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Cite as: AIP Conference Proceedings **2222**, 040015 (2020); https://doi.org/10.1063/5.0004045
Published Online: 16 April 2020

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An Inexpensive Unmanned Aquatic Vehicle For Underwater Human Detection

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Abstract. This paper discusses the designing, implementation and testing of an Autonomous Underwater Vehicle (AUV) robot, which travels underwater to detect possible human presence. This robot is expected to be extremely useful in human rescue operations during water accidents. The AUV is deployed above the water surface, near to the approximate target location and it swims underwater, checking for the target (human body), in real time. Once the target is detected, the AUV locks the targets position and move towards the target to verify and make a decision: whether it is a human body or not. After the confirmation, the robot swims back vertically up to the water surface, from where it can be easily noticed by the ground rescue crew. The diver can then dive there, to find the human body. Alternately, an air bag could also be inflated after locking it to the target, which will float back to the surface carrying the target. This technology is very helpful for underwater human detection since we need not have to search the whole water body and hence both time and resources are saved.

Keywords. Underwater human detection, autonomous underwater vehicle, surveillance and surveying, safety and rescue.

INTRODUCTION

Underwater human detection is a relatively unexploited field of study under marine technology. According to WHO, Drowning is the 3rd leading cause of unintentional injury death worldwide, accounting for 7% of all injury-related deaths, with an estimated 3,60,000 annual drowning deaths worldwide (2018). The main reason for this is that underwater domain is a dangerous and complex environment for human divers. Often, divers have to monitor their own life support systems as they navigate to the work site or while operating dangerous machinery. Military divers have to navigate for extended periods of time without surfacing or without using localization techniques that might give away their positions. Human divers have operated under these harsh conditions for decades with few advancements in technology. In fact, a diver performs the basic task of navigation by aligning the body with a compass and counting leg kicks (i.e., human-oriented dead reckoning).

The scope of the present research work is to improve the existing conventional methods used in search and rescue of drowned human body in water. Traditional procedures incorporating human divers searching underwater for human bodies (surviving or dead) are very inefficient due to visibility issues and the supply oxygen, which increases the delay and complexity in such operations. Hence developing a suitable mechanism to aid this is very

Proceedings of the International Conference on Microelectronics, Signals and Systems 2019
AIP Conf. Proc. 2222, 040015-1–040015-7; https://doi.org/10.1063/5.0004045
Published by AIP Publishing. 978-0-7354-1981-0/$30.00

much necessary. But research works in this field are advancing at a comparatively low pace, mainly due the difficulty and complexity in imaging and sensing technologies that could be employed under water. One of the main challenges in underwater communication is the inefficiency of Electromagnetic wave communication inside water. Water absorbs electromagnetic radiations and an information could not be easily transmitted across, without suffering from loss. Hence we have to depend on acoustic waves for underwater communication. One such approach is to power a beam of sound energy (ultrasound) at the assumed target location and calculate the absorption of an underwater body by looking at the received power of the signal reflected from the body. The material can then be recognised by suitable training.

Another approach is to focus on a special case of moving object detection under water in which the rate of motion degrades slowly. Since there is also possibility of change in degree of motion for other objects also due to water movement, this method comes with the cost of spending a lot of time. But all these methods have some serious disadvantages. Since the mass of the immersed body is far smaller than the mass of the water body, temperature of the body will level down or up to the water temperature. once the temperature of the 'body' equals the temperature of the body, infrared does not help. Also, in unstructured environments, current underwater robots are limited in their ability to localize and track human bodies because optical cameras can be rendered useless by the turbidity and murkiness of water. Localizing radio signals also do not propagate well through the water medium, and acoustic positioning systems can be very expensive to deploy. So a technique for underwater human detection must be developed which is economically and technologically feasible.

This paper proposes the application of Unmanned Aerial and Aqua Vehicles (UAAV) for underwater human rescue operation. The UAAV (a drone) with an Autonomous Underwater Vehicle (AUV) will fly over the water body and land on the water surface. It then deploys the AUV in to the water. AUV swims in to the water searching real time for its target - the human body. Once the target is detected, the AUV locks the targets position and move towards the target to verify and make a decision: whether it is a human body or not. After the confirmation, the robot swims back vertically up to the water surface, from where it can be easily noticed by the ground rescue crew. The diver can then dive there, to find the human body. Alternately, an air bag could also be inflated after locking it to the target, which will float back to the surface carrying the target. This technology is very helpful for underwater human detection since we need not have to search the whole water body and hence both time and resources are saved.

LITERATURE REVIEW

Fatma et al., [1] is a study to detect and to track the people under the water quickly. The paper focuses on underwater human-robot interaction via biological motion identification. Thresholding, Background Subtraction, Interframe Difference and Foreground Detection methods have been applied to create the silhouette of the people under the water. These methods have been demonstrated on videos. The paper discusses an algorithm for underwater robots to visually detect and track human motion. The objective is to enable human-robot interaction by allowing a robot to follow behind a human moving in (up to) six degrees of freedom. The authors have tried to develop a system to allow a robot to detect, track and follow a scuba diver by using frequency domain detection of biological motion patterns. The motion of the diver relative to the vehicle was then tracked using an Unscented Kalman Filter (UKF), an approach for non-linear estimation.

Sonia et al., [2] deals with the technology for human detection using ultrasonic waves. The approach is based on fuzzy rules that are extracted from the signal features in time and frequency domains. The performance of the human detector system (classifier) is assessed in terms of accuracy, true positive, and false positive rates. Human detection generally refers to the process of differentiating human beings from other animate or inanimate objects through the use of sensory technology. Human detection is a challenging task and forms a vital component of a range of applications which include human-robot interaction, surveillance and monitoring, search and rescue, and smart rooms. The challenge in realizing such a detector arises due to the facts that human beings are non-rigid in structure and are of various sizes and shapes. They are also dressed-up in different types of clothing and are non-stationary. Research on human detection concentrates mainly on vision-based techniques. However, there are many applications where vision-based techniques are not desirable. This situation is very similar to the underwater.

Sameer et al., [3] describes the new developments happening in the area wireless acoustic communications. Normally the underwater vehicles are remained isolated from above water, to preserve the stealth advantage that operations within it provide. Development of robust and stealthy inter-platform communications/network solutions has changed the scenario and has become the critical enabling technology for various future requirements of the navies across the globe. The main challenges of underwater communication as mentioned in this paper as High transmission loss, Ray bending due to Snell's law, High ambient noise, Multipath propagation, propagation delay. Since radio waves are highly attenuated in underwater, acoustic communication methods are preferred. The recent trends in communication like coherent communications, orthogonal frequency domain modulation(OFDM) are also discussed in this paper.

Ted S et al., [4] In order for underwater robots to communicate with land and air-based robots on an equal basis, high speed communications is required. If the robots are not to be tethered then wireless communications is the only possibility. Sonar communications is too slow. Unfortunately, radio waves are rapidly attenuated under water due to phenomena such as skin depth. This paper gives the methods for extending the underwater radio communication. Physical layer communications can be accomplished by a number of technologies, including wire-line, and wireless methods. Wireline communications could be established with all submarines, but the restrictions on mobility such as entanglement suggest wireless communications should be accommodated at some point, whether at the end of a wire, or from a communications device at the surface. Once communication is made to the surface, a surface vessel could relay signals to other swarms outside of the water.

S. Udupa et al., [5] suggested the design for a robot with functionalities for maneuvering, image recognition and depth control. Several simulations were studied and authors proposed a new design with minimal drag and good fluid dynamics.

Y. Jua et al., [6] introduces a new Monostatic-Bistatic Composite system for underwater moving target detection. The data fusion for monostatic and bistatic was described using the combination processing of imaging method, and the calibration algorithm of this system was discussed. The experiment result showed the observability of the small target in bistatic modes and the better performance of this imaging method used in the composite system.

B. Anwar et al., [7] demonstrated the application of both remotely operated underwater vehicles (ROV) and autonomous underwater vehicles (AUV) equipped with surveillance system in military, scientific research, film making under the water and monitoring underwater industrial structures and underwater network devices.

PROPOSED DESIGN

Due to inefficiency of popular underwater imaging technologies like thermal imaging [2], infrared imaging or laser scanning, the proposed ROV is expected to work using the combined action of an ultrasound detector and an underwater camera. Recognition of human body is achieved with the help of further signal processing and real-time feature extraction using both the underwater camera footage and the reflected sound signal. When the human body is under water, in a few minutes, most of the heat from the body would be dissipated and its nearly impossible to use thermal imaging here [3]. Hence a weighted decision from sound detection and normal imaging is used in the present work.

A lot of fluid-dynamic factors must be considered for comparing the existing designs with other design alternatives like cylindrical, elliptical and rectangular, along with Drag and stress calculations. The first ever developed underwater ROV was known as POODLE. The vehicle was mainly used for archaeological research [8]. Since then, till now the ROVs are being widely used both in industry and science for a variety of purposes including exploring hydrothermal vents, inspection of underwater oil derricks, inspection of high radiation area, inspection of sub-sea phenomena, surveying archaeological sites and fixing underwater infrastructure such as cabling and piping. One of their most challenging uses is in deep water search and rescue. The underwater robot system is expensive. As a result, in developing and under developed countries the production and deployment of ROVs are limited. Many of these countries consist of a large number of water bodies and are prone to maritime incidents. Some researchers have been involved in the design and development of low-cost underwater robots [6]. Our primary focus in the work was to reduce the cost to make a suitable ROV to be deployed into developing and under developed countries, for economically feasible underwater human detection. Compared with the work in the developed world, this is very essential as there is no point in developing a system which is not affordable. World class AUV's or ROV's are usually very costly. In 2013 a group of researchers provided a model of a comparatively low cost underwater robot named GUPPIE [8] which costed around 1 lakh INR and we our aim is to develop a system which is much less priced than the existing models.

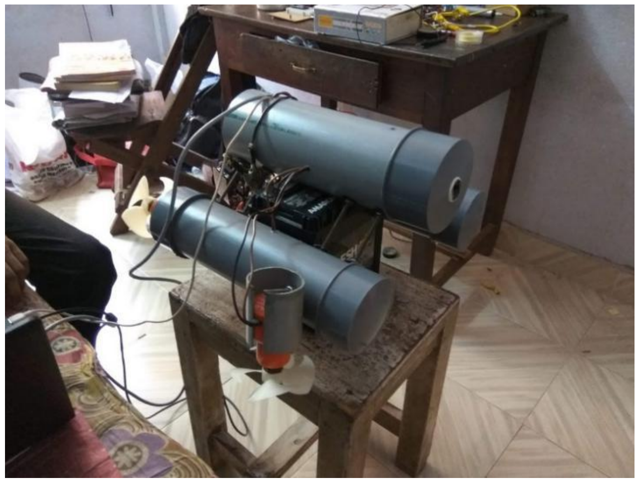


FIGURE 1. Working prototype model

The basic idea is to implement a diver-friendly rescue aiding machine for underwater human detection. The design is targeted at medium sized water bodies like swimming pool or a small lake or a pond. The proposed system uses an AUV mounted with thrusters which can dive into the water to detect the target (human body). The UAAV (drone) with an Autonomous Underwater Vehicle (AUV) will fly over the water body and land on the water surface. It then deploys the AUV in to the water. AUV swims in to the water, while searching for a possible human presence. AUV is supposed to work using the principles of ultrasound imaging, due to inefficiency of other detecting techniques like thermal imaging or laser scanning. Recognition of human body is achieved with the help of signal processing and feature extraction of the received signal after reflection from the target. Optional VR (Virtual Reality) mechanism may be provided to the controller man on the land for further optimized control of the AUV. AUV has a marking mechanism which makes it's location inside water, traceable by the controller on land. AUV then floats back to the water surface, which is detected by the UAAV. For more effective operation, many swarm AUV's can work together in real time to cover the whole area in a very short span of time using the principles of underwater acoustic communication [4]. Further application of the present research work can aid maritime and aerial surveillance [4], underwater archaeology, study and survey of marine flora and fauna, apart from aiding in human rescue operations.

Since thrusters are very much costly, we created thrusters by cutting opening bilge pumps and replacing the impellers with underwater grade propellers, used for making hobby boats. The bilge pumps used are of 1100 GPH capacity and 12V, 3A rating. So we used special Electronic Speed Control Units designed for brushed motors with current rating 30A for controlling the AUV. Power output is taken from a 12V 30AH rickshaw battery. For prototyping we've used Raspberry Pi 3 B+ as the processor which receives camera and sound sensor data and sends the control signals to the ESCs via the relays connected. We have used 4 thrusters, 2 for down motion (We make use of buoyancy to go upwards) and 2 side thrusters for direction change. Additionally 2 more thrusters can be introduced to account for improved stability of the AUV. For chassis, we've used PVC and tightly sealed it to protect the components inside. Since Raspberry Pi 3 is not that much computationally powerful, we connect Pi to a much more powerful computer (a laptop) via a LAN cable (pref. up to 150m length.) for fast processing of input data and faster decision making.

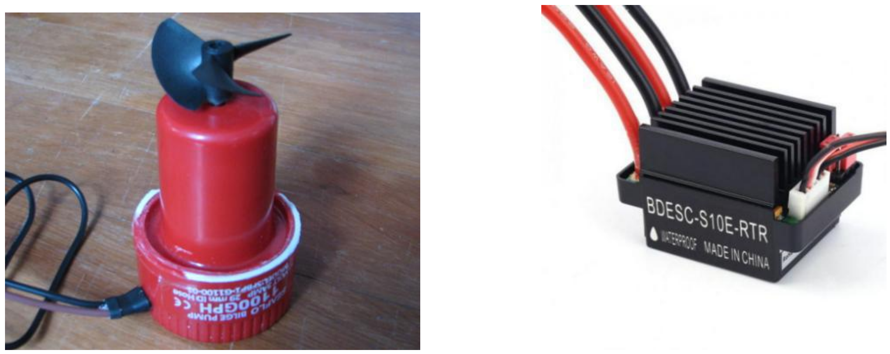
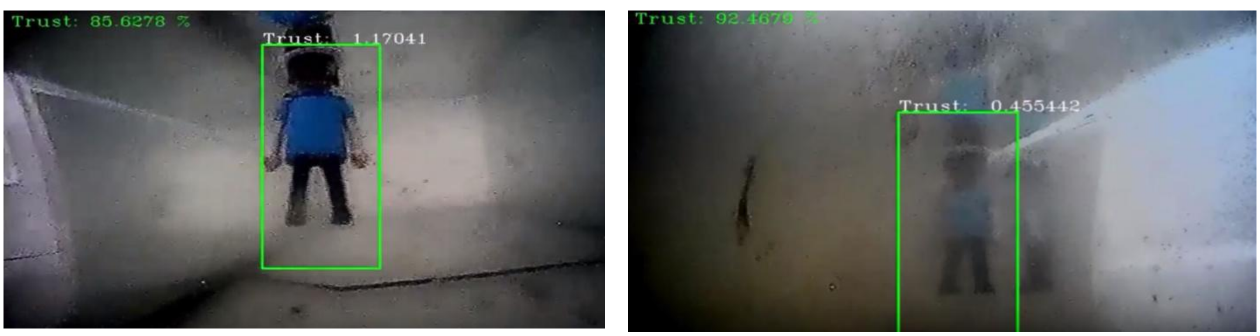


FIGURE 2. Bilge pump with impeller replaced with propeller and DC brushed motor ESC

We used ArduSub OS based on Raspbian (which is Debian Linux based) on the Raspberry Pi 3 B+ for this project. We used Mavelink Protocol for passing the manual control signals from the joystick to the Laptop. The laptop takes care of necessary processing (runs windows 10 OS) and sends necessary control signals to the raspberry pi connected to it via the LAN cable. Pi controls the pixhawk flight controller serially. Pixhwak (PX4) takes PI's instructions and control the 4 speed controllers connected to it. Speed Controllers control the motors (thrusters) as per the instruction received. Pi takes the video camera input from the USB camera connected to it and streams it to the laptop via UDP. We used UDP especially because of its low latency.



(a) (b)

FIGURE 3. Underwater human detection. (a) Normal water (b) Murky water

In underwater human detection part, we detected human body using modified Haar classifiers and edge detection techniques. We then translate the detected body's center of mass coordinates to the viewing frame's center. For each frame we do this, and this is how we lock the position to be able to track later. In Tracking part, we power up the thrusters suitably with different speeds to move suitable so as to lock the detected object in the view plane's center itself. We know we have reached near the object, when the object area becomes comparable to the view plane area. So then, we will slow down to maintain a safe distance from the target.

RESULTS & DISCUSSION

The overall making cost of an AUV can go nearly up to INR 1,00,000 or way beyond that. We require advanced acoustic imaging setup like side scan SONAR for human detection purposes which are very much costly and make underwater human detection economically unfeasible. So, in the present work, we are trying to develop a low cost AUV for underwater human detection.

TABLE 1. Component details

Item	Rating/Dimensions	Cost (INR)
Raspberry Pi 3 B+	standard (5V 2A)	3000
1100 GPH Bilge Pump	12V 3A	4400 (4x1100)
Brushed Motor ESC	(6-12)V 320A	5200 (4x1300)
Amaron Car Battery	12V 30AH	3000
Chassis and other miscellaneous expenses	50x40x30 cm	4400
Total Expense		20,000 (Approx)

In the present work, human detection was carried out both on pre-recorded videos and live USB camera videos. However we faced difficulties in scenarios like the comparatively high cost of DC brushless thrusters and their ESC's and relying on brushed DC motors and importing their ESC's from China. Water proofing and sealing the machine was a task and had to be properly done.

In our model, we have designed an ROV that is capable of scanning the rivers and locating human bodies. This will reduce the time required for triangulating the location of the body. But still, for rescuing the body, an expert diver must dive in and carry the body back. In the future, a hydraulic arm system can be made and attached to the ROV that can carry the body to the water surface. This will be a complete underwater human body rescuing system and will not require any divers. Human intervention required is minimum and hence the risk of divers losing their life is greatly reduced. Another advancement that can be made to this design is using an electromagnetic coupling system to attach the ROV with a drone. In this way, the ROV needs to travel less distance under water. When a particular area has been completely searched, the ROV will come up to the surface and couple with the drone. The drone will carry the ROV to the next area and deploy it under water. Both these alterations will improve the efficiency of underwater human body detection and make it faster.

Apart from human detection ROV will be used as full time surveillance mechanism. Illegal entry of boats to the coast will be detected. In this case coastal guard and navy will be alarmed about the intruders. Swarm technology will be implemented in the near future. Here multiple ROV's are linked to each other. Search and rescue mission will be more wide and efficient.

To promote eco-friendly measures of various NGO's, renewable sources of energy will be utilised. Sources such as solar energy will be used for working of ROV. Solar panels harness the energy of sun for the working of thrusters and electronic components. Life of solar panel is high. Hence less maintenance is required for a ROV full time involved in water. Other options worth considering are a completely autonomous aquatic vehicle with improved imaging under low light conditions and improved Fluid Dynamics.

CONCLUSION

Underwater human detection has been a distant dream for the past few decades. But with the advancement of technology and research studies in the past decade in the field of underwater communication, acoustics and signal processing, the goal of underwater human detection is no longer a distant dream. Several very good research works have been published in the last decade which continue to inspire the present research works. We designed, implemented and tested our prototype in pool and pond water and the detection accuracy were satisfactory. Our design is very low cost and is only about 10-20% of the current making costs of an AUV.

We are currently working on developing a low cost acoustic detection solution for integrating with AUV for more accurate underwater human detection. Our work was aimed at finding a suitable and foolproof instrument to rescue a drowning human body underwater with accuracy. We believe, it will have immense application for fire and rescue team who are currently the authorities for handling this kind of operations. We are currently working on ways to improve the fluid dynamics and control system and also on an improved anomaly detection algorithm for better surveillance, which gives it the potential to be extended for further operations like surveying and under water resource and vegetation analysis.

ACKNOWLEDGMENTS

This project work was carried out at T.K.M College of Engineering, Kollam, India with collaboration from Electronics and Mechanical engineering departments. We extend our warm acknowledgements to the professors at both departments for their help in the present research work.

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