DEVELOPMENT OF MULTI-INPUT SENSOR ALGORITHM FOR AUTONOMOUS UNDERWATER VEHICLE (AUV) SYSTEM STAGE 2

MOHD SHAHRIEEL MOHD ARAS, MOHAMAD HANIFF B HARUN,
MAHIRAH BINTI MOHAMAD
Mechatronics Department, Faculty of Electrical Engineering,
Universiti Teknikal Malaysia Melaka

ABSTRACT

This project is to develop a multi-input algorithm of sensors for Autonomous Underwater Vehicle (AUV) system for the stage two which is having high performance automated detection and monitoring on underwater application or for surveillances and defense application. The sensors implemented in AUV such as vision system, hydrophone system and sonar system successful develop in stage one. While in stage two we improved some multi-input sensor such as GPS system and compass module with pressure and temperature sensor system. In the stage one all multi-input sensor gives the best performances. The new design of vision system for AUV with the implementation of wireless camera, whereby, produce clearer image. The ultrasonic sensor is a main device to transmit and receive the signal from the obstacle. The ultrasonic sensor will be combined to the ultrasonic circuit. Hydrophone is an underwater microphone which with the help of pressure impulses of acoustic waves converts them into electrical signals which in further are used for communication. It was designed to be used underwater for recording or listening to underwater sound. In stage two GPS system uses to navigation the AUV which is using Smart GPS Receiver model EB-85A and GPS Engine Board EB-230. This design could easily be expended and made portable for use in AUV. In this project also aims to obtain data on pressure and temperature in the water around AUV and shows the relationship between pressure and water depth and pressure with temperature. The entire sensor produced the good result and all result analyzed stated in this paper.

Keywords: AUV; GPS system; Compass module; Pressure sensor; temperature sensor

INTRODUCTION

An Autonomous Underwater Vehicles (AUV) is very challenging research area and valued for both their expand ability and replace ability because they can be deployed in hazardous environments without risking human divers. This emerging field is very economical as AUVs has the potential for cheap scalability makes it ideal for large scale and long term data collection tasks. This level of control, under most environmental conditions, permits the vehicle to follow precise preprogrammed trajectories wherever and whenever required [1], [2], [3]. Sensor data collected by an AUV is automatically geospatially and temporally referenced and normally of superior quality [4]. In stage two GPS system uses to navigation the AUV which is using Smart GPS Receiver model EB-85A and GPS Engine Board EB-230.This design could easily be expended and made portable for use in AUV. In this project also aims to obtain data on pressure and temperature in the water around AUV and shows the relationship between pressure and water depth and pressure with temperature. The entire sensor produced the good result and all result analyzed stated in this paper.

Global Positioning System (GPS) is a satellite based on navigation system that sends and receives radio signals. A GPS receiver acquires these signals and provides with information of the location, velocity and time [5],[6]. Basically, GPS is usable everywhere except where it's impossible to receive the signal such as inside most buildings, in caves and other subterranean locations, and underwater. This project is design to guide the users especially the AUV’s because we know that GPS receiver cannot detect the signal when it placed under the water. So, this design is proposed to guide the users of AUV. This GPS is placed on top of the AUV so that, when the AUV hit upon the water surface, this device clearly at the airspace. Then it can work successfully. On pressure sensor, this project will only cover the pressure in the water about 1 to 2 meters depth. Besides that, the implementation of a barometric pressure sensor needs guidance from the PIC board by creating a simple program to switch on and off the pressure sensor. Last but not least, after the program being applied another source of medium needs to implement to make sure the pressure sensor make contact with LCD display by synchronized it with a simple program.

GENERAL DESIGN OF AN AUV

There are several aspects in AUV electrical and mechanical design need to be looked at closely so that the design will be successful. In order to design any underwater vehicle AUV, it is essential or compulsory to have strong background knowledge, fundamental concepts and theory about the processes and physical laws governing the underwater vehicle in its environment. Therefore, the major design aspects that need to be considered [7] are identifying hull design, propulsion, submerging and electric power. Figure 1 is the concept that we are applied to design an AUV.

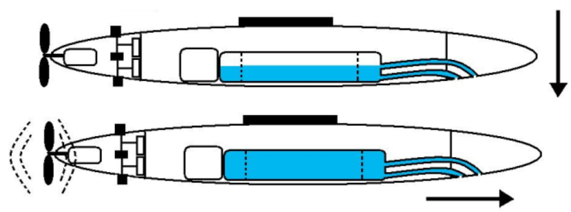

Figure 1: Concepts of AUV

Figure 2, 3 and 4 shows the real AUV for this project that will be attached with multi-input sensors system and Table 1 shows the basic specification of AUV. The buoyant force acts vertically upward to the centroid of the underwater vehicle and can be defined mathematically by Archimedes principal as follows:

$$F_b = \gamma_f V_d \qquad (1)$$

Where:

F_b : *Buoyant force*

γ_f : *Specific weight of the fluid*

V_d : *Displaced volume of the fluid*

When object floating:

$$F_b = w = \gamma_f V_d \qquad (2)$$

To submerge the underwater vehicle, we need external force. Therefore, the force is:

$$F_b = w + F_e = \gamma_f V_d + F_e \qquad (3)$$

Figure 2: An AUV (top view)

Figure 3: An AUV (side view)

Figure 4: An AUV (front view)

Table 1: Basic specification of AUV

Item	Specification
Displacement	7.7 kg on surface, 7.95 kg submerged
Overall length	774 mm
Beam	290 mm
Draft	200 mm
height	285 mm
Propulsion motor	12 V motor
propeller	40 mm Pitch:41 mm
Speed	1.45 knots (2.7 km/h) surface, 1.08 knots (2km/h) submerged
Operating diving depth	10 M
Maximum diving depth	Over 10 M (mechanical limit)
Sensor	Vision sensor, sonar sensor, hydrophone sensor, GPS , Compass module with pressure and temperature sensor

DESIGN PROCESS

This project is interface with desktop or personal computer or notebook and interface with GPS Module or GPS Receiver. The device was designed to interface with any GPS receiver capable of outputting NMEA v3.01 RMC, sentences via FT232R UART and USB connection. This project is using Smart GPS Receiver model EB-85A and GPS Engine Board model EB-230. The GPS Trace version 2.61 and GPS Locator Utility version 2.61 is an application program used to enable EB-85A to do the configuration on the unit. In order to follow AUV specification, the Wireless cannot apply to interface with desktop because wireless signals very weak or maybe lost under the water surface. Figure 5 shows project overview of GPS system implemented in AUV. GPS casing was developed by using the water proof container that was made by the plastic as shown in Figure 6.

Figure 5: Project Overview of GPS system

Figure 6: The complete GPS casing development

The PIC microcontroller start-up kit, barometric pressure sensor, capacitive sensor and compass module are combined to make one PIC board acts as a main controller. This PIC board will receive signal from barometric pressure sensor and send data to LCD display in order to get a data about pressure and temperature. The PR22 board will be immersed in the 3 different medium which is tap water, hot water and cold water. This board is design to configure pressure, temperature and also capacitance in surrounding. Figure 7 shows the result after combining all the components used and implemented in AUV.

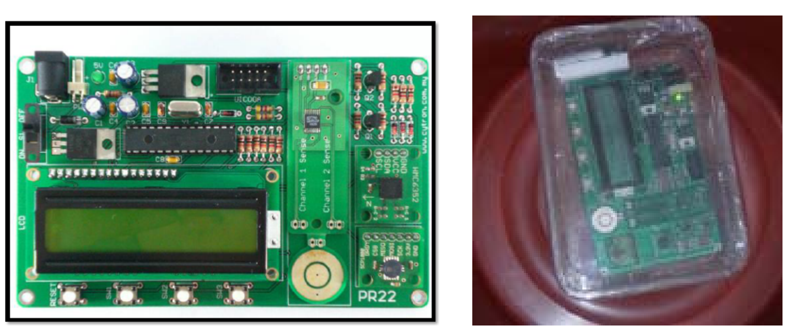

Figure 7: PCB Circuit board (PR22)

RESULT

A- GPS system

This objective of the experiment is to determine the signal strength of the GPS while the GPS is under the water surface by measured the depth of the GPS receiver from the water surface. The strength of the signal can be analysis by using the Signal Noise Ratio (SNR) data and the number of channel (CNR) viewed. SNR corresponds directly to the GPS received signal strength [6]. The larger value of the SNR, the stronger signal strength of the GPS received. A higher SNR value means that the signal strength is stronger in relation to the noise levels, which allows higher data rates and fewer retransmissions—all of which offers better throughput [7]. The data information is gathered into the table as shown in Table 2.

Table 2: The data information of the GPS consist the number of SNR when the experiment was in open area.

NO	Depth below water surface (cm)	Average SNR (dB)	No of channel available	GPS Quality (mode)
1	0 and above water surface	32	9	3D SPS
2	1	22	6	3D SPS
3	2	16	7	3D SPS
4	3	20	4	3D SPS
5	4	16	4	3D SPS
6	5	15	4	3D SPS
7	6	17	3	2D SPS
8	7	15	3	2D SPS
9	8	17	4	3D SPS
10	9	19	1	Invalid
11	10	21	1	invalid

From the Table 2, we can see that the GPS receiver cannot receive the signal in more than 8cm depth below the water surface. Signal strength is strong above the water surface because the average number gives by the SNR is the highest that was 32dB. The signal becomes weak when the GPS receiver is place below the water surface because at wet condition, the difficulty of acquiring fresh satellite orbital parameters (the ephemeris) in the presence of periodic wave washes over of the GPS antenna [8]. At this point, we can say that the signal strength is proportional to the depth below the water surface. The signal strength was determine by the average value of SNR(dB) and relative to the mode of GPS quality that was the 3D SPS mode, 2D SPS mode and NoFix mode or invalid. If the number of SNR is high and the GPS quality is 2D SPS, this signal is not accurate because the 2D SPS show that there are not enough messages from satellite for navigation message measurement to determine the position. The GPS navigation message contains information that is necessary to perform navigation computations [9]. To get the accurate positioning, the GPS receiver must be receive the signals from satellite. There must be at least 4 satellite channels with SNR value available [10]. If the channel available is less than 4, the positioning of the GPS location may not accurate. We can compare the coordinate in Figure 8 that was out of water with 3D SPS Mode, Figure 8 shows 8cm below the water surface with 2D SPS Mode and Figure 9 that was 9 cm below the water surface with NoFix Mode. All the data were illustrated in Table 2.

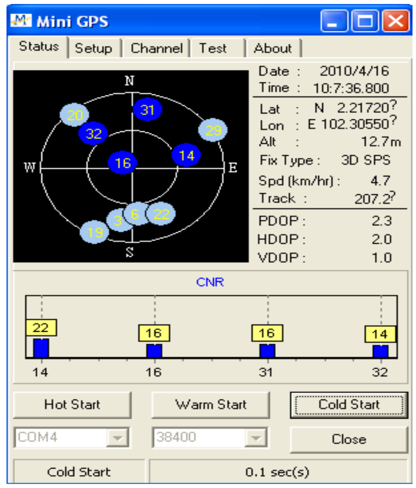

Figure 8: The GPS was tested 8cm under the water surface

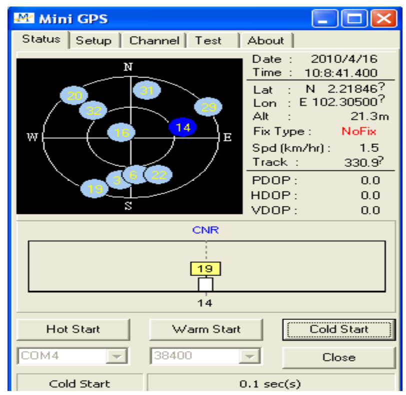

Figure 9: The GPS was tested 9cm under the water surface

The coordinate of the GPS assessed on the Earth surface is more accurate than the coordinate of the GPS assessed below the water surface such as under the sea surface. This is because the signal from satellite cannot pass through the water but from this experiment, the GPS receiver receives the satellite signal. From the Table 3, the coordinate of the GPS while out of the water was determined by latitude that is 2.217630 and the longitude that is 102.30580. This may be the accurate coordinate of the location that this experiment is done because the channels satellite available is more than 4 that was 9 channels with 3D SPS mode. The coordinate of the latitude and longitude of GPS location while the GPS is 1cm below the water surface is 2.217640 and 102.30580 is approximately the same with the accurate coordinate because the channel detected from GPS receiver is more than 4 that was 6 channel compared to the coordinate of the latitude and longitude of GPS location while the GPS is 7cm below the water surface is 2.217220 and 102.30560. The coordinate show the position is change to another position but not far from the actual position this is because GPS receiver can receive the signals from the 3 available satellite channel. This will cause the GPS receiver missing message navigation from the satellite. So, with the missing message navigation, the GPS receiver cannot give the exact position of the place. From here, we can conclude that the more depth of the GPS below the water surface, the less accuracy of the GPS location until at a point below the water surface, the location cannot be determine by the GPS because the signal from satellite cannot reach the GPS receiver.

Table 3: The accuracy of the location by comparing the coordinate of the location

Coordinate	GPS Quality Mode			
	3D SPS (GPS out of water)	3D SPS (GPS 1cm below the water surface)	2D SPS (GPS 7cm below the water surface	NoFix/invalid (GPS 10cm below the water surface)
Latitude	2.217630	2.217640	2.217220	2.216040
Longitude	102.30580	102.30580	102.30560	102.30480
No of channel available	9	6	3	1

B- Pressure and Temperature Sensor System

Based on the data obtained, 3 analyses are to determine the relationship between pressure, temperature and depth. Data are taken based on the experiment carried out in a bucket that has to 20cm by using tap water that has a moderate temperature such as shown in Table 4. Data were recorded every 2 cm depth PR22 immersed board. Figure 10 shows pressure versus depth graph, Figure 11 shows the graph temperature versus depth, and Figure 12 shows the pressure versus temperature graph.

Table 4: Experiment Data Using Pure Water

Depth (cm)	Temperature (ºC)	Pressure (kPa)	Compass (º)
0	32.1	102.383	188.5
2	32.1	102.598	181.3
4	32.2	102.813	186.2
6	32.3	102.980	178.4
8	32.3	103.189	176.2
10	32.4	103.351	181.4
12	32.4	103.585	184.3
14	32.4	103.763	183.5
16	32.4	103.967	181.6
18	32.4	104.165	187.1
20	32.5	104.464	180.8

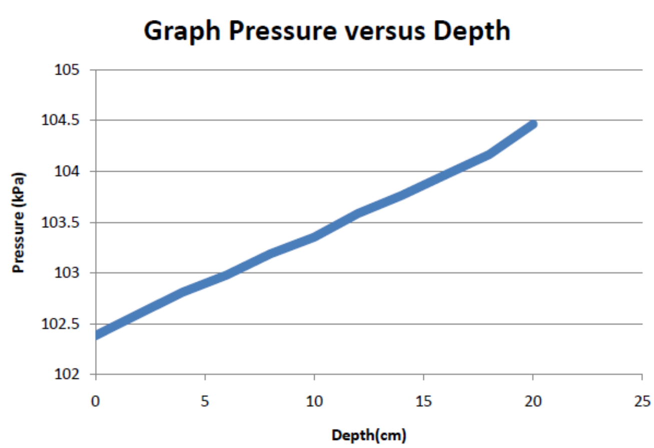

Figure 10: Graph pressure versus depth

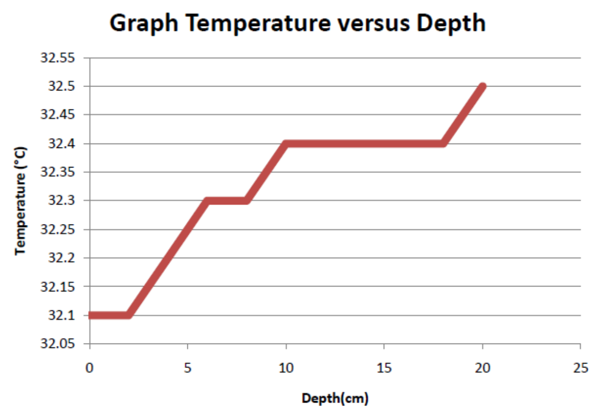

Figure 11: graph temperature versus depth

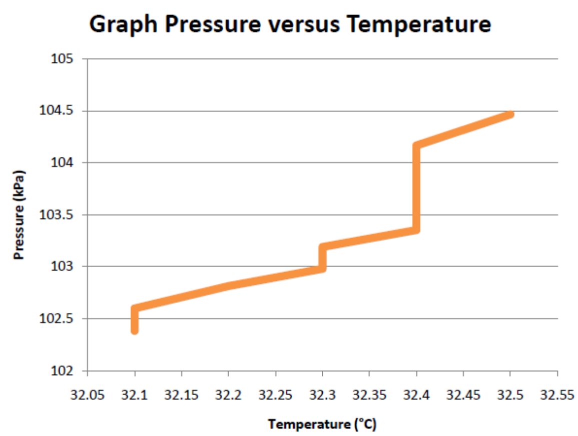

Figure 12: Graph pressure versus temperature

From the data obtained, the pressure will always increase when collaboration with increasing water in depth. The water pressure increase as the depth is being increased as shown in Figure 13. As we know, if we are in our water surface to breathe easy. So what will happen if we were bathing in the water for half an hour? This question was playing in our mind over the years. When we are in a swimming pool, the presence of the pressure is different that makes breathing become difficult with a different situation when we breathe in our normal situation. This is because our bodies have the pressure of the water pressing our bodies that cause our breathing cavity narrowing. As such, we will have difficulty in breathing.

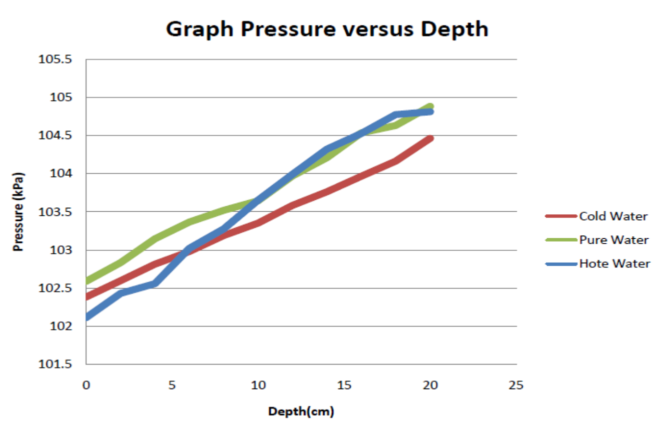

Figure 13: Graph pressure versus depth for three condition of water

When we try to relate the pressure with the temperature in this testing, it can be concluded that even in hot water or cold water pressure in the water level remains the same based on the depth of the water. This is because the theory says that pressure has no direct temperature influence on the pressure in the water. This can be shown by Figure 5.13. Although any high temperature or any temperature lower pressure level is the same only difference is that our body temperature in both cases is different. Based on the analysis done, it can be concluded that the pressure is directly proportional to the depth, but do not have any relationship with temperature. If we look at the theory of pressure, P = ρgh proved that the pressure associated with the depth of the water and can be seen is related to the density of the medium used.

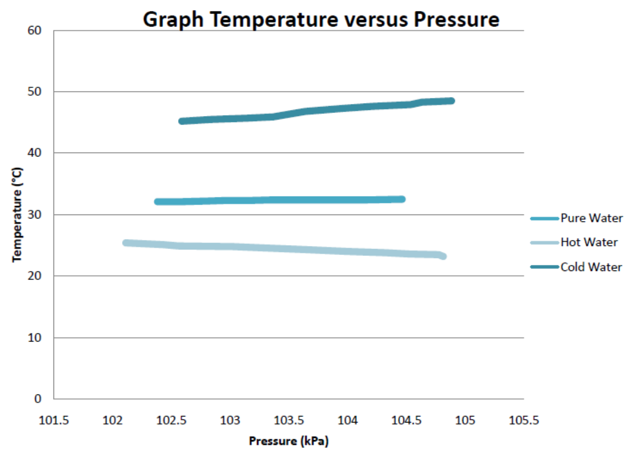

Figure14: Graph temperature versus pressure for three condition of water

CONCLUSION

AUV is very challenging research area and valued for both their expand ability and replace ability because they can be deployed in hazardous environments without risking human divers. This emerging field is very economical as AUVs has the potential for cheap scalability makes it ideal for large scale and long term data collection tasks. AUV is an important vehicle used need the navigation system to navigate their location, time and others parameter. By having a navigation system, they do not have to worry about their surrounding or where are they standing.

This project was successfully design and develops of GPS Navigation Guidance System for AUV. Here, we can conclude that the GPS receiver can receives the signal from satellite during the GPS receiver is under the water surface and the coordinate of the GPS can be use to navigate the AUV. We know that the pressure related to the depth of the water according to the pressure equation but temperature has nothing to do with the pressure and depth. The objective of this project is to synchronizing the compass module with pressure and temperature sensor. The results of this project show that the direction each times the pressure and temperature data being recorded. This project combines some of the useful technologies to develop a new system for ease of usage in underwater to determine pressure and temperature at surrounding of AUV. Not only that, this system can help the AUV to recognize its direction by using the compass module.

ACKNOWLEDGEMENTS

We wish to express our gratitude to honorable University (**Universiti Teknikal Malaysia Melaka**) especially to higher management for give the financial as well as moral support. And also would like to thank CRIM because their tolerance for complete this project successfully.