Introduction and Concept Design of the "AUVTECH&OPENROV's Hybrid AUV"

Faculty of Naval Architecture and Ocean Engineering, Istanbul Technical University, Istanbul, Turkey
www.auvtech.itu.edu.tr - auvtech@itu.edu.tr

Ahmet Gultekin AVCI, Abdul Jamil ARYAN, Ahmet AVCI, Kadir SOYUK, Baycan TOPTAS

Abstract: AUVTECH Vehicle is an Autonomous Underwater Vehicle (AUV) developed by a team of students at Istanbul Technical University. The vehicle is designed for the aim of completing unique underwater missions which involves the observation of aquatic life, undersea terrain shifts and geological transformations by its autonomy. The autonomy is provided by embedded intelligent system that can autonomously navigate beneath the surface of water based on inputs from image processing and digital signal processing. Therefore, it is able to fulfill predetermined task without any human control and to react against unexpected situation by its artificial intelligence. The embedded system receives input data from its precise sensors like Inertial Measurement Unit, hydrophones and pressure sensor for odometry and from two cameras for image processing. After the data is transformed into information, the system makes decision about actuation, maneuver, running tool and carries out the task by the support of the hardware. The electronic circuits which comprise the embedded system and the electronic equipment controlled by it are settled on easy moving polycarbonate board to allow for a fast response against hazard. The actuation is provided by thrusters. Pneumatic system is utilized for a special mission such as throwing torpedo, dropping marker or using any additional tool. The main hull is made of polycarbonate, which gives transparent scene. So it allows viewing the working component directly. Polycarbonate is used for the frame to combine the components together and to provide stability and hydrodynamics. This study includes the growing up process of AUVTECH vehicle.

1. INTRODUCTION

Robotic system has started to take place in human life in parallel with the development of the robotic technology and artificial intelligence applications though their acquisition.

Autonomous Underwater Vehicles (AUV) as a robotic system have come under the intense focus of interested academic circles thanks to the ongoing researches on versatile and challenging environmental phenomena existing in the fields of operations. The reasons such as long working time underwater, operating in hazardous environment and ability to operate in deep water etc. push the research activities of AUV forward.

Due to the hydrodynamic structure of nature, the observation of diverse aquatic life and the geological shifts beneath the surface of oceans and water bounds arouses interest to investigate. Moreover, new energy sources are required to discover by the reason of

rapid extension of existing source. Because of these, AUVs can be planned to developed to satisfy these and similar requirements

When the geographical situation of Turkey is taken into account, Turkey is surrounded by open waters from three sides; it is needed to achieve the aforementioned tasks. However, publicly there have been no or negligibly small efforts spent on studying the marine life and underwater terrestrial surfaces by hiring a researching robot.

Therefore, developing AUV to achieve these goals is the focus of the AUVTECH team's research. The team consists of eight students from different disciplines Istanbul Technical University for an international competition in order to prove the ability of AUVTECH vehicle in contributing to the existing marine challenges at home and abroad.

In this study, the design, the qualification and the operation structure of AUVTECH vehicle is described. And also the choice of material and manufacturing process selection is discussed. Figure 1 presents a view of the vehicle's concept design.

Figure 1. Concept design of Hybrid-AUV

2. QUALIFICATION OF AUVTECH VEHICLE

AUVTECH is designed to accomplish specific tasks which are defined by the competition and simulate real-world missions. The vehicle has ability to follow line, to navigate Through a Gate or Hoop, to define object and colors underwater by image processing without human control. And also it is capable of performing unique task such as dropping marker to specific location and firing torpedo to specific target.

The vehicle's dry weight is approximately 3 kg and its dimension is about 32x22x15 cm (length, width, height). As it can be seen in Figure 1, the vehicle has a one-piece main hull including the control mechanism and the frame on which includes the propulsion and pneumatic systems. The design of the AUV as a cylindrical shape is developed to provide hydrostatics and hydrodynamics. Three propellers are settled in the AUV to have over five degrees of freedom, which gives it flexible motion.

The AUV is designed to operate up to 5 bar or 40-50 meters underwater. The power system includes six Lithium ion batteries configured with six cells in parallel order. The total output voltage of the batteries is 12V. The batteries of computer can last for twenty hours if the thrusters don't work. The AUV is capable of performing about 2 hours for research tasks.

3. OPERATION STRUCTURE OF AUVTECH VEHICLE

The vehicle consists of mechanical, electronic and software systems as main sub-system. And these systems are also detailed into small subsystem interacting with each others as it shown in Figure 2. These subsystems are power system, control system, security system propulsion system, detectors, pneumatic system.

In this section, the interaction of the subsystem is discussed. The equipment and material used in subsystem are explained in a different section.

Data from the environment are collected via detectors such as pressure sensor, hydrophone, camera and Inertial measurement unit (IMU). Pressure sensor helps to identify the vehicle's depth. A Hydrophone and lasers will be used to identify the distance between the vehicle and objects. The object is defined by image processing with camera. IMU is utilized to provide balance and hydrodynamics of the vehicle.

Control system comprises embedded computer, arduino and motor driver. Data are collected from detectors and analyzed by embedded computer. After analysis, decision is made and embedded computer send command to the related sub-system for applying the decision. Arduino is utilized as an interface to control propulsion and pneumatic systems. Thrusters which are components of propulsion system are controlled by motor driver. Motor driver aids to adjust the operation speed.

For the special tasks such as throwing torpedo, dropping marker etc. the additional tools is driven by pneumatic.

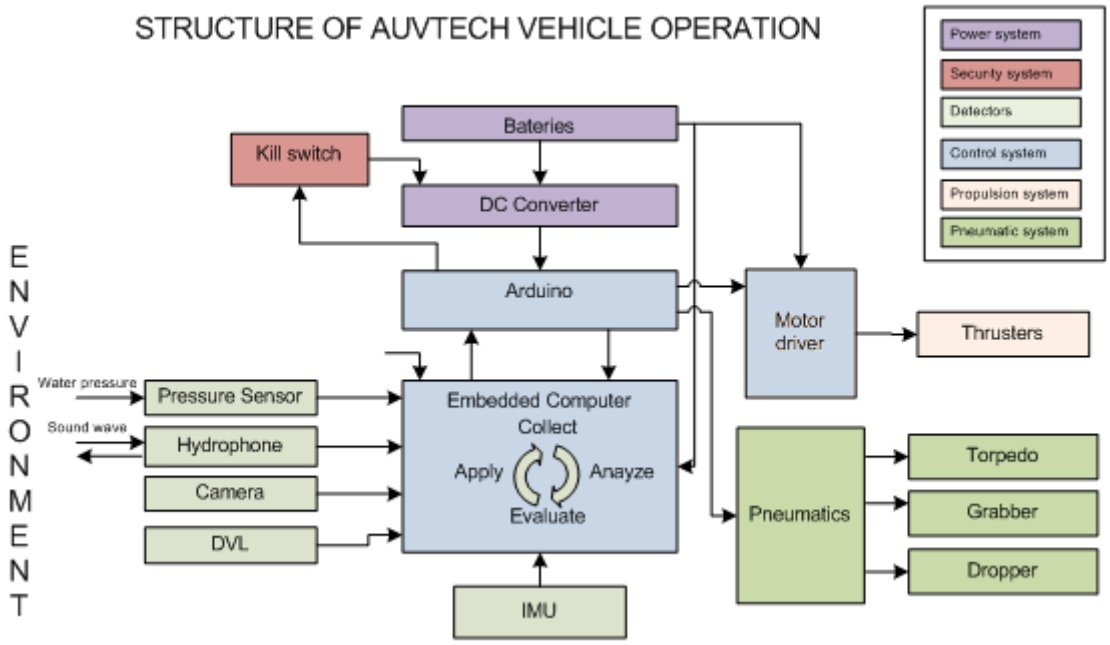

Figure 2. AUVTECH Sub-systems and their interactions.

4. MECHANICAL SYSTEMS

The mechanical systems in this study can be defined as a subsystem of the AUV that provides stability of it, protecting it against flooding, keeping the electronic equipment and movement capability. The main components of the AUV are a transparent cylinder main hull made of Plexiglas, polycarbonate frame All mechanical parts are built to be easily modifiable and can be restructured.

4.1 Main hull and frames

The main hull is the pressure vessel on the vehicle and contains electronic cards, sensors, batteries and embedded pc. The main hull is fabricated from Plexiglas cylinder. The main hull cylinder is particularly manufactured as one piece to decrease the probability of flooding. One side of the cylinder is enclosed with aluminum static cap which has two O-rings inside it. This cap is also fixed with liquid seal. The other side is enclosed with aluminum detachable aluminum cap which keeps connectors on it. Also this detachable aluminum cap has two O-rings to prevent flooding. It is easy to detach.

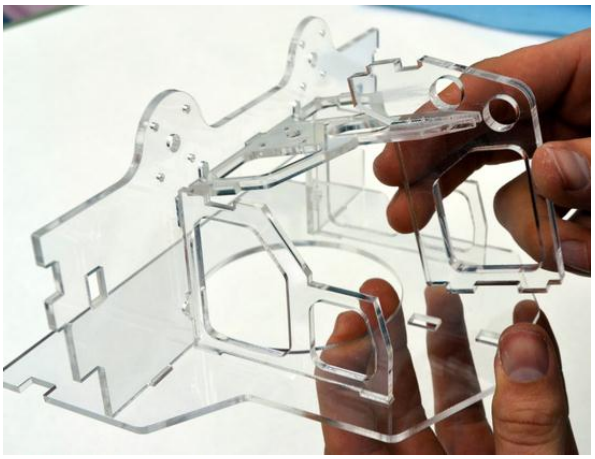

Figure 3. Main Frame

Three holes are drilled on detachable plexiglass cap for the connectors which connect electronic circuit inside the main hull with the outside hardware's. As a protection class IP68 is selected for the connectors. Its qualification is dust tight and protection against complete, continuous submersion in water. For the connection of cameras, USB connectors are chosen to prevent noise interference.

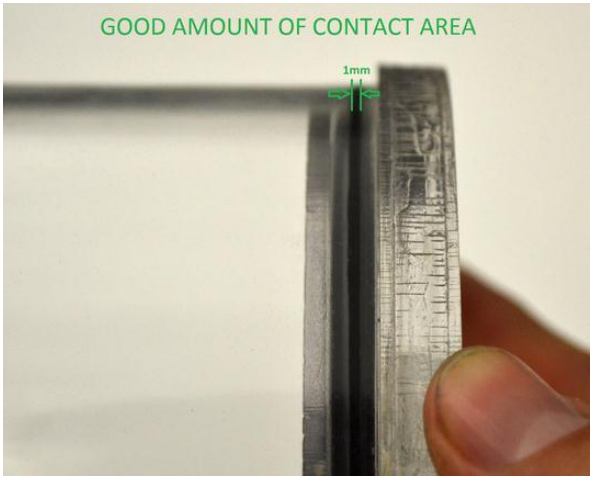

Figure 4. Plexi endcap with o-ring

The main hull is preferred to build from Plexiglas cylinder based on the transparency attribute of it. This attribute offers to observe the operating of electronic system easier. The cylinder main hull as a geometric shape has more durable than cornered main hull, because surface area is decreased and it is exposed to less water pressure force. Moreover, this shape has advantages in its ability to maneuver.

Two Plexiglas plates, which have very durable features, are processed to build frame and frame along with the main hull are bound together in such a way to maintain the stability. The propulsion system is also fixed to the frame.

4.2. Propulsion system

As it can be seen in Figure 6, three thrusters as the component of propulsion system are integrated to the vehicle to gain movement capability in every direction. All thrusters are fixed to the Polycarbonate frame. Two thrusters settled on front and back of the vehicle can move it forward and backwards.. They have also capability to rotate it when they run in reverse direction. However, the other two thrusters settled reversely below the main hull make the rotation motion easier.

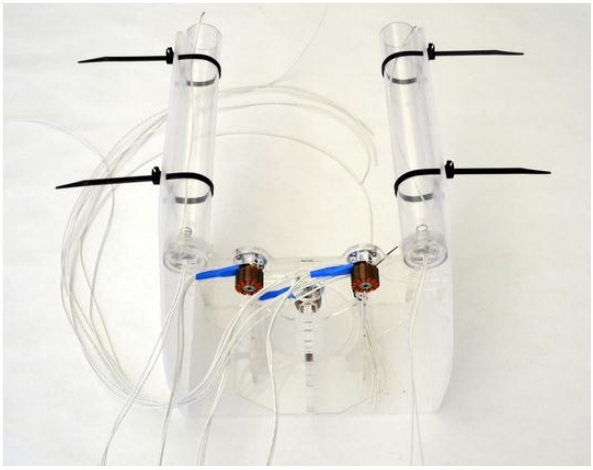

Figure 6. Perspective view of the concept design

5. ELECTRICAL AND ELECTRONIC SYSTEMS

5.1. Embedded computer system

AUVTECH has an embedded computer which runs the main software. This computer makes decisions according to sensor inputs and images from webcam. A microcontroller based "master board" gathers all sensor inputs and sends them to computer, while controlling motor speeds and actuator according to process made in computer.

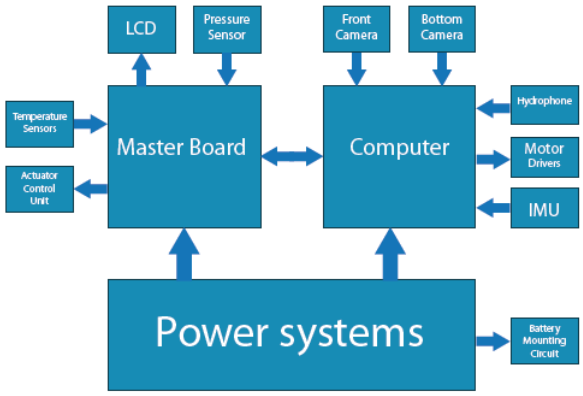

Figure 7. Electrical system block diagram[1]

5.2. Embedded computer system

Vehicle has 3 lithium ion batteries which are in 6 cells serial configuration and have 5Ah capacity. One of these batteries is dedicated for powering electronic circuits. Since 6 cells' nominal voltage is 12V, two switch mode regulators used to generate 5V and 12V outputs. 2 batteries are powering motors and actuators.

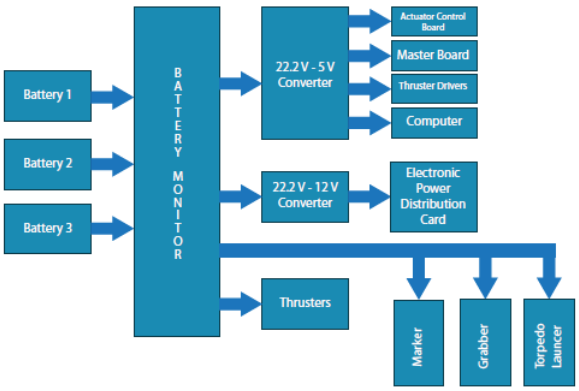

Figure 8. Electrical system block diagram[2]

5.3. Master Board

Master Board is a module which is connected to Arduino Mega as a shield. It is connected to all sensors and processing their signals and sends results to computer. It communicates with computer via USB connection. Motor drivers are on the master board and they can be replaced with ease in case of emergency

situations like failure of motor drivers just before competition. Motor drivers are controlled with direction and PWM inputs. Most efficient PWM frequency for driving motors is found by empirical experience. Actuators are controlled with I2C connection. They have their own microprocessor and current control is maintained by n-channel mosfets.

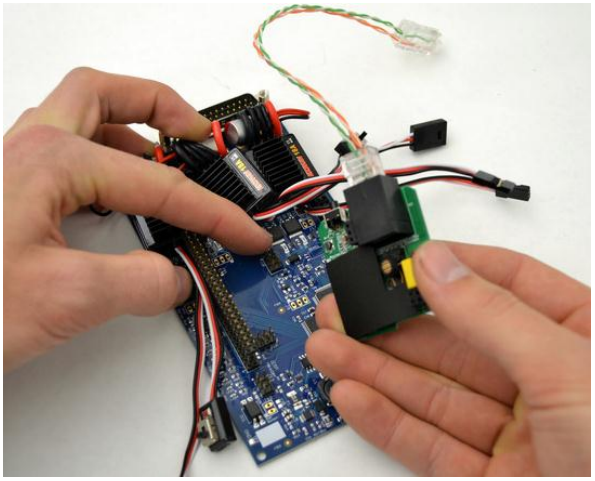

Figure 9. Master board

5.4. Inertial measurement unit (IMU)

The inertial measurement unit of the vehicle is a unit which provides 3D acceleration, rate of turn and magnetometer data through its sensors array. Moreover, the sensor has a signal processor which makes it possible to provide accurate measurements to the computer.

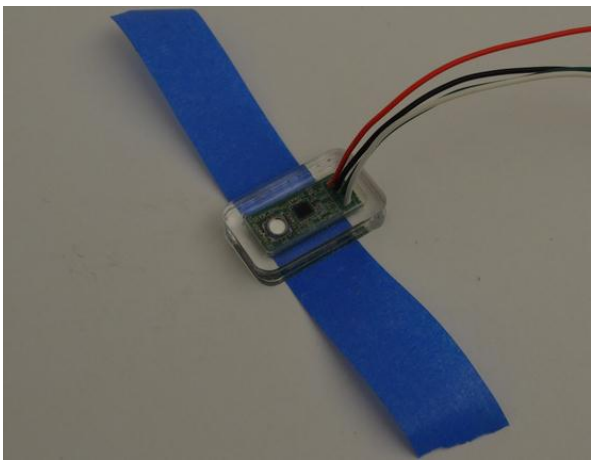

Figure 10. Depth sensor

5.5. Motor drivers

Motor drivers on master board are commercially available Ezrun Brushless motor drivers. While they are capable of continuous 5A, thrusters draw maximum of 5A and drivers remain cool while operating.

6. SOFTWARE SYSTEM

Fully functional Beaglebone processor is running main software in embedded computer. Mission objectives are coded in javascript and python environment and it gathers inputs from sensors and image processing. OpenCV is used for image processing.

7. CONCLUSION AND FUTURE STUDY

AUVTECH team whose members are students from different department of Istanbul Technical University aims to contribute research and development studies underwater through managing autonomous underwater vehicle design projects and the related subjects.

The efforts and knowledge experienced during the development of the AUV is thought to provide opportunity for developing new science and research area. By ensuring project success and the innovations in sector, new business area can arise and they can increase job opportunities.

To achieve these long term goals, an AUV was designed for the first step of them. In these study, the design qualifications, the main systems and sub-systems and interaction among sub-systems of AUVTECH vehicle was presented.

Eventually, an autonomous underwater vehicle was designed and built successfully. And the vehicle will participate AUVSI Foundation and ONR's 17th International

RoboSub Competition 2014 to compare the design success with other student-built AUV.

As a future work, a closed form solution for hydrodynamic optimization of AUV's will be considered. The study on performing real life scenario will also be continued by improving software and installing new hardware.

7. ACKNOWLEGMENT

We would especially like to thank David LANG and Eric STACKPOLE from Openrov.

REFERENCES

[1] Avci A G, Sarıoğlu B S, Kırca B, Aryan A J, Karakas S, Uz G, Atay S, Calıskan U and Merdivenci M S. (2012) Introduction and Concept Design of the "AUVTECH" Istanbul Technical University Autonomous Underwater Vehicle. AUVSI & ONR's 15th RoboSub Competition Journal Paper. On-line: http://www.auvsi.org/

[2] http://openrov.com/