Preliminary Design of Autonomous Underwater Vehicle with Higher Resolution Underwater Camera for Marine Exploration

Z.Salleh,[a,*] M.F.Ghani,[b] and M.A.H.Ramli,[c]

[a)]*Universiti Kuala Lumpur, Technical Foundation Section, Malaysian Institute of Marine Engineering Technology, Lumut, Perak, Malaysia.*
[b)]*Universiti Kuala Lumpur, Marine Electrical Electronics Technology Section, Malaysian Institute of Marine Engineering Technology, Lumut, Perak. Malaysia.*
[c)]*Universiti Kuala Lumpur, Marine Design Technology Section, Malaysian Institute of Marine Engineering Technology, Lumut, Perak, Malaysia.*

*Corresponding author: zulzamri@mimet.unikl.edu.my

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ABSTRACT

This research explains on a design and development of an Autonomous Underwater Vehicle (AUV). Definition of AUV is a robotic sub-sea that is a part of the emerging field of autonomous and unmanned vehicles. This project shows the design of implementation of an AUV as a test prototyping vehicle especially involved small-scale and low cost sub-sea robots. The AUV prototype has been design and simulate by using SolidWorks. The AUV assembled with mechanical system, module of electronic system for development of controller.

KEY WORDS: *Autonomous Underwater Vehicle; Prototyping.*

1.0 INTRODUCTION

Innovation for AUV is very tough research area and valuable study because it can be deploy in hazardous environments without risking the human divers in sub-sea exploration. If we refer the oceans covers about two-thirds of the earth and has a great effect on the future existence of all the human beings. It is about 37% of the world's population lives within 100km of the ocean. The ocean generally overlooked as we focus our attention more on land, atmospherics and cosmos issue, rather than have not been able to explore the full depths of the ocean and its abounding living and non-living resources. An example, estimated was finding that there are about 2000 billion tons of manganese nodules inside of the Pacific Ocean near the Hawaiian Islands[1]. Underwater robots can easily help us better understanding marine and other environmental issues, protected the ocean resources of earth from pollution and efficiency utilize them for human welfare. However, a number of complicated issues arise due to the instructed and hazardous undersea environment make it difficult to travel in the ocean even though today's technologies have allowed humans to land as discovered the moon and robots to travel the Mars. This high potential field is very economical as AUV's has been created for cheap scalability make it ideal for large scale and long term research for marine data collection. As mention earlier AUV is robotic device that is driven under the water with complete their propulsion system, controller and piloted by onboard computer and manoeuvrable in three dimensions. A lot numbers of universities all over the world focusing research on AUV[2]. The demand for AUV is growing up and will eventually lead to fully autonomous, specialized, reliable underwater robotics vehicles. This was support by [1] where from year 1990 to 1999 the numbers of AUV's are involved around the world more than 46 units only. The navigation and control [3]and imaging [4] technologies associated with manned submersibles, remotely operated vehicles (ROVs) and towed vehicles that service such needs today, are expensive, require large ships and infrastructure, and are in short supply. The technologies associated with autonomous underwater vehicles

(AUVs) are rapidly evolving to fill the requirements of these communities. A large number of AUVs are being designed, built and deployed in the support of such tasks. In the US there are a number of ongoing efforts, including commercial efforts such as those associated with the Bluefin Robotics AUVs and the Remus AUVs for oil and gas surveys and naval applications, the ABE AUV [5] designed for deep ocean scientific surveys, the Altex AUV designed for under-ice surveys in the Arctic, and the Ocean Explorer and Morpheus AUVs[6] designed for coastal surveys. Other notable efforts abroad include the British Autosub AUV [7] the Norwegian Hugin AUV [8] and the Japanese Urashima AUV [9]. In this paper, it will proposed the AUV preliminary design and development by using computational-aided software called SolidWorks Premium 2010 and some descriptions on the design concept which has been implemented. Furthermore, the next section discussed the step-by-step development of underwater camera the AUV and it will end with discussion of some factor that will affect the AUV design and development especially the AUV performance in the deep-sea or underwater.

2.0 RESEARCH BACKGROUND

2.1 Material

The material used in this research where the body made from fibreglass and some electrical components. While the propeller made from alloy-copper material. The primary structure of the design is making the mechanical parts especially the skeletal frame. The skeletal frame as is might be made from aluminium, chosen especially for its lightweight characteristic as well as its resistance to corrosion which helps protect the frame against the harsh saltwater and chlorine environment in which it is subjected to. As well as supporting the two hulls and four motors, the structure of the frame allows for the simple mounting of external devices and components. The design took into account the potential need for additional components in the future and for that reason ample space is available on the frame. The symmetrical and structurally simple nature of the frame design contributed to the relatively straightforward aligning of the thrusters with the centre of drag for increased dynamic stability.

2.2 Design

First of all, to design an AUV, the project process should be identified as shown in Figure 1 for the process flow. It can be classified into several stages. The first stage concentrates on the design concept of the AUV. The second stages can be described in two sections; the first section is the development of the mechanical structure. Thus, computer-aided software such as the SolidWorks software is used to draw and animate the AUV that are proposed and expected. Another section is the development of the internal and external electrical design of the AUV. The final stage is concluded with its testing, appraisal and minor adjustment of the project. The overall design flows of the design and development of AUV is shown in Figure 1.The overall design flows of the design and development of AUV is shown in Figure 1. Design of AUV's in Figure 2.

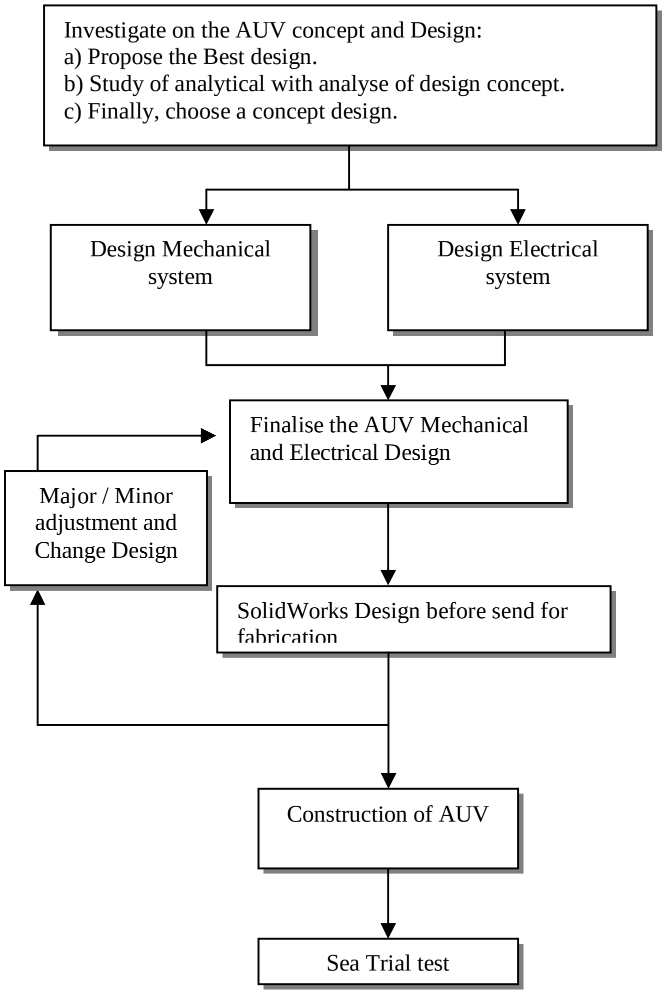

Figure 1: Development of AUV process flow.

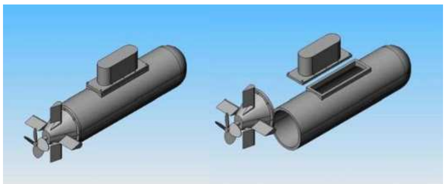

Figure 2: Design AUV using SolidWorks.

The AUV can be designed in 3D by using computer-aided software and hence, the SolidWorks is 3D mechanical CAD (MCAD) software used. The software enables the user to play around to make any changes or modification of the model an AUV. Actually this design is finalized after a selected the suitable and best design. Figure 2 is an example the AUV that design using SolidWorks software [2]. In addition, by using the tools given, the modification could easily handle and it the design can be separated. Some of AUV's uses two thruster motors in horizontal plane for turning and heading propulsion at Figure 3 [10].

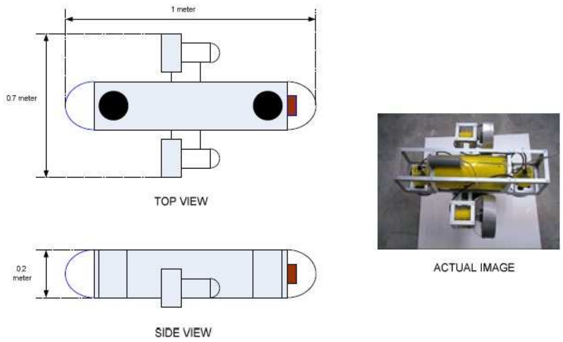

Figure 3: Design AUV's using two thruster motors.

The torpedo like structure of the design in Figure 4 provides a sleek, hydrodynamic form that houses components in a high structural integrity, cylindrical hull. Power consumption would be kept to a minimum due to the use of only one motor situated on the stern. Steering would be controlled by a rudder while bow planes and ballast tanks would controldepth. Ballast tanks would involve comprising tanks, pumps and compressed air onboard. Maintenance, inspection and addition of components would be inhibited due to the limited space available.

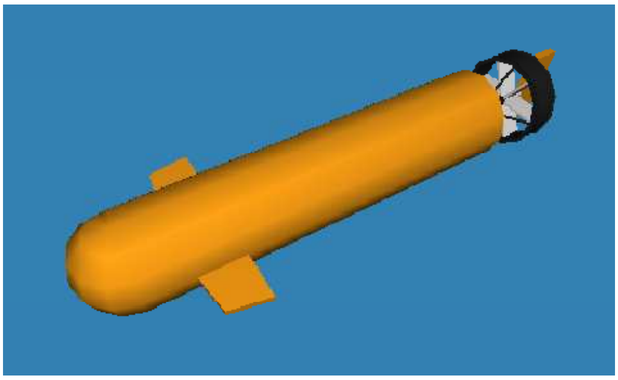

Figure 4: Torpedo shape concept design.

The need for servo-controlled rudders and bow planes would require through-hull connections capable of allowing rotational movement, thus introducing added complexity in ensuring watertight integrity. The nature of the vehicle's movement by way of its bow planes, rudder and ballast tanks would introduce a high level of complexity in the control of the vehicle. These mechanisms would involve intricate modelling in software in order to sufficiently and accurately control the vehicle's motion. The one-hull solution consists of a cylindrical tube with four thrusters attached to a skeletal frame (Figure 5). Two thrusters would be used for horizontal motion and the other two for depth control. Due to components being housed in just one hull, the need for through-hull connections would be minimal, however, the amount of available space would be restrictive. The stability of the vehicle would also be a problem as the centre of mass would be located very close to the centre of buoyancy. Due to the use of four thrusters, power consumption would be far greater than with the torpedo design, hence the need for more batteries and space. On the other hand, the four-thruster configuration would allow for easier modelling and control of the vehicle in software. The frame supporting the hull and thrusters would also allow for modularity and relative ease in attaching external devices.

The design in Figure 6 is similar with structure to the one-hull solution, but consists of two hulls; an upper and lower one. The added benefits of this design includes increased space for components and an innate metacentric righting moment produced from a dense lower hull and a highly buoyant upper hull. Batteries would be housed in the lower hull to lower the centre of mass while the remaining components would be situated in the upper hull.One disadvantage in comprising two hulls would be the need for more through-hull connections to link components in both hulls. Other advantages and disadvantages of this design are akin to those of the one-hull solution.

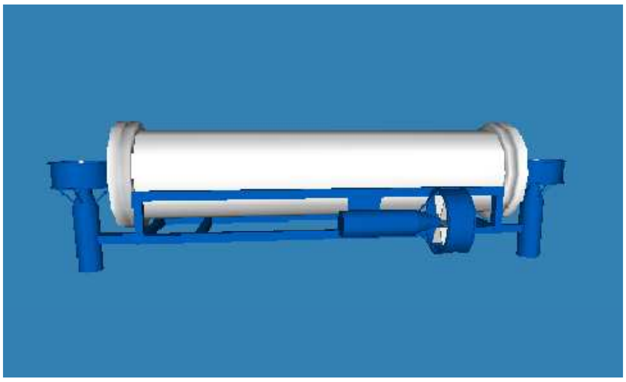

Figure 5: The one-hull, four-thruster concept design.

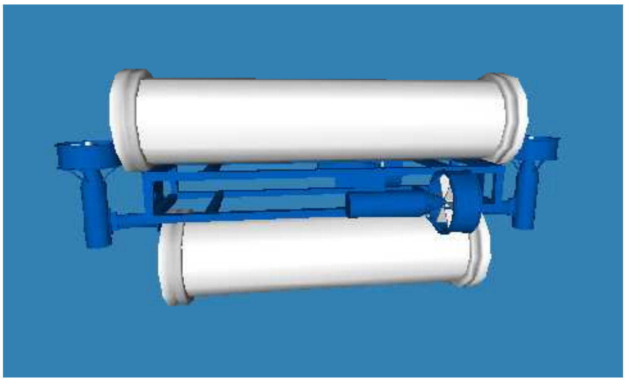

Figure 6: The two-hull, four-thruster concept design.

Following in the footsteps of the two hull design above, what makes the design in Figure 7 unique is its rotational thrusters which allow both horizontal and vertical motion simultaneously. Utilising only two thrusters, this design would require much less power and reduce construction complexity both mechanically and electronically.The main disadvantage to this design though would be the need for powerful servos to be able to effectively rotate the thrusters. Another disadvantage would be the difficulty in guaranteeing watertight seals around these rotating mechanisms. Software modelling as well would generate some difficulty mostly attributable to the rotational nature and dynamics of the thrusters.

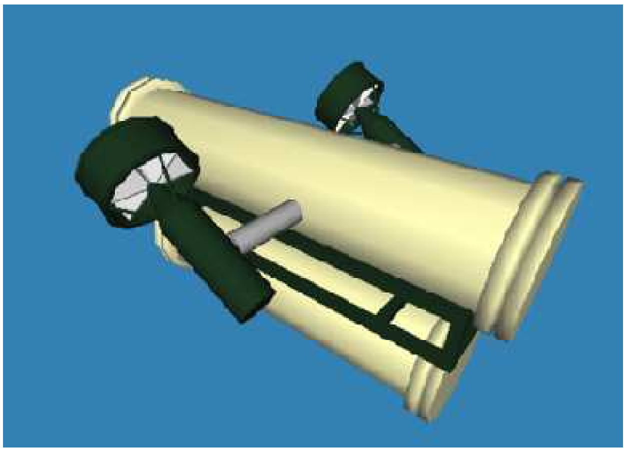

Figure 7: The two-hull, rotational thrusters concept design.

The mainframe structure of the design is making the mechanical parts especially the skeletal frame. An example skeletal frame as shown in Figure 8 and Figure 9 is made from aluminium, chosen especially for its lightweight characteristic as well as its resistance to corrosion which helps protect the frame against the harsh saltwater and chlorine environment in which it is subjected to. As well as supporting the two hulls and four motors, the structure of the frame allows for the simple mounting of external devices and components. The design took into account the potential need for additional components in the future and for that reason ample space is available on the frame. The symmetrical and structurally simple nature of the frame design contributed to the relatively straightforward aligning of the thrusters with the centres of drag for increased dynamic stability. The frame was pressure tested to ensure no leaks. Allowing water to enter the frame would upset the buoyancy and stability of the vehicle and would also prove very difficult to remove afterwards. The nature of the frame also allowed the thrusters to be easily mounted in positions where they would minimise potential magnetic interference with onboard electronic devices.

The body of AUV must make from lighter weight material such as fibres reinforce plastic and PVC material. The upper and lower hulls were made from PVC tubing utilising threaded end caps (Figure 10) with O-ring seals for easily opening and closing each end of the hull, but at the same time ensuring watertight integrity. Each tube measured approximately 50cm in length with an internal diameter of 15cm. To support the electronic components inside the upper hull, two Perspex boards were machined to size and PVC supports were attached inside the tube to allow the boards to be held in place and to easily slide in and out. In order to position the three batteries in the lower hull, an aluminium rack was made to hold the batteries together. Supports were attached inside the tube to prevent the bank of batteries moving from side to side.

Figure 8: Skeletal Frame front view of an Aluminium material.

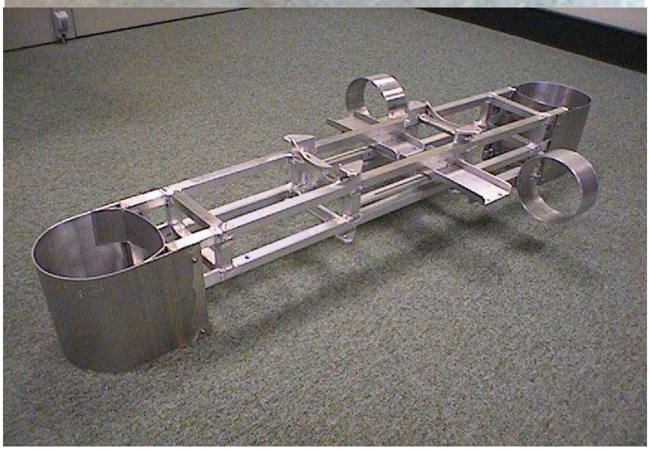

Figure 9: Skeletal Frame for two thrusters made from Aluminium.

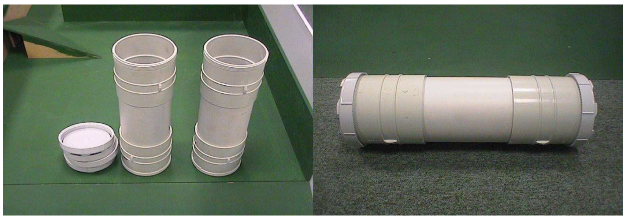

Figure 10: (Left) The two PVC tubes.
(Right) Tube with end caps in place.

2.2 Comparison Design

From our investigation with the previous work, a qualitative analysis of the four proposed AUV designs was made based upon particular attributes. From the literature also support that the design incorporates two hulls and four motors attached to a frame in a very symmetrical manner. By comprising two hulls, ample space is provided as well as the opportunity to create a low centre of mass and high centre of buoyancy for enhanced stability.The two horizontal motors control surge and yaw while the two vertical motors control heave and pitch. The positions of these motors are such that they align with the centres of drag and provide a significant amount of force and torque for moving the vehicle. Their positions also allow the relatively straightforward control and modelling of the vehicle.The frame was designed not only to accommodate the two hulls and motors, but also to allow external components to be easily attached to the vehicle, hence, adding to the vehicle's modularity. The size of the motors and hulls determined the dimensions of the frame to a great extent. Shrouds for the vertical motors were incorporated into the ends of the frame while an adjustable mount was designed for the horizontal motors to adjust the centre of mass in order to maintain the vehicle in a statically horizontal posture. A summary and comparison of the main advantages and disadvantages of the four concept designs is presented below in Table 1.

Table 1: Comparison of Proposed AUV Concept Designs.

ATRIBUTTES (DESIREBLE HAVE TO 'HIGH')	TORPEDO SHAPE	ONE HULL, FOUR THRUSTERS	TWO HULLS, FOUR THRUSTERS	TWO HULLS, TWO ROTATING THRUSTERS
Ease of machining and construction	Low	High	High	Moderate
Ease of ensuring water-tight integrity	Low	High	Moderate	Moderate
Power conservation	High	Low	Low	Moderate
Space available	Low	Moderate	High	High
Modularity	Low	Moderate	High	High
Cost-effectiveness	Low	High	High	Moderate
Ease of software control implementation	Low	High	High	Moderate
Range of motion	High	High	High	High
Ease in removing components	Low	Moderate	High	High
Ease in submerging	Low	High	High	High
Ability to withstand high pressure	High	Moderate	Moderate	Moderate
Sleekness/ Hydrodynamics	High	Moderate	Low	Low
Stability	Moderate	Moderate	High	High

*High = 1pt, Moderate = 0.5pt, Lower = 0pt

2.3Higher Resolution Camera

The feasibility of an underwater installation consisting of either cables for power or telecommunication, or pipelines for gas or petrol, can only be guaranteed by means of an adequate inspection programmed.This programmed has to provide the company with prompt information about potential hazardous situations or damages caused by the mobility of the seabed, corrosion, or human activities like marine traffic or fishing. Nowadays, those tasks of vigilance and inspection are carried out using video cameras attached to remotely operated vehicles (ROVs) controlled from the surface by trained operators. Obviously, this is a tedious task, requiring from the operator a long time of concentration in front of an any part of the inspection process can constitute an important improvement in the maintenance of such installations, not only regarding errors, but also as far as time and monetary costs are concerned. There are many types of camera install at ROV or AUV's vehicle. Current technology, the vision system consists of the mini PC connected to a standard parallel port web camera design for Mako AUV's[11]. The PC was mounted onto the component boards along with the other electronic components. An example, a chassis made from Perspex and aluminium was built to house the camera in a watertight enclosure. The chassis was attached to the underside of the vehicle's frame (Figure 11) so that the camera was pointing directly downwards. A through-hull connection was then made for connecting the camera to the PC located in the upper hull. The disadvantage of this camera was direction is bottom view not the front view. Unless if it was installed for both side front of bottom view.

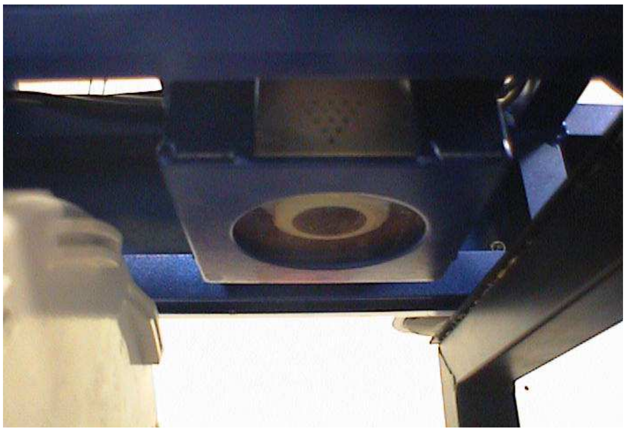

Figure 11: Camera chassis on underside of frame.

Another example was ORCA-XI installed a forward-facing Prosilica EC750C camera for imaging process [12]. The camera is mounted in an external compartment to allow for on-site adjustment. It was chosen primarily for its flexibility. If compare with other cameras, custom exposure times and gains suited to the mission and environment can be programmed ahead of time. Machine vision algorithms running on the main computer analyse the images provide real-time targeting information to higher-level control programs. The Figure 12 show the Prosilica EC750C camera. It was found that advantage of this camera, image can be process directly as long as pre-install the algorithm.

Figure 12: Prosilica EC750C Camera.

From literature also mention importantly, the camera might be choose should operate well in a wide variety of lighting conditions. The condition could be indoor, outdoor, or change on the fly from sunny to cloudy. A camera that reacts well to light changes and has contrast and iris adjustments is useful. In addition to selecting a camera, it also often needs to convert the analogue signal of the camera to a digital file (either video or still frame).Cornell University Autonomous Underwater Vehicle 2009 develop two camera's which can view for both side installed can used for the visual parts of the mission [13]. The downward camera is an AVT Guppy F-046 Colour CCD FireWire Camera with a 6 mm machine vision lens and the forward camera is a Logitech webcam. The captured image was process use software such as C++. The vision system is written in C++ and uses the open source Open CV and libdc1394 libraries. The vision system architecture allows the mission to enable and disable the various vision algorithms whenever visual data is required for a mission element. An integrated vision daemon combines processing daemons that were previously standalone entities (such as the pipe daemon, the buoy daemon, etc) and the camera capture daemon into one streamlined, multithreaded daemon. Each processing daemon becomes a 'module' that fits into a framework provided by the camera daemon. These modules are dynamically loaded and unloaded, depending on shared variables. Separate threads are used for each module and each capture source. Capture sources can be physical cameras, directories of images, or video files. Previously,images captured by the daemon were saved to disk and passed through paths stored in shared variables. Images are now passed in memory utilizing the module framework, resulting in significant performance improvements.

All of the machine vision algorithms work in a similar manner. The input image is converted from RGB space into HSV space and split into its three component channels: hue, saturation, and value. Each of these channels is segmented through predetermined thresholds, and the three segmented channels are recombined to form a binary image. Contours are detected in the binary image, and these contours are then run through a set of probabilistic filters and moment analyses to determine the location, orientation, and probability for a specific mission element.

RamSub 2011-AUV is the 10th entry from the University of Rhode Island (URI) use the camera chosen a Logitech Orbit at Figure 13, which has auto-focus capabilities and uses the RGB colour space for data output (Tyce;2011). The Logitech Orbit is capable of 8 mega-pixel resolution for still images and 2 mega-pixel resolutions for video output. The camera resolution is scaled down to 640x480 pixels to enhance processing speed and reduce computational power requirements. The resolution of the camera controls the amount of video frames per second that can be processed. Since pixels are processed in a matrix form, the more pixels, the longer processing time required for each frame.The camera and accompanied thermal sensor are mounted on a pan and tilt unit that allows a pan of 180 degrees and tilt of 90 degrees.

Figure 12: Logitech Camera.

This feature is utilized by C++ coding in OpenCV to command the mission computer through UDP communications to control the movement of the camera for certain tasks. Such tasks include object tracking, object following, and search patterns that allow the camera to search for necessary objects when none are located within the field of view. The image outputs are sent through universal serial bus 2.0 to the vision computer.

3.0 CONCLUSION

In this preliminary stage there were several requirements for the materials to be used in the construction of the vehicle. Firstly, the materials had to be considerate to the overall weight of the vehicle. Materials also had to be corrosion resistant as they would be subjected to a harsh saltwater environment. Durability was also needed from the materials as the vehicle was being designed for several years of use. Furthermore, materials had to be inexpensive and easily machine able. The design also considered the depth of water, if the materials chosen did not have to withstand significant amounts of pressure it might be effect the operation marine exploration. While for shape of AUV's it can be seen that result finding from table 1, it is clear the torpedo shape design was not an ideal design to pursue when compared to the other designs. The disadvantages of the torpedo design far outweighed its advantages. The other designs provided a much more feasible and advantageous approach to designing the AUV. Table 1 isserving as a guide to choosing the final design and the proposed design should be two hulls with four thrusters which give 10 points, many other factors not discussed were also taken into account and considered before making any definitive decision such electronic parts and control system for navigation of AUV's. For image vision high resolution camera, it suggested that Logitech model is convenient and practically to use for both side front and bottom views.

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