

Innovative Approach in Transportation- An Industry Life Line

Emerging Trends in Robotics, Navigation and Communication

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Abstract: The development of techniques for autonomous navigation in real-world environments constitutes one of the major trends in the current research on robotics. An important problem in autonomous navigation is the need to cope with the large amount of uncertainty that is inherent of natural environments. Fuzzy logic has features that make it an adequate tool to address this problem. In this paper, we review some of the possible uses of robots in the field of autonomous navigation. We focus on following topics: what is robots, what is slam robots, rov sensors, e- navigation, Arctic communication and so on.

Keywords: E-navigation, slam robot, AUV, ROV.

1.Introduction

Maritime communications will experience major changes during the next two decades. Not only will the evolution of e-Navigation require higher digital data exchange capacities, but new connectivity solutions for the crew will also increase bandwidth needs. New potential digital VHF services are envisioned while other innovative digital VHF implementations are also in the pipeline. These are only some examples of emerging trends, technologies or demands. Many initiatives are currently on-going within different organizations, such as IMO's 'e-Navigation Strategy' and the IALA Maritime Radio Communication Plan, with the ultimate overall goal of modernizing statutory maritime communications systems with an increased reliance on robust communications, including satellite communications. In addition, upcoming commercial satellite systems such as Inmarsat Global Xpress, O3b, Telenor THOR 7 in Ka-Band and Iridium NEXT in LBand are expected to increase competitiveness, reduce the cost per bit and pave the way for new broadband services that will complement legacy narrowband offerings.

Unmanned autonomous robots are gaining prominence in the marine sector. Key trending applications include: autonomous surface vessels, unmanned underwater vehicle/robots, and shipboard robots. Automation in the marine industry largely enhances the efficiency of shipping goods. Presently, research community is increasingly focusing in autonomous vessels and its applicability in the marine sector. Autonomous vessels will minimize human involvement and reduce shipping costs, while improving delivery efficiency of marine vessels. Robotic technologies for marine applications are largely leveraged by transportation and defence sectors. Robots will mitigate hazardous risks thereby increasing the safety of human personnel. Marine robots are used in off-shore oil and gas; investigation activities of the ocean, ship, and harbour maintenance; and in defence marine robotic vessels. Government funding is boosting development and adoption of robots for marine applications.

The technology and innovation report aims to capture the impact of robotic technologies for different applications in the marine sector.

2. Robotics

2.1 What is robot?

A robot is a mechanical or virtual artificial agent, usually an electro-mechanical machine that is guided by a computer programme or electronic circuitry and thus a type of an embedded system.

2.2 Slam Robots

One of the most widely researched subfields of robotics, SLAM robot navigation seems simple, but it's deceptively so. Imagine a simple mobile robot, which in this case, is a set of wheels connected to a motor and a camera, complete with actuators or physical devices for controlling the speed and direction of the unit. Now imagine this robot being remotely propelled by a human operator to map inaccessible places. The actuator allows the robot to move around while the camera provides enough visual information for the operator to understand where surrounding objects are and how the robot is oriented in reference to them. Maps could be made in areas which are too dangerous or inaccessible to humans, like deep-sea environments or unstable structures. It would make robot navigation possible in places like space stations and other planets, removing the need for localization methods like GPS or man-made beacons. GPS is currently only accurate to within about one half of a meter, which is often more than enough to be the difference between successful mapping and getting lost. Man-made beacons, on the other hand, are expensive in terms of time and money. SLAM robot navigation is a big but relatively new subfield of robotics. It was originally developed by Hugh Durrant-Whyte and John J. Leonard based on earlier work by Smith, Self and Cheeseman. It wasn't until the mid-1980s that Smith and Durrant-Whyte developed a concrete representation of uncertainty in feature location, which was a major step in establishing the significance of finding a practical rather than a theoretical solution to robot navigation.

The paper provided a foundation for finding ways to deal with the errors associated with navigation. Soon thereafter another study proved the existence of a correlation between feature location errors due to errors in motion, which affect all feature locations. There are other problems connected to SLAM robot navigation, as specific and detailed mapping is always complex. For example, if a map built using the measured distance and direction travelled by a robot has a set of inaccuracies, brought by inefficient sensors and additional ambient noise (distractions), then any features being added to the map will contain corresponding errors. Over time and motion, locating and mapping errors would then build cumulatively, inevitably distorting the map and the robot's ability to determine its actual location and move with sufficient accuracy. There are various techniques to compensate for errors, such as recognizing features that it has come across previously, and putting together recent parts of the map to make sure the two instances of that feature become one.

2.3 Remotely Operated Underwater Vehicle (ROV)

A remotely operated underwater vehicle, also referred to as ROV, is an underwater vehicle which is usually tethered. The unoccupied vehicle is similar to a robot, which is fitted out with sensors and sampling tools to collect various types of data. A network of cables is utilized to establish a connection between the operator and the remotely operated vehicle, which would enable the proper movement of the ROV.

A remotely operated underwater vehicle can also incorporate advanced instruments for an appropriate measurement and evaluation of current temperature, penetration of light and the water clarity.

ROVs or underwater robots were primarily invented to serve an industrial purpose, regarding regular pipeline inspection (both interior and exterior) and to conduct structural testing methods on certain platforms, from various offshore locations. The underwater ROVs are even useful for the exploration of oceanic water.

Interestingly, the indefinite locations famous shipwrecks like the RMS Titanic, USS Yorktown, SS Central America and the Bismarck have been discovered due to some help from the ROV industry. In the case of SS Central America, the remotely operated underwater vehicle has also been able to retrace and fetch some important materials from the sea floor of the shipwreck.

3. Communication

Current research activities and results in the area of the maritime satellite market will be evaluated and described in detail in this paper. These evaluations show that the maritime user applications requiring access to

communication systems can be divided into the following main areas: Safety & Security; Vessel operations; Regulations/Policy; Tracking & Monitoring; Crew Welfare; Shared Situational Awareness. Furthermore, the paper will investigate new opportunities for satellite systems, services and technologies addressing the maritime communications demands in 2020.

3.1 Identification and Selection of Use Case Scenarios

Relevant to the future of satellite communication for maritime nine key requirements were derived:

3.1.1 Safety and Security system/alerts: This requirement applies to voice and data communication, alerting, positioning information. Return link with high priority, availability and low latency is required for this purpose.

3.1.2 On Route information update: this requirement covers for example destination updates, waypoint and route optimization, maps update, weather information, ice information, or currents information. From a technological perspective it is expected that it principally requires a Forward Link capacity (from ground to vessel).

3.1.3 Remote Control of vessels: this requirement is mainly used in the scenario of unmanned vessels, but also as a help to the crew for monitoring and decision making. Remote Vessel Control requires bidirectional links. From a bandwidth perspective it is expected that significant capacity would be required mainly on the Return link (such as video, and audio and eventually data from vessel to ground).

3.1.4 Tracking/Monitoring: this requirement applies to vessels but also goods/oil/persons on-board the vessel. It is expected that from a technological perspective type of requirements would principally need capacity on the Return Link (from vessel to ground).

3.1.5 Worldwide available communication for vessels: It is expected that global coverage might be needed in areas where limited communication coverage is available. This is particularly applicable to the in the Arctic region.

3.1.6 Crew/Entertainment communication: cargo and passenger ships require communication access for entertainment purposes. High bandwidth capacity is needed in both directions.

3.1.7 Share of info among vessels during route/after route: this could apply among vessels of the same company, be open to partner's company or all ships.

3.1.8 Communication for under building sea platforms/ sea power plants: the application are relevant to wind, underwater turbines, others.). These are quasi static vessels for which High Altitude Platforms may apply.

3.1.9 Regulations and Policies: Today all the currently required systems as GMDSS, LRIT, AIS, etc. are being regulated. It is expected that regulatory bodies will remain key players in the definition of next generation services.

After capturing the set of high level requirements, they have been grouped in user scenario as in Table 1. This justifies the 4 user cases further investigated in this paper.

TABLE 1. Set of high level requirements.

	E-Nav	Arctic Comms	Autonomous Ships	Evolution of GMDSS
1. Tacking / Monitoring	X	X	X	X
2. On route information update	X		X	X
3. Remote control of vessels			X	
4. Safety and security systems / alerts	X	X	X	X
5. Worldwide available communications for vessels		X	X	
6. Crew/Entertainment communication	X	X		
7. Share of info among vessels during route / after route	X	X	X	X

8. Communication for under building sea platforms		X		
9. Regulation and policies			X	X

3.2 Arctic Communications

The Arctic comprises the latitudes above 60°N except for the area of sea between southern Greenland and northern Norway which is warmed by the Gulf Stream and remains ice free. The Arctic is currently experiencing a warmer climate which is slowly reducing the permanent ice cover and making more of the area accessible to shipping. Fishing fleets, cruise ships and cargo ships are operating above 80°N and oil/gas exploration is extending above 75°N. There are theoretically two passages for shipping to cross the Arctic, the Northern Sea Route along the Russian coast and the Northwest Passage along the Canadian coast. Both have political difficulties as the respective countries claim them as territorial waters and not international straits. Of the two, the Northern Sea Route (NSR) is the more practical for navigation, and a minor number of ships transit NSR each year. Communication using geostationary satellites is theoretically possible up to 81°N, which is 0° elevation, but the practical limit is typically assumed to be around 76°N. Inmarsat satellites serve the Arctic up to 76°N except for an area around 120°E of the Laptev Sea Russia and around 120°W of the Beaufort Sea Canada. The polar orbiting satellites of Iridium and Cospas-Sarsat serve the whole of the Arctic, and HEO orbiting satellites are under consideration. IMO has procedures in place to possibly recognize satellite systems in addition to the systems provided by Inmarsat and Cospas-Sarsat. Commercial ships visiting the Arctic need to comply with the GMDSS requirements of the SOLAS Convention, which requires them to be fit for Sea Area A4 when sailing above 76°N, necessitating an HF installation for distress alerting, communications and reception of Maritime Safety Information. The IMO is currently drafting a Polar Code intended to become mandatory, comprising among others requirements for communications and information exchange additional to the normal SOLAS requirements.

3.3 GMDSS Evolution

The Global Maritime Distress and Safety System (GMDSS) is the radio system whose techniques and frequencies are defined by the ITU and for which mandatory equipment carriage requirements has been adopted by the IMO for commercial vessels. There is currently a project within the IMO to review and modernize the GMDSS in the period 2012-2017. To date, a high level review has been completed which has concluded that the functional requirements of the GMDSS are still appropriate. The project is currently conducting a detailed review addressing issues including: the evolution of Maritime Safety Information (MSI) broadcast systems; problems which might arise due to lack of HF stations in the future; future definitions of Sea Area A3 (currently within geostationary satellite footprint) and Sea Area A4 (currently outside geostationary satellite footprint); integral use of voice communications; improved shore to shore communications between Rescue Coordination Centers. The final phase will be a modernization plan. One change that has occurred since the inception of the GMDSS in the 1970s is that radio equipment is now a consumer commodity and there will likely be many other radio systems on a ship besides the GMDSS. These may have a role to play in distress and safety in the future.

4. Navigation

4.1 e-Navigation

E-navigation is an IMO project that is underway and looking at a future digital concept for the maritime sector. Work to date has identified possible future developments in:

- improved, harmonized and user-friendly bridge design with improved reliability, resilience and integrity of bridge equipment and navigation information together with integration and presentation of information in graphical displays such as that received via communication equipment;
- improved reliability and resilience of on-board Position, Navigation and Timing (PNT) systems;
- improved shore-based services with means for standardized and automated ship-to-shore reporting, improved access to relevant information for Search and Rescue (SAR), and improved communication of VTS (vessel traffic system) information.

4.1.1 Requirements for e-navigation evolution

Potential user requirements that might be achievable with a satellite service in a future e-navigation scenario are described in the following.

First, improved access to navigational safety information is needed. At the moment Maritime Safety Information (MSI) which comprises navigational warnings, meteorological warnings and forecasts, and search and rescue (SAR) information, is promulgated by MSI providers via NAVTEX and Enhanced Group Call (EGC) systems (EGC is a part of the Inmarsat C system and supports two broadcast services: SafetyNET and FleetNET). The information is in text (ASCII) format only and is displayed on the receiver's screen and can be printed on the dedicated printer. Developments in the interfacing of bridge systems are expected to display this information in an increasingly centralized way, e.g., automatically routed to navigation displays (ECDIS and radar screen).

Second, integration of communication infrastructure is needed. e-Navigation will need data communications capacity and technical characteristics that support the harmonized collection, integration, exchange, presentation and analysis of marine information onboard and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment.

Third, low cost communication services are needed. In many parts of the world it is becoming increasingly difficult to recruit seafarers to work as crew on ships. Life at sea is not considered to be an attractive career in part due to the loneliness of the life. Crews are demanding the means to keep in touch with their families and friends and join in the types of entertainment services they would use at home. A wide variety of services are available for supplying entertainment to ships. Receive only satellite television is available for free to view and pay television channels. Wi-Fi can be made available on the ship so that it is possible for crew to use their personal laptop, smartphone or tablet to send and receive a call directly, send and receive SMS and MMS and obtain Internet access. Internet connection is available particularly from VSAT suppliers and from terrestrial suppliers in coastal areas. Services providing roaming from satellite to terrestrial communication are available.

Fourth, low cost data VHF services are needed. All ships which are equipped with radio equipment carry a VHF radio working on the maritime mobile channels and increasingly ships are equipping with AIS which also works in the VHF band. The VHF radio provides voice communication and the AIS provides information about surrounding ships and has a limited ability to send and receive short messages. Other data services however require additional equipment such as NAVTEX receivers working at 518 kHz for maritime safety information and satellite terminals which can provide maritime safety information and data exchange by e-mail.

4.2 Autonomous underwater vehicle (AUVs)

AUVs have revolutionized marine and ocean exploration. What was once an expensive, limited endeavor completely reliant on surface vessels is now accomplished by AUVs, or self-powered undersea robots that gather high-resolution remote spatial and temporal measurements.

AUVs offer a nimble, flexible alternative to traditional surface vessels. They can glide close to the surface, dive to depths of up to 6000 meters, explore shallow waters or hover in hazardous areas where navigation is difficult. The benefits are numerous. AUVs have reduced the high costs of ocean exploration and sampling while increasing the availability, quality and quantity of scientific marine data.

4.2.1 Advantages

The units are modular, allowing scientists to change the onboard instruments or payloads to better suit their needs; they can be operated from a vessel of opportunity, dedicated research ship and even the shoreline; and they can be used to explore open water or formerly inaccessible locations such as abyssal plains or under polar ice. Whether conducting an oceanographic investigation of a water column or a geophysical study of the sea bed, Hydroid AUVs allow researchers to achieve multiple objectives in a single dive.

Sensors can be placed close to the area of interest. Coupled with high quality navigation solutions this ensures the data is both meaningful and accurate.

They are quick and easy to deploy around the world, and most units require minimal installation and calibration, thereby reducing ship time and research assets.

The endurance of an AUV allows the vehicle to investigate a larger area for a longer period of time. In addition, the potential to network multiple AUVs together can increase productivity to levels never seen before in marine research.

4.3 e-Loran

eLoran is the latest in the longstanding and proven series of low-frequency, Long-Range Navigation (LORAN) systems, one that takes full advantage of 21st-century technology. It meets the accuracy, availability, integrity and continuity performance requirements for maritime harbour entrance and approach maneuvers, aviation non-precision instrument approaches, land-mobile vehicle navigation and location-based services. It's a precise source of time (phase) and frequency. Additionally, eLoran provides user bearing (azimuth) and has built-in integrity. In full disclosure, however, eLoran is only a 2D positioning solution unless integrated with a simple altimeter.

4.3.1 Applications

We are staunch advocates of GPS and believe it should be fully funded, kept technically advanced, protected, toughened and augmented. When GPS is available and trustworthy, it should be used. However, no technology is failsafe, and prudent users should not rely on a sole source for their PNT needs. GPS has been called "a single point of failure" for much of the U.S. economy and critical infrastructure. Applications and requirements vary widely from wireless network communications of ± 1.5 microseconds, to maritime harbor entrance and approach requirements of ± 20 meters, to phasor measurement unit requirements in the electric power grid of ± 500 nanoseconds.

Some key application areas in which eLoran can provide complementary PNT are telecommunications, energy, finance and transportation. We believe these will be some of the first sectors to adopt and exploit eLoran as a component of their critical infrastructure protection and possibly as a co-primary PNT solution alongside GPS.

5. Suggestions

- Fire Fighter Robots: The idea is not to replace humans in firefighting but to aid them in firefighting operations on ships. In the case of fire on ships, these robots would perform tasks such as turning

valves, picking up and dragging fire hoses, and putting water on fire. This concept can make use of different fire suppression technologies including PEAT grenade. The firefighting robot has a vision system to search for survivors and can withstand heat up to 500 degree Celsius. IR and UV camera help it to see through the smoke and detect the source of excess heat respectively.

- **Hull Cleaning Robots:** An innovative hull cleaning robot namely “HullBUG” has been developed by SeaRobotics and funded by U.S. Navy Office of Naval Research (ONR) to tackle this issue. It uses four wheels and attaches itself to the underside of ships, using a negative pressure device that creates a vortex between the BUG and the hull. Sensors provide obstacle avoidance, path cleaning, and navigational capabilities. A fluorometer lets the robot detect biofilm and then it uses rotary brushes or water-jets to scrub the fouling film off.
- **Anti-Piracy Robots:** Recon Scout throwbot developed by Recon Robotics, is an anti-piracy robot which will fight against maritime piracy. The dumbbell-sized robot can be fired from cannon within 5 seconds and can survive throws up to 120 feet. Its magnetic wheels help it to crawl on the ship’s hull before it reaches the deck. It can be controlled by joystick from the nearby command center. The robots can keep eye on piracy activities using its cameras that can see even in darkness using infrared camera
- **Shipbuilding Robotics:** Recent trends suggest that the shipbuilding industry is recognizing robotics as a driver of efficiency along with a method to prevent workers from doing dangerous tasks such as welding. The shortage of skilled labour is also one of the reasons to look upon robotics. Robots can carry out welding, blasting, painting, heavy lifting and other tasks in shipyards. Hyundai Heavy Industries (HHI), which has developed mini welding robots, is set to use robotics in shipbuilding. These trends clearly suggest that the future of shipyards will be smart and digital.
- **LNG Fueled engines:** Liquefied Natural Gas (LNG) surge in popularity as an alternate fuel for ships is visible these days because of its environmental friendliness. That is why, the market of LNG fueled ship engines is emerging and its prospects are high as well. In the LNG engines, CO2 emission is reduced by 20-25% as compared to diesel engines, NOX emissions are cut by almost 92%, while SOX and particulates emissions are almost completely eliminated.
- **Integrated Electric Propulsion:** The integrated electric propulsion technology is an arrangement wherein gas turbines or diesel generators or both generate three-phase electricity which can be used to power electric motors which turns propellers or water jets. The system uses electric transmission instead of mechanical transmission which eliminates the need for clutches and reduces or eliminates the use of gearboxes. Some of the advantages of using this technology are freedom of placement of engine, less noisy ships, reduction in weight and volume etc.

5. Conclusion

This paper documents the areas of intervention to satisfy the future demands for maritime communications, navigation and robotics. Identified areas are: e-Navigation, Arctic communications, GMDSS, slam robots, AUVs, ROVs.

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7. References

1. AUVs- marine research application.
2. Emerging trends in robotics navigation and communication- ieeexplore.
3. Maritime Communications- Identifying Current And Future Satellite Requirements & Technologies
4. Hybrid underwater robotic vehicle.

