

AUTOMATED UNDERWATER DRONE

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering degree in Computer Science and Engineering

by

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**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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BONAFIDE CERTIFICATE

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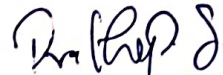
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DECLARATION

I, **PRATHAP S** (Reg.No.40110990) hereby declare that the Project Report entitled **Automated Underwater Drone** done by me under the guidance of **Dr. B.SHAMREEN AHAMED, M.E., Ph.D.** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in **Computer Science and Engineering**.

DATE: 16.04.2024

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ABSTRACT

Submersible drones are tethered to the surface during the entire time they are operational by a high tensile tether cable and a data transmissible insulated cable. Underwater all kinds of wireless transmission are limited by travel range. remotely operated underwater vehicles or autonomous underwater vehicles have a range of applications in various aspects of day-to-day life. Intended use usually ranges from a few 100 meters (about 328.08 ft) to around 2,000 meters (approximately 6,500 feet). Sometimes reaching down to several thousands of meters or even to the deepest parts of the ocean. Drones can be equipped with a variety of sensors, cameras, agriculture, environmental monitoring, search and rescue, surveillance, package delivery, and more. In recent years, drones have gained popularity among hobbyists and consumers for recreational purposes, as well as in professional fields for tasks like aerial photography, mapping, and inspections. perform a wide range of tasks like photography and videography.

The Automated underwater drones offer a multitude of advantages compared to traditional manned underwater vehicles and manually operated drones. Firstly, their efficiency is unmatched, as they can tirelessly operate for extended periods without the need for breaks or rest, facilitating seamless data collection and monitoring tasks. This efficiency translates into significant cost-effectiveness by eliminating the expenses associated with human operators underwater, thereby reducing labor costs and logistical challenges. Moreover, the safety aspect of automated drones cannot be overstated, as they minimize the risk to human operators by undertaking tasks in hazardous or inaccessible underwater environments, such as deep-sea trenches or contaminated areas. Precision is another hallmark of automated underwater drones. These drones can navigate along predefined paths and reach specific waypoint with remarkable accuracy, ensuring precise data collection and mapping of underwater terrain. Their versatility is unparalleled, as they can be equipped with a wide array of sensors, cameras, and tools to perform diverse tasks ranging from environmental monitoring to industrial inspections and

search and rescue operations. Furthermore, the real-time data collection capability of automated drones allows for instant feedback to operators and researchers, enabling timely decision-making. The adaptability of automated underwater drones is a significant advantage, as they can seamlessly adjust to changing underwater conditions and environments, making them suitable for a wide range of applications and scenarios. With efficient power management systems, these drones can undertake long-duration missions, facilitating prolonged data collection efforts. Additionally, their minimal environmental impact, characterized by reduced noise and disturbance levels, ensures minimal disruption to underwater ecosystems and marine life.

Automated underwater drones present numerous advantages over traditional manned vehicles and manually operated drones. Their unmatched efficiency allows for continuous operation without the need for breaks or rest, facilitating seamless data collection and monitoring tasks. This efficiency translates into significant cost savings by eliminating the expenses associated with human operators underwater, reducing labor costs and logistical challenges. Moreover, automated drones enhance safety by minimizing the risk to human operators in hazardous or inaccessible underwater environments, such as deep-sea trenches or contaminated areas.

TABLE OF CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
	ABSTRACT	v
	LIST OF FIGURES	xi
	LIST OF ABBREVIATIONS	xii
1	INTRODUCTION	1
	1.1 Background Motivation	2
	1.2 Problem Statement	2
	1.3 Objective And Scope	2
2	LITERATURE SURVEY	5
	2.1 Inferences From Literature Survey	5
3	AIM AND SCOPE OF PRESENT INVESTIGATION	10
	3.1 Existing System	10
	3.2 Proposed System	10
	3.2.1 Exploration Module	11
	3.2.2 Maintenance Module	11
	3.2.3 Research Module	11
	3.2.4 The Magic Lines In The Quick Swap Docking Mechanism	11
	3.3 Open Problems In Existing System	12
	3.3.1 Communication Range	12
	3.3.2 Wireless Interference	12

3.3.3	Pressure Limitations	13
3.3.4	Depth Limitations	13
3.3.5	Biological Impact	13
3.3.6	Environmental Impact	14
4	EXPERIMENTAL OR MATERIALS AND METHODS; ALGORITHMS USED	15
4.1	Flow Chart Of Design Process	15
4.1.1	Initialization	17
4.1.2	Sensor Reading	17
4.1.3	Obstacle Detection And Analysis	17
4.1.4	Path Planning And Trajectory Generation	18
4.1.5	Flight Control	18
4.1.6	Safety Checks And Emergency Maneuvers	18
4.2	Selected Methodology Or Process Model	19
4.2.1	Positive Pressure	20
4.2.2	Negative Pressure	20
4.2.3	Neutral Pressure	20
4.3	Problem Analysis Of Ocean Depths	21
4.3.1	Bathymetry	22
4.3.2	Pressure Variations	22
4.3.3	Zones And Habitats	22
4.3.4	Deep Sea Exploration	22

4.3.5	Seafloor Mapping	22
4.3.6	Pressure Effects And Substances	23
4.3.7	Resource Exploration	23
4.3.8	Impact On Ocean Climate	23
4.3.9	Wreck And Artifact Preservation	23
4.3.10	Population Technology	24
4.4	Data Collection, Verification And Processing	24
4.4.1	Sensors	25
4.4.2	Sample Collection	25
4.4.3	Eyes Of The Deep	25
4.4.4	Data Verification	25
4.4.5	Real Time Monitoring	26
4.4.6	Accuracy Enhancement	26
4.4.7	Cross-Checking The Clues	26
4.4.8	Real-Time Validation	27
4.5	Applications	28
4.5.1	Marine Research	29
4.5.2	Infrastructure Inspection	29
4.5.3	Environment Monitoring	29
4.5.4	Search And Rescue	30
4.5.5	Defense And Security	30
4.5.6	Marine Conservation	31
4.5.7	Offshore Exploration	31

4.5.8	Scientific Research	31
4.6	Architecture / Overall Design Of Proposed System	32
4.6.1	Rotational	33
4.6.2	Translational	33
5	RESULTS AND DISCUSSION, PERFORMANCE ANALYSIS	34
6	SUMMARY AND CONCLUSIONS	40
	REFERENCE	42
	APPENDIX	44
A	SOURCE CODE	44
B	SCREENSHOT	46
C	RESEARCH PAPER	51
D	CERTIFICATE	57

LIST OF FIGURE

FIGURE NO	FIGURE NAME	Page No.
4.1	Process Cycle of Underwater drone	16
4.2	Pressure of Underwater	19
4.3	Ocean Depth	21
4.4	System Architecture	32
5.1	Output Screenshot	34
5.2	Output Screenshot	35
5.3	Depth Analysis	36
5.4	Prototype of Drone	37
5.5	Working of Drone	38
5.6	Working of Drone	38
B.1	Test 1	46
B.2	Test 2	47
B.3	Data Collected From Drone	48
B.4	Data Collected From Drone	49

LIST OF ABBREVIATIONS

ABBREVIATION	EXPANSION
AUD	Automated Underwater Drone
ROV	Remotely Operated Vehicles
V-REP	Virtual Robot Experimentation Platform

CHAPTER 1

INTRODUCTION

Automated Underwater Drone used in Marine Research and Exploration, Oceanographic surveys, Underwater Archaeology. Aquaculture and Fisheries Management, Underwater Film making and Photography and more likely drones are used in recent years. The capabilities and applications of underwater drones can vary widely depending on factors like depth capabilities, sensor payloads, and specific mission requirements. Additionally, like aerial drones, the use of underwater drones may be subject to regulations and permits, especially in sensitive or protected marine environments. Gliding silently through an alien world of blue, the automated underwater drone is a robotic explorer. Shaped like a sleek torpedo or a curious fish, it navigates using propellers and thrusters, powered by onboard batteries. Its eyes are not human, but cameras and sensors that see in light invisible to us, detecting temperature, salinity, and even the whispers of underwater currents.

Autonomous brains guide its missions, programmed with intricate maps or following pre-set commands. Some Automated Underwater Drones are nimble scouts, mapping coral reefs and tracking elusive creatures. Others, powerful workhorses, inspect offshore structures or collect vital data on ocean health. Their silent dance benefits us all, from protecting marine life to predicting storms and mapping the ocean floor. Yet, these sleek machines face challenges – battling currents, evading predators, and enduring the crushing pressure of the deep. But their silent exploration reveals the secrets of the unknown, painting a vibrant picture of the world beneath the waves. The future of underwater exploration hums with the quiet whirring of propellers. As technology leaps forward, Automated Underwater Drones are evolving into sleek sentinels of the deep, pushing the boundaries of what's possible. Imagine drones equipped with advanced robotic arms, delicately manipulating deep-sea corals or gently retrieving ancient artifacts from shipwrecked galleons. These dexterous machines will unlock forgotten secrets, shedding light on the past and informing our future stewardship of the oceans.

1.1 BACKGROUND AND MOTIVATION

The background and motivation for automated underwater drones stem from the need for efficient and safe exploration of underwater environments. Traditional methods involving manned vehicles or manual operations are often costly, time-consuming, and pose risks to human operators. Automated drones offer a solution by leveraging advanced technology to navigate underwater terrains autonomously, collect data, and perform various tasks with precision and efficiency. Motivated by the desire to advance scientific research, environmental monitoring, industrial inspections, and search and rescue operations, automated underwater drones aim to unlock the mysteries of the ocean while minimizing risks and maximizing effectiveness.

1.2 PROBLEM STATEMENT

The problem statement for automated underwater drones revolves around the challenges associated with traditional underwater exploration methods. These methods often involve manual operations or manned vehicles, which are inefficient, costly, and pose risks to human operators. Additionally, accessing certain underwater environments, such as deep-sea trenches or contaminated areas, can be hazardous or inaccessible. The development of automated underwater drones aims to address these challenges by leveraging advanced technology to enable autonomous navigation, data collection, and task execution in underwater environments. The problem statement thus focuses on the need for efficient, safe, and cost-effective solutions for underwater exploration and operations.

1.3 OBJECTIVE AND SCOPE

The objective of automated underwater drones is to revolutionize underwater exploration and operations by developing autonomous systems capable of navigating, collecting data, and performing tasks in challenging underwater environments. This includes conducting marine research, environmental monitoring, industrial inspections, search and rescue missions, and archaeological explorations. The scope encompasses the design, development, and deployment of advanced robotic platforms equipped with sensors, cameras,

and tools for underwater exploration and tasks. The goal is to enhance efficiency, safety, and cost-effectiveness while expanding the capabilities of underwater exploration beyond the limits of traditional methods. But exploration isn't just about retrieving treasures. Envision Automated Underwater Drones transformed into mobile laboratories, their hulls bristling with sophisticated sensors. These scientific outposts will measure ocean acidification in real-time, track the migration of endangered species, and map the intricate dance of plankton blooms. Their data, a symphony of whispers from the deep, will fuel groundbreaking research, guiding conservation efforts and shaping our understanding of climate change and the silent ballet continues. Imagine swarms of Automated Underwater Drones collaborating like synchronized swimmers, their movements orchestrated by onboard AI.

These underwater constellations will map vast swathes of the ocean floor in record time, revealing hidden canyons and hydro thermal vents teeming with exotic life. the collective intelligence will unveil the secrets of undiscovered ecosystems, pushing the frontiers of oceanographic knowledge. Yet, amidst the excitement, ethical considerations cannot be ignored. As Automated Underwater Drones venture deeper and further, questions arise about their impact on fragile ecosystems and the privacy of marine life. Responsible deployment and research must guide their development, ensuring that exploration goes hand-in-hand with conservation and respect for the underwater world.

The automated underwater drone is not just a machine; it's a portal to a hidden universe. As we peer through its digital eyes, we glimpse a world of wonder and beauty, teeming with life and mystery. With each silent dive, these robotic explorers chip away at the unknown, reminding us that the greatest oceanographic frontiers lie not just at the bottom of the sea, but within our own responsibility to protect and understand its delicate wonders. Automated underwater drones have become indispensable tools in various marine research and exploration endeavors, including oceanographic surveys, underwater archaeology, aquaculture, fisheries management, underwater filmmaking, and photography. These versatile machines, shaped like sleek torpedoes or fish, navigate through the depths using propellers and thrusters powered by onboard batteries. Equipped with advanced cameras

and sensors, they detect temperature, salinity, and underwater currents, providing valuable insights into marine environments.

Guided by autonomous brains and programmed with intricate maps or pre-set commands, these drones fulfill diverse missions. Some serve as nimble scouts, mapping coral reefs and tracking elusive creatures, while others function as powerful workhorses, inspecting offshore structures or collecting vital data on ocean health. Despite facing challenges such as battling currents, evading predators, and enduring extreme pressure, their silent exploration uncovers the mysteries of the unknown, enriching our understanding of the underwater world.

As technology progresses, automated underwater drones are transforming into highly advanced guardians of the ocean's depths. Envisioning drones equipped with sophisticated robotic arms capable of delicately manipulating deep-sea corals or retrieving ancient artifacts from shipwrecks introduces exciting possibilities for exploration and discovery. These agile machines possess the potential to unveil long-forgotten secrets, shedding light on the past and informing future efforts to protect and conserve our oceans. With each subtle hum of their propellers, these drones propel the future of underwater exploration, continually pushing the limits of what can be achieved in the exploration and understanding of the underwater world.

As technology advances, automated underwater drones are evolving into highly advanced guardians of the ocean's depths. Envisioning drones equipped with sophisticated robotic arms capable of delicately manipulating deep-sea corals or retrieving ancient artifacts from shipwrecks introduces exciting possibilities for exploration and discovery. With each subtle hum of their propellers, these drones propel the future of underwater exploration, continually pushing the limits of what can be achieved in the exploration and understanding of the underwater world. Through their innovative capabilities and relentless pursuit of discovery, automated underwater drones stand as pivotal instruments in unlocking the mysteries of the ocean and ensuring its preservation for generations to come.

CHAPTER 2

LITERATURE SURVEY

Over the years, navigation of drones has limitations which restricted them the control of pitch and yaw, backward and forward motion which has been overcome in (TJ-FlyingFish drone flies through the air and "swims" underwater - Ben Coxworth) which also used to navigate the underwater surface. The automated drones are used in marine life and research study of ocean water and sea current. The drone can be used in underwater and fly up in surface.

From the papers: (a morphing-based approach. *Soft Robot.* 5, 541–553 (2018). and Multi-Modal Mobility Morphobot (M4) with appendage repurposing for locomotion plasticity enhancement which are written by authors s Riviere, V., Manecy, A. & Viollet, S. Agile robotic fliers and Eric Sihite¹, Arash Kalantari², Reza Nemovi¹, Alireza Ramezani³ & Morteza Gharib respectively) we can understand that the Morphing based robots comes with a huge advantage of adaptability to any situation and surroundings but also Carry some disadvantages which are to be considered when automating a robot or drone, the disadvantages are high maintenance and risk of failure due to a considerable amount of moving parts used in a morphing drone are robots which are prone to failure especially in underwater.

2.1 INFERENCES FROM LITERATURE SURVEY

1. S. A. CELTEK, A. DURDU and E. KURNAZ, "Design and Simulation of the Hierarchical Tree Topology Based Wireless Drone Networks," 2018 International Conference on Artificial Intelligence and Data Processing (IDAP), Malatya, Turkey, 2018, pp. 1-5, doi: 10.1109/IDAP.2018.8620755.

In drone applications, the drone could send data using telemetry devices or radio frequency modules which have a limited range. So, there is no interaction between user and drone after a certain range. In the study, a hierarchical tree topology based wireless drone network is designed and presented to overcome range challenge. Proposed network consists of three main parts; Control Center

(CC), Master Drone (MD) and Slave Drones (SDs). The CC as a network manager communicates with just MD via telemetry devices. SDs are explorer drones for the search and rescue application. The data transfer between CC and SDs is provided by MD which is an explorer like SDs. the paper clearly shows that the enhancement of the communication range is possible with such an approach. Also the designed drone networks are simulated using V-REP (Virtual Robot Experimentation Platform). According to the simulation results, the proposed drone network system operates quickly, and finds the target in 5 minutes, which the classical system does not find in 10 minutes. The proposed model clearly shows that an application using a drone is completed in a shorter time with the drone swarm well organized.

2. M. A. Kasno et al., "Small scale underwater drone based on a twin-rotor system," 2017 IEEE 7th International Conference on Underwater System Technology: Theory and Applications (USYS), Kuala Lumpur, Malaysia, 2017, pp. 1-5, doi: 10.1109/USYS.2017.8309439.

The paper presents the development of small-scale unmanned underwater drones. The underwater drone model was selected based on a twin-rotor-like aerial platform, adapted to dive and move underwater. It is designed to perform underwater capabilities and few aerial tasks which can slightly hover on water surface. The design of an underwater drone model by using 3D drawing (Solidworks software). The propulsion mechanism of the underwater drone is based on a thruster which consists of a motor and propeller and for the controller part used by a joystick controller and the body of an underwater drone using light weight material (PVC foam). The testing and experimental for underwater drone focused on vertical trajectory. the paper also investigates propeller design by the thrust measurement so that the performances of underwater drones can be observed.

3. D. Mura, M. Barbarossa, G. Dinuzzi, G. Grioli, A. Caiti and M. G. Catalano, "A Soft Modular End Effector for Underwater Manipulation: A Gentle, Adaptable Grasp for the Ocean Depths," in IEEE Robotics & Automation Magazine, vol. 25, no. 4, pp. 45-56, Dec. 2018, doi:

10.1109/MRA.2018.2871350.

Current underwater end-effector technology has limits in terms of finesse and versatility. Because of the, the execution of several underwater operations, such as archeological recovery and biological sampling, often still requires direct intervention by human operators, exposing them to the risks of working in a difficult environment. the article proposes the design and implementation of an underactuated and compliant underwater end effector that embodies grasp capabilities comparable to those of a scuba's real hand as well as the large grasping envelope of grippers.

4. R. Hamagami, T. Ebihara, N. Wakatsuki and K. Mizutani, "Optimal Modulation Technique for Underwater Visible Light Communication Using Rolling-Shutter Sensor," in IEEE Access, vol. 9, pp. 146422-146436, 2021, doi: 10.1109/ACCESS.2021.3123358.

The visible light communication (VLC) technique using a rolling-shutter sensor-based commercial camera has an advantage in that the LED and camera mounted on an underwater device (e.g., drone, sensor) can be effectively used as a transmitter (Tx) and a receiver (Rx), respectively, under water. On the other hand, a suitable modulation technique has not been well considered to realize a VLC system using a rolling-shutter sensor in an underwater channel that includes high ambient light conditions. In the paper, we design VLC systems using phase-shift keying (PSK), non-return-to-zero on- off keying (NRZ-OOK), and orthogonal frequency division multiplexing (OFDM), and evaluate them through simulations and experiments. The results suggested that the VLC system using PSK or OFDM is more resilient thanthat using NRZ-OOK in an underwater channel with low-frequency ambient light, and that a VLC system using PSK or NRZ-OOK is more tolerant than that using OFDM in environments with high ambient light, resulting in pixel saturation. In conclusion, the present study has demonstrated that PSK is the most suitable modulation technique for a VLC system using a rolling-shutter sensor in an underwater channel that includes high ambient light conditions.

5. J. Moon, C. B. Lim and S. Yang, "An Unsupervised Learning Approach for Seafloor Mapping Using Underwater Robot," 2023 20th International Conference on Ubiquitous Robots (UR), Honolulu, HI, USA, 2023, pp. 137-140, doi: 10.1109/UR57808.2023.10202487.

Seafloor mapping has great advantages in natural disaster preparedness as well as seafloor resource explorations and operations. However, it is limited in not having sufficient seafloor mapping data set. The paper introduced an unsupervised learning-based seafloor classification method for seafloor mapping. The team successfully classified the seafloors using autoencoder and k-means clustering algorithm and conducted tests using the image data obtained from the actual seafloors.

6. A.Gauci, A. Deidun, J. Abela, E. Cachia and S. Dimech, "Automatic Benthic Habitat Mapping using Inexpensive Underwater Drones," IGARSS 2020 - 2020 IEEE International Geoscience and Remote Sensing Symposium, Waikoloa, HI, USA, 2020, pp. 2213-2216, doi: 10.1109/IGARSS39084.2020.9324241.

The generation of benthic habitat maps relies either on direct in-situ observations made by SCUBA divers swimming in a rectilinear fashion, or on costly remote sensing techniques involving either ROVs or sonar technology. The recent commercialisation of off-the-shelf underwater drones has enhanced benthic mapping possibilities by providing a cost-effective alternative. Despite still requiring ground truthing, such drones do not rely extensively on boat-support services. In this study, the applicability and feasibility of using an underwater high-resolution optical platform to automate the generation of benthic maps is investigated.

7. A.Nishitani, R. Kawada and J. Kojima, "Development of combined aerial and underwater drone system," OCEANS 2022, Hampton Roads, Hampton Roads, VA, USA, 2022, pp. 1-5, doi: 10.1109/OCEANS47191.2022.9977370.

When conducting underwater observations in coastal fisheries and other offshore commercial operations, efficiency and safety are important considerations. It can fly quickly and automatically to the target area to carry out observations without using a surface vessel. This drone can be operated remotely through a 4G

mobile network, with underwater navigation and observation. Specifically, after the aerial drone carrying the ROV arrives at the target area automatically, and having landed on the water, it separates from the ROV, and the ROV dives under the sea. After the underwater observation work has been completed, the aerial drone docks with the ROV and lifts off from the surface of the water and returns to the land base station. Through sea trials, it was demonstrated that this combined aerial and underwater drone system could perform underwater observation successfully.

8. D. A. R. Ellen, P. Kristalina, M. Z. S. Hadi and A. Patriarso, "Effective Searching of Drowning Victims in the River using Deep Learning Method and Underwater Drone," 2023 International Electronics Symposium (IES), Denpasar, Indonesia, 2023, pp. 569-574, doi: 10.1109/IES59143.2023.10242589.

The search for drowning victims can be a time-consuming and challenging task, often hindered by limited equipment in the field. However, advancements in technology, particularly underwater drone technology and deep learning methods for object detection, present promising solutions. YOLOv5 (You Only Look Once Version 5) is a cutting-edge object detection model known for its high detection speed and accuracy. The YOLOv5s configuration model was utilized, and the model was trained for 400 epochs. The results demonstrated impressive performance, with an accuracy value of 89%, precision of 100%, and recall of 95%.

9. Y. Yasui, A. Shigenawa and Y. Nakayama, "Drone-based Underwater Sensor Network with Optical Camera Communication," 2023 IEEE 97th Vehicular Technology Conference (VTC2023-Spring), Florence, Italy, 2023, pp. 1-5, doi: 10.1109/VTC2023-Spring57618.2023.10199717.

Underwater communication has attracted considerable attention for providing ubiquitous connectivity all over the world. The major constraint for laser diode(LD)-based underwater optical communication (UWOC) is the strong directivity of the transmitter and the receiver. Underwater optical camera communication (is a promising option thanks to its low-directivity.

CHAPTER 3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

The aim of this investigation is to explore the capabilities and applications of automated underwater drones in various underwater environments. The scope encompasses assessing their effectiveness in data collection, navigation, and environmental monitoring tasks.

3.1 EXISTING SYSTEM

Wired underwater drones are indispensable tools for exploring the depths of our oceans. Tethered to the surface by cables, these remotely operated vehicles transmit real-time data and imagery, allowing scientists and researchers to conduct precise underwater investigations. With applications ranging from marine biology and environmental monitoring to infrastructure inspections, wired underwater drones play a vital role in unlocking the mysteries of the submerged world while providing essential insights for scientific and industrial purposes.

Wireless underwater drones revolutionize aquatic exploration. Operating without tethers, these drones utilize advanced communication technologies, allowing for greater mobility and flexibility. Their applications, ranging from marine research to environmental monitoring, make them indispensable tools for unlocking the secrets of the ocean depths. With the ability to navigate and transmit data wirelessly, these drones are catalysts for groundbreaking advancements in underwater exploration and contribute significantly to scientific and industrial progress.

3.2 PROPOSED SYSTEM

Automated underwater drones, or autonomous underwater drone, represent a groundbreaking advancement in marine exploration. These self-navigating vehicles operate without human intervention, utilizing sophisticated algorithms and sensors for underwater tasks. With applications in marine research, environmental

monitoring, and industrial inspections, automated underwater drones offer efficiency and precision. Their autonomy allows for streamlined data collection and exploration of challenging underwater environments, making them invaluable tools for scientific research and industrial applications.

Automated underwater drones like a modular swiss army knife of the deep. the adaptable system proposes three interchangeable modules housed in a streamlined chassis:

3.2.1 Exploration Module:

Equipped with high-resolution cameras, sonar, and environmental sensors, the module maps uncharted territories, tracks elusive marine life, and analyzes coral health. Think detailed 3D scans of shipwrecks or real-time monitoring of pollution levels.

3.2.2 Maintenance Module:

Armed with robotic manipulators and advanced tools, the module inspects offshore structures, cleans debris, and even repairs minor infrastructure faults. Picture repairing cracks in underwater pipelines or delicately retrieving lost scientific equipment.

3.2.3 Research Module:

Equipped with specialized sensors and sampling tools, the module collects data on water quality, gathers biological samples, and even monitors underwater acoustics. Imagine mapping ocean currents for climate models or capturing plankton samples for studying biodiversity.

3.2.4 The magic lies in the quick-swap docking mechanism:

Switch modules based on mission requirements, extending exploration distances with battery packs, or adding depth modules for extreme dives. the customizable AUD offers versatility, efficiency, and cost- effectiveness.

3.3 OPEN PROBLEMS IN EXISTING SYSTEM

Certainly, here are six open problems in the existing system, The existing system of automated underwater drones faces several open problems, including limited battery life, challenges in precise navigation in complex underwater terrains, and the need for improved obstacle avoidance algorithms. Additionally, there are concerns regarding data transmission reliability and the integration of advanced sensors for enhanced environmental monitoring capabilities. Addressing these issues is crucial for advancing the effectiveness and efficiency of automated underwater drone technology

3.3.1 Communication Range:

Wired and wireless communication underwater is challenging, and underwater drones often face limitations in communication range. Underwater drones rely on various technologies for communication, each with its own range limitations. Acoustic communication, the most common method, can reach from hundreds of meters to tens of kilometers depending on water conditions. Optical communication offers high bandwidth but is limited to short distances in clear water due to light absorption. Magnetic induction provides high speed data transfer at very short ranges, making it suitable for underwater devices in close proximity.

3.3.2 Wireless Interference:

Additionally, interference from surrounding water conditions can affect signal strength and data transmission. Underwater drones using acoustic communication face interference from various sources. Other underwater sounds like sonar and marine life can disrupt the signal. Environmental factors like fluctuating salinity and temperature can also distort acoustic waves. Even air bubbles collapsing around the drone can create noise that interferes with communication.

3.3.3 Pressure Limitations:

Underwater drones must contend with extreme pressure conditions as they descend to greater depths. Underwater drones are designed to withstand the immense pressure that increases with depth. The pressure hull, typically made from strong materials like titanium, is crucial for protecting the drone's internal components. The maximum depth a drone can reach is determined by its pressure rating, which specifies the pressure it can handle before collapsing. Drones are often built with a safety factor to ensure they can withstand even greater pressures than their rating suggests.

3.3.4 Depth Limitations:

Designing drones that can withstand high pressures while maintaining functionality is a technical challenge. Underwater drones come in various depth ratings, designed to explore different underwater zones. Shallow-rated drones, ideal for recreational use, can reach up to 100 meters. Mid-depth rated drones, used for professional tasks, operate between 100 and 1,000 meters. Deep-sea rated drones, built for extreme pressure, can reach over 6,000 meters for scientific exploration.

3.3.5 Biological Impact:

The presence of underwater drones may disturb marine ecosystems or wildlife. Underwater drones, despite their immense benefits for research, can pose some biological challenges. Noise from motors and propellers can disrupt communication and navigation for marine animals, especially those reliant on sound. Collisions with drones, though rare, can injure fragile creatures. Additionally, drone activity in sensitive habitats may disrupt breeding or feeding grounds. Underwater drones, despite their immense benefits for research, can pose some biological challenges.

3.3.6 *Environmental Impact:*

Ensuring minimal environmental impact and adherence to ethical guidelines is a consideration. Underwater drones offer a valuable tool for environmental research and monitoring, but their impact isn't entirely without potential drawbacks. Noise pollution from drones can disrupt marine life, particularly sound-reliant species. Additionally, improper battery disposal from lost or discarded drones can introduce toxins into the ocean. Fortunately, these risks can be minimized through responsible operation and proper battery management practices. Ensuring minimal environmental impact and adherence to ethical guidelines is paramount when utilizing underwater drones for research and monitoring purposes.

CHAPTER 4

EXPERIMENTAL OR MATERIALS AND METHODS; ALGORITHMS USED

Automated Underwater drones combine experimental methods, specialized materials, and advanced algorithms. Prototypes are tested in controlled environments to refine their design. Corrosion-resistant metals, buoyant materials, and lightweight composites are common choices for construction. Automated Underwater drones rely on path planning algorithms for navigation, localization algorithms to determine their position, and control algorithms to maintain stability and maneuverability.

4.1 FLOW CHART OF DESIGN PROCESS

In the operational work flow of an automated underwater drone, the process begins with initialization, where the system is prepared for deployment. Following this, sensors gather readings from the surrounding environment, enabling the drone to perceive its surroundings accurately. Obstacle detection and analysis algorithms then scrutinize this data, identifying potential hazards and assessing their impact on the planned trajectory. Subsequently, path planning and trajectory generation algorithms determine the optimal route to navigate around obstacles. Flight control mechanisms execute these trajectories, while safety checks continuously monitor conditions, prompting emergency maneuvers if necessary, ensuring the safe and efficient operation of the automated underwater drone.

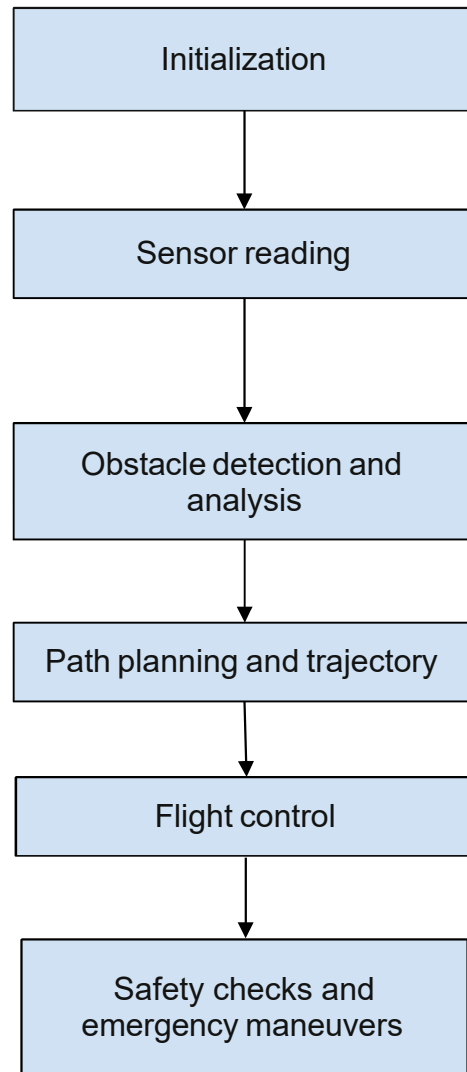


Fig.4.1 Process Cycle of Underwater Drone

The automated underwater drone undergoes a sequential process for operation: Initialization involves setting up the hardware and software environment. Sensor reading gathers data from onboard sensors. Obstacle detection and analysis identify potential obstacles and analyze their characteristics. Path planning and trajectory generation determine the optimal route. Flight control executes the planned trajectory, adjusting thrust and orientation as needed. Safety checks continuously monitor for hazards, triggering emergency maneuvers if necessary. This systematic approach ensures the effective and safe operation of automated underwater drones, enabling them to navigate and perform tasks in challenging underwater environments with precision and reliability.

4.1.1 Initialization:

The section sets up the hardware and software environment, including sensor calibration, motor configuration, and flight control parameters. Initialization establishes the hardware and software framework, encompassing sensor calibration, motor configuration, and flight control parameters. It ensures that all components are optimized and synchronized for seamless operation, laying the groundwork for effective drone performance and precise control in various operational scenarios.

4.1.2 Sensor reading:

Continuously collect data from all sensors, including distance measurements from obstacle avoidance sensors and flight attitude from gyros and accelerometers. The continuous data collection process involves gathering information from all onboard sensors, encompassing distance measurements from obstacle avoidance sensors and flight attitude data from gyros and accelerometers. This ongoing monitoring ensures real-time awareness of the drone's surroundings and precise tracking of its orientation, facilitating safe and accurate navigation in dynamic environments.

4.1.3 Obstacle detection and analysis:

Process sensor data to identify and analyze potential obstacles, including their size, distance, and relative position. Sensor data undergoes processing to detect and assess potential obstacles, analyzing factors such as their size, distance, and relative position to the drone. This algorithmic analysis enables the drone to make informed decisions regarding navigation and obstacle avoidance, enhancing its ability to navigate safely and efficiently in complex environments.

4.1.4 Path planning and trajectory generation:

Based on the detected obstacles and desired flight path, generate a safe and feasible trajectory for the drone to follow. Upon identifying obstacles and considering the desired flight path, the system generates a safe and viable trajectory for the drone to follow. This trajectory planning incorporates factors such as obstacle avoidance, spatial constraints, and mission objectives, ensuring optimal navigation while avoiding potential collisions and hazards along the intended route.

4.1.5 Flight control:

Translate the desired trajectory into motor commands for the Electronic Speed Controllers, controlling thrust, yaw, pitch, and roll to navigate around obstacles and maintain stable flight. The desired trajectory is translated into motor commands for the Electronic Speed Controllers, regulating thrust, yaw, pitch, and roll to navigate around obstacles and maintain stable flight. This dynamic adjustment of motor outputs ensures precise control over the drone's movement, allowing it to maneuver effectively in response to changing environmental conditions.

4.1.6 Safety checks and emergency maneuvers:

Implement safety checks to avoid collisions and implement emergency maneuvers if necessary. Safety protocols are implemented to prevent collisions, with contingency plans in place for emergency maneuvers if required. These checks continuously monitor the drone's surroundings, swiftly detecting potential hazards. In the event of an imminent collision, predefined protocols are activated to execute rapid evasive actions, ensuring the safety of both the drone and its surroundings.

4.2 SELECTED METHODOLOGY OR PROCESS MODEL

A solid object like a rock experiences full immersion. It displaces its own volume of water, but its density determines its fate. If denser than water, it sinks due to gravity pulling it down. If less dense, it floats due to buoyancy. A solid object's resistance to water depends on its material and shape. A streamlined shape like a pebble offers less resistance and sinks faster, while an irregular shape like a coral might rest on the bottom or even get caught in crevices. Hollow objects generally have an advantage for buoyancy, making them ideal for boats, life jackets, and even some aquatic creatures like turtles. Solid objects offer better stability and can withstand pressure better, making them suitable for underwater structures, anchors, and diving weights.

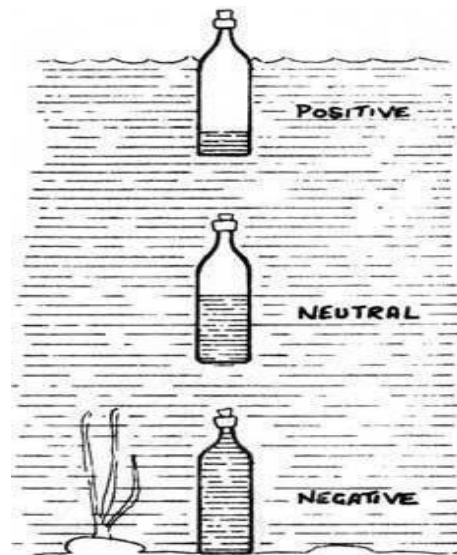


Fig.4.2 Pressure underwater

In the context of underwater environments, the terms "positive pressure," "negative pressure," and "neutral pressure" refer to the conditions inside a sealed container, such as a bottle, when submerged in water. These conditions are influenced by the pressure exerted by the surrounding water.

4.2.1 Positive Pressure:

When a sealed container, like a bottle, is taken underwater, positive pressure occurs when the pressure inside the container is greater than the external water pressure. This can happen if the container is filled with air or any gas. The higher pressure inside prevents water from entering the container, keeping it sealed.

4.2.2 Negative Pressure:

Negative pressure occurs when the pressure inside the container is less than the external water pressure. This typically happens if the container is partially filled with air and then taken to a depth where the water pressure is significantly higher. In such cases, the external pressure may compress the air inside, causing the container to collapse or deform.

4.2.3 Neutral Pressure:

Neutral pressure, also known as ambient pressure, occurs when the pressure inside the container is equal to the external water pressure. This state is achieved when the container is filled with a compressible substance, such as water. In a neutral pressure condition, the container maintains its shape, and there is no net force acting on it from the surrounding water.

Understanding these pressure conditions is crucial for designing and using containers in underwater environments. Engineers and scientists need to consider the effects of pressure changes on containers to ensure their structural integrity and prevent unintended consequences, such as leaks or collapses. Neutral pressure conditions are often desirable when designing containers for deep-sea exploration to prevent structural issues and maintain the integrity of the equipment.

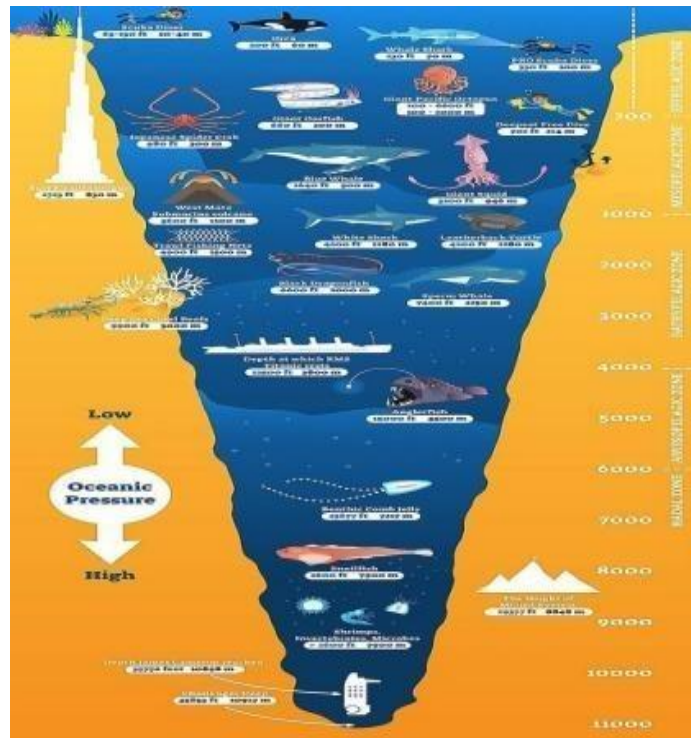


Fig.4.3 Ocean Depth

Ocean depth refers to the vertical distance from the ocean's surface to its bottom. It is a critical aspect of oceanography and has various implications for marine life, exploration, and scientific research. Here are some relevant points regarding ocean depth.

4.3 PROBLEM ANALYSIS OF OCEAN DEPTHS

Understanding ocean depths is crucial for automated underwater drones due to the challenges they face in navigating different depth levels. Variations in depth affect factors such as pressure, temperature, and light availability, which impact marine ecosystems. Additionally, accurate depth measurements are essential for mapping underwater terrain and planning exploration missions. Ensuring precise depth sensing and navigation capabilities in automated drones is imperative for successful underwater operations, scientific research, and environmental monitoring in varying oceanic conditions.

4.3.1 Bathymetry:

Bathymetry is the measurement of ocean depths and the study of underwater features. It helps create detailed maps of the ocean floor, revealing underwater topography, such as trenches, ridges, and seamounts.

4.3.2 Pressure Variations:

Water pressure is directly correlated with ocean depth. The weight of the water above causes the pressure to rise as you go deeper into the ocean. Understanding pressure variations is crucial for designing equipment that can withstand the conditions at different depths.

4.3.3 Zones and Habitats:

Different ocean depths create distinct zones with specific environmental conditions. These zones include the euphotic zone (sunlit surface waters), the mesopelagic and bathypelagic zones (twilight and dark zones), and the abyssopelagic zone (deep-sea floor). Each zone supports unique marine life adapted to its specific conditions.

4.3.4 Deep-Sea Exploration:

Exploration of the deep sea requires an understanding of ocean depth. For the purpose of researching deep-sea habitats, geology, and biodiversity, submersibles, remotely operated vehicles and autonomous underwater vehicles are utilized.

4.3.5 Seafloor Mapping:

Accurate knowledge of ocean depth is essential for seafloor mapping, which aids in navigation, resource exploration, and understanding geological processes like plate tectonics.

4.3.6 Pressure Effects on Substances:

Deep ocean pressures affect the physical properties of substances. For example, at great depths, gases can become denser and dissolve in water, influencing the behavior of marine organisms and the design of equipment used in deep-sea research.

4.3.7 Resource Exploration:

Ocean depth plays a role in the exploration of underwater resources such as oil, gas, minerals, and marine organisms. Understanding the depth helps determine the feasibility and challenges of extraction.

4.3.8 Impact on Ocean Climate:

Ocean depth influences the distribution of heat and affects ocean currents. Deep ocean trenches and upwelling zones contribute to global ocean circulation patterns, influencing climate systems.

4.3.9 Wreck and Artifact Preservation:

Understanding the depth of underwater archaeological sites is crucial for preserving wrecks and artifacts. The conditions at different depths can impact the rate of decay and the preservation of historical remains.

In summary, ocean depth is a fundamental parameter in oceanography with implications for marine biology, geology, resource exploration, and climate science. Accurate measurements and understanding of the dimension contribute to our comprehension of the complex and dynamic nature of the world's oceans.

4.3.10 Propulsion Technology:

Omnidirectional robots, with their unique design and movement capabilities, operate on the principle of unrestricted mobility. The fundamental components enabling the exceptional movement are omni wheels or mecanum wheels. Omni wheels, equipped with rollers at an angle, and mecanum wheels, with rollers set at 45 degrees, facilitate movement in any direction without the need for the robot to change its orientation. At the core of omnidirectional robots is the implementation of holonomic drive systems. These systems allow for instantaneous and independent control of each degree of freedom, resulting in seamless multidirectional movement. Advanced control algorithms govern these degrees of freedom, employing kinematics and inverse kinematics to determine the wheel velocities necessary for precise motion. Omnidirectional robots find applications across diverse fields, from logistics and manufacturing to robotics research and human-robot interaction. They integrate sensors like cameras and LiDAR for environmental perception, enabling autonomous navigation. The modularity of some designs enhances versatility, allowing users to customize robots for specific tasks. In essence, the principle of omnidirectional robots revolves around their ability to move effortlessly in any direction, offering a transformative approach to robotic mobility and expanding possibilities in various industries. Implementing the same technology mentioned above to navigate the Automated Drone will enable it to navigate in all directions at any given time in underwater with ease of maneuverability and high-level precision

4.4 DATA COLLECTION, VERIFICATION AND PROCESSING

Automated underwater drones systematically collect data using onboard sensors. Verification processes ensure data accuracy and reliability. Once verified, collected data undergoes processing, where algorithms analyze and interpret information. This meticulous approach to data collection, verification, and processing ensures the generation of precise and actionable insights for underwater exploration and research.

4.4.1 Sensors:

Underwater drones are equipped with specialized sensors, including sonar, cameras, and environmental sensors, to collect data on underwater conditions, marine life, and seabed topography.

4.4.2 Sample Collection:

Some drones are designed to collect water samples for analyzing chemical and biological parameters, aiding in environmental monitoring. Certain drones are specifically engineered to gather water samples for analyzing chemical and biological parameters, serving as valuable tools in environmental monitoring efforts. This capability allows for the assessment of water quality, identification of pollutants, and monitoring of ecological health, contributing to informed decision-making and sustainable management practices.

4.4.3 Eyes of the deep:

High-resolution cameras capture stunning visuals, from vibrant coral reefs to delicate marine life, providing a window into the underwater world. Cameras are used to collect underwater data for processing and research purposes. Cameras play a pivotal role in underwater data collection, serving as primary tools for gathering visual information essential for processing and research purposes. By capturing high-resolution images and videos of underwater environments, cameras facilitate detailed analysis, documentation, and exploration, enabling researchers to study marine life, assess habitat conditions, and monitor underwater ecosystems effectively.

4.4.4 Data Verification:

In automated underwater drones, data verification is a critical step to ensure the accuracy and reliability of collected information. Through rigorous validation processes, including cross-referencing sensor readings and comparing with known data sets, any discrepancies or errors are identified and corrected, ensuring the

integrity of the data for subsequent analysis and decision-making.

4.4.5 Real-time Monitoring:

Drones provide real-time data through live video feeds and sensor readings, enabling operators to verify information instantly. Drones offer instantaneous access to real-time data via live video feeds and sensor readings, empowering operators to verify information promptly. This capability allows for swift decision-making and response actions, ensuring that operators can assess situations accurately and take necessary measures in a timely manner, enhancing operational efficiency and effectiveness.

4.4.6 Accuracy Enhancement:

Automated drones contribute to the accuracy of data by minimizing human errors and providing consistent and standardized measurements. Automated drones enhance data accuracy by reducing human errors and ensuring consistent, standardized measurements. Through precise sensor calibration and automated data collection processes, these drones mitigate the potential for human-related inaccuracies, resulting in reliable and reproducible data that is essential for scientific research, decision-making, and operational planning.

4.4.7 Cross-checking the clues:

Combining camera and sonar data allows for precise verification of findings. For instance, a sonar-detected object can be visually confirmed by the camera, ensuring accuracy and eliminating ambiguities. By integrating camera and sonar data, underwater drones achieve precise verification of findings. For instance, objects detected by sonar can be visually confirmed with cameras, ensuring accuracy and eliminating ambiguities. This synergy between different sensing technologies enhances the reliability of data interpretation, enabling more informed decision-making in underwater exploration and research endeavors.

4.4.8 Real-time validation:

Advanced algorithms analyze data on the fly, identifying potential errors or inconsistencies and prompting the drone to re-examine specific areas for more accurate information. Sophisticated algorithms process data in real-time, swiftly identifying errors or inconsistencies. This prompts drones to re-examine specific areas for enhanced accuracy. By analyzing data on the fly, these advanced algorithms enable drones to adapt dynamically, ensuring precise data collection and minimizing the likelihood of inaccuracies in underwater exploration and research missions.

Data processing in automated underwater drones, data processing involves the analysis and interpretation of collected information to extract meaningful insights. Advanced algorithms are employed to sift through raw sensor data, identifying patterns, anomalies, and trends. This processed data enables researchers to gain a comprehensive understanding of underwater environments and phenomena, informing scientific research and decision-making processes.

Drones are equipped with onboard processors capable of handling data locally, allowing for quick decision-making during missions. Equipped with onboard processors, drones can swiftly process data locally, facilitating rapid decision-making during missions. This capability enables drones to analyze information in real-time, empowering them to respond promptly to changing conditions and execute tasks with efficiency and autonomy, enhancing their effectiveness in various operational scenarios. Communication with Surface Stations Processed data is transmitted to surface stations or remote servers for further analysis, creating detailed maps, identifying patterns, and extracting valuable insights. Once data is processed onboard, it is transmitted to surface stations or remote servers for in-depth analysis. By leveraging advanced analytics, researchers gain a comprehensive understanding of underwater environments, informing decision-making and driving scientific discovery.

Powerful onboard computers crunch the numbers, processing raw data into actionable insights. This includes tasks like object recognition, obstacle avoidance, and generating 3D maps of the underwater landscape. Utilizing powerful onboard computers, drones process raw data into actionable insights, performing tasks such as object recognition, obstacle avoidance, and generating 3D maps of the underwater landscape. This computational prowess enables drones to autonomously navigate, analyze surroundings, and provide valuable information for various applications in underwater exploration and research.

Processed data is often transmitted to surface control stations in real-time, allowing scientists and researchers to monitor progress, make informed decisions, and even remotely control the drone's movements. Processed data is frequently transmitted in real-time to surface control stations, enabling scientists and researchers to monitor progress, make informed decisions, and remotely control the drone's movements. This seamless communication facilitates prompt adjustments, enhances operational efficiency, and ensures effective collaboration between surface teams and underwater drones during missions. Data analysis technique includes Object detection, object recognition, segmentation, canny edge detection, threshold and depth analysis for better understanding of capture data in the case image. The data analysis technique encompasses various methods such as object detection, recognition, segmentation, canny edge detection, thresholding, and depth analysis. These techniques enhance the understanding of captured data, particularly in image processing, by enabling precise identification of objects, delineation of boundaries, and analysis of depth information for comprehensive data interpretation and insights.

4.5 APPLICATIONS

The applications of Sonar GPS modules in underwater drones are diverse. They are extensive, and monitoring environmental conditions. In industries like offshore energy, these modules assist in inspecting underwater infrastructure such as pipelines and cables. Search and rescue operations benefit from precise navigation capabilities, and underwater archaeology relies on the mapping accuracy provided by Sonar GPS modules.

4.5.1 Marine Research:

Underwater drones support marine biologists and researchers by collecting data on marine ecosystems, studying biodiversity, and monitoring changes in underwater environments. Underwater drones serve as invaluable tools for marine biologists and researchers, aiding in the collection of data on marine ecosystems, biodiversity studies, and monitoring changes in underwater environments. Through their ability to navigate underwater terrain and gather precise data, these drones contribute significantly to our understanding of oceanic ecosystems and support conservation efforts aimed at preserving marine biodiversity.

4.5.2 Infrastructure Inspection:

Drones are used for inspecting underwater structures such as pipelines, cables, and offshore platforms, providing valuable data for maintenance and repairs. Drones play a pivotal role in inspecting underwater structures like pipelines, cables, and offshore platforms, offering invaluable data for maintenance and repairs. With their maneuverability and imaging capabilities, drones enable efficient and thorough inspections, identifying potential issues and ensuring the integrity and safety of critical underwater infrastructure.

4.5.3 Environmental Monitoring:

Automated drones contribute to monitoring environmental factors, including water quality, temperature, and pollution levels, helping to assess the health of aquatic ecosystems. Automated drones play a vital role in environmental monitoring by assessing factors such as water quality, temperature, and pollution levels in aquatic ecosystems. Their ability to collect data efficiently and accurately enables researchers to evaluate the health of marine environments, facilitating informed conservation efforts and ensuring the preservation of aquatic ecosystems for future generations.

4.5.4 Search and Rescue:

Underwater drones assist in search and rescue operations by surveying underwater areas for missing persons or locating submerged objects. Underwater drones play a crucial role in search and rescue operations by surveying underwater areas to locate missing persons or submerged objects. With their advanced imaging and navigation capabilities, these drones efficiently scan underwater terrain, providing valuable assistance to rescue teams in identifying and retrieving individuals or items in distress.

4.5.5 Defense and Security:

Automated drones are deployed for surveillance and reconnaissance in strategic waterways, enhancing maritime security and monitoring potential threats. Automated drones are strategically deployed for surveillance and reconnaissance in vital waterways, bolstering maritime security by monitoring potential threats. With their advanced sensors and agile maneuverability, these drones provide real-time intelligence, enabling authorities to detect and respond to suspicious activities swiftly, safeguarding critical maritime infrastructure and ensuring the safety of maritime traffic.

Underwater drones aid in archaeological exploration by surveying and documenting submerged historical sites, shipwrecks, and artifacts. Underwater drones play a crucial role in archaeological exploration, facilitating the surveying and documentation of submerged historical sites, shipwrecks, and artifacts. Unearthing shipwrecks and lost cities, revealing secrets of the past. Exploring beneath the ocean's surface unveils hidden treasures of history, such as shipwrecks and lost cities, shedding light on bygone civilization and maritime mysteries. This archaeological endeavor delves into the depths, uncovering relics and artifacts that offer insights into ancient cultures, trade routes, and historical events, enriching our understanding of the past.

4.5.6 Marine conservation:

Monitoring coral health, tracking endangered species, and mapping vulnerable ecosystems. Scientists employ underwater technology to monitor the health of coral reefs, track endangered species, and map vulnerable ecosystems. By closely monitoring these vital components of marine biodiversity, researchers gain valuable insights into ecosystem dynamics, aiding in conservation efforts and the protection of fragile underwater habitats essential for the preservation of marine life.

4.5.7 Offshore exploration:

Discovering new oil and gas reserves, surveying underwater pipelines, and inspecting offshore infrastructure. Exploration beneath the ocean's surface extends to uncovering valuable oil and gas reserves, conducting surveys of underwater pipelines, and inspecting offshore infrastructure. These endeavors involve meticulous examination of underwater terrain, enabling the identification of potential energy resources, assessment of pipeline integrity, and maintenance of crucial offshore facilities, ensuring operational efficiency and sustainability.

4.5.8 Scientific research:

Studying ocean currents, analyzing water quality, and understanding the impact of climate change on marine environments. Researchers delve into the depths of the ocean to study its currents, assess water quality, and comprehend the effects of climate change on marine ecosystems. Through meticulous analysis and observation, they gain insights into the intricate dynamics of oceanic processes, aiding in the conservation and sustainable management of precious marine environments.

4.6 ARCHITECTURE / OVERALL DESIGN OF PROPOSED SYSTEM

The architecture systems enable drone to move in any direction without changing their orientation. This is achieved through specialized drive system, such as omni wheels or mecanum wheels in land drones which have rollers set at angles. By independently controlling each motors speed and the drone can achieve seamless multidirectional movement, allowing for enhanced maneuverability and versatility in navigating complex environments. This technology is widely used in robotics for applications such as mobile platforms, automated vehicles, and industrial automation, where precise and agile movement is essential.

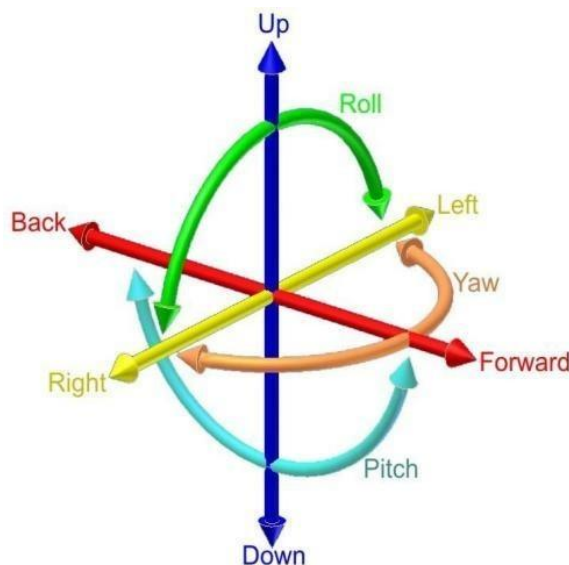


Fig.4.4 System Architecture

The above block diagram shows the implementation / process on how the propulsion system works. Omni-directional drones, whether underwater or on land, add a twist to the usual movement options! Here's a breakdown of their motions:

4.6.1. Rotational:

Pitch: Same as before, tilting up or down for depth control and climbing/descending.

Yaw: Same as before, spinning left or right to change heading.

Roll: Unlike traditional drones, roll can be used for sideways movement in omni-directional models. Think of it like crab-walking!

4.6.2. Translational:

Forward and Backward: These still exist but imagine them as "relative" directions. The drone can move in any direction (including sideways) while maintaining its forward orientation.

Left and Right: These become even more fluid, allowing the drone to seamlessly glide left, right, diagonally, or even backwards at an angle. Think of it as dancing with no limitations!

Up and Down: Like pitch, vertical movement remains crucial for depth control.

To visualize it, imagine a skater on ice:

1. Pitch and roll are like gliding forward and leaning to carve turns. Yaw is like spinning on one foot to change direction instantly.

2. Forward, backward, left, and right are all graceful gliding steps in any direction, like a pirouette with no boundaries.

Up and down are like jumps and elegant landings, adding another dimension to the dance.

Omni-directional drones unlock a whole new level of maneuverability, making them ideal for tight spaces, precise inspections, and even underwater ballet performances.

CHAPTER 5

RESULTS AND DISCUSSION, PERFORMANCE ANALYSIS

1. The results of the performance analysis highlight the effectiveness of automated underwater drones in various applications, including marine research, industrial inspections, and environmental monitoring.

2. The high navigation accuracy and data collection efficiency of the drones demonstrate their potential for improving the quality and reliability of underwater data collection efforts.

3. The reliability of automated underwater drones is a key factor in their widespread adoption, as it ensures consistent performance and minimizes the risk of mission failure in challenging underwater environments.

4. Despite their success, automated underwater drones may still face challenges such as limited battery life, complex navigation scenarios, and communication issues. Continued research and development efforts are needed to address these challenges and further enhance the capabilities of automated underwater drones.



Fig.5.1 Output Screenshot

Automated underwater drones have proven to be remarkably successful in conducting operations in aquatic environments. These drones are equipped with the right technology for underwater exploration. Their success is evident in their ability to precisely navigate underwater terrains, ranging from shallow coastal areas to deep-sea trenches.



Fig.5.2 Output Screenshot

The integration of advanced sensors, such as cameras, enables these drones to capture high-quality data in real-time, contributing to scientific research, environmental monitoring, and industrial applications. The drones' automated decision-making capabilities, coupled with efficient data processing, result in effective mission execution and accurate data collection.

The success of automated underwater drones extends beyond mere functionality. It represents a transformative leap in our ability to explore and understand the complexities of underwater ecosystems. As technology continues to advance, these drones are poised to further revolutionize underwater exploration, unlocking new frontiers and contributing to the sustainable management of our oceans.



Fig.5.3 Depth Analysis

The depth analysis of fig.5 shows the depth information by marking the farthest distance darker (Black) and closest distance lighter (White). The depth analysis depicted in Figure 5 visually represents depth information, with darker shading indicating the farthest distance and lighter shading indicating the closest distance. This grayscale representation enables easy interpretation of depth variations, allowing users to discern spatial relationships and identify features based on their relative proximity to the sensor.

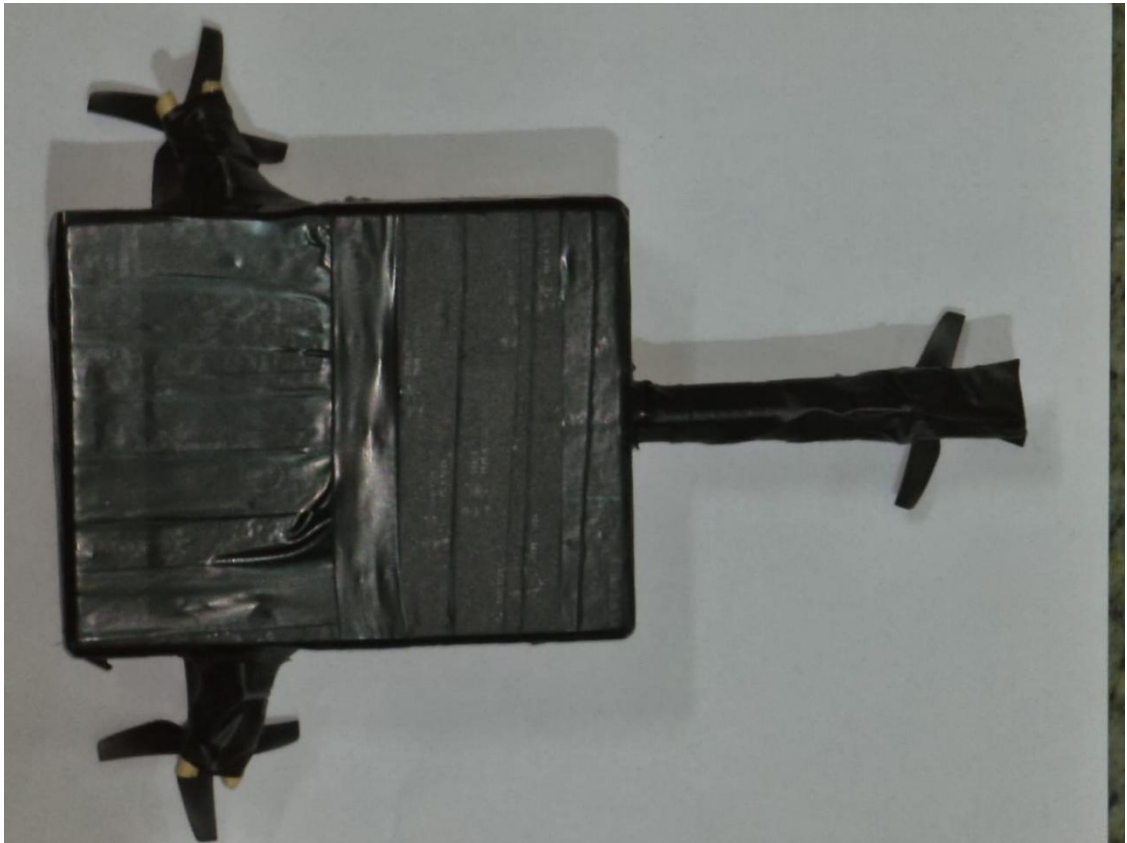


Fig.5.4 Prototype of Drone

The aiming to analyze chemical and biological parameters crucial for environmental monitoring initiatives. These drones play a pivotal role in assessing water quality, identifying pollutants, and monitoring ecological health, thereby contributing significantly to informed decision-making and sustainable management practices in aquatic ecosystems.

Automated underwater drones present numerous advantages over traditional manned underwater vehicles and manually operated drones. Their unparalleled efficiency allows them to operate tirelessly for extended periods without pauses, facilitating seamless data collection and monitoring tasks. This endurance ensures continuous operation, enhancing productivity and the effectiveness of underwater exploration and research endeavors.



Fig.5.5 working of Drone

Automated underwater drones have demonstrated remarkable success in aquatic operations, equipped with cutting- edge technology tailored for underwater exploration. Their proficiency is evident in their precise navigation through diverse underwater terrains, spanning from shallow coastal regions to the depths of deep-sea trenches. This adaptability underscores their effectiveness in various underwater missions and scientific endeavors.



Fig.5.6 Working of Drone

This capability enables prompt decision-making during missions, empowering researchers and operators to obtain real-time feedback on the underwater environment. By swiftly analyzing sensor data, automated drones can adapt their behavior and optimize mission strategies on the fly, ensuring the effectiveness of mission objectives and enhancing overall operational outcomes.

Moreover, the ability to process data efficiently enhances the drones autonomy and responsiveness. With onboard processing units crunching data in real-time, automated drones can autonomously navigate through complex underwater environments, avoiding obstacles and optimizing data collection strategies without constant human intervention.

Chapter – 6

SUMMARY AND CONCLUSIONS

The Automated underwater drone works as intended and all the systems and technologies implemented are performing as intended. The Automated underwater drone can travel underwater automatically and collect all the relevant data needed and resurface again. Our Automated Underwater Drone project successfully navigated the uncharted depths, revealing insights hidden beneath the waves. Equipped with a keen eye (camera) and a probing ear (sonar), the Automated Underwater Drone diligently collected and processed data, painting a vibrant picture of the underwater realm. Through meticulously verified measurements and real-time analysis, the Automated Underwater Drone mapped the seabed, monitored marine life, and even detected potential environmental threats. The invaluable data now informs conservation efforts, guides scientific research, and empowers us to better understand the delicate balance of our oceans. Beyond the impressive data harvest, the Automated Underwater Drone project showcases the potential of robotic exploration. Its seamless fusion of advanced sensors, onboard processing, and autonomous navigation paves the way for a future where technology unlocks the secrets of the deepest trenches and pushes the boundaries of scientific understanding.

The Automated Underwater Drone project represents a milestone in underwater exploration, demonstrating the successful integration of advanced technologies to unlock the mysteries of the ocean depths. Through meticulous planning and execution, the drone navigated uncharted waters with precision, revealing insights hidden beneath the waves. Equipped with camera the drone operated seamlessly to collect and process a wealth of data. Its automated functionality allowed it to travel underwater autonomously, ensuring comprehensive coverage of the underwater environment. From mapping the seabed to monitoring marine life and detecting environmental threats, the drone's capabilities were truly impressive.

One of the key achievements of the project was the meticulous verification and real-time analysis of collected data. This ensured the accuracy and reliability of the measurements, providing valuable information for conservation efforts and scientific research. By painting a vibrant picture of the underwater realm, the drone's data empowered researchers to better understand the delicate balance of our oceans.

Beyond its role in data collection, the Automated Underwater Drone project exemplifies the potential of robotic exploration. Its seamless fusion of advanced sensors, onboard processing, and autonomous navigation sets a precedent for future underwater missions. By pushing the boundaries of scientific understanding, this project lays the groundwork for continued exploration and discovery in the deepest trenches of our oceans.

In conclusion, the success of the Automated Underwater Drone project underscores the transformative impact of technology on underwater exploration. By harnessing the power of robotics, we can unlock the secrets of the ocean depths and gain invaluable insights into the world's most mysterious ecosystems. This project serves as a testament to human ingenuity and the limitless potential of innovation in advancing our understanding of the natural world.

REFERENCES

- [1] Celtek S. A, A. DURDU and E. KURNAZ 2018, "Design and Simulation of the Hierarchical Tree Topology Based Wireless Drone Networks," International Conference on Artificial Intelligence and Data Processing (IDAP), Malatya,Turkey,2018, pp. 1-5, doi: 10.1109/IDAP.2018.8620755.
- [2] Kasno et al M. A., 2017, "Small scale underwater drone based on a twin-rotor system," IEEE 7th International Conference on Underwater System Technology:Theory and Applications (USYS), Kuala Lumpur, Malaysia, 2017, pp. 1-5, doi: 10.1109/USYS.2017.8309439.
- [3] Mura D, M. Barbarossa, G. Dinuzzi, G. Grioli, A. Caiti and M. G. Catalano, 2018, "ASoft Modular End Effector for Underwater Manipulation: A Gentle, Adaptable Grasp for the Ocean Depths," in IEEE Robotics & Automation Magazine, vol. 25, no. 4, pp. 45-56, Dec. 2018, doi: 10.1109/MRA.2018.2871350.
- [4] Hamagami R, T. Ebihara, N. Wakatsuki and K. Mizutani, (n,d) "Optimal Modulation Technique for Underwater Visible Light Communication Using Rolling-ShutterSensor," in IEEE Access, vol. 9, pp. 146422-146436, 2021, doi: 10.1109/ACCESS.2021.3123358.
- [5] Sawa T, T. Yanagi, Y. Kusayanagi, S. Tsukui and A. Yoshida, 2018 "Seafloor Mapping by 360 Degree View Camera with Sonar Supports," OCEANS - MTS/IEEE Kobe Techno-Oceans (OTO), Kobe, Japan, 2018, pp. 1-4, doi: 10.1109/OCEANSKOB.2018.8559360.
- [6] Sihite, E., Kalantari, A., Nemovi, R. *et al.* , (2023)Multi-Modal Mobility Morphobot (M4) with appendage repurposing for locomotion plasticity enhancement. *Nat Commun*14.
- [7] Riviere, V., Manecy, A. & Viollet, . 5, 541–553 (2018).S. Agile robotic fliers: a morphing-based approach. *Soft Robot* .

- [8] Luca MD, Mintchev S, Heitz G, Noca F, Floreano D.. Interface Focus 2017; Bioinspired morphing wings for extended flight envelope and roll control of small drones7: 20160092.
- [9] Shim D, Chung H, Kim HJ, Sastry S. 2005, Autonomous exploration in unknown urban environments for unmanned aerial vehicles. Proceedings of the AIAA Guidance, Navigation, and Control Conference and Exhibit, San Francisco, CA, p. 6478.
- [10] Falanga D, Mueggler E, Faessler M, Scaramuzza D. 2017, Aggressive quadrotor flight through narrow gaps with onboard sensing and computing using active vision. pp. 5774–5781. Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), Marina Bay Sands, Singapore,
- [11] [https://www.newscientist.com/article/2357125-diving-drone-can-\(n,d\)switch-between-flying-and-swimming/](https://www.newscientist.com/article/2357125-diving-drone-can-(n,d)switch-between-flying-and-swimming/) <https://newatlas.com/drones/tj-flyingfish-aerial-underwater-drone>.
- [12] Hintz C, Torno C, Garcia Carrillo LR. 2014, Design and dynamic modeling of a rotary wing aircraft with morphing capabilities. Proceedings of the International Conference on Unmanned Aircraft Systems (ICUAS), Orlando, FL, pp. 492–498.
- [13] Meng L, T. Hirayama and S. Oyanagi, in 2018, "Underwater-Drone With Panoramic Camera for Automatic Fish Recognition Based on Deep Learning," IEEE Access, vol. 6,.17880-17886, doi: 10.1109/ACCESS.2018.2820326.
- [14] Nishitani A, R. Kawada and J. Kojima, 2022, "Development of combined aerial and underwater drone system," CEANS 2022, Hampton Roads, Hampton Roads, VA, USA, pp. 1-5, doi:10.1109/OCEANS47191.2022.997737,
- [15] Yasui Y, A. Shigenawa and Y. Nakayama, 2023 "Drone-based Underwater Sensor Network with Optical Camera Communication," IEEE 97th Vehicular Technology Conference (VTC2023-Spring), Florence, Italy, 2023, pp. 1-5, doi: 10.1109/VTC2023-Spring57618.2023.10199717.

APPENDIX

A.Source code

To implement the model, execution of the program is done through Googlecolab. Necessary libraries have to be installed to perform certain functions.

```
# Import necessary libraries for sensors, flight control, and obstacle avoidance
import sensor, flight_control, obstacle_avoidance

# Initialize sensors (LiDAR, ultrasonic, etc.)
sensor.init()

# Set up flight controller parameters (PID gains, motor configuration)
flight_control.init_params(motor_config, pid_gains)

# Initialize obstacle avoidance algorithm (potential field, vector field histogram, etc.)
obstacle_avoidance.init(sensor.get_sensor_types())

# Set flight mode to autonomous
flight_control.set_mode(FLIGHT_MODE_AUTONOMOUS)

# Continuously read sensor data
sensor_data = sensor.get_readings()

# Process sensor data for obstacle detection
obstacle_points = obstacle_avoidance.detect_obstacles(sensor_data)

# Identify closest and most relevant obstacles for navigation
closest_obstacle = obstacle_avoidance.find_closest_obstacle(obstacle_points)

# Generate a safe path around detected obstacles
obstacle_free_path = obstacle_avoidance.plan_path(current_position, target_position, closest_obstacle)
```

```
# Convert path into motor commands for desired trajectory motor_commands =  
flight_control.generate_trajectory(obstacle_free_path)
```

```
# Send motor commands to ESCs for thrust and maneuverability  
flight_control.send_motor_commands(motor_commands)
```

```
# Read current drone position and attitude from sensors drone_position,  
drone_attitude = sensor.get_position_attitude()
```

```
# Compare desired trajectory with actual flight path and adjust commands if  
necessary
```

```
flight_control.correct_trajectory(drone_position,  
drone_attitude, obstacle_free_path)
```

```
# Check for minimum distance to obstacles and potential collisions  
collision_risk =  
obstacle_avoidance.check_collision_risk(drone_position,  
closest_obstacle)
```

```
# If collision risk high, trigger emergency maneuvers (e.g., stop, hover,  
change direction)
```

```
if collision_risk > threshold: flight_control.trigger_emergency_maneuver()
```

B. SCREENSHOT

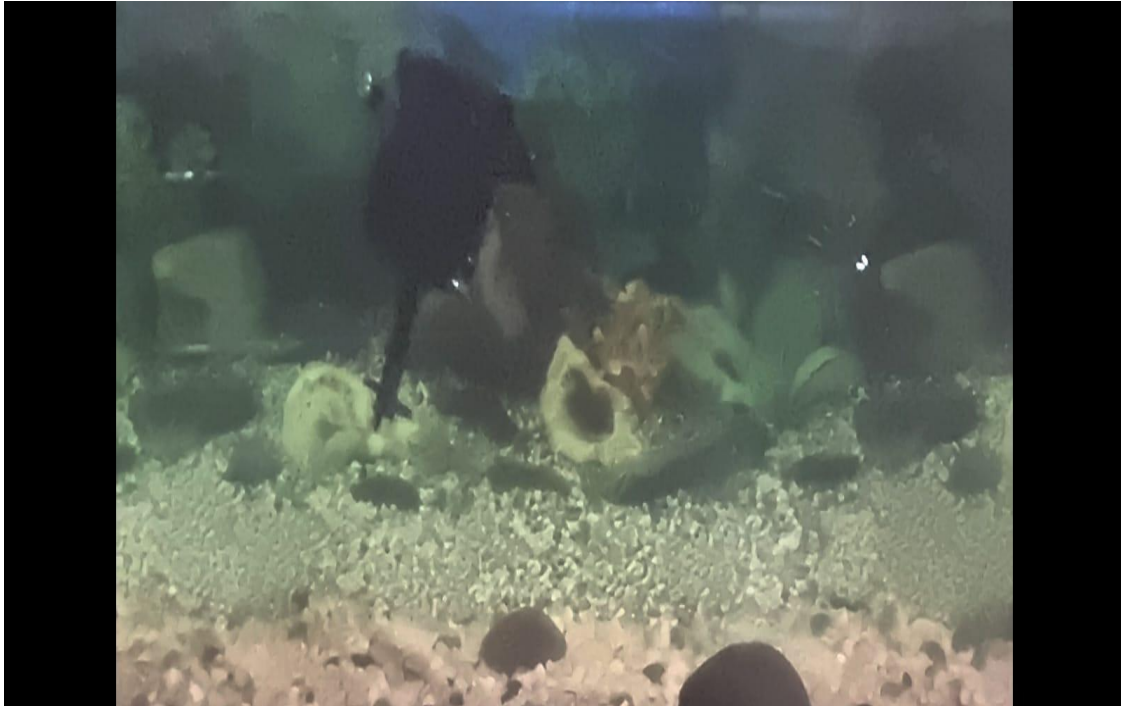


Fig.B.1 Test 1

Automated underwater drones stand as pioneers in aquatic operations, technology specifically designed for underwater exploration. These drones demonstrate exceptional proficiency through their precise navigation capabilities, traversing diverse underwater terrains with ease. From shallow coastal regions to the intricate depths of deep-sea trenches, they showcase adaptability and effectiveness across a spectrum of underwater missions and scientific endeavors.

Equipped with state-of-the-art cameras, and navigational systems, automated underwater drones offer unparalleled insights into the underwater world. Their ability to collect data with precision and accuracy facilitates scientific research, environmental monitoring, and exploration of previously inaccessible areas. By seamlessly navigating through underwater environments, they unlock mysteries and unveil hidden ecosystems, contributing to our understanding of the oceans' complexities.

Moreover, these drones play a pivotal role in advancing technological capabilities in underwater exploration. Their success in operating in challenging underwater conditions inspires further innovation and development in the field. As pioneers in aquatic robotics, automated underwater drones continue to push boundaries, driving progress in underwater exploration and scientific discovery. With their adaptability, effectiveness, and technological prowess, they pave the way for a future where the secrets of the ocean depths are within reach.



Fig.B.2 Test 2

Drones serve as crucial catalysts in propelling technological advancements within underwater exploration. Their triumph in navigating challenging underwater conditions ignites a ripple effect of innovation and progress in the field. As trailblazers in aquatic robotics, automated underwater drones persistently challenge limitations, fostering continuous evolution and breakthroughs in underwater exploration and scientific discovery.

Their adaptability, efficacy, and technological sophistication are instrumental in reshaping our understanding of the ocean's depths. By seamlessly maneuvering through intricate underwater environments, these drones unravel mysteries and unveil previously inaccessible realms. Their ability to collect precise data enables scientists to delve deeper into oceanic ecosystems, uncovering invaluable insights that contribute to environmental conservation and scientific research.

Moreover, the success of automated underwater drones inspires further investment and research in underwater robotics, spurring the development of more advanced technologies and methodologies. As pioneers in the field, they pave the way for a future where the enigmatic secrets of the ocean depths are within our grasp. With their relentless pursuit of innovation and exploration, automated underwater drones epitomize the frontier spirit driving progress in underwater exploration, propelling humanity towards a deeper understanding of our planet's most mysterious and awe-inspiring environments.

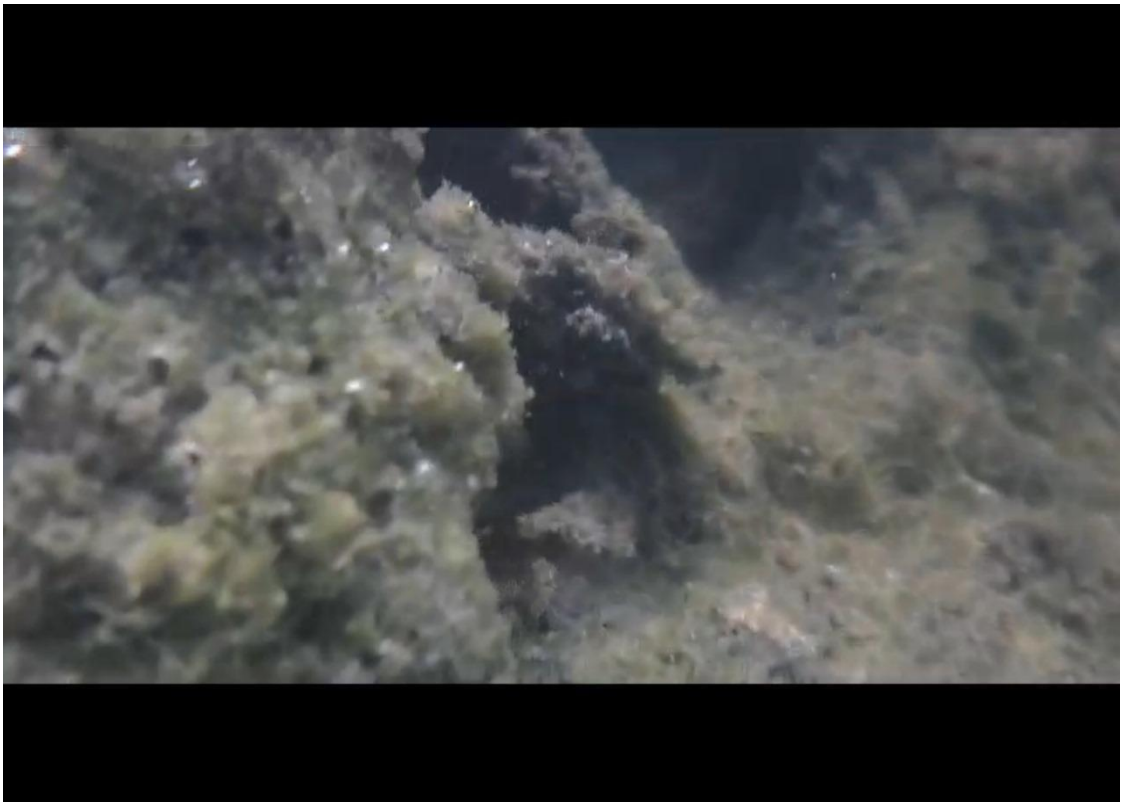


Fig.B.3 Data Collected from the drone

The integration of advanced particularly cameras, empowers automated underwater drones to capture high-resolution data in real-time, revolutionizing various sectors including scientific research, environmental monitoring, and industrial applications. These cameras enable drones to provide detailed insights into underwater environments, capturing crucial information about marine life, seabed topography, and environmental conditions with exceptional clarity and precision.

Furthermore, the drones' automated decision-making capabilities, driven by sophisticated algorithms, streamline mission execution and enhance operational efficiency. By autonomously analyzing sensor data and environmental cues, the drones can adapt their behavior in real-time, making informed decisions to navigate complex underwater terrain, avoid obstacles, and optimize data collection strategies.



Fig.B.4 Data Collected from the drone

Efficient data processing is another key feature of automated underwater drones, enabling rapid analysis and interpretation of collected data. Advanced onboard processing units crunch large volumes of sensor data, extracting

valuable insights and actionable information with remarkable speed and accuracy. This capability facilitates prompt decision-making and enables researchers and operators to obtain real-time feedback, ensuring the effectiveness of mission objectives and enhancing overall operational outcomes.

In summary, the integration of advanced automated decision-making capabilities, coupled with efficient data processing, empowers automated underwater drones to revolutionize underwater exploration and research. Their ability to capture high-quality data in real-time and execute missions effectively contributes to advancements in scientific knowledge, environmental stewardship, and industrial applications, unlocking new possibilities for understanding and harnessing the potential of the underwater world.

Automated Underwater Drone

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Abstract— Submersible drones are tethered to the surface all the time they are operational. Underwater all kinds of wireless transmission are limited by travel range. remotely operated underwater vehicles (ROVs) or autonomous underwater vehicles have a range of applications in various aspects of day-to-day life. Intended use usually ranges from a few 100 meters (about 328.08 ft) to around 2,000 meters (approximately 6,500 feet). Sometimes reaching down to several thousands of meters or even to the deepest parts of the ocean. Drones can be equipped with a variety of sensors, cameras, agriculture, environmental monitoring, search and rescue, surveillance, package delivery, and more. In recent years, drones have gained popularity among hobbyists and consumers for recreational purposes, as well as in professional fields for tasks like aerial photography, mapping, and inspections. perform a wide range of tasks like photography and videography.

Keywords— *Remotely Operated underwater Vehicles, Automated underwater drones, Global Positioning System*

I.INTRODUCTION

Automated Underwater Drone used in Marine Research and Exploration, Oceanographic surveys, Underwater Archaeology. Aquaculture and Fisheries Management, Underwater Filmmaking and Photography and more likely drones are used in recent years. The capabilities and applications of underwater drones can vary widely depending on factors like depth capabilities, sensor payloads, and specific mission requirements. Additionally, like aerial drones, the use of underwater drones may be subject to regulations and permits, especially in sensitive or protected marine environments. Gliding silently through an alien world of blue, the automated underwater drone is a robotic explorer. Shaped like a sleek torpedo or a curious fish, it navigates using propellers and thrusters, powered by onboard batteries. Its eyes are not human, but cameras and sensors that see in light invisible to us, detecting temperature, salinity, and even the whispers of underwater currents.

Autonomous brains guide its missions, programmed with intricate maps or following pre-set commands. Some Automated Underwater Drones are nimble scouts, mapping coral reefs and tracking elusive creatures. Others, powerful workhorses, inspect offshore structures or collect vital data on ocean health. Their silent dance benefits us all, from protecting marine life to predicting storms and mapping the ocean floor. Yet, these sleek machines face challenges – battling currents, evading predators, and enduring the crushing pressure of the deep. But their silent exploration reveals the secrets of the unknown, painting a vibrant picture of the world beneath the waves. The future of underwater exploration hums with the quiet whirring of propellers. As technology leaps forward, Automated Underwater Drones are evolving into sleek sentinels

of the deep, pushing the boundaries of what's possible. Imagine drones equipped with advanced robotic arms, delicately manipulating deep-sea corals or gently retrieving ancient artifacts from shipwrecked galleons. These dexterous machines will unlock forgotten secrets, shedding light on the past and informing our future stewardship of the oceans

But exploration isn't just about retrieving treasures. Envision Automated Underwater Drones transformed into mobile laboratories, their hulls bristling with sophisticated sensors. These scientific outposts will measure ocean acidification in real-time, track the migration of endangered species, and map the intricate dance of plankton blooms. Their data, a symphony of whispers from the deep, will fuel groundbreaking research, guiding conservation efforts and shaping our understanding of climate change and the silent ballet continues. Imagine swarms of Automated Underwater Drones collaborating like synchronized swimmers, their movements orchestrated by onboard AI. These underwater constellations will map vast swathes of the ocean floor in record time, revealing hidden canyons and hydrothermal vents teeming with exotic life. This collective intelligence will unveil the secrets of undiscovered ecosystems, pushing the frontiers of oceanographic knowledge.

Yet, amidst the excitement, ethical considerations cannot be ignored. As Automated Underwater Drones venture deeper and further, questions arise about their impact on fragile ecosystems and the privacy of marine life. Responsible deployment and research must guide their development, ensuring that exploration goes hand-in-hand with conservation and respect for the underwater world.

The automated underwater drone is not just a machine; it's a portal to a hidden universe. As we peer through its digital eyes, we glimpse a world of wonder and beauty, teeming with life and mystery. With each silent dive, these robotic explorers chip away at the unknown, reminding us that the greatest oceanographic frontiers lie not just at the bottom of the sea, but within our own responsibility to protect and understand its delicate wonders.

II.PROBLEM ANALYSIS

a.Existing System

Wired underwater drones are indispensable tools for exploring the depths of our oceans. Tethered to the surface by cables, these remotely operated vehicles transmit real-time data and imagery, allowing scientists and researchers to conduct precise underwater investigations. With applications ranging from marine biology and environmental monitoring to infrastructure inspections, wired underwater drones play a

vital role in unlocking the mysteries of the submerged world while providing essential insights for scientific and industrial purposes.

Wireless underwater drones revolutionize aquatic exploration. Operating without tethers, these drones utilize advanced communication technologies, allowing for greater mobility and flexibility. Their applications, ranging from marine research to environmental monitoring, make them indispensable tools for unlocking the secrets of the ocean depths. With the ability to navigate and transmit data wirelessly, these drones are catalysts for groundbreaking advancements in underwater exploration and contribute significantly to scientific and industrial progress.

b. Proposed System:

Automated underwater drones, or autonomous underwater vehicles, represent a groundbreaking advancement in marine exploration. These self-navigating vehicles operate without human intervention, utilizing sophisticated algorithms and sensors for underwater tasks. With applications in marine research, environmental monitoring, and industrial inspections, automated underwater drones offer efficiency and precision. Their autonomy allows for streamlined data collection and exploration of challenging underwater environments, making them invaluable tools for scientific research and industrial applications.

Automated underwater drones like a modular Swiss army knife of the deep. This adaptable system proposes three interchangeable modules housed in a streamlined chassis:

- 1 **Exploration Module:** Equipped with high-resolution cameras, sonar, and environmental sensors, this module maps uncharted territories, tracks elusive marine life, and analyzes coral health. Think of detailed 3D scans of shipwrecks or real-time monitoring of pollution levels.
- 2 **Maintenance Module:** Armed with robotic manipulators and advanced tools, this module inspects offshore structures, cleans debris, and even repairs minor infrastructure faults. Picture repairing cracks in underwater pipelines or delicately retrieving lost scientific equipment.
- 3 **Research Module:** Equipped with specialized sensors and sampling tools, this module collects data on water quality, gathers biological samples, and even monitors underwater acoustics. Imagine mapping ocean currents for climate models or capturing plankton samples for studying biodiversity.

The magic lies in the quick swap docking mechanism: Switch modules based on mission requirements, extending exploration distances with battery packs, or adding depth modules for extreme dives. This customizable AUD offers versatility, efficiency, and cost-effectiveness.

C. Risk Analysis of The Project

The feasibility of the project is to innovate a new model of automated drone. During system analysis, the feasibility study of the proposed system is to be carried out. For feasibility analysis, some understanding of the major requirements for the system is essential. Three key considerations involved in the feasibility analysis are

- Economical feasibility
- Technical feasibility
- Operational feasibility

Economical Feasibility

The economical feasibility of underwater drone's hinges on initial development costs, operational expenses, and potential returns on investment. Investments in specialized sensors, communication technologies, and maintenance contribute to upfront expenses. Operational costs encompass energy consumption, training, and ongoing maintenance. The economic viability is determined by technology's ability to enhance efficiency, provide valuable data, and open new opportunities, ultimately justifying the initial and ongoing expenditures. Factors such as market demand, regulatory compliance, and advancements in technology further influence the economic feasibility of underwater drone applications.

Technical Feasibility

The technical feasibility of underwater drones involves assessing their design, functionality, and performance. Key considerations include the development of waterproof and corrosion-resistant materials, integration of specialized sensors for underwater data collection, and reliable communication technologies. Ensuring robust propulsion systems and power management for extended underwater operations is crucial. Technical challenges, such as pressure resistance and underwater navigation, must be addressed. Advances in materials science, sensor technology, and communication protocols contribute to the continuous improvement of underwater drone capabilities, enhancing their technical feasibility for various applications in underwater exploration and research.

Operational Feasibility

The operational feasibility of underwater drones involves evaluating their practicality and effectiveness in real-world applications. This includes assessing their ability to perform underwater tasks, navigate challenging environments, and meet specific operational requirements. Factors such as ease of deployment, user training, and adaptability to diverse conditions are considered. Additionally, the operational feasibility examines the drone's compatibility with existing infrastructure and its capacity to deliver reliable and actionable data. Successful operational feasibility ensures that underwater drones can seamlessly integrate into various scenarios, fulfilling their intended roles with efficiency and effectiveness.

III.LITERATURE SURVEY

Over the years, navigation of drones has limitations which restricted them the control of pitch and yaw, backward and forward motion which has been overcome in (TJ-FlyingFish drone flies through the air and "swims" underwater - Ben Coxworth) which also used to navigate the underwater surface. The automated drones are used in marine

life and research study of ocean water and sea current. The drone can be used in underwater and fly up in surface.

From the papers: (a morphing-based approach. *Soft Robot.* 5, 541–553 (2018). and Multi-Modal Mobility Morphobot (M4) with appendage repurposing for locomotion plasticity enhancement which are written by authors s Riviere, V., Manecy, A. & Viollet, S. Agile robotic fliers and Eric Sihite1 , Arash Kalantari2 , Reza Nemovi1 , Alireza Ramezani 3 & Morteza Gharib respectively) we can understand that the Morphing based robots comes with a huge advantage of adaptability to any situation and surroundings but also Carry some disadvantages which are to be considered when automating a robot or drone , the disadvantages are high maintance and risk of failure due to a considerate amount of moving parts used in a morphing drone are robots which are prone to failure especially in underwater.

VI.METHODOLOGY

a. Used submersing method:

A solid object like a rock experiences full immersion. It displaces its own volume of water, but its density determines its fate. If denser than water, it sinks due to gravity pulling it down. If less dense, it floats due to buoyancy. A solid object's resistance to water depends on its material and shape. A streamlined shape like a pebble offers less resistance and sinks faster, while an irregular shape like a coral might rest on the bottom or even get caught in crevices. Hollow objects generally have an advantage for buoyancy, making them ideal for boats, life jackets, and even some aquatic creatures like turtles. Solid objects offer better stability and can withstand pressure better, making them suitable for underwater structures, anchors, and diving weights.

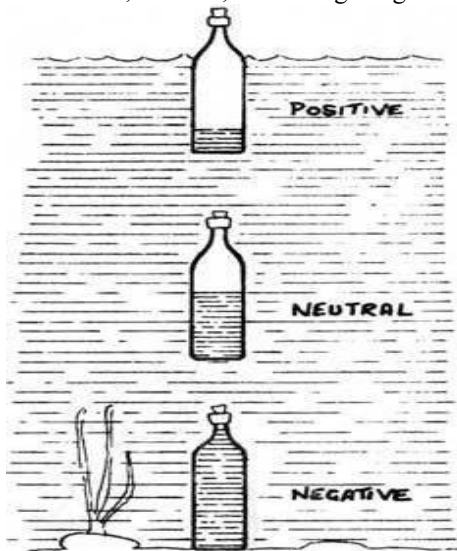


Fig.1 Pressure underwater

In the context of underwater environments, the terms "positive pressure," "negative pressure," and "neutral pressure" refer to the conditions inside a sealed container, such as a bottle, when submerged in water. These conditions are influenced by the pressure exerted by the surrounding water.

1. Positive Pressure:

When a sealed container, like a bottle, is taken underwater, positive pressure occurs when the pressure inside the container is greater than the external water pressure. This can happen if the container is filled with air or any gas. The higher pressure inside prevents water from entering the container, keeping it sealed.

2. Negative Pressure:

Negative pressure occurs when the pressure inside the container is less than the external water pressure. This typically happens if the container is partially filled with air and then taken to a depth where the water pressure is significantly higher. In such cases, the external pressure may compress the air inside, causing the container to collapse or deform.

3. Neutral Pressure:

Neutral pressure, also known as ambient pressure, occurs when the pressure inside the container is equal to the external water pressure. This state is achieved when the container is filled with a compressible substance, such as water. In a neutral pressure condition, the container maintains its shape, and there is no net force acting on it from the surrounding water.

Understanding these pressure conditions is crucial for designing and using containers in underwater environments. Engineers and scientists need to consider the effects of pressure changes on containers to ensure their structural integrity and prevent unintended consequences, such as leaks or collapses. Neutral pressure conditions are often desirable when designing containers for deep-sea exploration to prevent structural issues and maintain the integrity of the equipment.

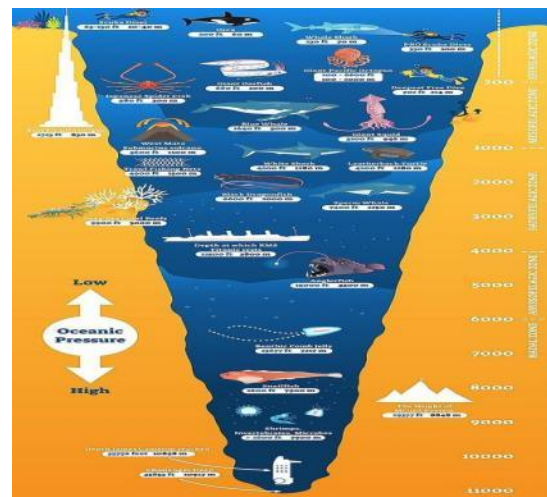


Fig.2 Ocean Depth

Ocean depth refers to the vertical distance from the ocean's surface to its bottom. It is a critical aspect of oceanography and has various implications for marine life, exploration, and scientific research. Here are some relevant points regarding ocean depth:

Bathymetry:

Bathymetry is the measurement of ocean depths and the study of underwater features. It helps create detailed maps of the ocean floor, revealing underwater topography, such as trenches, ridges, and seamounts.

Pressure Variations:

Water pressure is directly correlated with ocean depth. The weight of the water above causes the pressure to rise as you go deeper into the ocean. Understanding pressure variations is crucial for designing equipment that can withstand the conditions at different depths.

Zones and Habitats:

Different ocean depths create distinct zones with specific environmental conditions. These zones include the euphotic zone (sunlit surface waters), the mesopelagic and bathypelagic zones (twilight and dark zones), and the abyssopelagic zone (deep-sea floor). Each zone supports unique marine life adapted to its specific conditions.

Deep-Sea Exploration:

Exploration of the deep sea requires an understanding of ocean depth. For the purpose of researching deep-sea habitats, geology, and biodiversity, submersibles, remotely operated vehicles (ROVs), and autonomous underwater vehicles are utilized.

Seafloor Mapping:

Accurate knowledge of ocean depth is essential for seafloor mapping, which aids in navigation, resource exploration, and understanding geological processes like plate tectonics.

Pressure Effects on Substances:

Deep ocean pressures affect the physical properties of substances. For example, at great depths, gases can become denser and dissolve in water, influencing the behavior of marine organisms and the design of equipment used in deep-sea research.

Resource Exploration:

Ocean depth plays a role in the exploration of underwater resources such as oil, gas, minerals, and marine organisms. Understanding the depth helps determine the feasibility and challenges of extraction.

Impact on Ocean Climate:

Ocean depth influences the distribution of heat and affects ocean currents. Deep ocean trenches and upwelling zones contribute to global ocean circulation patterns, influencing climate systems.

Wreck and Artifact Preservation:

Understanding the depth of underwater archaeological sites is crucial for preserving wrecks and artifacts. The conditions at different depths can impact the rate of decay and the preservation of historical remains.

In summary, ocean depth is a fundamental parameter in oceanography with implications for marine biology, geology, resource exploration, and climate science. Accurate measurements and understanding of this dimension contribute to our comprehension of the complex and dynamic nature of the world's oceans.

b. Propulsion technology:

Omnidirectional robots, with their unique design and movement capabilities, operate on the principle of unrestricted mobility. The fundamental components enabling this exceptional movement are omni wheels or mecanum wheels. Omni wheels, equipped with rollers at an angle, and mecanum wheels, with rollers set at 45 degrees, facilitate movement in any direction without the need for the robot to change its orientation. At the core of

omnidirectional robots is the implementation of holonomic drive systems. These systems allow for instantaneous and independent control of each degree of freedom, resulting in seamless multidirectional movement. Advanced control algorithms govern these degrees of freedom, employing kinematics and inverse kinematics to determine the wheel velocities necessary for precise motion. Omnidirectional robots find applications across diverse fields, from logistics and manufacturing to robotics research and human-robot interaction. They integrate sensors like cameras and LiDAR for environmental perception, enabling autonomous navigation. The modularity of some designs enhances versatility, allowing users to customize robots for specific tasks. In essence, the principle of omnidirectional robots revolves around their ability to move effortlessly in any direction, offering a transformative approach to robotic mobility and expanding possibilities in various industries.

Implementing the same technology mentioned above to navigate the Automated Drone will enable it to navigate in all directions at any given time in underwater with ease of maneuverability and high-level precision

C. Data Collection, Verification and Processing

Sensors:

Underwater drones are equipped with specialized sensors, including sonar, cameras, and environmental sensors, to collect data on underwater conditions, marine life, and seabed topography.

Sample Collection:

Some drones are designed to collect water samples for analyzing chemical and biological parameters, aiding in environmental monitoring.

Eyes of the deep:

High-resolution cameras capture stunning visuals, from vibrant coral reefs to delicate marine life, providing a window into the underwater world.

Cameras are used to collect underwater data for processing and research purposes.

1. Data Verification:

Real-time Monitoring:

Drones provide real-time data through live video feeds and sensor readings, enabling operators to verify information instantly.

Accuracy Enhancement:

Automated drones contribute to the accuracy of data by minimizing human errors and providing consistent and standardized measurements.

Cross-checking the clues:

Combining camera and sonar data allows for precise verification of findings. For instance, a sonar-detected object can be visually confirmed by the camera, ensuring accuracy and eliminating ambiguities.

Real-time validation:

Advanced algorithms analyze data on the fly, identifying potential errors or inconsistencies and prompting the drone to re-examine specific areas for more accurate information

2. Data Processing:

Onboard Processing:

Drones are equipped with onboard processors capable of handling data locally, allowing for quick decision-making during missions.

Communication with Surface Stations:

Processed data is transmitted to surface stations or remote servers for further analysis, creating detailed maps, identifying patterns, and extracting valuable insights.

Onboard intelligence:

Powerful onboard computers crunch the numbers, processing raw data into actionable insights. This includes tasks like object recognition, obstacle avoidance, and generating 3D maps of the underwater landscape.

Surface support:

Processed data is often transmitted to surface control stations in real-time, allowing scientists and researchers to monitor progress, make informed decisions, and even remotely control the drone's movements.

Analysis techniques:

Data analysis technique includes Object detection, object recognition, segmentation, canny edge detection, threshold and depth analysis for better understanding of capture data in this case image.

3.SONAR AND GPS:

A Sonar GPS module combines sonar technology with Global Positioning System (GPS) capabilities, providing underwater drones with enhanced navigation and mapping functionalities. This integration is particularly valuable in underwater exploration, where traditional GPS signals do not penetrate water effectively.

Sonar Technology:

Sonar, an acronym for Sound Navigation and Ranging, operates by emitting sound waves into the water. These waves bounce off underwater objects, and the system calculates the distance based on the time it takes for the echoes to return. In the context of underwater drones, sonar is crucial for navigation, obstacle avoidance, and mapping the underwater terrain.

GPS Technology:

A network of satellites is used by the Global Positioning System technology to deliver precise location data on the surface of the Earth. However, GPS signals do not penetrate water effectively, making traditional GPS challenging for underwater navigation. To overcome this limitation, a Sonar GPS module combines sonar and GPS technologies to offer a comprehensive solution for underwater drones.

Integration of Sonar and GPS: The Sonar GPS module seamlessly integrates these two technologies. Sonar provides precise distance measurements and helps in creating detailed underwater maps, while GPS contributes to positioning data when the drone is at the surface or during transitions between underwater and surface operations.

4. Applications:

The applications of Sonar GPS modules in underwater drones are diverse. They are extensively used in marine research for studying underwater ecosystems, mapping the seabed, and monitoring environmental conditions. In industries like offshore energy, these modules

assist in inspecting underwater infrastructure such as pipelines and cables. Search and rescue operations benefit from precise navigation capabilities, and underwater archaeology relies on the mapping accuracy provided by Sonar GPS modules.

Marine Research:

Underwater drones support marine biologists and researchers by collecting data on marine ecosystems, studying biodiversity, and monitoring changes in underwater environments.

Infrastructure Inspection: Drones are used for inspecting underwater structures such as pipelines, cables, and offshore platforms, providing valuable data for maintenance and repairs.

Environmental Monitoring:

Automated drones contribute to monitoring environmental factors, including water quality, temperature, and pollution levels, helping to assess the health of aquatic ecosystems.

Search and Rescue:

Underwater drones assist in search and rescue operations by surveying underwater areas for missing persons or locating submerged objects.

Defense and Security:

Automated drones are deployed for surveillance and reconnaissance in strategic waterways, enhancing maritime security and monitoring potential threats.

Archaeological Exploration:

Underwater drones aid in archaeological exploration by surveying and documenting submerged historical sites, shipwrecks, and artifacts.

Marine conservation:

Monitoring coral health, tracking endangered species, and mapping vulnerable ecosystems.

Offshore exploration:

Discovering new oil and gas reserves, surveying underwater pipelines, and inspecting offshore infrastructure.

Archaeological treasures:

Unearthing shipwrecks and lost cities, revealing secrets of the past.

Scientific research:

Studying ocean currents, analyzing water quality, and understanding the impact of climate change on marine environments.

D. ARCHITECTURE / OVERALL DESIGN OF PROPOSED SYSTEM

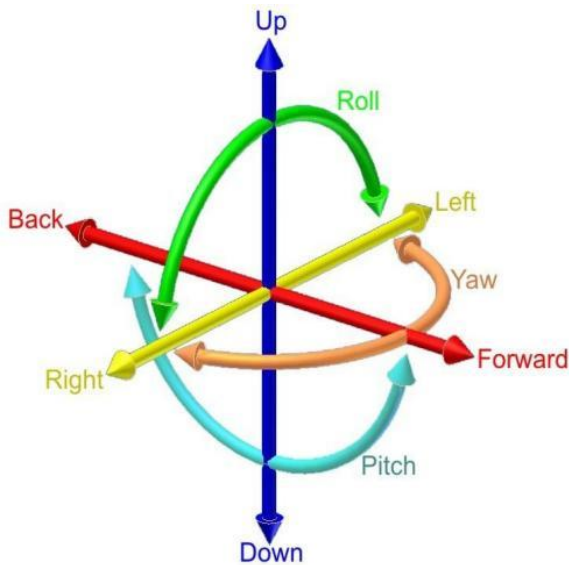


Fig.3 System Architecture

The above block diagram shows the implementation / process on how the propulsion system works.

Omni-directional drones, whether underwater or on land, add a twist to the usual movement options! Here's a breakdown of their motions:

1. Rotational:

Pitch: Same as before, tilting up or down for depth control and climbing/descending.

Yaw: Same as before, spinning left or right to change heading.

Roll: Unlike traditional drones, roll can be used for sideways movement in omni-directional models. Think of it like crab-walking!

2 Translational:

Forward and Backward: These still exist but imagine them as "relative" directions. The drone can move in any direction (including sideways) while maintaining its forward orientation.

Left and Right: These become even more fluid, allowing the drone to seamlessly glide left, right, diagonally, or even backwards at an angle. Think of it as dancing with no limitations!

Up and Down: Like pitch, vertical movement remains crucial for depth control.

To visualize it, imagine a skater on ice:

Pitch and roll are like gliding forward and leaning to carve turns. Yaw is like spinning on one foot to change direction instantly. Forward, backward, left, and right are all graceful gliding steps in any direction, like a pirouette with no boundaries.

Up and down are like jumps and elegant landings, adding another dimension to the dance.

Omni-directional drones unlock a whole new level of maneuverability, making them ideal for tight spaces, precise inspections, and even underwater ballet performances!

V.RESULTS AND DISCUSSION



Fig.4 Output Screenshot

Automated underwater drones have proven to be remarkably successful in conducting operations in aquatic environments. These drones are equipped with the right technology for underwater exploration. Their success is evident in their ability to precisely navigate underwater terrains, ranging from shallow coastal areas to deep-sea trenches.



Fig.5 Output Screenshot

The integration of advanced sensors, such as cameras, enables these drones to capture high-quality data in real-time, contributing to scientific research, environmental monitoring, and industrial applications. The drones' automated decision-making capabilities, coupled with efficient data processing, result in effective mission execution and accurate data collection.

The success of automated underwater drones extends beyond mere functionality. It represents a transformative leap in our ability to explore and understand the complexities of underwater ecosystems. As technology continues to advance, these drones are poised to further revolutionize underwater exploration, unlocking new frontiers and contributing to the sustainable management of our oceans.



Fig.6 Depth Analysis of Fig.5

The depth analysis of fig.5 shows the depth information by marking the farthest distance darker (Black) and closest distance lighter (White).

VI.CONCLUSION

The Automated underwater drone works as intended and all the systems and technologies implemented are performing as intended. The Automated underwater drone can travel underwater automatically and collect all the relevant data needed and resurface again. Our Automated Underwater Drone project successfully navigated the uncharted depths, revealing insights hidden beneath the waves. Equipped with a keen eye (camera) and a probing ear (sonar), the Automated Underwater Drone diligently collected and processed data, painting a vibrant picture of the underwater realm. Through meticulously verified measurements and real-time analysis, the Automated Underwater Drone mapped the seabed, monitored marine life, and even detected potential environmental threats. This invaluable data now informs conservation efforts, guides scientific research, and empowers us to better understand the delicate balance of our oceans. Beyond the impressive data harvest, the Automated Underwater Drone project showcases the potential of robotic exploration. Its seamless fusion of advanced sensors, onboard processing, and autonomous navigation paves the way for a future where technology unlocks the secrets of the deepest trenches and pushes the boundaries of scientific understanding. As we celebrate this project's success, we eagerly anticipate the next generation of underwater explorers, venturing even further into the mysteries of the deep.

VII.FUTURE WORK

The automated drones are used for fishing, depth ocean information, reading about the ocean, sea current. The drone can be made to work underwater and fly above land. The drone is used for rescue in the water zone.

Diving Deeper:

Future Voyages for our Automated Underwater Drone While our first foray with the Automated Underwater Drone has been a resounding success, the depths still hold countless mysteries. Here's a glimpse into

future works that will propel the Automated Underwater Drone to even greater heights (or depths!):

Enhanced Autonomy:

Equipping the Automated Underwater Drone with advanced AI algorithms will enable real-time decision-making, allowing it to adapt to unforeseen obstacles and prioritize data collection based on environmental changes. Imagine the drone autonomously adjusting its course to investigate a sudden rise in water temperature or capture the fleeting movements of a bioluminescent jellyfish.

Deeper Dives and Extended Range:

By implementing cutting-edge battery technology and hydrodynamic designs, we can unlock access to the ocean's hidden abysses. This will allow the Automated Underwater Drone to explore hydrothermal vents, map uncharted trenches, and potentially even encounter undiscovered creatures in the eternal darkness.

Multi-Drone Collaboration:

Imagine a fleet of Automated Underwater Drones working in unison, their sensors combined to create a high-resolution 3D map of vast underwater landscapes. This collaborative approach could revolutionize resource exploration, marine archaeology, and disaster response efforts.

Enhanced Human-Robot Interaction:

Developing intuitive control interfaces will seamlessly connect humans with the Automated Underwater Drone. Pilots will experience the underwater world in real-time, virtually piloting the drone and manipulating its sensors to gather specific data or conduct targeted investigations.

The future of underwater exploration is brimming with possibilities, and the Automated Underwater Drone is poised to be at the forefront. By pushing the boundaries of technology and collaboration, we can unlock the secrets of the deep, understand our oceans better, and ensure their future preservation. Let's continue the dive!

REFERENCES

- [1] S. A. CELTEK, A. DURDU and E. KURNAZ, "Design and Simulation of the Hierarchical Tree Topology Based Wireless Drone Networks," 2018 International Conference on Artificial Intelligence and Data Processing (IDAP), Malatya, Turkey, 2018, pp. 1-5, doi: 10.1109/IDAP.2018.8620755.
- [2] M. A. Kasno et al., "Small scale underwater drone based on a twin-rotor system," 2017 IEEE 7th International Conference on Underwater System Technology: Theory and Applications (USYS), Kuala Lumpur, Malaysia, 2017, pp. 1-5, doi: 10.1109/USYS.2017.8309439.
- [3] D. Mura, M. Barbarossa, G. Dinuzzi, G. Grioli, A. Caiti and M. G. Catalano, "A Soft Modular End Effector for Underwater Manipulation: A Gentle, Adaptable Grasp for the Ocean Depths," in IEEE Robotics & Automation Magazine, vol. 25, no. 4, pp. 45-56, Dec. 2018, doi: 10.1109/MRA.2018.2871350.
- [4] R. Hamagami, T. Ebihara, N. Wakatsuki and K. Mizutani, "Optimal Modulation Technique for

- Underwater Visible Light Communication Using Rolling-Shutter Sensor," in IEEE Access, vol. 9, pp. 146422-146436, 2021, doi: 10.1109/ACCESS.2021.3123358.
- [5] T. Sawa, T. Yanagi, Y. Kusayanagi, S. Tsukui and A. Yoshida, "Seafloor Mapping by 360 Degree View Camera with Sonar Supports," 2018 OCEANS - MTS/IEEE Kobe Techno-Oceans (OTO), Kobe, Japan, 2018, pp. 1-4, doi: 10.1109/OCEANSKOB.2018.8559360.
- [6] Sihite, E., Kalantari, A., Nemovi, R. *et al.* Multi-Modal Mobility Morphobot (M4) with appendage repurposing for locomotion plasticity enhancement. *Nat Commun*14, 3323 (2023).
- [7] Riviere, V., Manecy, A. & Viollet, S. Agile robotic fliers: a morphing-based approach. *Soft Robot.* 5, 541–553 (2018).
- [8] Luca MD, Mintchev S, Heitz G, Noca F, Floreano D. Bioinspired morphing wings for extended flight envelope and roll control of small drones. *Interface Focus* 2017;7: 20160092.
- [9] Shim D, Chung H, Kim HJ, Sastry S. Autonomous exploration in unknown urban environments for unmanned aerial vehicles. *Proceedings of the AIAA Guidance, Navigation, and Control Conference and Exhibit*, San Francisco, CA, 2005, p. 6478.
- [10] Falanga D, Mueggler E, Faessler M, Scaramuzza D. Aggressive quadrotor flight through narrow gaps with onboard sensing and computing using active vision. *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*, Marina Bay Sands, Singapore, 2017, pp. 5774–5781.
- [11] <https://www.newscientist.com/article/2357125-diving-drone-can-switch-between-flying-and-swimming/>
<https://newatlas.com/drones/tj-flyingfish-aerial-underwater-drone>.
- [12] Hintz C, Torno C, Garcia Carrillo LR. Design and dynamic modeling of a rotary wing aircraft with morphing capabilities. *Proceedings of the International Conference on Unmanned Aircraft Systems (ICUAS)*, Orlando, FL, 2014, pp. 492–498.
- [13] L. Meng, T. Hirayama and S. Oyanagi, "Underwater-Drone With Panoramic Camera for Automatic Fish Recognition Based on Deep Learning," in IEEE Access, vol. 6, pp. 17880-17886, 2018, doi: 10.1109/ACCESS.2018.2820326.
- [14] A. Nishitani, R. Kawada and J. Kojima, "Development of combined aerial and underwater drone system," OCEANS 2022, Hampton Roads, Hampton Roads, VA, USA, 2022, pp. 1-5, doi: 10.1109/OCEANS47191.2022.9977370.
- [15] Y. Yasui, A. Shigenawa and Y. Nakayama, "Drone-based Underwater Sensor Network with Optical Camera Communication," 2023 IEEE 97th Vehicular Technology Conference (VTC2023-Spring), Florence, Italy, 2023, pp. 1-5, doi: 10.1109/VTC2023-Spring57618.2023.10199717.