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EXTREMITY OF INDIAN AUTONOMUS UNDERWATER VEHICLE: A SURVEY

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***Abstract*—Unmanned autonomous underwater vehicles are free swimming marine robots without any human intervention with sensors, navigation and on-board intelligence system. Autonomous underwater vehicles (AUV) are cost effective and efficient unsupervised vehicle suitable for complicated aquatic operations. Initially the information about AUV is in hypothetical and conceptual manner but now more attention is paid in practical development. Over the past few years India is unfolding her wings in the field of AUV research and development. In this survey paper we are going to discuss the essential architectural attributes and subsystems of autonomous underwater vehicle and also comprise the edge of autonomous underwater vehicle development in India.**

Keywords—Autonomus; navigation; underwater; sensor; AUV;

I. INTRODUCTION

Over the past few years, a number of unmanned underwater vehicles are designed and developed to serve various purposes. The unmanned autonomous underwater vehicles are free swimming marine robots without any human intervention. Autonomous vehicles are compact, self contained vehicle, having onboard computers, GPS, sensors, power packs, vehicle payloads etc. These vehicles may also contain other required biological, chemical or other equipments as per their operations.

The fundamental motivation for developing Autonomous underwater vehicle is safety, security and economy. There are a wide range of activities for which the AUV is irresistible because of cost or safety. These deep sea-diving autonomous vehicles have been demonstrated to the world several years ago and by the end of this decade it is vastly acceptable to the modern world. Unmanned vehicle can be either remotely operated or autonomous. The remotely operated underwater vehicles or RUV's are needed to be connected by tethers to control the vehicle remotely from the shore or from the boat. Unmanned operation without tethering is much more challenging but the vehicle can float under the water more freely and the coverage area can be more. But, the autonomous underwater vehicles, as said before, are untethered mobile instrumentation machines which have actuators, sensors, navigation system and on-board intelligence to successfully complete the unsupervised underwater operations. Previously, the small vehicles did not have the required payload capacity, durability for successful operations. But, in recent years there are many vivid advancements have been seen and now small, high performance, low cost AUVs can be developed by adapting those modern technologies by minimizing the cost of hardware and operations.

The wide ranges of AUVs are intended to organize different tasks in military, commercial and ocean and underwater research areas. These AUV systems have different architectural attributes based on their use, user requirements and operational environments. Beside the similarity in architectural design of AUVs, changes can be done in command and control, tracking, sensing, recovery, navigation and many more. In this paper we are going to discuss the common architecture of AUVs and AUV development in India.

II. ARCHITECTURAL ATTRIBUTES

In this portion of our survey paper, we are going to discuss about the architectural attributes and considerations that influences the infrastructure of AUVs [2]. The Efficiency of an AUV is depends upon the following considerations:

1. **Vehicle Layout:** The vehicle layout is a combination of the AUV form factor, the geometric inventory of components, interface requirements of various components, sensors etc. The layout of a vehicle can be divided into some sections like nose section, payload section, energy components section, control and propulsion section etc.
2. **Propulsors and Control Surfaces:** The form factor of an AUV system is required to gain smooth hydrodynamic form. In general the form factor of any AUV is like torpedoes with different shapes and diameters which is helpful to increase the efficiency of the vehicle.

The propulsor system of an AUV may vary but can be fall in the following category;

i) Single rotating propeller, which generates the required torque on the AUV.
ii) Twin counter rotation propeller, which exert the torque in the opposite directions to help to balance the rotational speed for the vehicle.
iii) Single propeller-like rotor shrouded with pre-swirl stators, which creates more efficient flow and a counter torque.

The control surface of the vehicle is used in dynamic control and it also controls the vehicle at slow speed. Control surface is generally place near to the propeller section but the architecture can be different based upon different vehicle.

3. **Energy:** The energy system in a AUV is a major component. The energy system can be battery, which drives the system performance, vehicle speed, on board power etc. Several types of batteries can be found for AUV system but selection of the energy cell is a very important factor in the AUV development. In most of the AUV system architecture used lithium ion batteries for their efficient power supply and energy density.
4. **Pressure Hulls:** Another important attribute of AUV is its pressure Hulls and wet volume. A significant driver for pressure hulls is depth pressure and dry volumes. For lesser depth AUVs cylindrical pressure vessels are suitable while for the deeper depth capabilities spherical pressure vessels are suitable. The material used for the pressure vehicle is depends upon the user requirements and also the depth capabilities, can be thermoplastic, acrylic, aluminium, carbon fiber, fibre class, steel etc. The buoyancy of AUV depends upon on the following factors like Vehicle's overall displacement, weight and density of the water etc. The buoyancy of AUVs that have considerable volumetric displacement can face significant changes in it, even with small changes in water density or weight.
5. **Sensors:** Sensors in a AUV have multiple important functions like measuring depth, altitude, water conductivity, water temperature, water density, geo-location, oxygen level etc.

Some of the important sensors:

a. **Aanderaa dissolved oxygen sensor:** since oxygen is directly or indirectly related to most of the biological and chemical process in aquatic life, so its important to measure the level of oxygen available at certain region where the probability of demanded oxygen might below the sufficient level .Some of the regions are as follows:

i) In shallow coastal areas with significant algae blooms.
ii) In the areas where the exchange of water is limited.
iii) Around the fish farms.
iv) In the areas like dredging wastes or dumping of mine.

The Aanderaa Oxygen Optodes[8](41300 can operate down to 300 meters) are used in the AUV to measure the oxygen level in some aquatic region .Its contains a gaseous fluorescent indicator made up of special platinum porphyrin which is molded in a gas permeable foil A black optical isolation coating is been used since this foil need to protect from sunlight as well as from fluorescent particles present in the water .During the operations the foil is exposed to the water .Now the sensing foil attached to the watertight housing window ,modulated the blue light in the water and the phase of red light is measured. To obtain the proper oxygen level from the sample region, the data in the form of red light is measured by linearizing and compensating the temperature with the help of an incorporated temperature compensating sensor.

Figure1: Aanderaa dissolved oxygen sensor

b. **Turbidity sensor**: The word turbidity means the haziness in a fluid due to the presence of large number of minute particles which are invisible to the naked eye. The presence of individual particles may due to the presence of phytoplankton or may be due to human activity like construction ,agriculture ,mining etc. which are washed out by rain and enters into the water bodies. Most widely the turbidity is measured in Formazin Turbidity Unit(FTU) which is referred as Formazine Nephelometric Units(FNU) by ISO.The principle of light scattering is implemented with an instrument called Nephelometer. A light beam emitted from the turbidity sensor is focused into the monitored water .Now the measurement occurs in the way that more the scattered light i.e more the intensity of light reaches the nephelometre the occurrence of particles is more and vice versa. The unit of turbidity using Nephelometer is called Nephelometric Turbidity Unit(NTU) .

Figure 2: Turbidity sensor

c. **Sonar sensor**: Sonar sensor works on the principle of sound rather let us mention it as acoustic signal .It is used as a navigation .Sonar sensor navigation comes under the classification of acoustic and geophysical category. An acoustic signals is externally emitted from the beacons or modems to navigate its location.

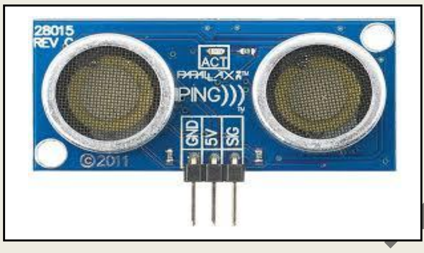

Figure 3: sonar sensor

6. **Communications:** The communication over the AUV is done through communication devices (basically GPS navigation system) that are operated by water and Air communication systems like radio or satellite frequency. But the problem start with AUV when it is immersed in deep water, the GPS navigation signal fail to operate as radio wave cannot penetrate water at a very depth. So to overcome this problem three major navigation techniques[5][9] are used in AUV like:

i) Inertial/Dead reckoning: This is a motion sensor based technique of navigation,which uses accelerometers and gyroscopes to increase the accuracy of the current state.

ii) Acoustic transponders and modems: this is another technique of navigation based on TOI i.e. Time Of Flight signals from acoustic beacons or modems.It includes Ultra-short baseline(USBL) or short-baseline(SBL) technique for positioning calculation.

iii) Geophysical : in this technique, external environmental information are been considered as reference for navigation.

7. **Mission Control:** Autonomous underwater vehicles (AUVs) are used to accomplish various missions which are unfeasible for the user to carry out successfully. For example, AVs have been used for search-and-rescue missions or in deep sea exploration. The mission control provides a solution to control and monitor the autonomous vehicle from the mother ship or from the sea shore, river bed through monitoring software present in the computer of the user. The planning algorithms of mission control used to provide a large degree of sovereignty for these vehicles, though human supervision is still required to monitor the position of the vehicle. Mission control can be defined as a framework where the user can design a mission plan for the AUV. This plan can contain depth, latitude, longitude etc co-ordinates for the AUV in which it can perform in the ocean. Mission control designs the specifications for elementary operations performed by the vehicle. Vehicle primitives are obtained from previous concurrent system tasks and that will help to design the functionality of the vehicle. Vehicle primitives and mission plan can be developed using specially designed software environments. In mission control procedure, the user enters the mission plan on this specially designed program presented in the computer. The mission plan is downloaded over the radio frequency device linked to the AUV, and executes.

The figure[7] below shows the co-ordination of mission control with other sub system of AUV.

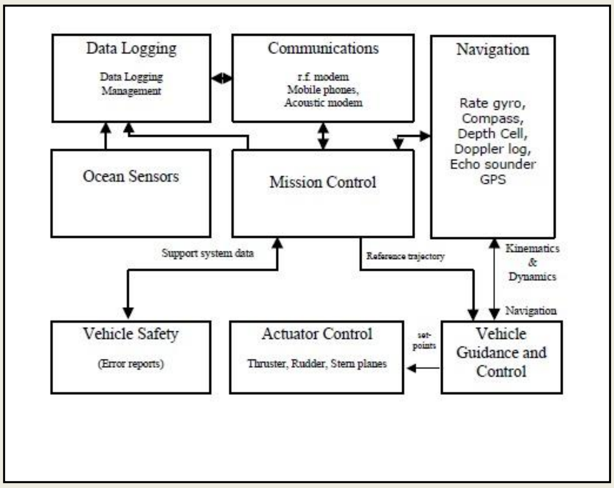

Figure 4: coordination of mission control with other sub system of AUV

III. AUV DEVELOPMENTS IN INDIA

The growth of technologies had made human beings to think beyond the limits. One of its effects is now became a major requirement for the Indian Navy in the field of autonomous machines. At last after a long trial and experimental progress from 2003 was started, India was able to fly her wing of success in the field of Automaton. With the support of DRDO two automated submarines were developed.
First was named as MAYA-AUV where as the second one in named as AUV-150.

An Autonomous Underwater Vehicle idea was started in the year 2003.The output of AUV idea came to known as MAYA, developed at NIO, Goa. Then after 2 years it was completed for its horizontal plan testing on May, 2005 and at last on May 12, 2006 it was ready for the missions. The vehicle (made up of Aluminium alloy) can operate at an instance for 7.2 hours , with its approximate length of 1.7m, a diameter of 0.234m with a shape of slender-ellipsoid. It can operated at a depth of 100m.Apart from the physical structure , it carries a navigation sensors(including Aanderaa dissolved oxygen sensor, Wet Labs chlorophyll and turbidity sensors) including GPS on mast and communication antenna, Lithium batteries as well as the actuators for the rudder and fins , RBRCTD(instrument) and a TRIOS (hyper spectral radiometers). The total weight of the vehicle in air is about 54kg and can move with a speed of 2.91577 knot. Since it was a joint venture of India and Portugal, its aim was to build and test the joint operation of two AUVs for marine science applications via AdI Portugal[1].

Figure 5: Maya-AUV India

The second achievement was in the form of AUV-150.Its was a Joint venture of ECIL and NSTL ,to develop an extended version of MAYA-AUV so that its can conduct more frontline activities like mine-laying, sea-floor mapping, and monitoring of environmental parameters like current, temperature ,depth and salinity. AUV-150[3] was developed by CMERI, Durgapur , a unit of CSIR with technical assistance of IIT,KGP .After its completion ,it was take into consideration for a trial in freshwater on January,2010 at Idukki reservoir(Kerala).The test was conducted up to October,2010.After its satisfactory performance in Freshwater, it was tested in sea water from 13july,2011 to 17July,2011,where it was proved to be work properly at a depth of 150 m with the satisfactory criteria. The main focus of development of this project was to fulfil the military applications like mine counter-measures, coastal monitoring and reconnaissance[4]. Its is 4.8 meter long and 50cm in diameter of torpedo shaped structure made up of Aluminium Alloy with a total weight of 490kg in air and can operate at a depth of 150 meter with a speed of 2-4 knots. As per communication system concern,AUV-150 carries a sensor (including payload sensor), altimeter, sonar, GPS and with a hybrid radio wave communication system. To operate the communication system, a Lithium Polymer battery as a source is been used.

Figure 6: AUV-150 India

To support naval operations after CSIR's AUV-150, Larsen and Turbo (L&T) have started to unfold their wing in the field of autonomous underwater vehicle. After a long strategic workout from 2011 to 2016 i.e. 5 years, they have completed their research work on AUV and as an output they are going to achieve their success in the name of "ADAMYA"[6].

Figure 7: "ADAMYA" India

"ADAMYA" can be ejaculated from a submarine torpedo tube or can be launched from a surface vehicle as well. The physical structure comprises of 18.7 feet in length and 533mm in diameter has a 50kg payload capacity. Its operable range is Expected up to 500 metre depth, where as for trial purpose it has been operated up to 300 metre only with a speed of 4knots (with a maximum forward speed of 6knots) at a constant power supply of 8 hours from the lithium-polymer batteries. Apart from short around time , "ADAMYA" satisfies Naval requirement like hydro graphic survey, mine countermeasures, intelligence-surveillance reconnaissance (ISR), offshore survey, clandestine monitoring, environmental monitoring and anti-submarine warfare .

With the flexible strategies and new ideas, Indian Navy is now looking for an advanced AUV which can be able to work on variable payloads like high definition sonar and underwater cameras of high resolution for surveillance reconnaissance activities of the sea-bed which includes oceanographic survey.

TABLE 1: Specification comparisons of AUVs

Specifications	MAYA-AUV	AUV-150	ADAMYA
Length	1.8 m	4.8 meters	18.7 ft
Diameter	0.234 meter	50 cm	53cm
Weight	55 kg	490 kg	850 kg
Depth covers	200 meter	150 meter	500 meter
Speed	1.5m/s	2.05m/s	4.12m/s
Nose Shape / Type	low-drag slender ellipsoid	Torpedo	Torpedo
Energy System	Li-polymer	Li-Polymer	Li-Polymer
Payload	Doppler velocity log, micro sonar, GPS, RF, rate gyro	Underwater video camera, side scan sonar, CTD or conductivity-temperature-depth recorder, several sensors that can measure orientation, current and speed.	Underwater camera, CTD or conductivity-temperature-depth sensor, Altimeter etc.
Navigation	GPS on surface, dead reckoning underwater using the DVL.	Inertial navigation system, depth sonar, altimeter, Doppler velocity log, global positioning system through ultra-short baseline system and forward looking sonar.	Inertial navigation system, a combination of Doppler velocity logger, global positioning system, a Forward Looking Sonar (FLS) etc.
Communication	GPS and RF antenna	Radio frequency on surface and acoustic under water.	Radio frequency, acoustic or Ethernet via attached cable.
Launch and Recovery	Small boat	Ship/Crane	Ship

IV. Application

Autonomous underwater vehicle has become acceptable to the world because of its vast functional areas. Previously, the underwater missions were costly and life risky, but now, the AUV give the world its huge application like as follows;

Military:

Autonomous underwater vehicles can have vast number of applications in military and defense missions[10] like Information operations, Inspection, Reconnaissance, Seafloor mapping, Emitting jamming, Anti-submarine warfare, Identification, Time critical strikes, Transportation, Mine detection, Mine neutralization, Navigation, Barrier control, Communication, Detection of vessels, Oceanography, Spying, Surveillance, False data transmission etc. AUVs can send to the critical areas where human interaction is difficult or there is risk of life.

Oil and Gas Industry:

AUVs can be used in the oil and gas industry to make detailed maps of the seafloor to make subsea infrastructure. Oil and gas pipeline can be installed under the seabed or river bed with less number of times and difficulty with it. Oil and gas companies can also do the under ocean surveys with help of AUVs in lower cost and man power.

Research:

AUVs are very useful in underwater researches by sending the UUVs under the lakes, river as well as into ocean and ocean floors also. To measure PH factor of a lake, or to measure the pollution in water at different depth AUVs can be used. Different type of sensors can be used in AUV to measure different type of compounds and elements, to investigate undersea life, microscopic elements etc.

V. Conclusion

The underwater vehicles opens a new way in oceanographic research and security. From the past few decades AUV changes enormously, but it is not the edge of its advancement. The scope of research and development areas in Autonomous underwater vehicle is vast. The navigation, sensors and mission control algorithms can be more improved to get better research and surveillance results.

References

[1] E. Desa, R. Madhan and P. Maurya, Potential of autonomous underwater vehicles as new generation ocean data platforms, current SCIENCE, vol. 90, no. 9, 10 may2006.

[2] Daniel W. French, Analysis of unmanned undersea vehicle architecture and assesment of uuv integration into undersea application, a Thesis, Naval Post graduate School, California, Sept 2010.

[3] CSIR News, ISSN 0409-7467, vol.61 no.17 & 18 September 2011.

[4] S. N. Shome, S. Nandy, D. Pal, S. K. Das, S. R. K. Vadali, Jhankar Basu,Sukamal Ghosh, Development of Modular Shallow Water AUV: Issues & Trial Results, Journal of The Institution of Engineers (India): Series C, July 2012, Volume 93, Issue 3, pp 217–228.

[5] Liam Paull, Sajad Saeedi, Mae Seto, and Howard Li, AUV Navigation and Localization: A Review, IEEE JOURNAL OF OCEANIC ENGINEERING, VOL. 39, NO. 1, JANUARY 2014

[6] Dinakar Peri, Developing Indigenous Technologies: A Leap Forward, Scholar warrior,Autumn 2014,pg-137.

[7] Oliveira, P., Paschoal, A., Silva, V. and Silvestre,C., Mission control of the MARIUS autonomous underwater vehicle: system design, implementation and sea trials. Int. J. Syst. Sci., 1998, 10, 1065–1080.

[8] ERIC A. D'ASARO, CRAIG MCNEIL, Calibration and Stability of Oxygen Sensors on Autonomous Floats, JOURNAL OF ATMOSPHERIC AND OCEANIC TECHNOLOGY VOLUME 30, march 2013.

[9] Liam Paull, Sajad Saeedi, Mae Seto and Howard Li, AUV Navigation and Localization - A Review, IEEE Journal of Oceanic Engineering (Volume: 39, Issue: 1, Jan. 2014)

[10] Robert W.Button, John Kamp ,Thomas B. Curtin, James Dryden, A survey mission for unmanned undersea vehicles , RAND National Defence Institute.