APPLICATION OF INFORMATION TECHNOLOGY IN AUTONOMOUS SHIP NAVIGATION THROUGH INTELLIGENCE IN NETWORKS

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Abstract: Autonomous vehicles are already state-of-the-art in many land based transport modes e.g.Google self-driving car is also in a range of autonomous cars.There exist several examples of automated subways, self-driving intra-logistics vehicles or automated guided vehicles (AGV) on modern container terminals. There are also very wide-ranging approaches of autonomous control concepts in modern aviation e.g. Drone.Consequently, autonomy is also seen as a possibility for maritime transport to meet today's and tomorrow's competitiveness, safety and sustainability challenges. With recent advances in Electronics and communication technology, Control protocols, Information Technology and Robotics technology, the concept of Drone Ship is also taking shape for future unmanned ship navigation through intelligence network [2].
Keywords: Unmanned ship, Autonomous ship, Intelligence network, E-navigation.

1. Introduction

Drone ships would be safer, cheaper and less polluting for the $375 billion shipping industry that carries 90 percent of world trade. Captains on dry land will use similar control centers to command hundreds of crewless ships. Crew costs of $3,299 a day account for about 44 percent of total operating expenses for a large container ship. That has spurred some groups to develop more autonomous technologies that would all but remove humans from the equation. Such "drone ships" would be remotely piloted by onshore captains, but all the onboard operations that crew members currently carry out, like navigation and power management, would be handled by computer systems. It would make shipping safer, less expensive, and more environmentally friendly. But the proposals have been met with skepticism from shipping labor unions, and there are major regulatory hurdles that still need to be cleared. The development will not happen overnight. The idea is that within the coming decades, nearly all of a ship's functions would be carried out automatically. Vessels would be able to navigate their way across oceans, and would automatically manage and optimize the power they use. Humans would still need to conduct maintenance and repairs when the ship comes into port, but some of the more basic operations could be handled by robots.Underground trains, cars, transport vehicles and people movers in airports – they can all be operated unmanned already. Now the first of such projects is being launched for container shipping.Consequently, autonomy is also seen as a possibility for maritime transport to meet today's and tomorrow's competitiveness, safety and sustainability challenges.

2. Maritime Unmanned Navigation through Intelligence in Networks

Autonomous and unmanned vessels are seen as a key element for a competitive and sustainable shipping industry in the future. The research is going on for the contribution to the realization of the vision of autonomous and unmanned vessels by developing and verifying a concept for the autonomous ship. Thus the purpose is to independently and safely bringing cargo to its intended destination.Next generation modular control systems and communications technology will enable wireless monitoring and control functions both on and off board. These will include advanced decision support systems to provide a capability to operate ships remotely under semi or fully autonomous control [12].

Figure 2. 1 E-Navigation through intelligence network

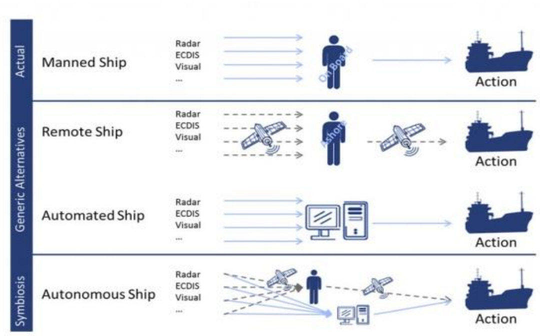

Figure 2. 2 Autonomous ship

2.1 Why is autonomous shipping needed?

Maritime trade volumes are expected to increase in the future and accordingly the numbers of ships needed to transport the freight will grow, as will the number of seamen required to operate the vessels. At the same time shipping industry faces a lack of skilled seafaring personnel for sailing. An often cited reason for this lies in the unattractiveness of seagoing professions, especially for youngsters. To some extend this is caused by seafaring's inherent problem of lacking family friendliness and the high degree of isolation from social life that comes along with working on a seagoing ship. The current trend towards slower sailing speeds justified by environmental and economic considerations increases the length of the ship's voyage and with that the time seamen spend on sea increases even further. This is the reason for increasing dropout rate of sailors after initial period of training. Particularly due to high responsibility and risk involved, the officers and engineers are also not willing to continue the same profession after sufficient earning and they wish to get settle down in some of the shore based industry.

Here, the unmanned autonomous vessel represents a way out for the shortage of seafarer. On the one hand, it could reduce the expected pressure on the labor market for seafarer as it would enable, at least partly, to reduce the labor intensity of ship operation. On the other hand, routine tasks on board would be automated and only the demanding but interesting navigational and technical jobs transferred from ship to a shore side operation center making “seafaring” jobs more attractive and family friendly than today. Furthermore, economic and environmental benefits are also expected when implementing unmanned shipping [3, 7].

2.2 Objectives & Impact of unmanned ship

The overall goal of the research project originates form the vision of autonomous and unmanned vessels. Specifically, aims to develop and verify a concept of an autonomous ship. For this purpose a number of particular objectives are combined in the project’s scope:

- Develop the technology concept needed to implement the autonomous and unmanned ship.
- Develop the critical integration mechanisms, including the ICT architecture and the cooperative procedural specifications, which ensure that the technology works seamlessly enabling safe and efficient implementation of autonomy.
- Verify and validate the concept through tests runs in a range of scenarios and critical situations.
- Document how legislation and commercial contracts need to be changed to allow for autonomous and unmanned ships.
- Provide an in-depth economic, safety and legal assessment showing how the results will impact overall shipping’s competitiveness and safety.
- Show how the concept gives direct benefits, e.g. in reduced off-hire due to fewer unexpected technical problems, and provides efficiency, safety and sustainability advantages for existing vessels in short term, without necessitating the use of autonomous ships.
- Develop a feasible and useful IT architecture for autonomous operation,Analyze the tasks performed on today’s bridge and derive a concept for an autonomous bridge,
- Examine the tasks in relation with a vessel’s technical system and develop a concept for autonomous operation of the engine room,
- Define the processes in a shore side operation center required to enable a remote control of the vessel, Validate the feasibility of the developed solutions combined into the concept of an autonomous and unmanned vessel and Identify and investigate legal and liability barriers for unmanned vessels.
- The remote ship where the tasks of operating the ship are performed via a remote control mechanism e.g. by a shore based human operator.

- The automated ship where advanced decision support systems on board undertake all the operational decisions independently without intervention of a human operator.The Autonomous Ship is a symbiosis of the Remote Ship and the Automatic Ship.

2.3 The project set-upand technology required for unmanned ship

The project consists of ten individual work packages. Hereof the central scientific and technical parts of the project will be shown in the figure below [1].

- An Advanced Sensor Module, which takes care of the lookout duties on board the vessel by continuously fusing sensor data from existing navigational systems, like e.g. Radar and AIS, combined with modern daylight and infrared cameras.
- An Autonomous Navigation System, which follows a predefined voyage plan, but with a certain degree of freedom to adjust the route in accordance with legislation and good seamanship autonomously, e.g., due to an arising collision situation or significant weather change.

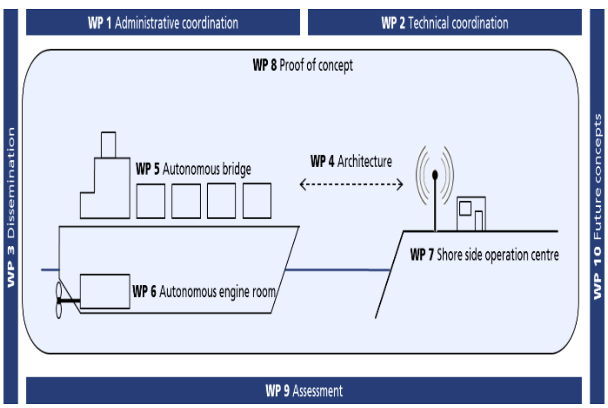

Figure 5. 1Ten work packages for ship navigation

Figure 5. 2 Simulated view of unmanned ship's control

- An Autonomous Engine and Monitoring Control system, which enriches ship engine automation systems with certain failure-pre-detection functionalities while keeping the optimal efficiency and which takes care of the additionally installed pump-jet that acts as a certain rudder and propulsion redundancy.
- A Shore Control Centre, which continuously monitors and controls the autonomously operated vessel after its being released from its crew by its skilled nautical officers and engineers. It comprises amongst others the certain positions.
- A Shore Control Centre Operator, who monitors the ship operation of several autonomous ships at the same time from a desktop cubicle station and controls the vessels by giving high level command like, e.g., updating the voyage plan or the operation envelope of the autonomous system.[6]
- A Shore Control Centre Engineer, who assist the operator in case of technical questions and who is in charge of the maintenance plan for the vessels based on a

condition-based maintenance system ensuring sufficient reliability of the technical system for the next autonomous journey.

- A Shore Control Centre Situation Room Team that can take over direct remote control of one vessel in certain situations via a shore side replica of the unmanned vessels bridge including a Remote Maneuvering Support System that ensures an appropriate situation awareness in direct control despite the physical distance of crew and vessel.

Figure 5. 3 Various types of ship navigation for autonomous and remote controlled ship.

- The majority of the necessary technology already exists. On the bridges of modern ships, the command centers from which these container giants are steered, many tasks are already fully automated today. An autopilot can set the course, cruise control can maintain the speed, and radars and ship identification systems monitor the surroundings at sea and sound the alarm if there is any danger. On unmanned ships, however, there would be no sailors to oversee the technology on the bridge; it would simply be monitored by a captain onshore at a control station. He could intervene whenever necessary and use the computer to take control of the ship. In order to have all the information he needs, additional conventional cameras as well as infrared cameras would be mounted to recognise small vessels.These workers would have better quality of life compared with working at sea [10].
- The computers would be constantly analyzing operations data to improve efficiency and save money e.g. big data transmission around 30 terra-bytes via satellite links every month.Cameras and sensors can detect obstacles in the water better than the human eye[3].
- The RFI seeks information in three areas: 1) Maritime Perception Sensors (passive optical or non-radar active), 2) Maritime Perception Software (algorithms and software to support Maritime Perception Software for detection, tracking and classification from passive optical or non-radar active imagers to address real-time command and control), and 3) Classification Software for Day-Shapes/Navigation Lights (algorithms and software to support detection, tracking and classification for passive optical or non-radar active imagers for the purpose of detecting day shapes and lights in a marine environment)[5].

- Unmanned ship would normally rely on automatic and fully deterministic control functions to run the ship. However, various sensor systems will be needed to detect problematic situations such as unexpected objects in the sea, dangerous weather conditions or danger of collision. If an unexpected situation occurs, an autonomous control module will be invoked trying to remedy the situation within its given constraints. Properly implemented, this type of autonomy will reduce the need for human supervision while maintaining a high and well defined level of safety. However, a major challenge will be to device sensor systems so that all relevant dangerous situations are reliably detected and appropriately acted upon.

3. Benefits of unmanned ship

The concept of an unmanned and autonomous ship which is developed for contributing to all aspects of sustainable waterborne transport offers various benefits which are mentioned below,

- Economically sustainable transport due to reduced crew cost, slower sailing speeds and more efficient ship operation. Manning costs typically represent more than 40 % of the total ship operation costs. Unmanned shipping brings along a significant potential to reduce cost. The benefits seem clear. On unmanned ships, the space currently occupied by the bridge and crew quarters could be used to store extra cargo. Shipping companies would save on personnel expenses.
- Socially sustainable transport by significantly increasing the social compatibility and attractiveness of seafaring professions and positively affecting the safety of maritime transport.Seagoing professions are increasingly perceived as unattractive today. Sea passages are long and often lacking in variety. Port calls that might offer some change to the daily routine are short nowadays allowing for little time to spend ashore. Mariners are confronted with a disconnection from their social environment due to the long time periods they spend away from family and friends. As a result, a shortage of nautical officers is already perceived by the industry today[7].
- Ecological sustainability currently gains ever more public awareness and the shipping industry acknowledges its responsibility to contribute towards it. Further, slower sailing speeds become economically viable if crew costs can be reduced and more efficient ship operation and the total trip costs by a reduction of the vessel’s speed. A reduction of the greenhouse gas emissions associated with maritime transport is an important objective in order to make maritime transport more environment-friendly in the future. Slow steaming is maybe the most obvious approach to achieve this objective. By diminishing the fuel consumption of a vessel its emissions are reduced equally. Hence the effects of unmanned autonomous vessels on a wider deployment of slow steaming will not only contribute towards economic but also significantly towards the ecological sustainability of maritime transport. Further increases of the efficiency of ship operation, that are expected to be an outcome of the research project, will contribute towards ecological but also economical sustainability.

- The research project will provide much improved technology for the surveillance of the vicinity of the ship. This will not only allow for a better identification of objects nearby but also highly functional detection and situation assessment capabilities will aid human operators to deal with complex situations and help to avoid situations where human fatigue or failure in situation awareness lead to maritime accidents. It's not unheard of for cargo ships to sink 49 sank or were submerged in 2014 [8].
- Autonomous vessel, which is equipped with modular control systems and communication technology to enable wireless monitoring and control, including advanced decision support systems and the capabilities for remote and autonomous operation. Project developed a technical concept for the operation of an unmanned merchant vessel and assesses its technical, economic and legal feasibility. The research study has intention of developing a concept that is completely unmanned at least for parts of the voyage, short-term exploitation potentials of the technological progress for unmanned shipping is also under investigation[9].
- Also, risks from engine and other system breakdown should be lower for unmanned ships if proper redundancy is implemented and improved maintenance and monitoring schemes are followed. Fire and explosion represents a relatively small part of all incidents and with the possibility to use more efficient extinguishing systems in fully enclosed spaces, it is likely that the unmanned ship will be much less risk prone than the manned ship. Human error causes most maritime accidents, often relating to fatigue. Therefore accidents caused by human error would be avoided with unmanned ships and thus sailing become even safer[4].
- Risks from cyber-attacks and pirates are issues that cause concern. However, as it should be possible to design ships and systems that have a very high resilience against such attacks and one could assume that unmanned ships are less vulnerable to attacks than manned ships in this context as well.Unmanned ships would also reduce risks such as piracy, since there would be no hostages to capture.
- Ship-owners would spend less to maintain their crews, and the lower weight resulting from the elimination of crew bunks, latrines, and kitchens would bring down fuel costs. The technology would put fewer people in danger; in 2012, an estimated 75 to 96 percent of all marine casualties were attributed to human error, according to a study from the insurance group Allianz. Workers wouldn't be at risk of attacks from pirates, and instead of spending months at sea, they could live at home and commute to port to service incoming ships.

4. Limitations

1. Unmanned ships are currently illegal under international conventions that set minimum crew requirements. The IMO hasn’t received any proposals on unmanned, remote-controlled ships. IMO regulations apply to seagoing vessels trading internationally and exceeding 500 gross tons, except warships and fishing boats. As long as drone ships don’t comply with IMO rules, they would be considered unseaworthy and ineligible for insurance.
2. The International Transport Workers’ Federation, the union representing about 600,000 of the world’s more than 1 million seafarers, is opposed. They said “It cannot

and will never replace the eyes, ears and thought processes of professional seafarers," "The human element is one of the first lines of defense in the event of machinery failure and the kind of unexpected and sudden changes of conditions in which the world's seas specialize.

3. A reduction of vessel speed from 16 to 11 knots for example brings along fuel savings of about 50% per distance sailed. However, a reduced speed also results in a longer voyage time. As a result amongst others charter and crew cost increase per trip which at some point offsets the savings due to less consumption of fuel.
4. Unmanned ships would still require captains to operate them remotely and people to repair and unload them in port. Drone ships would become vulnerable to a different kind of hijacking from computer hackers. While the technology needs to be fully secure.
5. At the moment, there is a requirement of crew on board to carry out regular maintenance tasks and keep the ship in good condition e.g. by dealing with rust caused by the salt water. Reefer containers and dangerous goods must also be checked daily to make sure that the cargo does not suffer any damage.Steering the ships from land is not necessarily safer than from sea since it would still be a person doing the job.And there are always unforeseen circumstances that will require humans to make quick decisions.
6. A vessel controlled by computers would also be a target for hackers and pirates. They may be able to hack the system and cause the ship to deviate from its set course. Another argument against unmanned ships is that it might take days to reach the ship in the event of an emergency such as a fire or leak. Maritime laws would also have to be amended.International maritime laws demand that a ship has a minimum crew on board for security reasons – unmanned ships are currently deemed abandoned[11].
7. Marine engineer and Deck officer has to gain knowledge & skills of Electronics & Telecommunication, Control protocols and Information technology for getting acquainted with this upcoming technology.

Figure 7. 1 Bridge simulation for unmanned ship

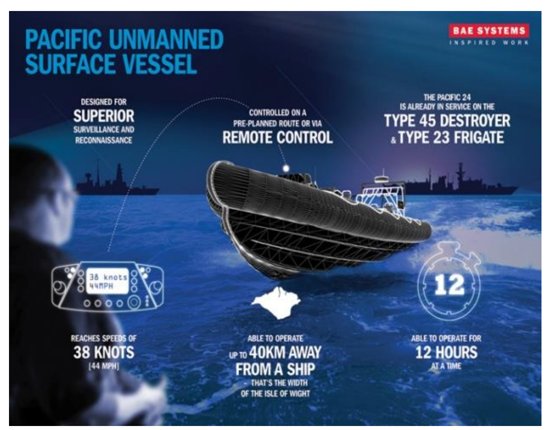

Figure 7. 2 Pacific unmanned surface vessel

5. Conclusions:

Seafarers have always been very good at adapting to technological change. We believes the technology's benefits will eventually push the industry forward.Thus, unmanned vessels can contribute to the aim of a more sustainable maritime transport industry. Especially, shipping companies have to deal with a demographic change within a highly competitive industry, while at the same time the rising ecological awareness exerts additional pressure on them. The autonomous ship represents a long-term, but comprehensive solution to meet these challenges, as it bears the potential to,reduce operational expenses, reduce environmental impact and attract seagoing professionals.This shift of nautical and engineering tasks from ship to shore and also opens new professional perspectives for mariners that can now remain connected to family, friends and their social life. This can help to attract new, highly qualified professionals for "shore-based seafaring". Indirectly, this can also further promote sustainable maritime transport.So, we hope within coming ten to fifteen years one can able to see the proper use of unmanned ship for sustainable maritime transport.

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