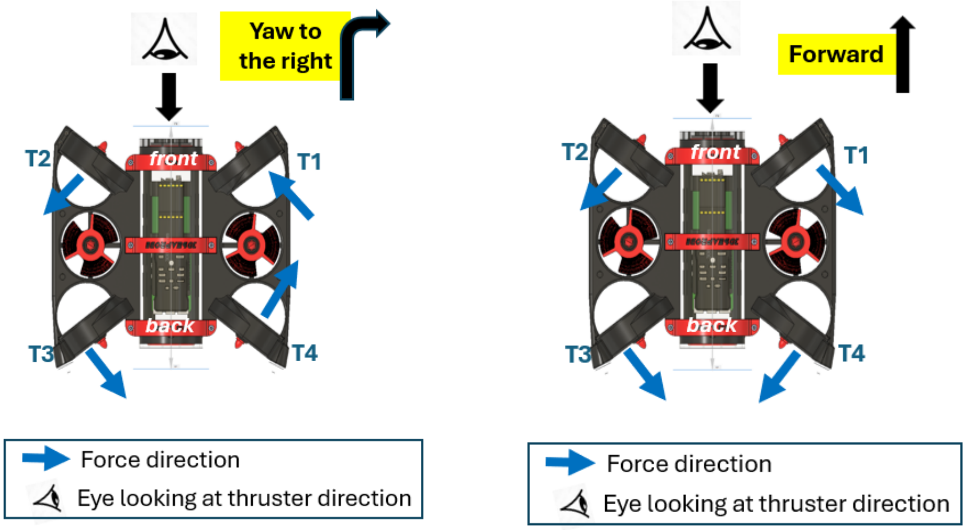
Fig. 3 *3DSeaProbe block diagram*

Buoyancy calibration is necessary for variations in water density across different water bodies; therefore, it is a good practice to have an adjustable ballast weight near the center of mass for balance.

3. Results and Discussion

The 3DSeaProbe is equipped with six thrusters, enabling precise underwater maneuverability. This configuration allows the ROV to move forward and reverse for linear navigation, yaw to the right and left for rotational movement, and control vertical positioning through diving and submerging. The thrusters' strategic placement and coordination ensure the ROV can navigate in underwater environments efficiently, making it ideal for tasks such as underwater exploration, inspection, and research [18-20].

Figure 4(a) illustrates a sample for thruster direction in relation to the motion of the 3DSeaProbe yaw to the right, and Figure 4(b) shows the 3DSeaProbe going forward. Next, Table 2 tabulates the movement configuration of the thrusters when the 3DSeaProbe moves forward, reverses, yaws to the right, and yaws to the left, where CC represents clockwise rotation, and CCW represents counter-clockwise rotation.



(a) **(b)**

Fig. 4 *Thruster direction (a) Yaw motion to right motion; (b) Forward motion*

Testing was conducted at two locations to evaluate the durability of 3D design & fabrication in environments near ponds in Johor, Malaysia. By utilizing different settings, it is aimed to observe how varying conditions influence the outcomes across diverse environmental factors, enhancing the reliability and validity of the findings.

Table 2 *3DSeaProbe movement configuration*

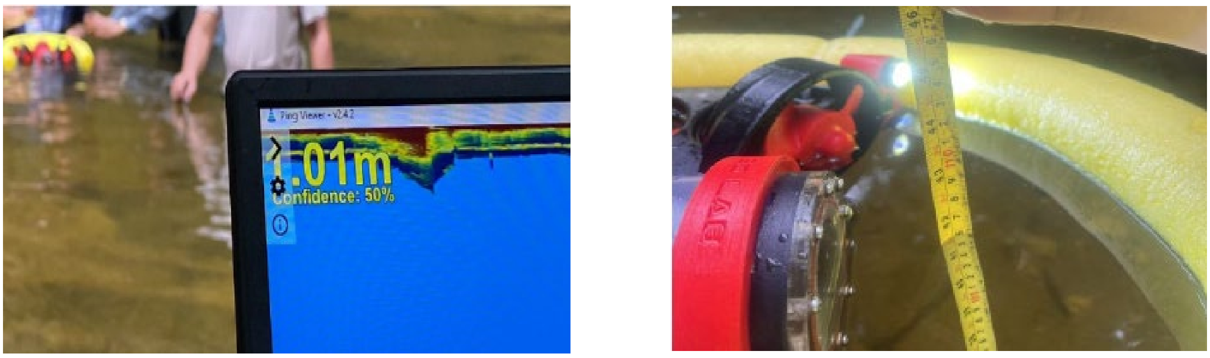
Thruster (T)	Forward	Reverse	Yaw to Right	Yaw to Left
1	CCW	CW	CW	CCW
2	CCW	CW	CCW	CW
3	CW	CCW	CW	CCW
4	CW	CCW	CCW	CW
5	-	-	-	-
6	-	-	-	-

The first testing location is at Kolam 20 Kaki, Gunung Ledang, Johor. The testing conducted presented significant challenges due to the strong water flow, as shown in Figure 5. The 3DSeaProbe body and propeller were able to withstand the force created by the waterfall without any leakage. Although the confident reading of the echo sounder was 50% due to unstable motion contributed by strong water turbulence, the 3DSeaProbe was able to navigate to the desired point.

(a) **(b)**

Fig. 5 *Testing for depth measurement (a) ROV during testing at the waterfall; (b) Depth reading*

To validate the confident reading effect, another test was carried out at a nearby location with similar characteristics but a more manageable water flow. This adjustment facilitated the acquisition of accurate data as shown in Figure 6(a). It shows the depth is 1.01m. The measurements were re-evaluated using a tape measure, as shown in Figure 6(b), to ensure precision and reliability in the results, yielding a result of approximately 1.07m. The difference between sonar placement and camera placement is around 71.22mm. Therefore, reading accuracy is around 99% which is quite high, although with a low confidence level.



(a) **(b)**

Fig. 6 *Validation of echo sounder reading (a) Confidence depth reading; (b) Depth ground truth*

Next, the second testing was conducted at UTHM Lake. Data was acquired using an echo sounder, revealing that the center depth of the lake is 1.60 meters, as shown in Table 3. When the 3DSeaProb e moves to a location near the land surface, the depth decreases to 0.99m.

Table 3 *Data collected at UTHM lake*

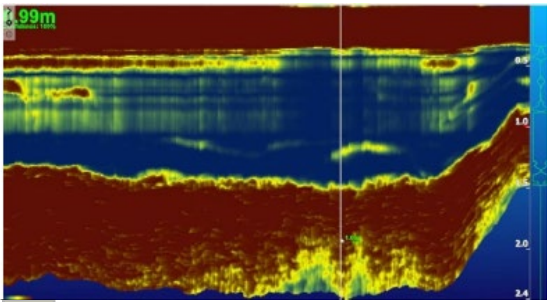
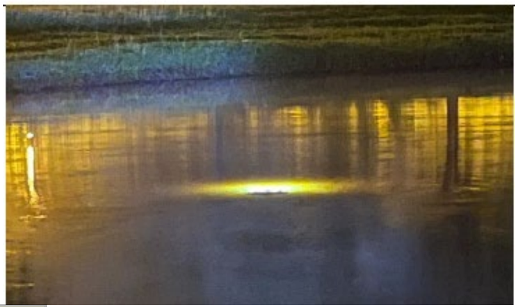
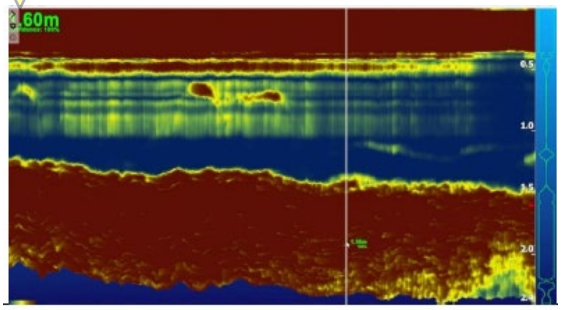
Depth (m)	PingViewer	Location
0.99		
1.60		

Table 3 also includes graphical representation of depth patterns across UTHM Lake. However, visual assessments using a camera were hindered by the murky water, preventing clear observation of the lake environment. Furthermore, the uneven surface of the lake resulted in varying depths at different points.

4. Conclusion

Through the 3DSeaProbe design and development phase, 3D printing technology proved to be an effective method for creating customized and complex ROV structures. The use of 3D printing allowed rapid prototyping and iterative improvements, resulting in a robust and functional ROV design suitable for underwater operations. The integration of advanced navigation control modules enabled the ROVs to perform precise maneuvers and maintain stability across different underwater depths. This integration was critical for ensuring that the ROVs could adapt to varying underwater conditions, demonstrating flexibility and reliability in their operations. Performance assessments of the ROVs indicated successful maneuverability across several depths and underwater environments. The ROVs exhibited consistent control and responsiveness, validating the effectiveness of the design and navigation systems. These assessments confirmed that the ROVs could operate efficiently in diverse underwater scenarios.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

Muhammad Zulfauzan Fahmi bin Che Alias and Nur Nazifa binti Mod Arsad: ***Author, Conceptualization, Methodology, Software; Writing- Original Draft Preparation****; Herdawatie Abdul Kadir:* ***Supervision, Author, Validation, Writing-Reviewing and Editing****; Iffan Darwis Mohd Ibrahim:* ***Writing-Reviewing and Methodology****; Khalid Isa:* ***Supervision, Validation, Advisor****; Mohd Adib Mohammad Razi:* ***Advisor and Validation****; Radzi Ambar:* ***Supervision, Validation, Advisor****.*

References

[1] Ahsan Tanveer & Sarvat Ahmad (2023) Design and testing of a compact inexpensive prototype remotely operated underwater vehicle for shallow water operation, *Journal of Naval Architecture & Marine Engineering*, 20(1), https://doi.org/10.3329/jname.v20i1.64301

[2] Hosam Abu Zeid & Hani Elshahawi (2023) Advances in ROV & AUV capabilities and tooling for energy applications, *Offshore Technology Conference*, https://doi.org/10.4043/32298-MS

[3] Kanagaraj Venusamy, Rhijaz K. P, Nithin Rajan, Sepastin Joshi & E. Prakash (2023) Systematic analysis of application challenges with ROV components, *2023 Eighth International Conference on Science Technology Engineering and Mathematics (ICONSTEM)*, pp. 1-6, https://doi.org/10.1109/ICONSTEM56934.2023.10142659

[4] Nadir Kapetanović, Kristijan Krčmar, Nikola Mišković & Đula Nad (2022) Tether management system for autonomous inspection missions in mariculture using an ASV and an ROV, *IFAC-PapersOnLine*, 55(31), 327-332, https://doi.org/10.1016/j.ifacol.2022.10.450

[5] Dianne L. McLean, Miles J. G. Parsons, Andrew R. Gates, Mark C. Benfield, Todd Bond, David J. Booth, Michael Bunce, Ashley M. Fowler, Euan S. Harvey, Peter I. Macreadie, Charitha B. Pattiaratchi, Sally Rouse, Julian C. Patridge, Paul G. Thomson, Victoria L. G. Todd & Daniel O. B. Jones (2020) Enhancing the scientific value of industry remotely operated vehicles (ROVs) in our oceans, *Frontiers in Marine Science*, 7, 220, https://doi.org/10.3389/fmars.2020.00220

[6] Fausto Ferreira, Đula Nađ, Nikola Mišković, Antonio Blažina, Lovro Maglić & Livia Maglić (2023) Training inspection class mini-ROV operators, *OCEANS 2023-Limerick*, 1-6, https://doi.org/10.1109/OCEANSLimerick52467.2023.10244471

[7] Ahmad Zarei, Ali Ashouri, S. M. J. Hashemi, S. A. S. Farrahi Bushehri, Ehsan Izadpanah & Yaser Amini (2020) Experimental and numerical study of hydrodynamic performance of remotely operated vehicle, *Ocean Engineering*, 212, 107612, https://doi.org/10.1016/j.oceaneng.2020.10762

[8] Yuan Lin, Jin Guo, Haonan Li, Zhikun Wang, Ying Chen, & Haocai Huang (2022) Improvement of hydrodynamic performance of the disk-shaped autonomous underwater helicopter by local shape modification, *Ocean Engineering*, 260, 112056, https://doi.org/10.1016/j.oceaneng.2022.112056

[9] Yuming Zhao, Zhen He, Gelun Li, Yabiao Wang & Zhigang Li (2020) Design and application of a small ROV control system based on ArduSub system, *2020 IEEE 2nd International Conference on Civil Aviation Safety and Information Technology (ICCASIT)*, 585-589, https://doi.org/10.1109/ICCASIT50869.2020.9368667

[10] Sourjyadip Ray, Rahil Bhowal & Purvik Patel (2021) An overview of the design and development of a 6 DOF remotely operated vehicle for underwater structural inspection, *2021 International Conference on Communication, Control and Information Sciences (ICCISc)*, 1, 1-6, https://doi.org/10.1109/ICCISc52257.2021.9484879

[11] Khaleed Husain, Irfan Anjum Badruddin, Yaser H. Alahmadi, Amin A. G. Haider, Vineet Tirth, Ali A. Rajhi, Ali Algahtani, Ali E. Anqi, Sagr Alamri, Sarfaraz Kamangar, Yunus Khan T. M & Abou Bakr Elshalakany (2022) Comparison of 3D printed underwater propeller using polymers and conventionally developed AA6061, *Journal of Materials Engineering and Performance*, 31(6), 5149-5158, https://doi.org/10.1007/s11665-022-06576-z

[12] Javier Neira, Cristhel Sequeiros, Richard Huamani, Elfer Machaca, Paola Fonseca, Wilder Nina (2021) Review on Unmanned Underwater Robotics, Structure Designs, Materials, Sensors, Actuators, and Navigation Control, *Journal of Robotics*, 2021(1), 5542920, https://doi.org/10.1155/2021/5542920

[13] Seyed Mostafa Hosseini, Albolfazl Ranjbar Noei & S. J. Sadati Rostami (2023) Trajectory tracking control of an underwater vehicle in the presence of disturbance, measurement errors, and actuator dynamic and nonlinearity, *Robotica*, 41(10), 3059-3078, https://doi.org/10.1017/S0263574723000875

[14] Ranvijay Kumar, Roopkaran Singh & M. S. J. Hashmi (2022) Polymer-Ceramic composites: A state of art review and future applications, *Advances in Materials and Processing Technologies*, 8(1), 895-908, https://doi.org/10.1080/2374068X.2020.1835013

[15] Zeyu Sha, Xiaorui Wang, Mingyang Yang, Hong Lei & Feitian Zhang (2025) A portable autonomous underwater vehicle with multi-thruster propulsion: Design, development, and vision-based tracking control, *IEEE Robotics and Automation Letters*, 10(4), 3046-3053, https://doi.org/10.1109/LRA.2025.3540380

[16] Parker Baillon, Suzanne Dixon, Katlyn Faust, Payton Herman, Harpoon Seabring & Stephen Wood (2023) Project R3MORA: Resin 3D-Printed Mission Oriented Research Assistant, *OCEANS 2023 - MTS/IEEE U.S. Gulf Coast*, 1-7, https://doi.org/10.23919/OCEANS52994.2023.10337376

[17] Marios Vasileiou, Nikolaos Manos & Ergina Kavallieratou (2021) A low-cost 3D printed mini underwater vehicle: Design and Fabrication, *2021 20th International Conference on Advanced Robotics (ICAR)*, 390-395, https://doi.org/10.1109/ICAR53236.2021.9659412

[18] Thineshwaran Satiamurti & Herdawatie Abdul Kadir (2024) Design and development of a remotely operated underwater vehicle (ROV), *Evolution in Electrical and Electronic Engineering*, 5(1), 427-435, https://publisher.uthm.edu.my/periodicals/index.php/eeee/article/view/15349

[19] S. Mohanty, A. Garg, Shiv Sahaya Shukla, Santosha Kumar Dwivedy, S. Dutta & Rishikesh Bharti (2024) River and lake monitoring through underwater remotely operated vehicle, *Advances in River Corridor Research and Applications: Select Proceedings of RCRM 2023*, 470, 265-276, https://doi.org/10.1007/978-981-97-1227-4_19

[20] Lianjie Zhang, Qi Lan, Liang Yu, Cong Wang, Weicong Chen & Yong Lei (2024) Development of a cleaning ROV for high-temperature radioactive environment, *International Conference on Intelligent Robotics and Applications*, 116-130, https://doi.org/10.1007/978-981-96-0792-1_10