International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 05 | May 2019 www.irjet.net p-ISSN: 2395-0072

Unmanned Underwater Vehicle

Allen Isaac Jose[1], Ajay M Rajan[1], Akshay S[1], Arjun K R[1], Arun K L[2]

[1]B.Tech, Dept. of Electronics and Communication, M A College of Engineering Kothamangalam, Kerala, India
[2]Professor, Dept. of Electronics and Communication, M A College of Engineering Kothamangalam, Kerala, India

***

Abstract - *Over a past few years the major research focuses on the underwater world. It is difficult to reach these locations manually and unmanned underwater vehicles(UUV) were made for observing and analysing these regions. These remotely operated vehicles are available in the market but most of us could not afford it because of its huge price. So we have designed a low cost economical model which can be easily acquired and maintained by anyone. The design and development of the vehicle consisted of implementing a mechanical and electrical system, as well as the integration of subsystems. This Underwater Vehicle is designed base on low cost material and low electricity consumption. The application of the remotely operated underwater vehicle widely used in industry due to features like camera, robotic arm and etc that can be add on, it is very famous in underwater field. Beside this, the UUV is remotely controlled, so it can ensure the operator's safety from the unknown condition under sea.*

***Key Words*: Underwater vehicle, Underwater exploration, Low cost design, Sample collection, Underwater vision, ARDUINO controller**

1. INTRODUCTION

UUVs were created to help people to fulfil their needs fast and with minimum risk for their lives. The first advanced UUV was created in the 1970's by the navy and used to recover practice torpedoes and mines. They were also created by offshore oil and gas industries in order to assist in the development of offshore oil fields later on, when the new offshore development exceeded the reach of human divers. Nowadays you can find UUVs designed for different purposes, such as science, education, military and for hobby as well. In this project the main goal is to explain the theoretical, but also the practical aspects of UUV in order to understand how a small scale economical UUV works. In the following chapters step by step instructions will be given in order explain how to make a fully operated UUV, which is able to manoeuvre in any direction the water. The manoeuvring of the robot is achieved with the help of four brushless motors. The UUV has two parts:- A moving vehicle and a stationary floating buoy. The vehicle has an on board camera for monitoring and recording the underwater life. Also it has a robotic arm and in-housed sensors. Finally, the robot is tethered with the buoy's side via an Ethernet cable. From there to the surface via wi-fi module. The controls for motion are given via Bluetooth module. Underwater vehicles, which can work at depths beyond the reach of scuba divers, give us the opportunity to explore and fill the information gap between near shore and offshore habitats. This is critical for developing comprehensive management strategies for the ocean's resources. Small UUVs are the future for exploring oceans and lakes. Being more cost effective and requiring less people, these UUVs will allow for more opportunities to research our waterbodies. The same can be also implemented in search and rescue missions. By conducting surveys and market analysis we found that a lot of buyers are ready to purchase the product if it is available at a low reasonable price. This gave us the motivation in bringing down the product to more economical level. Due to its potential contributions and high benefit in many fields, a lot of research is going on underwater vehicles, but most of them are not designed for small scale of inspection or recreational needs. Most of the ROV are large size, high deployment weigh and expensive ownership. The idea of this UUV project is small, low cost, and underwater research vessel that capable of performing in depths of waterbodies.

2. LITREATURE SURVEY

A lot of studies and researches have been done related to structure and control systems of underwater vehicles. We have reviewed many works and this led towards our objective.

2.1 Design of an Inexpensive Waterproof Housing

The article, "Design of an Inexpensive Waterproof Housing"[1] by four students at Lake Superior State University, contains a detailed description of one of the most difficult tasks with underwater robotics, which is water proofing the electronics so they can be used even at the greatest depths of the ocean. There are many ways electronics can be waterproofed. This article deals with two possibilities: epoxy resin dunking (permanently sealing electronics in epoxy) and bottling. This article discusses all the considerations that need to be taken into account when bottling electronics. Some of these considerations are chemical resistance, abuse when handling the vehicle and, of course, making the bottle able to withstand high pressures, their system was tested to a depth of 300 feet. We used the acetoxy silicone sealant which we found very cheap and reliable.

2.2 Design and Manufacture of a Low Cost Underwater Remote Operated Vehicle (ROV)

In 2004, David Buecher made a low cost remotely operated vehicle and his thesis, “Design and Manufacture of a Low Cost Underwater Remote Operated Vehicle(ROV)”[2], explains how he did it. This is relevant to this project because Buecher’s goals were to make this robot out of commonly found items and for less than $1500. Our goal was to make a smaller and less expensive model than Triton, an existing ROV the RSL uses. Buecher highlighted how he was able to find most of the pieces he needed for the robot at places like Lowes and Home Depot. Anything he could not find inexpensively, he made himself. For example, the tether required to communicate with the ROV that he wanted to purchase was too expensive for his budget so he instead made a neutrally buoyant tether himself (Buecher). The projects are different in that our budget was not as small as Buecher’s. His ROV consisted of motor controllers, an AVR mini board, and a camera. Top-side, he had a computer and Logitech joystick to control the robot via tether, and a VCR to record images from the camera. This thesis helped show how to weigh cost versus quality and helped us maintain our budget.

2.3 Marine Heterogeneous Multi-Robot Systems at the Great Eastern Japan Tsunami

The article, “Marine Heterogeneous Multi-Robot Systems at the Great Eastern Japan Tsunami Recovery”[3] by Robin R. Murphy, describes the response and recovery efforts by a team of heterogeneous unmanned vehicles at the 2011 Great Eastern Japan Earthquake. Three different remotely operated vehicles (ROVs) were used in the effort to recover victims and clear ports. ROVs were chosen over autonomous underwater vehicles (AUVs) for the following reason: ROVs are tethered, so if communication is lost or an ROV is grounded, it can be retrieved using the umbilical. AUVs also usually use side scan sonars, which have a lower resolution than the imaging found on ROVs (Murphy). The ROVs required specific pieces of technology to complete these missions effectively. The ROVs all had video capabilities, as well as sonar imaging for when the water was too turbulent to see. Three different systems were used for resilience; one system could succeed where the other failed. Each ROV’s position could be found using an external sonar, or simply by tether length. All the systems chosen were small, portable, and could fit in a personal truck. This article also gives good insight into the uncertainty of field deployments and the need for a flexible system. Some launch locations were large and capable of deploying several ROVs at once, while others had physical limitations and only one ROV could be deployed. Some systems also could not run in close proximity because their sensors would interfere with each other, as well as there being a danger of tether entanglement.

2.4 Assisting Micro-ROV Operators During Surveys in Fragile Environments

The article, "Assisting Micro-ROV Operators During Surveys in Fragile Environments"[4] by David Scaradozzi, Giuseppe Conte, and Laura Sorbi, is about how a team of ROV engineers came up with a way for inexperienced ROV operators to pilot an ROV in a highly sensitive area without any expert training. What they did was essentially nest a Micro-ROV inside of a larger ROV, which was brought down to a certain depth. The larger ROV would be controlled automatically to navigate a certain path at a specific depth, while the Micro-ROV was allowed to roam free at the depths below. This is a good improvement because not only does it allow for a smaller ROV to be less intrusive, but it also takes some human element out of the process.

Another important part of the system is what they call the Assisted Guidance System. This system makes the operator’s job even easier. The Assisted Guidance System is implemented on the Micro-ROV, and essentially creates boundaries within which the Micro-ROV has to stay. When the ROV starts to drift out of these boundaries the joystick resistance starts to increase, which encourages the operator to return it to the centre. In sensitive areas where ecosystems need to be maintained, this level of precision operation is crucial (Scaradozzi). The article does show that our small UUV could be good for more precision work and tight spaces, such as pipes.

2.5 ROVs Continue to Develop Capacity for Deepwater Operations

Martin Wareham wrote the article “ROVs Continue to Develop Capacity for Deepwater Operations”[5], where he discusses the many uses of an underwater ROV as well as how they will continue to improve over the next few decades. There is a large variety of ROVs due to the wide range of different underwater tasks that they can perform. Smaller ROVs are now capable of doing things that only large ROVs could do before, while larger ROVs are pushing the boundaries as to what was thought possible. These huge improvements are due to the ongoing developments in robotic technology. Some of these developments include more capable sensing products, lighter/stronger materials, and more advanced control systems. These are just a few of the current improvements, and these advancements will continue to grow along with the rise of offshore exploration and subsea field development (Wareham).

2.6 Underwater Robotics

The article, “Underwater Robotics”[6] by Gianluca Antonelli, Thor I. Fossen, Dana R. Yoerger, gives an idea about modelling the structure of the underwater vehicle. Using the theorems from rigid body dynamics the equivalent pressure at a particular height could be found. This explains at how much quantity and size the water sealant has to be used. The motion vectors can be derived which can be used to estimate the angular velocity using the available thrusters. Various sensor and actuating systems are also explained and the according to the need one can select among those.

3 DESIGN ALTERNATIVES

3.1 Design Alternative 1

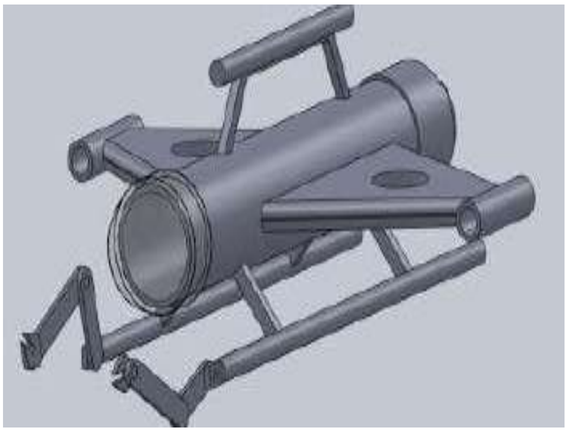

Fig -1: Design alternative 1 model

The first design that was observed is shown above in Figure 1. This design employs the usage of 2 legs at the bottom of the UUV that serve several purposes. The ability to insert lead rods into the legs, and apply positively buoyant material at the top will always ensure that the UUV will remain upright. Another purpose is that if the unit is operating on the ocean floor, it will be able to rest on the ground while performing the predetermined duties. The last advantage would be to mount the claws on these legs, which would be aligned right in front of the camera. This design also utilizes the implementation of four thrusters. The two mounted horizontally in the wing will provide the ascent and descent, while the other two mounted at the end of the wings will provide the manoeuvrability in the horizontal plane. The main body material was not chosen for this alternative, but there were a few materials that were considered. The first one was aluminium. Although aluminium is not relatively expensive, machining all the parts would be. The other material was PVC. This material was highly likely to be chosen due to the very low cost, and ease of availability. Not to mention that it comes in many diameters with all types of fittings. Since the testing will take place in a pool, the hydrostatic pressure will not cause failure since schedule 80 PVC pipe is rated to withstand 200 psi.

3.2 Design Alternative 2

Fig -2: Design alternative 2 model

The second alternative of the design was to make it in the shape of a box. This setup follows the traditional design of UUVs. The whole system would be enclosed in a cage with foam on the top, weights on the bottom and all the electronics in the middle of the UUV such as Figure 2. Having a box setup allows the components to be fixed on the cage, which makes it easier to construct and increases stability. The robotic arm and weights would be placed on a plate at the bottom of the cage followed by dividing the foam into four sections and placing them in specific locations above the whole UUV to achieve the desired buoyancy. The camera together with the four thrusters would be placed around the outside of the cage to balance each other out (the camera is located directly above the robotic arm). All electrical components would be at the center, housed in a cylindrical body for their protection. The materials considered to this design are the same as Design Alternative 1. UUVs constructed in this fashion are not as hydrodynamic as the Design Alternative 1, due to their cage-like structure. Also this structure is considerably bigger than an UUV without the cage. On the other hand, having the cage permits the addition of parts even after the UUV has been built and used compared to an un-caged setup where the UUV can only carry the instruments it was designed to.

3.3 Proposed Design

Fig -3: Proposed model

For the proposed design shown above, the team decided to incorporate the same functions but at a lower cost. The goal is to be as hydrodynamic as possible, but keeping the stability of the system and ability to add components. This design would be compact meaning all the parts would be placed as close as possible while leaving space for specific additions. A smaller ROV increases the manoeuvrability of the system under water. The model will have a cylindrical body with a transparent dome in the front where the camera will be located. Total 4 thrusters are used out of which 2 are positioned at the point where weight is concentrated (almost near to middle) for up and down motion and 2 are placed at the rear end for the planar motions. The control systems are placed water tight in the hull. For this design, the team plans to make the body using different materials and test the buoyancies. Also the electric power required for motion of each designed hull.

3.4 Actual Design

Fig -4: Actual design outcome

The actual design is a culmination of first design alternative and proposed design model. The main difference was that there was no cage-like structure and the thrusters were mounted inside smaller diameter PVC pipes that were mounted onto the body. This gives a better flow of water which helps in motion. This also helps to protect the thrusters from damage if the UUV gets too close to a wall or encounters any objects or debris. The robotic arm can be placed just in front of the camera. This is customizable and could be replaced by any similar tool. Also instead of risking the chance of damage to circuits due to water leakage it is placed in a separate unit on the surface of the water in the form of a buoy.

4. ANALYTICAL ANALYSIS

The task was to determine how deep into ocean the Remotely Operated Underwater Vehicle (the pressure vessel) can dive while maintaining a safety factor of 1.5, and additionally figure out which material would allow us to achieve this goal with the best cost. The different materials will be tested according to the size of the pressure vessel. It is to be noted that this is a simplified version of the actual model, which will be used as a preliminary test in order to understand the effects of hydrostatic pressures on an object under water. The model being tested has a cylindrical body that is hollow inside. This will assimilate the body of the actual ROV without the two wing-like components of the model.

The pressure vessel has a length of 0.4752 meters (1 foot and 5 inches) and a diameter of 0.1524 meters (6 inches) consistent with the real model. These measurements were kept the same for all the materials being tested and the only measurement that was changed was the thickness due to the fact that each material is sold with a certain thickness. The materials tested were PVC Schedule 40, PVC Schedule 80, Aluminium 7075, Stainless Steel 316, Titanium (Grade 2) and Titanium (Grade 5). The yield strength, tensile strength, and cost for each material were collected for the analysis. In order to measure the factor of safety of the pressure vessel to ensure that the material will not fail, the following values we calculated depending on the depth at which the pressure vessel is located: Tangential stresses, Axial stresses, Principles stresses and Von Misses stresses.

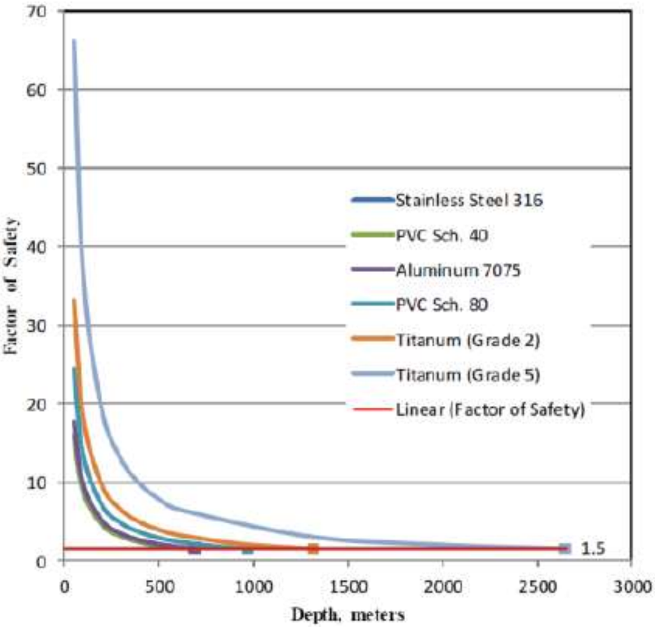

Chart -1: Factor of safety in comparison to depth

With the factor of safety calculations done, the attention was turned to the cost analysis. Due to the fact that each material is sold with a certain diameter, the cost of the material depends on solely its length. Keeping in mind that all models accounted for have the same length, it can be said that price will not change with the depth at which the specimen is sent. The prices were placed side by side with the maximum depth each material reached. In doing this, the material that went the deepest for the least amount of the cost would be the one selected. Of course there are some obvious assumptions that could be made, for example Titanium (Grade 5) would go deeper than any other material but its cost would to be high and PVC Schedule 40 is the cheapest but it will not go very deep. These assumptions cannot influence the selection of the material because the material of the lowest cost would prevail.

Finally, with everything taken into consideration, the material that used the lowest cost and with the best Depth to Cost Ratio was selected. Taking the lowest depth achieved and dividing it by the price of the material calculate this Depth to Cost Ratio. Of course, the higher the ratio the better the selection was. PVC Schedule 80, although having a price that was slightly higher than that of PVC Schedule 40, had a better Depth to Cost Ratio. This means PVC Schedule 80 reached a depth of 969 meters, while PVC Schedule 40 only reached 624 meters. All the other materials had a low depth to cost ratio and used much more of the money than the two PVC tubes. In conclusion, the best material was the PVC Schedule 40, further testing will be done but this material seems to be the best choice to house the body of the UUV.

Table -1: Depth to cost analysis

Cost Analysis	Percent of Budget	Depth to Cost Ratio
PVC Sch. 40	0.56%	55.4
Stainless Steel 316	3.64%	8.6
Aluminum 7075	4.82%	7.2
PVC Sch. 80	0.74%	65.2
Titanium (Grade 2)	17.07%	3.9
Titanium (Grade 5)	47.15%	2.8

5. COMPONENTS USED

5.1 Propeller

UUV uses motors and propellers to move itself through water. Such combination of motor and propellers are called thrusters. After choosing a motor, the proper propeller must be chosen for the task. Two sets of numbers describe the size of the propeller to be used. These numbers specify the diameter and the pitch. The diameter will always be first and then the pitch. When doing so, we must select the diameter of the propeller to be bigger than the motor diameter. The pitch of the blade will depend on the diameter and the rotational speed of the motor in RPMs. The width of the blade determines the amount of water it pushes, thus lighter or thinner blades are used for higher speed applications. Even though these characteristics will help us determine which combination will be the most adequate for our scenario, the final combination will be chosen during experimentation. Even though the propeller can be 3D printed according to required diameter and pitch we went for easily available ones from the market because of lower cost. The propeller is of dimension 6 cm in diameter and made of plastic.

5.2 Polyvinyl Chloride (PVC)

Following the conclusion drawn by our Material Analysis above, PVC Schedule 40 was chosen to house the electrical components of the UUV. The pipe was of 160 mm in diameter and 40 cm in height. Another PVC pipe of smaller diameter and schedule was selected in order to create the other sub-structures. The smaller PVC pipes were used to place the motors in them, this would protect from external damage. Also this would increase the force exerted on water to move ahead. The pressure analysis was only done for the single large PVC Schedule 40 pipe in the middle because it would be the only part of the UUV subjected to pressure under water. The side pipes are just for supporting the motor. PVC end caps are used for closing both the ends of the main middle hull.

5.3 Silicone Sealant

Silicone sealants are used to provide the water sealing at the joints. It is non -soluble in water which gives the advantage of using it underwater. It is available at a low cost and can be easily applied through a nozzle. The curing time is about 16 hours by the time which it adheres well onto the surface. It has great adhesion over glass, fibres and plastics. This type of sealing can withstand underwater pressure at about 30 meters in depth.

5.4 Brushless DC Motor

To assure the proper movement of the ROV inside the water four powerful brushless motors were used. Propulsion is provided by four modified 12V, 3A brushless DC motors that allow horizontal and vertical movement of the vehicle. This motor can provide a speed of 1700 rpm. These motors were chosen for their small size and the fact that they are intended for underwater use; a feature that minimized construction complexity substantially and provided inherent watertight integrity. Brushless motors are suitable for working underwater since they do not have contacts, and they are powered by the stationary coils. The stationary coils are powered by an AC signal to spin the casing containing the magnets. So there is nothing for the water to interfere with electrically speaking (assuming the wiring is all insulated). When choosing the motor, significant consideration was taken to ensure that the power is the output of the motor. Thus, when having a big motor it may draw sufficient current that could reduce performance but will be able to operate at low efficiency. In the other hand, when it is too small, the amount of thrust will be inadequate.

5.5 Camera

UUVs provide the opportunity to view the underwater environment. In order to achieve this, we must have an onboard camera capable of providing a live video feed up the tether for the user to see. The camera must output a composite signal, be small, easy to use, low cost, and waterproof up to 80 ft. The main objective for the camera is to operate at low voltage, with a high resolution, and low Lux light sensitivity rating. The lower the Lux rating, the better the camera can function in low-light situations. Since the UUV will be descending to depths of about 80 feet, the light will definitely be a factor. The UUV has built in lights, but the lower Lux rating cameras will benefit from this the most. Out of the cameras that were researched the GoPro Hero was the most efficient one. Because it has the best resolution and a rechargeable battery that can allow us to eliminate power consumption from the onboard batteries that will be used to power the thrusters to manoeuvre the UUV. Also it is waterproofed. But due to the low budget option we went for HIKVISION DS-2CD122P-I3 Network Camera. The specifications are 1/2.8" Progressive Scan CMOS, 2 megapixel resolution, Digital WDR, 3D DNR, 30 meters IR range, 12V DC, 10%, ICR. When the available light is less, its vision will automatically change to IR type which ensures proper result.

5.6 Battery

In order to power all the motors, camera and other control systems, two batteries each of 12V and 7Ah are used. The two batteries are connected in serial and the power is provided to motor for improved performance.

5.7 Cable Design

One of the most important part of the UUV are the cables used for the communication of the UUV with the outside world. The pressure that the cables must withstand is enormous. Vehicle size, weight, temperature, duration of the operation, and operating depth, as well as the vehicles motors, subsystems, and payloads, all combine to determine the UUVs cable design. In order to design an ideal cable for an UUV, designer must consider the power, signal and strength needed for the specific application that will be used. Here we are using three cables:- 2 data cables and 1 ethernet cable. The first data cable is used to supply the control signal to the motors. The second data cable is used to power camera, robotic arm and control the sensors. Each data cable consists of 4 pair of small sub-wires. It has strengthening fibres inside to give toughness. The ethernet cable is used to transmit live video vision from camera to Wi-Fi modem at the surface. We need to use 3 cables because the control systems are situated at the surface buoy. All the cables are of 15m in length.

5.8 Robotic Arm

A robotic arm is placed in the front of camera to grab objects and other samples from underwater. It is customizable. That is any such sample collecting instruments can be fitted like water sample collector, driller etc. The robotic arm can be controlled using motor driver which controls the opening and closure of the arms.

5.9 Arduino MEGA2560

Arduino MEGA2560 is used as the microcontroller. The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analogue inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The main advantage is the more number of digital and analogue pins which can be used to control many motors and sensors at a time. The cost of this board is also less compared to other similar boards. Also it is more user friendly. It is placed on the surface buoy along with other control circuits.

5.10 Temperature & Humidity Sensor

We use the sensor DHT11 which can measure both temperature in degree Celsius and humidity in percentage. It is placed inside the hull. This could be used to find the temperature in Fahrenheit and heat index. The DHT11 is a basic, low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analogue input pins needed). It is fairly simple to use, but requires careful timing to grab data. This is placed in inside the main hull of the vehicle to make sure that the conditions in the water will not damage the vehicle and the water sealant.

5.11 Water Leakage Sensor

We use the sensor FC-37 which is actually a moisture sensor to detect any water leakage into the hull. Here the data from the sensor is detected via analogue pin of Arduino. Its values are calibrated such that the serial output shows GOOD if there is no water leakage and shows ALERT if there is water leakage. If water leaks occur the vehicle could be suddenly brought to surface before severe damages occur due to short circuits.

5.12 Bluetooth Module

The Bluetooth module used here is HC-06. Allows our device to both send or receive the TTL data via Bluetooth technology without connecting a serial cable to your computer. Here we are connecting the Bluetooth with the mobile and the motion controls are sent via the controller on phone. Also the sensor data can be obtained on the mobile application serially via Bluetooth. The default baud rate is

9600. It has built in antenna which can provide a coverage up to 30ft. This module is connected with the Arduino module on the surface buoy.

5.13 Motor Driver

The motor driver used here is L298N-2A motor driver. Two motors can be connected on each of the motor driver. So a we need 2 motor drivers in total for all operations. L298N-2A motor driver is a high power motor driver perfect for driving DC Motors and Stepper Motors. It can support 2 amperes of current. It uses the popular L298 motor driver IC and has an onboard 5V regulator which it can supply to an external circuit. It can control up to 4 DC motors, or 2 DC motors with directional and speed control. It works on the principle of dual H-Bridge. In this mechanism enable signals can be used to control the direction of rotation of motors by changing positive voltage to negative and vice versa occurring at the motor terminals. It is placed on the surface buoy along with the Arduino module.

5.14 Wi-Fi Router

The router used is I-ball Baton wireless wi-fi router that has a range of about 100m. The ethernet cable from the camera placed in the vehicle is connected to the router on the surface buoy. This signal is transmitted wireless to the laptop in which we can see the live vision. We can record videos and take pictures from the camera.

5.15 Arduino IDE

Arduino IDE is used to compile and upload the program into the Arduino MEGA board. It is a simple user friendly software with easy error detection and correction options.

5.16 Arduino Bluetooth Controller

Arduino Bluetooth Controller is application used in android device to control the UUV via Bluetooth. It can receive the serial data available from the sensors. Also commands can be given in the form of a joystick control within the application itself. It can control the motion of the vehicle and also the opening and closure of robotic arms. The application is easily customizable.

5.17 Proteus IDE

Proteus IDE is the software used initially to design the circuit diagram. Connections can be easily done in this software.

6. CONSTRUCTION

6.1 Structural Design of UUV

Initially the outer mechanical structure is made. The central main frame is made of schedule 40" PVC pipe of diameter 160mm and height 400mm. Another pipe of 105mm diameter is cut into four equal parts of 90mm height. These are motor holding attachments which protect the motor from damage due to obstacles. For the initial buoyancy tests these attachments are just joined by means of tape. Two are placed vertically at the middle for protecting the up-down motors and two are placed horizontally at the rear end for other two motors.

Fig -5: Initial layout

Now buoyancy tests are made to find the dead weight required to cancel out the buoyant force. The magnitude of the buoyant force, B, exerted on a body, floating or submerged, is equal to the weight of the volume of water displaced by that body. The ability of an object to float depends on whether or not the magnitude of the weight of the body, W, is greater than the buoyant force. Clearly, if B > W, then the body will float, while if B < W it will sink. If B and W equate, then the body remains where it is.

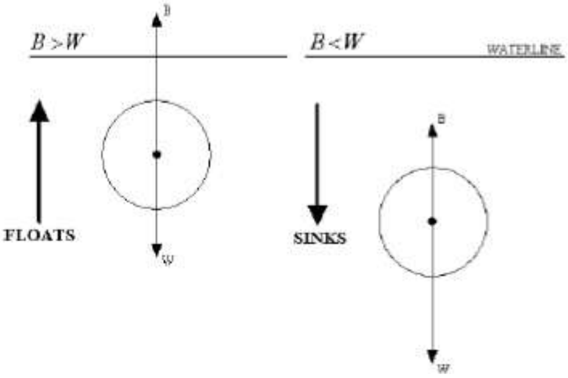

Fig -6: Effects of buoyancy and weight on an underwater body

Initially the dead weight we used was bricks and stones. After finalising the dead weight only we planned to buy the required iron rods which has higher mass density. After conducting the initial buoyancy tests we got the dead weight value as 9.5kg. This means that we need to put a weight of 9.5kg to make the UUV balanced under the waterline.

The front end cap was removed and drilled to make a rectangular hole of 8cm length and 5cm width to accommodate the camera lens. This hole is covered by using a glass plate of 11cm length and 7cm width. This piece is attached to the end cap using glue stick and also silicone to give it a water sealing. After this sets in, the camera we use is attached to the front glass plate.

Fig -7: Camera placed at the end cap

The next task is to permanently attach the PVC motor holdings on the sides and at the back. The two of them are positioned vertically at the middle of about 200mm from both sides. Then they are permanently attached to the main pipe by welded metal clips. Inside these attachments are the metal clips to screw and tighten the motors. The attachment pipes at the rear end are positioned horizontally at an elevated position and screwed into the main pipe. Motors are attached to these PVC holdings and propellers are connected to the motors. The welded metal ring has an T-shaped end piece onto which the robotic arm can be clipped tightly.

Fig -8: Finalized structure with thrusters and arm

Now the initial mechanical structure of the underwater vehicle is ready. The next step is to setup all circuits and control systems and integrate into the mechanical structure.

6.2 Hardware Implementation

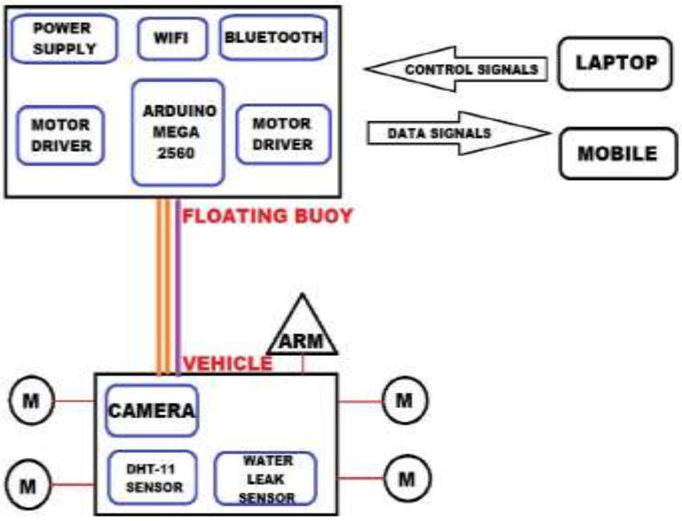

Fig -9: Basic block diagram of components

This block diagram shows the main components of the whole system. We can see that the underwater vehicle and the surface buoy is connected via 3 cables. The two orange cables represent data cables which has 4 pair of wires inside. This is used to provide the supply power and acquire the data from sensors. The violet cable is the ethernet cable. It is used by camera for live vision. The user at the surface acquires sensor data via Bluetooth on android mobile and camera live feed via Wi-Fi on laptop. Also control signals can be given from mobile via Bluetooth.

The motors and arm is interfaced with the ARDUINO MEGA board via the motor drivers. Each motor driver can control 2 motors at a time. There are two motor drivers used. The control signals for the motor driver are given by the program in the ARDUINO board. The two motors used for up and down motion is shorted and given to the output A of first motor driver. Because both rotates in same direction during up and down movement. The output B of first motor is used to control the robotic arm. The output A and output B of second motor driver is connected to each rear motors. These motor drivers work on the principle of H-bridge. That is the clockwise and anticlockwise rotation of motor can be controlled by the ARDUINO board via the program. The 5V power supply for the motor driver is given from the ARDUINO board. The 24V supply for the motor is given from the battery. The 6,7,8 and 9 digital out pins of ARDUINO MEGA board is used to control the planar motion motors. The 12 and 13 pins are used for up-down motors. The 10 and 11 pins are used for the arm.

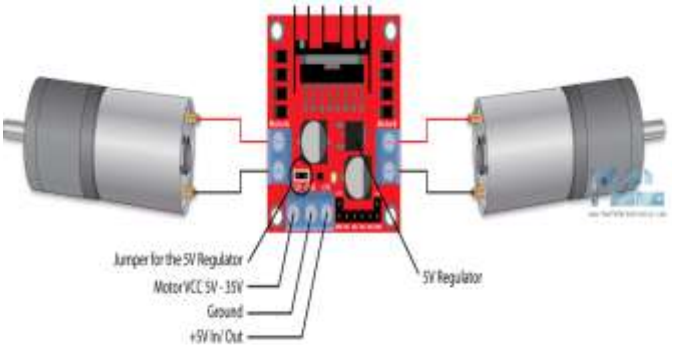

Fig -10: Interfacing of motor driver

The camera is interfaced with the Wi-Fi router using a 10m long ethernet cable. Before the camera is connected to the Wi-Fi router, it is connected to laptop directly and the IP address is configured. After being connected to the Wi-Fi router, we can access the camera by typing the IP address in the web browser and live video streaming is obtained. In the laptop the signal is received via Wi-Fi. Pictures and videos can be recorded in the laptop. The 12V power supply is given through a pair of wires in one of the data cables.

The power supply of both the sensors are shorted and given together to a pair of power supply wires in the data cable. The DHT-11 sensor uses digital out pin 2 to transmit the signals to the ARDUINO board and from there to the mobile via Bluetooth. The FC-37 sensor uses the A0 analogue pin of the board to transfer the data. This gives a more accurate data. One pair of wire in data cable is used for transmitting data of each sensor.

The power supply is provided from the ARDUINO board. The TXr pin of Bluetooth module is connected to the RXr pin of ARDUINO board and vice versa. The Bluetooth module is also provided with a password for safety. The sensors transmits the data to the mobile via Bluetooth and from mobile the control signal for motor is sent to the ARDUINO board. These are 1 and 2 pins of ARDUINO board.

6.3 Floating Buoy

All the hardware systems except camera and sensors are placed on the floating buoy. We used a tyre tube to support the weight of the hardware. The hardware is attached on a glass plate using glue stick. This is then placed on the tube. The two data cables and one ethernet cable is also attached to this buoy. In addition we can place a small solar panel to charge these batteries as it is placed in an open place.

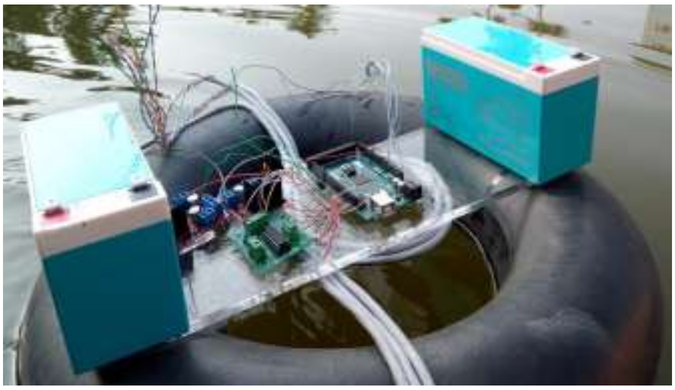

Fig -11: Floating buoy

6.4 Final Integration

Finally all components are interconnected. The floating body is connected to the underwater vehicle by means of a 10m long cables:- two data cables and one ethernet cable. These cables are inserted into the vehicle by drilling a hole in it. Silicone sealant is applied at all the open joints to make it water tight. It is pasted in different layers thick. All wires are soldered to make the connections strong and it is glued to make it stiff. The power supply to ARDUINO can be given either by using power bank or voltage regulator from batteries.

After fixing all these hardware components we have to test the stability of the vehicle. Otherwise the vehicle will be tilted to one side. Assuming no water movement, the stability of a static body underwater is predominantly affected by the positions of the centres of mass, C_M, and buoyancy, C_B. The centre of buoyancy is the centroid of the volumetric displacement of the body. If C_M and C_B are not aligned vertically with each other in either the longitudinal or lateral directions, then instability will exist due to the creation of a nonzero moment.

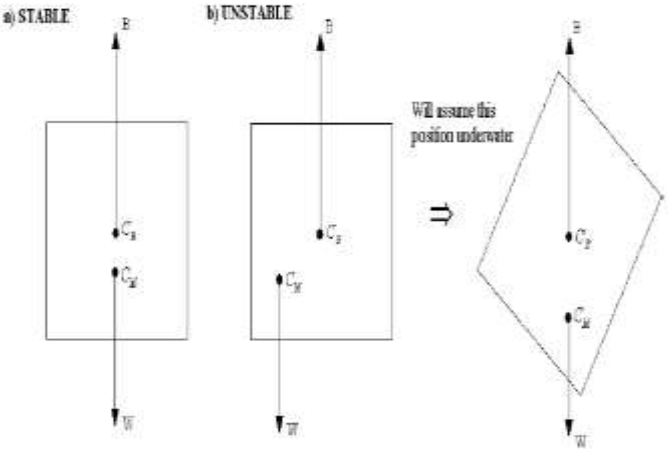

Fig -12: **a**) Stable configuration of underwater body
b) Instability of an underwater body through misalignment of centers of mass and buoyancy.

If CM and CB coincide in the same position in space, the vehicle will be very susceptible to perturbations. Ideally, the two centroids should be aligned vertically some distance apart from each other with CM below CB. This results in an ideal bottom-heavy configuration with innate stability.

Fig -13: Testing stability

After checking all stability tests and checking connections we can conclude all the assembling works. Finally adhesion primer is coated over the surface. It helps in giving a rough surface for painting. The works can be finished with spray painting.

7. TESTING & RESULT

The UUV should exhibit stability and very precise manoeuvring. The testing involved leaving the UUV underwater for approximately two hours to ensure that there was no water leakage. In addition, the controls were tested as well to make sure the vessel was able to maintain a position, as well as submerge and emerge without any problems. The UUV surpassed all expectations, and was able to turn on its axis without any issues.

Fig -14: UUV during testing

These two pictures were taken while testing its ability to submerge and emerge on its own. As it's shown the vessel maintains stability. The time spent testing the manoeuvrability was roughly ten minutes underwater. Everything remained operational throughout testing deeming the operation successful. Also the live video from the camera is received via Wi-Fi. This can be recorded or pictures can be saved in laptop. The sensor readings is received in mobile via Bluetooth.

8. CONCLUSION

The aim of this project was to design and construct a small scale UUV from the start. In order for the project to be successful, all the right parts and components had to be found and put together properly. This was one of the parts during the whole process and took most the time and effort. During this project, some problems appeared. Most of them were solved, but not all of them. Therefore the project has a lot of space for further improvements. Even though the UUV does not have all intended features implemented, the system is functional at this point. Therefore, the main goal, constructing and controlling a small scale UUV, can be considered as accomplished. As further improvements, the UUV could have a turbidity sensor that provide the quality of water and pressure sensor that shows the depth of the UUV. For the purpose of this project, a relationship between buoyancy, materials, propulsion, and size was determined. In early discussion, there was some consideration of a neutrally buoyant UUV compared to a variable ballast tank. The fact that a neutrally buoyant UUV can be directed in all axes with the proper placement of thrusters made this option more appealing and cost effective. A variable ballast tank would also hinder performance because it would be another variable to control while attempting to complete the competition tasks at hand. The UUV proved to be capable of completing all task within a timely manner. The path to complete this yearlong project was certainly an arduous one, and many different design decisions had to be made. However, there was much to learn and the team, in general, has grown as engineers, ready for the professional engineering environment. There has been experience in research, design, construction, implementation, and testing, and all of these areas required analysis and comprehensive thought to alleviate any problems that occurred. Ultimately, the team is very proud to accomplish a robotics project that integrates three separate systems. The UUV, the buoy, and the base station communicate together nicely and solve the issue of being able to successfully navigate through water. Moving forward, this project can be improved in the coming years and could eventually become a prototype that is adopted by various industries related with water. The team is optimistic of the future of this project and is very happy with the outcome.

REFERENCES

[1] D. Harrington, J.V. Parker, A.M Waligora and T.M Walworth, "Design of an inexpensive waterproof housing", OCEANS 2003 Proceedings , vol.5, no.pp.SP2880,SP2887 Vol.5, 22-26 Sept. 2003

[2] M. Buecher and David, "Design and Manufacture of a Low Cost Underwater Remote Operated Vehicle (ROV)", Thesis. Santa Clara University, School of Engineering,

[3] Murphy and Robin R., "Marine Heterogeneous Multirobot Systems at the Great Eastern Japan Tsunami Recovery", Journal of Field Robotics 29.5 (2012): 819-831.EBSCO. Web. 16 Oct 2013.

[4] R Scaradozzi, David, Giuseppe Conte and Laura Sorbi, "Assisting Micro-ROV Operators During Surveys in Fragile Environments", Sea Technology 53.4 (2012): 56-60. Santa Clara Library Applies Science & Technology. Web. 17 Oct. 2013

[5] K Wareham and Martin, "ROVs Continue to Develop Capacity for Deepwater Operations", Offshore Magazine Apr. 2013: 108-09. EBSCO. Web. 17 Oct. 2013.

[6] Thor I. Fossen and Dana Yoerger, "Underwater Robotics" https://www.researchgate.net/publication/227168671, DOI: 10.1007/978-3-540-30301-5_44

BIOGRAPHIES

Prof. Arun K L

Project guide, Dept of ECE, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India

Allen Isaac Jose

Student, B-tech ECE 2015-19, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India

Arjun K R

Student, B-tech ECE 2015-19, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India

Ajay M Rajan

Student, B-tech ECE 2015-19, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India

Akshay S

Student, B-tech ECE 2015-19, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India