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AN EVOLUTION OF UNDERWATER VEHICLE FOR UNDERWATER COMMUNICATION

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Abstract: The literature survey on underwater unmanned vehicles (UUVs) reveals a diverse array of applications stretching across underwater exploration, defense, and various commercial implementations. The technological landscape encompasses sonar-based navigation systems, acoustic communications, and adaptive control algorithms, which propel UUVs to undertake complex missions such as seabed mapping, oceanographic research, mine countermeasures, and offshore infrastructure inspection. Defense applications include mine warfare, autonomous surveillance, and reconnaissance missions. Moreover, commercial applications comprise underwater inspection, maintenance of subsea installations, and environmental monitoring. Advanced technologies are employed in UUVs, such as autonomous underwater vehicle (AUV) designs, sensor fusion, underwater acoustic communication systems, and high-precision navigation algorithms, reflecting the interdisciplinary nature and extensive potential of UUVs in addressing a wide spectrum of underwater challenges and opportunities. This paper compares the evolution of underwater vehicle with technology and advancement for the purpose of underwater communication.

Keywords: Underwater unmanned vehicle, Autonomous underwater vehicle, Underwater communication.

INTRODUCTION

The Underwater vehicle have a wide range of applications in marine geoscience, and are increasingly being used in the scientific, military, commercial, and policy sectors. Design and development of a low cost Autonomous Underwater Vehicle (AUV) for the purpose of visual inspection in an underwater environment [7]. Design and fabricate an Underwater Vehicle (UV) which consisted of two vertical thruster, two horizontal thruster [16]. It will have a fixed mechanical system and body, having a modular electronic system that allows development of various controllers [15]. The controller and motors has been tested in small scale surface water and the result is encouraging [8]. The development of a small unmanned submarine is to work instead of human beings because there is a risk to use human beings to explore in a difficult to reach and hazardous areas. When such underwater vehicles are made, it is necessary to consider about the following things. 1) Seawater and Water Pressure Environment, 2) Sink, 3)There are no Gas or Battery Charge Stations, 4) Global Positioning System cannot be use, 5) Radio waves cannot be use. In addition, they can undertake tasks such as target tracking and mapping at low depths with the cameras to be used in the vehicle.

The ocean covers about 71% of the Earth's surface, making it a focal point for various studies and developments concerning marine environments, submarine earthquakes, oceanic life, and marine resource exploration, among others. Conducting surveys and observations in the actual ocean is imperative for advancing these studies and developments. Due to the limited transparency of ocean waters and the inability

to thoroughly observe the deep sea from the surface, relying solely on ship-based methods for surveying and observation proves inadequate [9].
Moreover, the challenge of increasing water pressure with depth poses a significant barrier to deep-sea exploration, with atmospheric pressure increasing by approximately 1 atmosphere for every 10 meters of descent [14]. AUVs are used for mainly military purposes and extended to other field's applications as inspection of underwater structure in Oil and Gas industries/Offshore structures [13]. Also used in an underwater mining operation, mapping of seabed, Intelligence Surveillance and Reconnaissance (ISR), Mine Countermeasures (MCM), Anti Submarine Warfare (ASW), Inspection/Identification (ID), Oceanography / Hydrography, Communication / Navigation Network Nodes (CN3), Payload Delivery [12], Influence Activities (IA), Time Critical Strike (TCS), Environmental effects monitoring [10], Seafloor mapping, Geological sampling [11], Long term monitoring (e.g. pollution, radiation leakage), Submarine off-board sensing, Water mine search and disposal, Ship hull inspections, Nuclear power plant inspections, Underwater cable inspection as shown in figure 1. Survey of the underwater AUVs are the most complex as they have to rely on autonomous function since water does not allow radio-frequency transmission, and acoustic transmission does not allow sufficient bandwidth for direct control at a distance [17]. AUV have gradually evolved, notably with increasing computing power and growing energy density stored on-board. Small sensors, inertial navigation systems, and a required high overall reliability due to little room left for error, have rendered AUVs expensive.

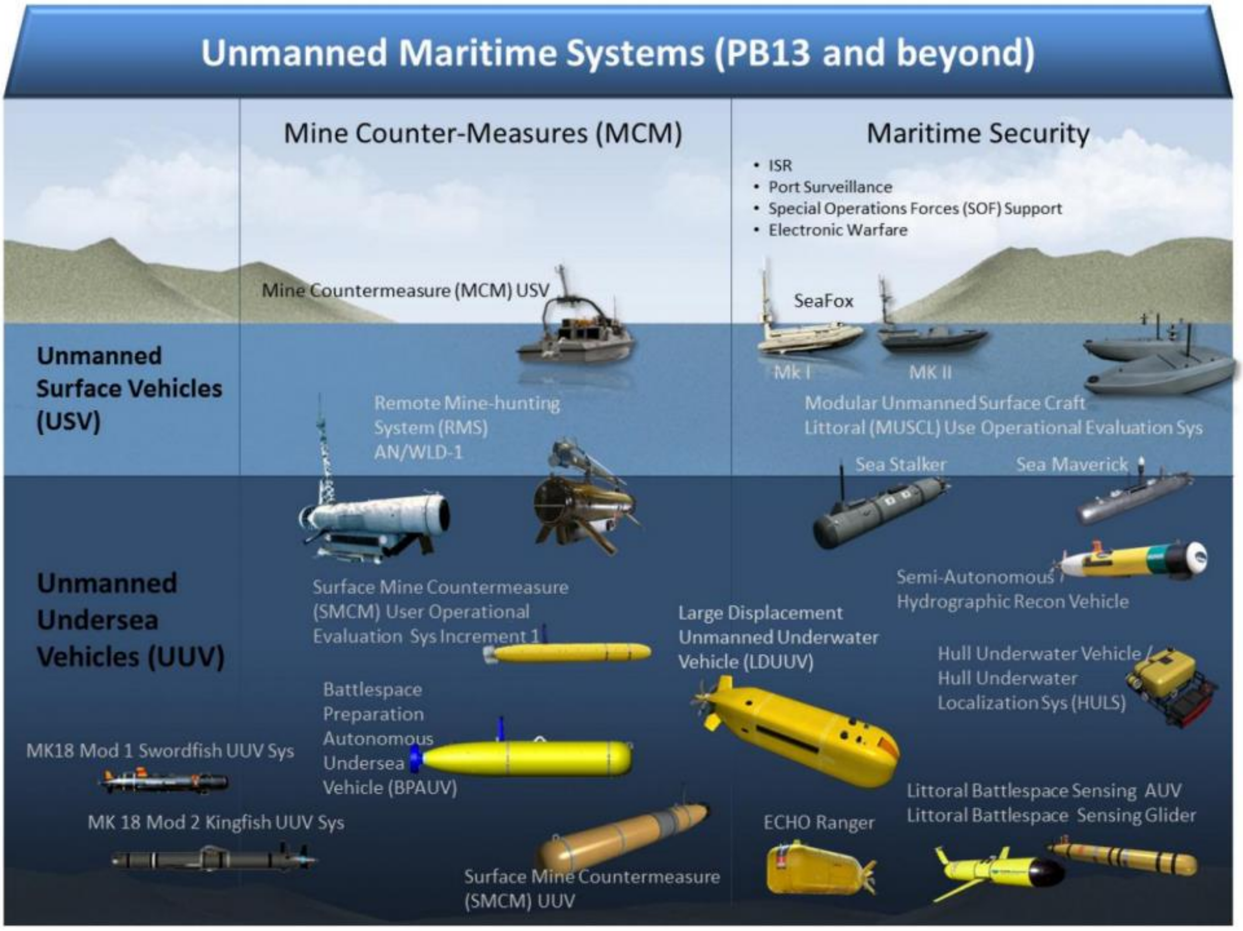

Fig 1: Evolution of Unmanned Underwater vehicle [26]

An underwater vehicle is any member of the class of vehicles (machines that transports people or cargo) that is intended to operate in the underwater environment. This article lists the types of underwater vehicle, with a brief description of each type. An underwater vehicle can be crewed, remotely operated or autonomous, and will generally, but not necessarily, have some form of onboard propulsion system. – Unmanned underwater vehicle with autonomous guidance system Remotely operated underwater vehicle (ROUV) – A tethered underwater mobile device operated by a remote crew. Submarine – Watercraft capable of independent operation underwater. AUVs are the most complex as they have to rely on autonomous functions since water does not allow radio-frequency transmission, and acoustic transmission does not allow sufficient bandwidth for direct control at a distance.

LITERATURE REVIEW

Bian et. al. introduces an autonomous underwater vehicle (AUV) manipulator system specifically engineered for capturing underwater targets. It delineates the architectural design and operational functionalities of the system, underscoring its autonomous features and proficiency in tasks related to target capture. The authors elucidate the crucial components and their seamless integration, emphasizing the system's adeptness in navigating through demanding underwater conditions [1].

Nalla et. al. in this paper introduces a Systems Engineering V-Cycle approach tailored for the design and development phases of Autonomous Underwater Vehicles (AUVs). It delineates a systematic methodology, underscoring the seamless integration of requirements analysis, design, verification, and validation stages. Through a detailed case study, the authors exemplify the practical application of this approach, highlighting its efficacy in steering the development trajectory of AUVs. By embracing this methodological framework, the paper endeavors to augment the efficacy and dependability of AUV development endeavors, while concurrently ensuring alignment with operational prerequisites [2].

Wang et. al. presents a novel modular design methodology and module interface development intended for small reconfigurable underwater vehicles. It delineates a comprehensive approach for designing modular components and interfaces, with a strong emphasis on enhancing the vehicle's flexibility and adaptability. Through the presentation of case studies, the authors vividly illustrate the efficacy of this approach in facilitating swift reconfiguration and customization of underwater vehicles to suit various tasks. Furthermore, through rigorous experimental validation, they substantiate the performance and versatility achieved through the adoption of modular design and interface development [3].

Spears et. al. The paper delineates the design and development trajectory of an under-ice autonomous underwater vehicle (AUV) meticulously crafted for operations within Polar regions. It succinctly outlines the unique challenges and requisite specifications pertinent to polar environments, while also elucidating the strategic methodologies deployed to address these challenges in the AUV's design [4].
Aras et. al. introduces a 3-degree-of-freedom (3DOF) small-scale underwater manipulator system, specifically focusing on a gripper designed for unmanned underwater vehicles (UUVs). It elucidates the architectural framework and operational capabilities of the system, accentuating its compact dimensions and adaptability across diverse underwater tasks [5].

Safiyah et. al. introduces the development of a buoyancy control device (BCD) tailored for Autonomous Underwater Vehicles (AUVs). It delineates the design and execution phases of the BCD, underscoring its pivotal role in regulating the vehicle's buoyancy to ensure stable operation underwater. The authors delve into the intricacies of the BCD, elucidating the integration of key components and mechanisms aimed at precise buoyancy control [6]. The below table 1 showcases the evolution of underwater vehicle and its key development as per centuries.

Table 1: An outline of evolution of underwater vehicle

Time Period	Key Developments
Mid-20th Century	- Inception of basic remote-controlled submersibles for military and scientific exploration purposes.
	- Limited sensing capabilities and reliance on manual operation.
Late 20th Century	- Advancements in materials, electronics, and propulsion systems lead to the e mergence of early autonomous underwater vehicles (AUVs).
	- Introduction of autonomous navigation and basic decision-making capabiliti es.
Early 21st Century	- Significant focus on miniaturization, energy efficiency, and enhanced maneu verability and endurance.

	- Integration of advanced sensors, including sonar arrays, cameras, and enviro nmental sensors for improved data collection and analysis.
Present Day	- Continued focus on autonomy, energy efficiency, and adaptability in dynami c underwater environments.
	- Integration of artificial intelligence and machine learning algorithms for intel ligent decision-making process.
	- Advancements in communication technologies, including underwater acousti c communication systems and high-bandwidth data transmission.

GAPS IN LITERATURE

Several previous works have focused on the design and development of Design and Development of Underwater Vehicle for various applications in marine geoscience and other sectors. One notable area of research is the advancement of low-cost AUVs capable of performing visual inspections in underwater environments [22]. These efforts have led to the creation of prototypes with fixed mechanical structures and modular electronic systems, enabling the development of versatile controllers to suit different tasks [23]. In the realm of AUV design, the integration of propulsion systems is crucial for maneuverability and navigation. Previous projects have explored configurations involving multiple thrusters, such as two vertical thrusters and two horizontal thrusters, as seen in the proposed underwater vehicle [24]. These configurations have been tested in small-scale surface water environments, yielding promising results for underwater operation [18].

Furthermore, the development of small unmanned submarines has garnered attention due to their potential to replace human divers in hazardous and hard-to-reach areas. This approach mitigates risks associated with human exploration and allows for safer and more efficient data collection and inspection tasks. However, the design and construction of such submarines must address several critical considerations unique to underwater environments [19]. One major challenge is ensuring the vehicle's resilience to seawater and water pressure, which can exert significant forces on the vehicle's structure and components. Additionally, the absence of gas or battery charge stations necessitates careful energy management and conservation strategies to extend mission duration and range [25]. Moreover, limitations in communication technologies, such as the inability to use GPS or radio waves, require alternative methods for navigation and data transmission [20]. Despite these challenges, recent advancements in sensor technology have enabled AUVs to undertake complex tasks, including target tracking and mapping, even at low depths [21]. Cameras and other sensing devices play a crucial role in facilitating these capabilities, allowing the vehicle to gather valuable data and imagery for scientific research, commercial applications, and policy-making purposes.

Overall, the integration of mechanical, electronic, and software systems in AUV development continues to push the boundaries of underwater exploration and monitoring. By addressing key challenges and leveraging emerging technologies, researchers and engineers strive to enhance the capabilities and reliability of underwater vehicles for diverse applications in marine science and beyond.

PROPOSED SYSTEM

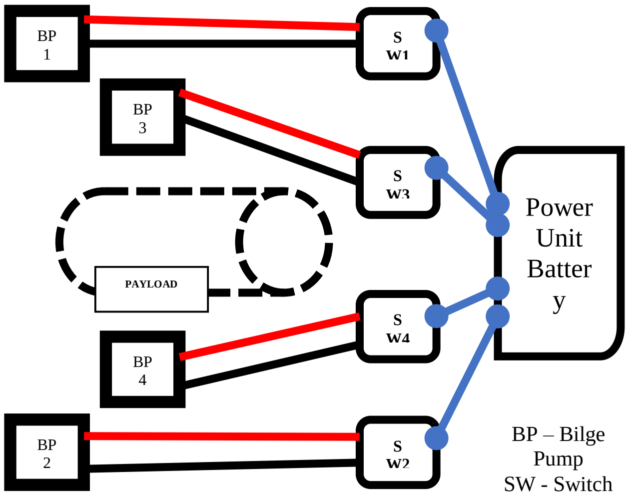

Fig 2: UAV motor and power unit

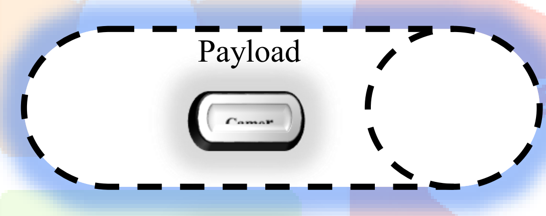

Fig 3: Payload

The block diagram in figure 2 contains the four motors that is pumps along with the switches that are connected to each one of the motors. The motor M1 and M2 functions heave movement and the M3 M4 motors will carry over front and backward directions. The Payload contains the In the preliminary design phase, the motion of the ROV is initially constrained to two primary directions: forward/backward (surge) and upward/downward (heave). Forward propulsion of the ROV is facilitated by a thruster mounted at the rear section of the main payload, while vertical movement is regulated by adjusting the overall density of the vehicle. Two water chambers are positioned parallel to the main payload, housing the primary electronic components, and are filled with water via water pumps. The main payload is engineered to maintain a sealed environment to accommodate the vehicle's control system effectively as shown in figure 3. Additionally, two acrylic disks are affixed to the front and back sections of the main payload to enhance visibility and provide protection. The hull configuration plays a pivotal role in minimizing the overall power consumption of the ROV. Typically, two main designs are employed for such vehicles. Firstly, the torpedo-shaped hull, referred to as the cruising type, is commonly utilized for surveying tasks spanning from short distances to several hundred kilometers. Conversely, the hovering type is tailored for surveys conducted at depths of up to several hundred meters. While torpedo-shaped vehicles typically require only one thruster, hovering types often necessitate more than four.

FUTURE WORK

Enhanced Autonomous Capabilities: Future underwater vehicles can benefit from advancements in artificial intelligence and machine learning to enhance their autonomy. This includes improved decision-making algorithms for navigation, obstacle avoidance, and adaptive mission planning, allowing the vehicles to operate more efficiently and autonomously in complex underwater environments.

Increased Sensing and Data Processing: Integration of advanced sensors, such as multi-spectral cameras, LiDAR, and sonar systems, can enable underwater vehicles to the marine environment. Enhanced data processing capabilities will allow for real-time analysis and interpretation of collected data, facilitating applications in marine science, environmental monitoring, and resource exploration.

Extended Operating Range and Endurance: Research efforts are underway to develop underwater vehicles with extended operating ranges and endurance capabilities. This involves advancements in energy storage technologies, such as high-capacity batteries and fuel cells, improvements in propulsion efficiency and hydrodynamic design. These developments will enable underwater vehicles to undertake longer-duration missions and explore deeper and more remote regions in ocean.

Collaborative Swarms and Cooperative Missions: The notion of underwater swarm robotics, characterized by the collective action of multiple autonomous underwater vehicles, presents an auspicious avenue for future endeavors. Collaborative swarms hold the potential to undertake various missions, encompassing distributed sensing, environmental surveillance, and underwater cartography. infrastructure inspection more effectively and efficiently than individual vehicles. Future research will focus on developing communication and coordination algorithms to enable seamless collaboration among swarm members.

Environmental Monitoring and Climate Research: With growing concerns about climate change and its impact on marine ecosystems, there is a pressing need for advanced underwater vehicles capable of conducting long-term environmental monitoring and climate research. Future underwater vehicles equipped with state-of-the-art sensors and sampling systems will play a crucial role in studying ocean dynamics, biodiversity, carbon sequestration, and other key environmental parameters.

Commercial and Industrial Applications: In addition to scientific research, underwater vehicles have significant potential for commercial and industrial applications. These include offshore oil and gas exploration, underwater construction and maintenance, aquaculture monitoring, underwater archaeology, and search and rescue operations. Future advancements in underwater vehicle technology will open up new opportunities for businesses and industries to leverage the capabilities of these platforms for various applications.

CONCLUSION

The comprehensive literature survey of underwater unmanned vehicles (UUVs) has provided a rich understanding of their multifaceted applications in underwater exploration, defense, and commercial domains. The technological progression in UUVs' systems, including sonar-based navigation, acoustic communications, and adaptive control algorithms, has enabled their involvement in diverse and complex missions, ranging from seabed mapping and mine countermeasures to autonomous surveillance and environmental monitoring. The advancement of technologies, such as autonomous underwater vehicle (AUV) designs, sensor fusion, and high-precision navigation algorithms, signifies the interdisciplinary nature of UUVs and their extensive potential in addressing underwater challenges and opportunities.

However, despite the significant progress outlined in the literature survey, a noticeable gap exists in the depth of exploration of the evolution of underwater vehicle designs, particularly with a focus on their role in advancing underwater communication. The survey predominantly highlights the functionalities and applications of UUVs, but there is a dearth of detailed analysis concerning the specific evolution of UUV designs in the context of underwater communication technology. This gap hinders a comprehensive understanding of how the advancements in underwater vehicle designs have specifically contributed to the improvement of communication capabilities in challenging underwater environments.

Furthermore, the literature survey emphasizes the application-centric evolution and the enhancement of operational capabilities of UUVs; however, it lacks a focused examination of the direct correlation between technological advancements in UUV designs and the corresponding enhancements in underwater communication systems. Understanding this relationship is crucial for bridging the gap between UUV design evolution and the state-of-the-art underwater communication technology. Therefore, future research endeavors should aim to delve deeper into this connection to uncover the precise contributions of UUV design advancements to the progress of underwater communication capabilities. Such an investigation would significantly enrich the existing knowledge base and pave the way for more targeted and effective developments in UUV technology for underwater communication.

REFERENCES

[1]. X. Bian, T. Jiang, T. Guo, Z. Zhang, Z. Wang and H. Huang, "An Autonomous Underwater Vehicle Manipulator System for Underwater Target Capturing," 2022 IEEE International Conference on Unmanned Systems (ICUS), Guangzhou, China, 2022, pp. 1021-1026, doi: 10.1109/ICUS55513.2022.9986631.

[2]. S. K. K. Nalla et al., "Systems Engineering V - Cycle approach for Design and Development of Autonomous Underwater Vehicle," OCEANS 2021: San Diego – Porto, San Diego, CA, USA, 2021, pp. 1-6, doi: 10.23919/OCEANS44145.2021.9705756.

[3]. Y. Wang, M. Zhang and H. Su, "Modular design method and module interface development for small reconfigurable underwater vehicle," 2011 IEEE International Conference on Mechatronics and Automation, Beijing, China, 2011, pp. 1479-1484, doi: 10.1109/ICMA.2011.5985968.

[4]. A. Spears, A. M. Howard, B. Schmidt, M. Meister, M. West and T. Collins, "Design and development of an under-ice autonomous underwater vehicle for use in Polar regions," 2014 Oceans - St. John's, St. John's, NL, Canada, 2014, pp. 1-6, doi: 10.1109/OCEANS.2014.7002991.

[5]. M. S. M. Aras, M. K. Aripin, M. W. N. Azmi, A. Khamis, M. K. M. Zambri and M. F. M. A. Halim, "3DOF small scale underwater manipulator — Gripper for unmanned underwater vehicle," 2017 IEEE 7th International Conference on Underwater System Technology: Theory and Applications (USYS), Kuala Lumpur, Malaysia, 2017, pp. 1-4, doi: 10.1109/USYS.2017.8309437.

[6]. L. Safiyah Binti Syafie, Z. Bin Zainal Abidin and N. K. Bin Alang Md Rashid, "Development of a buoyancy control device for Autonomous Underwater Vehicle," 2016 IEEE International Conference on Underwater System Technology: Theory and Applications (USYS), Penang, Malaysia, 2016, pp. 89-93, doi: 10.1109/USYS.2016.7893923.

[7]. Azizie, Asmawi, “Development of remotely operated vehicle (ROV) for underwater exploration”, faculty of Mechanical Engineering, Universiti Malaysia Pahang – 2009.

[8]. Collar, P. G. et al. (1995). “Autosub: an autonomous unmanned submersible for ocean data collection,” Electronics & Communication Engineering Journal,Vol.7 issue 3 pp.105-114.

[9]. Kristensen, J. et al. (1998). “Hugin-an untethered underwater vehicle for seabed surveying,” OCEANS ’98, Conf. Proc. Vol.1 pp.118-123.

[10]. AOKI T., MURASHIMA T. TSUKIOKA S., NAKAJYOH H., IDA M., 1999. Development of Deep Sea Free Swimming ROV “UROV7K”. IEEE, Oceans ‘99 MTS, v.3, p.1307-1311, September.

[11]. BARROS, E. A., SOARES, F. J. A., 2002. Desenvolvimento de um Robô Submarino de Baixo Custo. In: CONGRESSO BRASILEIRO DE AUTOMÁTICA, XIV, Natal-RN. p. 2121-2126

[12]. Yu Wang, Ruy Tan, Guoliang Xing, Jianuxun Wang, and Xiaobo Tan. (2014). Profiling Aquatic Diffusion Process Using Robotic Sensor Networks- IEEE Transactions on Mobile Computing, (vol 13, No.4).

[13]. Xuri Yu, Tommy Dickey, James, Bellingham, Derek Manov, and Knut Streitlien. (2012). The Application of Autonomous Under Water Vehicles for Inter Disciplinary Measurements in Massachusetts and Cape Cod Bays, (Continental Shelf Research 22)

[14]. Nana.L, Singhoff.F, Legrand.J and Marce.L. (2010). Embedded Intelligent Supervision and piloting for Oceanographic AUV

[15]. Ferguson, J. S. (1998). "The Theseus autonomous underwater vehicle. Two successful missions," Underwater Technology'98 Proc. 1998 Symposium pp.109-114.

[16]. Mellingham, J. G. et al. (1993). "Demonstration of a high-performance, low-cost autonomous underwater vehicle," MITSG 93-28.

[17]. Chetan Naik J, L Pinjare and Cyril Prasannaraj P, Underwater OFDM Model Using Dwt and FFT Methods, International Journal of Civil Engineering and Technology (IJCIET), 9(3), 2018, pp. 1075–1086 doi: https://doi.org/10.17605/OSF.IO/8U32T.

[18]. Chetan Naik J, S L Pinjare and Cyril Prasanna Raj P, Design of an OFDM Model Using Rayleigh and Rician Channel, International Journal of Civil Engineering and Technology (IJCIET) 10(1), 2019, pp. 3345-3355 doi: https://doi.org/10.17605/OSF.IO/RQYKH.

[19]. Girish H, Jharna Majumdar, Chetan Naik, Jenita Subhash, Sneh Rachna, D.Antony Louis Piriyakumar, Performance Analysis of adaptive enhancement algorithms using Quality Metric Parameters for autonomous navigation of an unmanned mobile platform in a low illumination environment, River Publishers Series in 4th International Virtual Conference on Advances in Computing & Information Technology – 2022, article-56, e-ISBN: 9788770229005, doi: https://doi.org/10.13052/rp-9788770229005.

[20]. Naik J, Chetan & Malu, S.K. & Majumdar, Jharna. (2014). Image based visual servoing with linear-quadratic regulator control for mobile robots. International Journal of Applied Engineering Research. 9. 1359-1372.

[21]. Chetan Naik J, S L Pinjare, Jharna Majumdar, Linear-Quadratic Regulator Control for Human Following Robot in Straight Path, International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075 (Online), Volume-4 Issue-2, pp. 65-67, July 2014.

[22]. Chetan Naik J, Dr. S L Pinjare, Pooja PM, Design and Simulation of Underwater Acoustic Sensor Materials, AIP conference proceedings (Publication in progress), Third International Conference on "Materials, Computing & Communication Technologies" (ICMCCT 2022).

[23]. Chetan Naik J, L Pinjare and Cyril Prasannaraj P, DESIGN OF DWT BASED OFDM MODEL FOR UNDERWATER APPLICATIONS, International conference on Nano composites for Aerospace applications, CIT Bangalore, Feb 2023.

[24]. Chetan Naik J, L Pinjare and Cyril Prasannaraj P, DESIGN OF FFT BASED OFDM MODEL USING SIMULINK, International conference on Nano composites for Aerospace applications, CIT Bangalore, Feb 2023.

[25]. Bradley, A. M. et al. (2000). "Extending the Endurance of an Operational Scientific AUV using Lithium-ion Batteries," Proc. of Unmanned Underwater Vehicle Showcase (UUVS) 2000.

[26]. India Navy's Unmanned Underwater Vehicles (UUV) (ssbcrackexams.com)