Marine Autonomous Systems – Technology, Opportunities and Use Cases

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Introduction

Despite water covering two-thirds of the earth's surface, there are very few data that we have from the water cover. It is a known fact that we have more information about outer space than underwater. Our knowledge about underwater life and environment is very thin. There is a staggering 92% of the underwater surface that is yet to be explored or mapped. Various technologies have been developed for research and mapping purposes. The highlight of them is the usage of autonomous systems. The systems can be made use of in dynamic environments of the ocean without compromising human safety. Therefore creating a wide range of research opportunities and fields to explore.

Marine Autonomy

While land vehicles and airborne vehicles have a rather clear path for traversing when compared to underwater. The land and air vehicles can be localized, connected or mapped easily with various technologies such as GPS, Wi-Fi, and other wireless technologies. In the case of underwater systems, this luxury is not available since the generally used wireless technologies are rendered ineffective. These signals do not have the capability to function underwater and they become either non-penetrable or distorted. When compared to other modes of travel, water systems, and underwater systems require automation more as the environment is completely unpredictable and dynamic. These autonomous systems can thus replace human divers to do dangerous tasks and missions. Automating an underwater vehicle is a very challenging task as none of the variables can be predicted and the actions of the vehicle cannot be pre-programmed. The vehicle has to face a number of challenges and obstacles such as random floating objects, sea creatures and unforeseeable climate changes. These have to be avoided and bypassed for the system to complete the task successfully. The processor that is used for the integration of the data collected from all the sensors is served with a 'self-thinking' algorithm framework that can decide the course and track of the vehicle with respect to the data readings.

Untethered in the physical sense, but there remains an acoustic tether. There are advantages and disadvantages to this. Without external signals from a shore controller, ROV is dependent upon positioning input from vehicle-mounted marine sensors. In case of real time applications, a mother vessel to provide this input is therefore required. However, the presence of the mother vessel allows for continuous monitoring of AUV control and payload systems. This provides assurance that the system will return with adequate data and provides for more than a minimum of quality control information allowing for provisional data interpretation and mission re-planning.

The way forward is to build flexibility into the AUV control systems, to allow autonomous operations but also to have control and real-time quality control capabilities when required. For the ROV system, this will require improvements to the AUV navigation system. For the AUV system, significantly greater mission endurance is necessary. For both, the launch and recovery weather window should be carefully curated.

Some systems can all follow pre-programmed missions and have a (largely untested) collision avoidance capability. Their payloads may contain bathymetry, side scan sonar, and profiler. However, they do not address all areas of oil industry requirements where, with further development, there is potential for the AUV technology to be applied. Other potential applications include:

- Environmental inspection
- Engineering inspection.
- Underwater engineering intervention.

Inspection is undertaken using sonar, photography and physical measurement. Intervention currently uses tethered remotely operated vehicles (ROVs) for valve manipulation, component replacement, etc.

Types of Marine Autonomous Systems (MAS)

- Remotely Operated Vehicle (ROV)
- Autonomous Underwater Vehicle (AUV)
- Unmanned Surface Vehicle (USV)
- Autonomous Ships
- Research Vehicles

Sensing and Processing

- Multibeam Echosounder (MBES)
- Side Scan Sonar

- Synthetic Aperture Sonar (SAS)
- Differential Global Positioning System (DGPS)
- Inertial Measurement Unit (IMU)
- Underwater Acoustics
- Doppler Velocity Log (DVL)

Advanced Technologies in MAS

- Autonomous Marine Cloud Processing
- Subsea Artificial Intelligence
- Marine Big Data
- Marine Cybernetics
- Subsea Data Storages
- Collaborative Systems

Autonomously Taking ActiON (ATON)**

Every Autonomous vehicle requires a framework capable of making decisions without human support. It should be able to take the input from various sensors connected to the vehicle, process the information accordingly, and then control the vehicle motion with respect to the decisions made.

ATON is an indigenously developed framework for Underwater Robotics and Autonomous Systems. The features of ATON are:

- Identifies the best and safest model to which system can perform the Autonomous operation.
- Apart from understanding the risk, in the background, it derives alternatives to mitigate the unexpected risks.
- It works on a **Parallel Redundant Storage Algorithm**, in which numerous multi-core process run simultaneously, the risk factor is constituted from the data received and the actions will be forwarded accordingly.
- Every 18 seconds, it will formulate a reference safe model to keep updating system status.
- **Set Points** and **Risk Points** are the prime decision making factors.
- In the event of any failure, ATON will change the weightage to other sensors, which can manage the risk, and the system will remodel immediately for the maximum risk to be diverted with the current setup.
- ATON comprises of 124 internal algorithm to support any marine sensor attached with the vehicle.

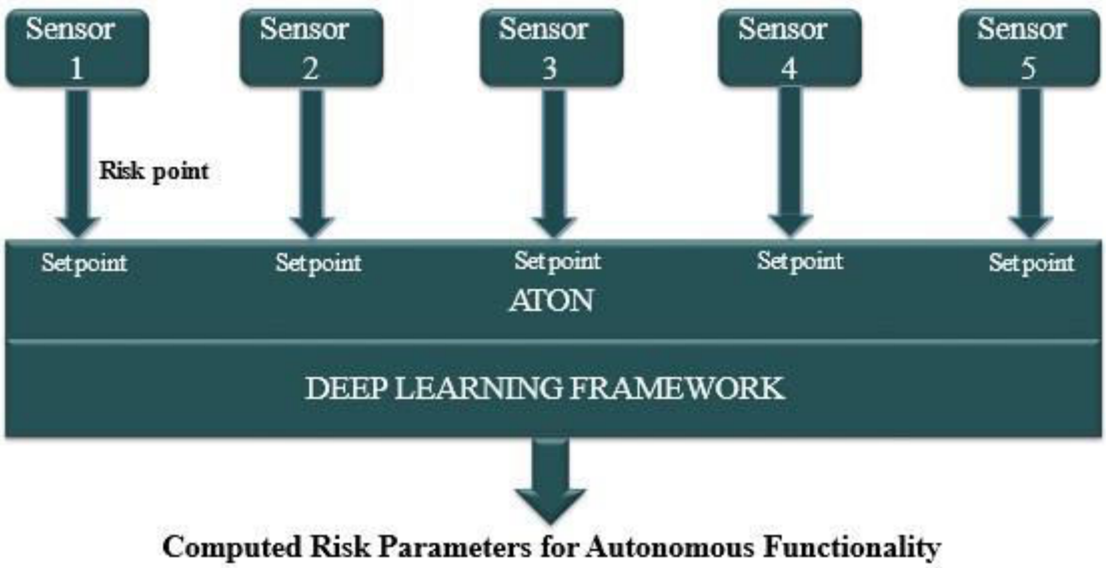

Figure 1 – ATON Framework Illustration

Set Points - The calibrated points or data

Risk Points - Fault characterized by ATON

Example - While obtaining the DGPS data, where PDOP* > 2, the data will be incorrect that leads to risk

**Position Dilution of Precision - PDOP is a risk and will become a risk point*

Experimental Setup

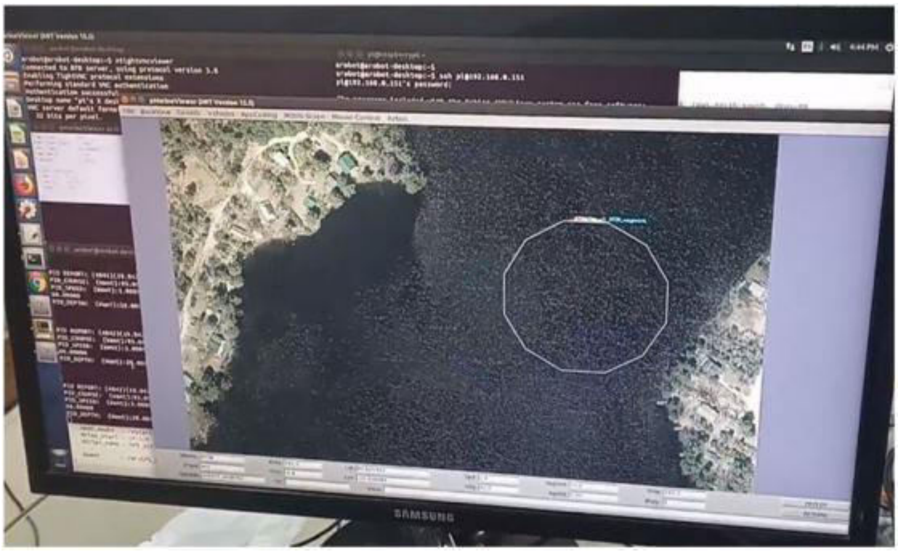

Figure 2 – ATON Framework Software Implementation

- The above figure shows the **Way Point** for a virtual mission.
- The mission is to complete the circular path without any support from the human controller.
- Though the path is circular, it is seen that the path resembles more like a polygon.
- Each point on the polygon denotes a Setpoint as illustrated in Figure 1.
- When the vehicle reaches each Setpoint, the path is evaluated for further maneuvering.
- This is done using the input obtained from various sensors attached to the vehicle.
- At this stage the risk evaluation and mitigation tasks (if any) are carried out.
- In case of emergency task abortion and in case of successful task completion, the vehicle returns to its **Home Set Point** that is the start point.

Figure 3 – ATON Framework Hardware/Vehicle Setup

- Figure 3 shows the hardware setup of the system.
- The trial is conducted using a self-built Remotely Operated Vehicle (ROV).
- The connections to the software and hardware with the necessary sensors are established with respect to the vehicle application.

Opportunities

Marine Autonomous Systems that includes AUV, USV, ROV and autonomous ships account for about $5 billion. As the automation in the systems increase, it calls for more sensors and computation. Each of the systems has its unique computations.

With the emergence of autonomous systems, other prominent technologies such as cloud computing and artificial intelligence have also gained traction in the marine industry. IT services for marine autonomy saves at least $1 billion by the year 2020 that leads to tremendous scope extension.

The amount of data collected from the marine surveys have to be processed to get valid information. The heavy data comprises the output of various sensors used in the mission. Fields like Machine Learning have had a huge impact on analyzing the data patterns, ocean patterns and for various other analytics. In the recent advancements along with Cloud and ML, Artificial Intelligence and IoT have been used extensively.

Use Cases

There have been numerous discoveries of shipwrecks and other debris in the recent past. This has proven to be decisive in knowing the history of various shipbuilding mechanics of the past along with other related discoveries. This has intrigued the marine archaeologists to survey potential areas for shipwreck discoveries. This, in turn, helps in widespread knowledge of the systems and the technology being used in the surveys.

Along with archaeological applications, the ROV's, AUV's along with the sensor suite have been deployed immensely for identification of debris. Numerous salvage operations related to flight crashes and oil spills have used these technologies to map the required piece of ocean area.

Since the existing mapped area of the underwater surface is very less, any new search operation requires a complete mapping from the basic levels. Therefore, for one search operation, it makes use of all available sensors for diverse data collection that in turn takes a completely new computation system for the particularly large dataset.

Along with these industries, the Oil & Gas industry, Defense, Environmental and Climatic applications usage of these latest technologies have been on the rise. The analytic methodologies have been vastly used for prediction of the data.

Note

References

- https://www.researchandmarkets.com/reports/4071016/risk-assessment-in-underwater-systems
- https://en.wikipedia.org/wiki/Autonomous_underwater_vehicle
- https://en.wikipedia.org/wiki/Remotely_operated_underwater_vehicle
- http://www.marketsandmarkets.com/Market-Reports/autonomous-underwater-vehicles-market-141855626.html

About the authors

Madhan is an Industrial Instrumentation Engineer, Educator, Researcher and Innovator. He is an Embedded System Design and Development Engineer, has worked in various fields of engineering like Industrial Automation, Pneumatics Design and Development, Perception and Analytics, etc. He is researching and developing technologies to monitor and preserve our Blue planet from human expedition. His principle exploration is in Bio- mimetic inspired Autonomous Systems and Robots Development in Marine Engineering. He has developed Cognitive based Technical curriculum for students and professionals to enhance their learning and betterment of technical skills. His key fields of research are: Robotics Vision and Perception; Sensor Data Validation; Cognitive Analytics and Cognitive Psychology; Bio-Mimetic Engineering and Development; Ocean Archaeology; Product Conceptualization; and Innovative Structural Design Development.

Darshan is a Mechatronics Engineer with Masters Graduation from VIT University. His areas of work include Sensor fusion, Autonomous Mobility and Vision and Perception analytics. He has been a Research Enthusiast on Sensors pertinent to Autonomy from his post graduation years. His principal research work includes Sensor Data Fusion and Perception for Autonomous Systems (Marine/Automobile). He has been working on an affordable solution that can be used as a primary perception device for distance mapping and obstacle avoidance for Autonomous vehicles. He has Co-authored a technical report 'Risk Assessment in Underwater Systems' based on the Autonomous system framework Autonomously Taking actiON (ATON) indigenously developed by AROBOT. His key fields of research are: Automated Vibration control in Machine Tools; Fault tree analysis for Sensor Failures in an Automated System; Vision and Perception for Autonomous Mobility and Sensor Fusion; Risk analysis in Autonomous Systems; and Sensor Architecture Design for Autonomous Systems