Article

Marine Robotics: Upcoming Trends and Challenges

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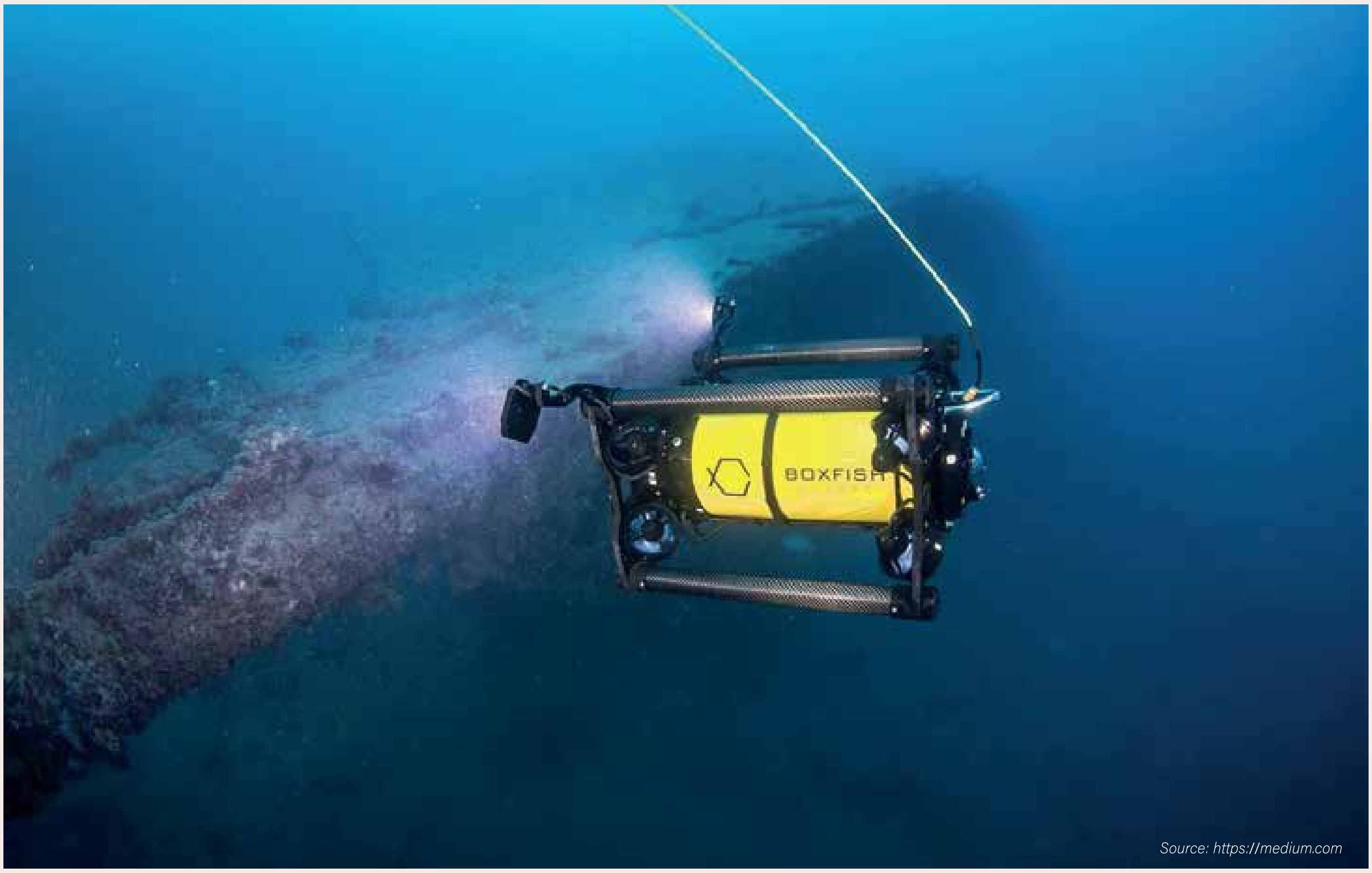

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Marine robotics is an important part of robotics, which is certainly a vital outcome of maritime literacy. The idea of marine robotics started in the early 1970s (Yuh et al., 2011). It is a complex field, as huge challenges exist in the maritime environment that are not faced by ground and aerial robotics. However, marine robotics has gradually become a vital technology that enables us to carry out challenging and dangerous missions in the ocean. Rigorous research and development in this area have led to substantial progress and shown the utility of marine robotics in numerous fields. The core cause behind this success was the fruitful dialogue between marine robotic developers and end-users to address application-driven requirements. Nevertheless, various challenges are yet to be addressed despite the advancements in this field. It is, therefore, the appropriate time to overview the recent applications of marine robots and upcoming trends in this field to reach excellence in maritime literacy in Bangladesh.

Classification of Marine Robots

Operation Area

Unmanned Surface Vehicle (USV): USVs are marine robots that operate without a crew on the water surface as an easy and inexpensive alternative to other water-borne surface platforms. These are smarter than buoys and have better flexibility compared to commercial ships. Renewable energy may be used to run their equipment and propulsion system, allowing them longer oceanic activity. When a survey vessel involves a USV, it can increase the active survey area and decrease the operation time. A significant role can also be performed by USVs by making connectivity of manned and/ or unmanned vehicles by acting as communication hubs of Radio Frequency (RF) networks (surface and air), acoustic frequency networks (water), and satellite networks (Sánchez-García et al., 2018).

Unmanned Underwater Vehicle (UUV): Numerous UUVs have been developed over time to assemble data from the subsurface of the sea. Progress in this field has not been encouraging due to difficulties of data transmission underwater which is yet to be resolved. However, not withstanding these limitations, some UUVs have been used effectively.

Unmanned Wave-piercing Vehicle (UWV): UWV is an option that stands amid the USVs and the UUVs. It encompasses the swiftness, durability, GPS positioning, and radio communication of USVs with enhanced stability and stealth of UUVs. However, it does not possess the complete criteria of either. Consequently, two strategies have been taken in the advancement of UWVs. One is with a surface platform with a slight liquid-plane area and spar of a minor size to pierce the waves (Unmanned Wave-piercing Surface Vehicle), and the second is a submarine hull immediately beneath the water level with a permanent snorkel penetrating the waves (Unmanned Wave-piercing Underwater Vehicle). As completely submerged vehicles have complicacy in finding precise locations because of the ineffectiveness of GPS and lack of accuracy of Inertial Navigation System (INS) in subsurface areas, UWVs overcome the gap between USVs and completely sunken UUVs (Roberts & Sutton, 2006). These can be treated as a budget alternative to surface platforms for transporting sensors to considerable distances, collecting information, and transmitting back the information in real-time. The usage of UWVs also facilitates the elimination of noise and bubbles around sensors and corrosion in the ship's keel.

Control Mechanism

Remotely Operated Vehicle (ROV): Marine robots that are tethered and controlled from distant locations are named Remotely Operated Vehicles or ROVs. However, their utility is restricted to a limited number of applications as it is a tiring task for operators. Besides, its operational cost is huge and safety concerns are also there. Still, ROVs have some utility like activities beyond the diver's depth where it is difficult to reach by divers but manual intervention is required.

Autonomous Underwater Vehicle (AUV): No navigator or tether is required to control AUVs. They are free-swimming vehicles. Built-in power supply and communication systems are available in AUVs. However, from time-to-time human intervention may be required for routine maintenance or change of assignment or reconfiguration due to changed marine environment, etc.

Movement Mechanism

Wave-Propelled Vehicle: A USV that moves itself using waves is named as wave-propelled vehicle or wave glider. Its sensors, data, and navigation system are managed by its operating system.

Drifter: Drifters are USVs that move with the current. These are ideal marine robots for the study of current, wind, temperature and salinity of the ocean, air pressure, transportation system, etc.

Glider: A glider is an AUV that glides horizontally and vertically in the water by use of buoyancy engines and lifting surfaces. A glider maneuvers by the hydrodynamic lift and drag forces created due to variations in the weight of the glider (Jenkins et al., 2003). Presently, underwater gliders have become useful platforms in the sea for their low cost, long endurance, easy deployment, and noiselessness.

Propeller: Some marine robots use propellers for their movement in some parts of their maneuver to gain higher speed. Propellers are basically run by battery-driven motors and batteries are charged by solar power or available electric power when it is docked. The use of propellers in marine robots is mostly restricted to make them energy efficient.

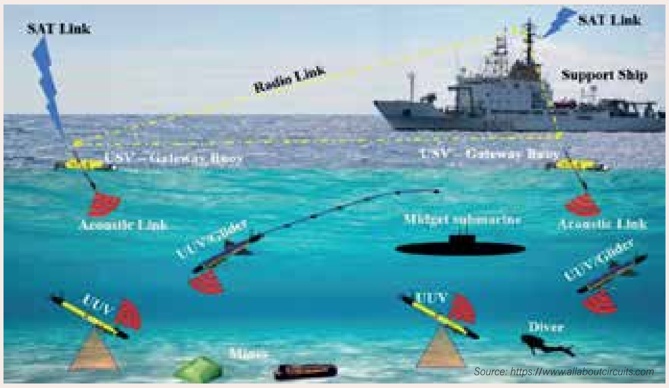

Figure 01: Different Marine Robots

Marine Robot Applications

Bathymetry/ Hydrography: Marine robots integrated with the necessary sensors can perform bathymetry and hydrography.

Survey: Marine robots are employed to conduct surveys in the water to detect harmful elements and pollution. Marine organisms and ecosystems can also be monitored by the said robots. The survey is also carried out by these robots for seafloor mapping.

Photography and Visual Inspection: Video footage and high-resolution pictures can be taken by the cameras of marine robots to conduct visual inspections. This capability is useful in many applications like aquaculture inspection, ship/boat inspection, infrastructure inspection, pipe inspection, etc.

Object Recovery: Marine robots can assist with the search to recover lost objects. Many concerned have already begun to utilize them.

Intrusion Detection: Marine robots can have an important role in monitoring the security of a port or waterside of a defense or key installation and prevent intrusion by coordinating with surface and subsurface observation points. Thereby, the deployment of a group of marine robots to carry out patrolling may be quite effective to improve waterside security.

Asymmetric Warfare: Explosive may be carried by marine robots to attack maritime platforms, jetties, docks, etc., and thereby marine robots can be used as an asymmetric warfare platform. Besides, UUVs can be used as silent intruders because of their negligible signature than the ones of a diver, and they can travel faster, remaining below the detection level of active sonars.

Upcoming Trend

Marine robotics has advanced very quickly due to the ample inventions in relevant areas. However, upcoming development trends of marine robotics may be grouped into two categories: platform aspect and information aspect.

Platform Aspect

Marine Animal Alike Robot: Due to the developments in high-tech materials, various soft actuators or artificial muscles are presently available for creating animal-like movement in the water (Díez et al., 2021). These technologies have evolved a different research field to develop bioinspired water-borne platforms resembling marine animals. Most of such platforms are yet models that have only been verified in laboratory and mild natural environments. However, significant developments are required in the bioinspired platforms for their real-time utility.

Complete Autonomous Marine Robot: Independent response by marine robots is one of the significant requirements for future marine robotics. It is therefore required to develop totally autonomous marine robots that should identify the intervention zone, select the job to be executed and act accordingly without any human participation.

Marine Robot for Critical Operation: Operating in critical conditions or extreme environments will be an essential task for marine robots in the future. Extremely shallow waters, very deep ocean bottoms, areas with tremendous fast currents or large waves, polar areas with ice concealment, areas with weak GPS signals, and environments with nuclear hazards are some examples of extreme environments. New advancements are being stimulated to operate marine robots in these critical environments (Trevelyan et al., 2016).

Information Aspect

Computing Power of Marine Robot: Many intelligent features are not available with marine robots due to their inadequate computing elements. Regular route planning of marine robots needs a considerable volume of computation. It is therefore apprehensible that additional investments will be made to upsurge the computing capability of marine robots.

Organized Network of Marine Robots: To create the map of ocean environments, normally a group of marine robots (gliders) connected by communication networks are involved. Arranging the movements of marine robots as well as an organized network is a vital issue to get a good map. New research plans are evolving in this field as well.

Challenges

Endurance: The endurance of a marine robot greatly depends on its power storage or generation system. This power decides the time-on-task of the marine robots. Research is being made to improve the power management of marine robots to increase endurance, which is a great challenge to be materialized.

Communication: Only sound waves can be used for communication in the underwater environment, which is limited by range and bandwidth. Improvement of communication range and bandwidth is one of the critical challenges for underwater communication of marine robots.

Determination of Subsurface Location: The navigation ability of a UUV is limited due to the ineffectiveness of GPS underwater. Besides, the INS also does not give accurate location as the accelerometers can not sense accurate underwater gravity. A GPS feed is needed to eliminate the error compelling the marine robots to come up to the surface. Thus, a challenge remains to establish an effective subsurface positioning system.

Universal Protocol: A universal protocol for marine robotics is required to ensure compatibility and interchangeability with other devices which is a challenge for all concerned to take care of.

Bangladesh Context

Different stakeholders are working silently in the field of marine robotics in Bangladesh on a small scale. BRACU Duburi and Dubotech are some of the privately owned pioneers in this field in Bangladesh, where people can easily share their thoughts and facts on maritime robotics. An underwater robotics laboratory is also there in Bangladesh University of Engineering and Technology (BUET), which is an effective platform for the research and development of marine robotics. Bangladesh Oceanographic Research Institute (BORI) could be one of the important end users of marine robotics in Bangladesh, which is planning to have some surface and underwater marine robots in the near future to conduct surveys in the ocean. There is also a "National Strategy for Robotics" prepared by the Bangladesh's government to encourage this field as well as maritime literacy.

Marine robotics has developed a lot by refining control and navigation algorithms and heading toward its full autonomous capability. Marine robots are presently diving beyond 6000 meters regularly (Stel, 2021). Submerged gliders already traversed the Atlantic Ocean, and USVs crossed the Pacific. Upcoming marine robotics will allow scientists with cutting-edge gears to discover and use the sea in a workable manner. Marine animal-like robots and completely autonomous robots are vital future trends in this field. However, the key recognized challenges are endurance and underwater communication, etc., and it is still to go a long way in this field, which will certainly be exciting and challenging. Bangladesh is no exception to it as a developing coastal state playing an encouraging role in maritime literacy.

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