CONDITION MONITORING FOR AUTOMATED FERRIES

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Abstract Automated ferries can be considered as an important step along the road to autonomous vessels. With the currently available technologies, ferries can easily be automated to perform predefined journeys. This means that it can be retro-fitted to many existing ferries around the world, creating significant scope for the future roll out of the concept. The shift from having a crew on board to having land-based technicians/operators observing and/or controlling the ferry remotely will no doubt revolutionize the ferry industry. Even though the idea is promising the major challenge is to make the operation reliable and safe.

This paper aims at investigating the important of continuous monitoring of the conditions of key elements to achieve high reliability in future automated ferries. The full paper will identify key elements in an automated ferry such as propulsion system and power generation system and lists the parameters that should be monitored in these systems to assess their condition. Moreover, algorithms that can be used to assess the health of individual subsystems, and development of a reliability centered maintenance program for the ferry will be discussed.

Keywords: condition monitoring, autonomous, ferries, vessels, technologies

Introduction

During the last decade autonomous ships was just an idea and was considered almost impossible. In fact, the actual idea of a ship without crew is not new, though. To some extent, the idea of crewless ships is the phase of a process that has been going on ever since humans put the first boat in the water. As technology has advanced, ship builders have gradually replaced crew members with mechanical parts(Andrews, 2016). Two years ago talk of intelligent ships was considered a fantasy. Today, the prospect of a remote controlled ship in commercial used by the end of the decade is a reality.

The technology of an autonomous and unmanned ship has been a subject of lively discussion in recent journals, conferences and seminars on development of marine technology.
An autonomous ship is a sea going surface vessel which is capable of operating without any crew on board. Although things are still at the research and development stage, but Rolls-Royce anticipate the first commercial vessel to navigate entirely by itself to carry the cars at a short distance. The Advanced Autonomous Waterborne Applications (AAWA) Initiative is a €6.6 million project funded by Tekes (Finnish Funding Agency for Technology and Innovation) aims to produce the specification and preliminary designs for the next generation of advanced ship solutions. It brings together universities, ship designers, equipment manufacturers, and classification societies to explore the economic, social, legal, regulatory and technological factors, which need to be addressed to make autonomous ships a reality. The project will run until the end of 2017 and will pave the way for solutions designed to validate the project's research.

Technologies for Autonomous Vessels

The development of crewless vehicle in sea has seen with great progress during the last 10 years. This has been enabled by advances in technologies, which enables perception of the surrounding environment, path planning and vehicle control in real time. With a combination of an array of advanced sensor technologies becoming available also beyond earlier military and scientific use and rapidly increasing data processing performance, we have reached a technological level on which full vehicular autonomy is indeed feasible. Research on autonomous cars offers the most extensive source of publicly available information on technologies developed for autonomous vehicles.
The key aspect to successful vehicular autonomy is reliability and safety. Despite all of the recent technological advances, conclusive demonstrations of sufficiently reliable autonomous car navigation in varying real-world conditions have not been presented. The available technologies that can be applied for ship autonomy and the remaining challenges ahead to reach required technological readiness for a proof of concept demonstrator by the year 2017.

Although, these ships where crew work hard, now have been converting into the concept of autonomous vessels means crewless ships. By coming of this advanced concept, technologists do their serious effort to less the work hard of seamen. Moreover ship builders have gradually replaced crew members with mechanical parts, hence autonomous ferry is the stepping stone towards autonomous ships and the aim of this paper is to investigate the importance of condition monitoring to achieve required reliability.

1. Autonomous navigation of the vessel

Collision-free motion techniques can be divided into either global methods, based on path planning using a priori information, or local methods which are based on reactive navigation using sensory information (Campbell, Naeem, & Irwin, 2012; Pietrzykowski & Uriasz, 2009; Statheros, Howells, & McDonald-Maier, 2008; Tam, Bucknall, & Greig, 2009). Planning a collision free path for an autonomous machine through an environment containing static or moving obstacles, in this case a vessel moving in both harbor area and open sea, is a problem that has been extensively studied during the past decades. Different systems require different planning strategies.

Two ofthe most common path planning approaches are graph based and sampling based approaches. Graph based approaches and their numerous variants have been the most studied algorithms for optimal path planning problems. The main advantage of sampling based approaches, such as probabilistic road map (PRM) and rapidly exploring random tree (RRT) and their variants, is the ability to easily include dynamic and kinematic constraints of the vehicle. For reactive obstacle avoidance, these optimal path planning approaches may not be efficient enough. Therefore, algorithms such as velocity obstacles are commonly used (Campbell et al., 2012; Statheros et al., 2008; Tam et al., 2009).

In AAWA, a solution for the integration of a complete autonomous ship navigation architecture is being developed, which takes advantage of a Rolls-Royce Dynamic Positioning (DP) system developed for future autonomous ships and links it with an Automatic Navigation System (ANS), including Situational Awareness (SA), Collision Avoidance (CA), Route Planning (RP), and Ship State Definition (SSD) modules developed in the AAWA project.

Map information is used in for path planning, obstacle avoidance, and localization of the autonomous ship. On sea and harbour area, it is possible to use nautical and terrain charts to obtain information about shipping lanes, shoals and coastal terrain. Dynamic obstacles, such as other vessels, are mapped by using the ship's situational awareness system, combined with e.g. AIS data. Many methods have been developed for processingperception data for modelling and representing a 2D or 3D world, to mention for example occupanc grid maps, height grid and Quadtree type of maps (Mooney).

Two of the most common approaches for presenting the world are topological and metric maps. Topological approaches describe the connectivity of spatial locations in the environment, whereas metric maps describe the world through a geometric presentation. Topological maps are best suited for high-level path and mission planning. Metric maps contain geometric information that is necessary to plan and execute trajectories safely while avoiding collisions. The mapping process creates a representation of the surrounding world (Broten, MacKay, & Collier, 2012).

2. Situational Awareness (SA) for autonomous ships

The main task of sensor fusion is to combine the data from different sensor source in such a way that optimal SA perception is guaranteed under all conditions and in all situations. SA data is then used to map local obstacles to enable reactive collision avoidance.

There are some important sensor technologies for Situational Awareness:

Cameras are a natural choice for SA. They are cheap, small in size and durable, and can provide very high spatial resolution with colour information for object identification. True night-vision is possible with thermal IR imagers and a pair of cameras can be used in a stereoscopic configuration for 3D sensing. Due to the huge range of both commercial and niche applications, camera technology is still constantly improving. The large existing knowledge-base on visual analysis algorithms provides many potential solutions also for marine Situational Awareness. In maritime application the use of radar has a long history. Therefore, several radar system suppliers can be found in the market for obstacle detection and mapping. Radar capability is influenced by the operating frequency band of the radar, so that typically higher frequencies offer better angle and range resolution. There is a wide variety of radars in the market, intended for different purposes, having specific carrier frequencies, bandwidths, transmit durations, waveforms, antennas etc. Typically, marine radars are microwave radars using S or X-bands, which are robust in different weather conditions (Heuel, 2013). However, the resolution of traditional marine radar may not be sufficient for reactive collision avoidance.

3. Off-ship communication

The capability for remote human interaction and control has to be enabled for situations, which the ship autonomy cannot resolve or is not allowed to handle by itself. Relaying the SA information gathered by the ship's sensors to a remote operator may require the transfer of significant amounts of data. Due to practical limitations on e.g. satellite communications at open sea, the same amount of bandwidth may not be available at all times. Methods for reducing the amount of sensor data only to what is absolutely needed for the human operator to perceive the environment of the ship needs to be considered. Also issues such as data security (intentional tampering) and link reliability should be addressed and the possibilities of using multiple alternative communication networks (satellite, VHF, 4G) depending on availability and performance needs should be examined.

Possible effects of weather or multi-user congestion on communication performance should be considered carefully when implementing the control and intelligence of the whole autonomy system through the Virtual Captain. Difficult situations may arise if poor weather simultaneously causes reduction of SA system capability, requiring more shore control intervention or decision making, and a reduction in datalink capability required to transfer sensor data from the ship. Correct behaviors and precautions for such situations should be defined.

Why we need condition monitoring

The purpose of condition monitoring is to give better understanding of problems such as alarm and shut downs and to provide procedures of trouble shooting and problem investigation.

What is Conditioned Monitoring of autonomous Vessels?

Cyber influx provides enormous opportunities for maximizing the performance and efficiency of a product. Due to this it becomes easier to assess appropriateness level of large vessels. Conditioned monitoring of a vessel involves careful observation and maintenance of vessel's equipment's like testing of acoustic emission, vibration monitoring and oil and temperature analysis. Conditioned monitoring is vital for predictive maintenance so that necessary steps could be taken to prevent from major failure by early detection of possible threats.

This report will take a closer look at the available technologies that can be applied for ship autonomy and the remaining challenges ahead to reach required technological readiness for a proof-of-concept demonstrator by the year 2017.

Methods Used For Conditioned Monitoring Of Crewless Vessels

There are two main methods used for condition monitoring, and these are trend monitoring and condition checking. Trend monitoring is the continuous or regular measurement and interpretation of data, collected during machine operation, to indicate variations in the condition of the machine or its components, in the interests of safe and economical operation. This involves the selection of some suitable and measurable indication of machine or component deterioration, and the study of the trend in this measurement with running time to indicate when deterioration is exceeding a critical rate. The principle involved which shows the way in which such trend monitoring can give a lead time before the deterioration reaches a level at which the machine would have to be shut down. This lead time is one of the main advantages of using trend monitoring rather than simple alarms or automatic shutdown devices (Neale & Woodley, 1975).

Condition inspection is where a check estimation is taken with the machine running, utilizing some suitable indicator and this is then utilized as a measure of the machine condition around that period. To make it effective measurements must be precise and quantifiable, and there must be known limiting figures which must not be exceeded for more than a specific number of further allowable running hours. To get these limiting figures, it requires a big amount of recorded past data for the specific type of machine, therefore this strategy is less flexible than the trend monitoring, especially if it is required to give lead time as well as machine information. It can be especially valuable , be that as it may, in a circumstance where there are numerous similar machineries working together as in this case comparative checking can be possible between the machine which is observed, and other similar machineries which are new or in great condition(Neale & Woodley, 1975).

Advantages of Conditioned Monitoring in autonomous Vessels

1) Condition monitoring allows engineers to anticipate a potential failure and take action. Let’s say a certain piece of equipment usually vibrates at a given frequency. If that frequency starts to vary, or changes substantially, it could mean something inside the machine is starting to fail or needs to be replaced.

2) Ships are dangerous workplaces, so there is good reason to remove human crews as much as possible.
3) Ships are also good candidates for automation because they are slow moving (especially compared to aircraft) so longer voyages are tiring and exhausting for humans.
4) Condition monitoring helps cost saving, time, and resources. While there is cost involved with monitoring, it is usually minimal compared to the downtime associated with doing maintenance too often or making unexpected repairs.

What people have done so far in condition monitoring?

The autonomous ship including the computer equipment that controls the operation of the ship are designed and constructed by a human being. The software, i.e. the behavior of the system in different operational situations, is also designed by a human being. It is obvious that the human element is involved in every single act of the autonomous ship, even though it is unmanned. In case of an unmanned ship, the total size of software package is massive and the structure of this package is amazingly complex. It is divided into subsystems and minor entities inside a huge amount of several devices communicating with each other. Potentially there can be one or more software bugs caused by a human error in every single piece of the large system. The process of developing and testing the control software for the autonomous ship is therefore extremely critical. What kind of errors could the software engineers make? The development of a real-time software system is a complicated iterative process consisting of different phases, such as requirement definition and analysis, planning of data structures and operation algorithms, planning of data transmission, designing the structure of the software, defining the scheduling and priorities of the tasks, designing the self-diagnostics and the algorithms for exceptional situations, coding the modules, testing on the module level, integration, testing on the system level etc.

It is beyond the scope of this paper to discuss the methods of creating good software for critic al systems. There are hundreds of books and papers written on this topic and many international standards published to support the development of safety-critical systems. Human potentially can make huge errors, even a simple error can lead to a total failure of software such as typing errors during the coding phase. A bit more irritating errors result from poor interface design and unpractical operating algorithms but the good thing about this kind of software errors is that they are obvious and can be easily corrected. Mature software does not contain this kind of error. Since the software not suffer from aging effect that is the amount of error will not increase with age, so we can use these software for many decades. The most difficult and dangerous software errors are those that are connected with abnormal situations and algorithms in exceptional circumstances. Many maritime accidents have resulted from a poorly designed algorithm leading to an unexpected and dangerous operation under exceptional circumstances. Nobody knew before hand how the system would behave in such situation. Some accidents of this type are analysed in Ahvenjarvi (Ahvenjarvi, 2002). The problem of this kind of software design errors is that they are very difficult to reveal beforehand. It may happen that the exceptional situation was not anticipated by the group of experts who wrote the requirement definition for the software.

Future trends and Challenges

How can an autonomous vessel be made at least as safe as existing ships, what new risks will it face and how can they be mitigated

Concluding remarks

Introduction of the autonomous ship does not mean that there is no more a human element involved in the navigation process. However this paper depend on the report of condition monitoring. The information extricated from it will demonstrate the technical and economic importance of condition monitoring. This paper will develop an interest of Ship builder and operators to change conventional monitoring system to condition monitoring system.

The outcome Phase II will be the technical, legal and safety specifications for a full model and it will be demonstrate before the end of this year. The revolution has begun and an autonomous commercial ships will be use by the end of the decade.

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