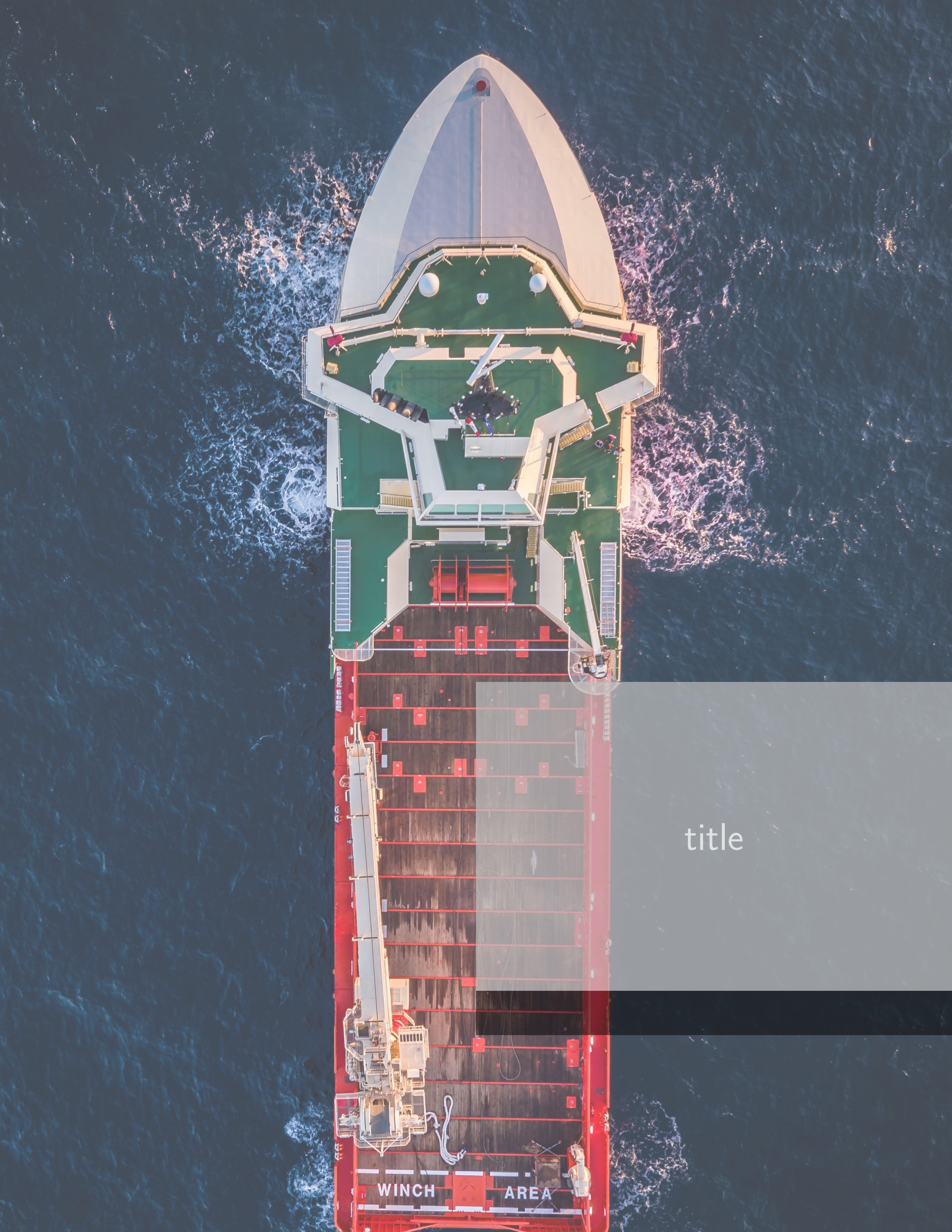

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MSc Thesis - Current Knowledge

Model for the complexity of maritime operations

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Notes

Abbreviations

TEU Twenty foot Equivalent Unit

AIS Automatic Identification System

SOLAS International Convention for the Safety of Life at Sea

STCW International Convention on Standards of Training, Certification and Watchkeeping for Seafarers

MARPOL International Convention for the Prevention of Pollution from Ships

Contents

Introduction

This document will give a summary of current knowledge and papers which will support my research to: The complexity of maritime situations and how this can be communicated to the crew. As described in the Dutch National Research Agenda an fundamental question we have to ask ourselves: How do we get grip on unpredictability of complex networks and chaotic systems? This research will have two main tracks. The first part is for the department of Maritime Technology and Transport. Where I will try to specify a scale for the complexity where a ship can be in, leading up to an probability value for failure. The second part of the research will be for the Interactive Intelligence department. Where will be looked at the interaction between computers and people. In this case more specific, which information does the crew currently get and what information do they need. So they can improve their situation awareness and make better decisions.

Extend purpose of research with TKI NML

First projects will be described who are the frontiers and which are seen as the future of shipping. After that a literature review is done on subjects like situation awareness, decision making and mental models. This will be the foundation of the research for computer science. Followed by a research into the physical world of the ship, why does it behave like it does, and which forces work on the ship. Using this information a model will be created where also route-planning and collision avoidance are discussed. Information on how information for the model is acquired is the next important step. The model should finally lead to a cost function and this will be presented to the crew. At last an discussion about the scope is being presented to really demarcate where my research will foucs on and what potential iterative steps are.

Check if this is really the structure

Occurred accidents

Why would we change the current situation? Investigation reports

List some accidents and how these won't occur with different systems

1 Future of shipping

The shipping industry is traditionally driven by regulations. Digitalization and de-carbonization are watch words for the coming decade. Those will be leading so the shipping industry can become safer, more efficient and at the same time reduce its environmental footprint [1].

Describe in short what will be discussed in future of shipping section

1.1 Steps to be taken

Focussing on the digitalization, ships will become more sophisticated. More data is generated by sensors, improved connectivity and new ways to visualise data. This enables ships to continuously communicate with managers and traffic controllers. At first this can be used to analyse data and give better advice based on expected weather, fuel consumption and arrivals at bottlenecks like ports and bridges. Later on this can results in unmanned vessels. Either remotely operated from shore, on autopilot or completely autonomous, as shown in figure 1. The different projects around the world follow this same path. Below some of these projects are mentioned with their current status.

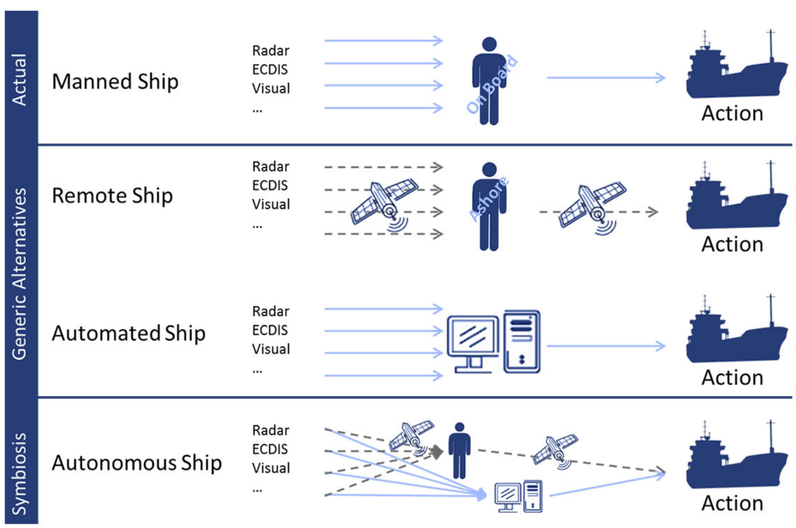

Figure 1: From manned to autonomous ships

The research project MUNIN consists of a constortium of shipbuilders and scientists. The name is an abbreviation for Maritime Unmanned Navigation trough Intelligence in Networks. They did an initial research. Focussing on different elements of an autonomous concept: The development of an IT architecture. Analyse tasks preformed on today's bridge and how this will be on 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 centre required to enable a remote control of the vessel. Thereby taking into account the feasibility of the developed solution, including legal and liability barriers for unmanned vessels. They concluded that unmanned vessels can contribute to the aim of a more sustainable maritime transport industry. Especially in Europe, 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 and environmental impact. An concept was developed for a bulker vessel, enabling the consortium to do a financial analysis. Showing the viability, but admitting the limited scope of the project [2].

1.2 Current industry projects

Rolls-Royce Marine is involved in different projects which are in some way follow-ups on the MUNIN project. Well-known are the videos of the virtual bridge concept and the Electric Blue. Electric blue is a concept ship, based on a standard 1000 Twenty foot Equivalent Unit (TEU) feeder. The ship is very adaptable, it can sail for example on both diesel and electricity. The modularity enables it to adapt for specific routes and meet environmental requirements now, and in the future. Keeping in mind the way towards autonomous, will it have a virtual bridge, housed below the containers. Utilizing the opportunities of sensors for safe navigation, employing radar, camera, IR camera, lidar and Automatic Identification System (AIS). The roadmap for this concept is to have partial autonomy by 2020, remote operation between 2025 and 2030, starting with a reduced passive crew on board. And be fully autonomous in 2035 [3]. To make these steps they were aware from the start on, that the control room is the nerve centre of remote operations. Using an interactive environment with screen for decision support and improving situation awareness with augmented reality. With these developments does their vision look very promising. However it is still in a concept phase.

Just like MUNIN did this project also originate from WATERBORNE, an initiative from the EU and Maritime Industries Forum, supporting cooperation and exchange of knowledge between stakeholders within the deep and short sea shipping industry. Since June 2017 is Rolls-Royce also involved in the unmanned cargo ship development alliance, which is initiated by Asian companies and classification bureaus. Many of the projects where Rolls-Royce is involved, has DNV GL also a role. But beside these projects they are involved in other projects which look very promising.

First the projects on Norwegian ferries, which are likely to start sailing automated from 2018, just like an automated shuttle service for offshore installations. Already a step further is the Yara Birkeland, and 120 TEU container ship. This vessel will initially operate as fully electric manned vessel, but plans are that it will sail autonomously in 2020. Operating between different Yara facilities, transporting fertilizers and raw materials. Kongsberg is responsible for the development and delivery of all key enabling technologies. Including the sensors and integration required for remote and autonomous operations, in addition to the electric drive, battery and propulsion control systems [4].

Where most of the previous projects were focussed around developing a vessel which has to operate in the current environment. Does the smart shipping challenge focus on combining technological developments within different parts of the inland shipping industry. This will help to steer ships remotely, smarter sharing of information and optimisation of waterway maintenance. A good example are the new vessels from Nedcargo, the Gouwenaar 2 and 3. These vessels will be able to transport more containers, while reducing the fuel consumption. This will not only be acquired by improving the hull shape and machinery, but also by sailing smarter. For example by optimising the speed, based on opening times for bridges and availability of the quay [5].

Praat met Boudewijn Baan - Sales Manager - involved vanuit Damen bij Gouwenaar

2 Knowledge of the crew

Seafarers are a group which are protected by international maritime treaties: International Convention for the Safety of Life at Sea (SOLAS), International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) and International Convention for the Prevention of Pollution from Ships (MARPOL). Despite the regulations does human behaviour still lead to most accidents at sea. This complex multi-dimensional issue affects maritime safety and marine environmental protection. It involves the entire spectrum of human activities, performed by ships' crews, shore based management, regulatory bodies, recognized organizations, shipyards, legislators, and other relevant parties, all of whom need to cooperate to address human element issues effectively [6]. Fortunately a lot of research is preformed around human behaviour, there is thus an opportunity to keep improving the way people are involved. And there capabilities are utilized while mitigating there vulnerabilities. The ships' crew is leading in this research. Therefore is looked at education they receive and how there knowledge developed. As this determines how they interpret a situation. Regardless of the entry level, every seafarer has to gain years of experience to earn the job title of ship captain, beside several licences and certificates.

extend which licenses and the amount of experience needed

Experience is helps to improve situation awareness, as the skill to scan for hazards is more developed [7]. Hereby is important to notice that situation awareness is not limited to perceiving, but has multiple levels. This is known as the Endsley model (figure 2), the three levels are [8]:

- *Perception*. Data is merely perceived.
- *Comprehension*. Interpretation of data, enabling understanding of relevance in relation to tasks performed and goals to be attained. Forming an holistic picture of the operational environment. Identifying the significance of objects and events in that environment.
- *Projection*. Making a forecast for likely future states of the situation . This is based on the interpreted data, experience and knowledge.

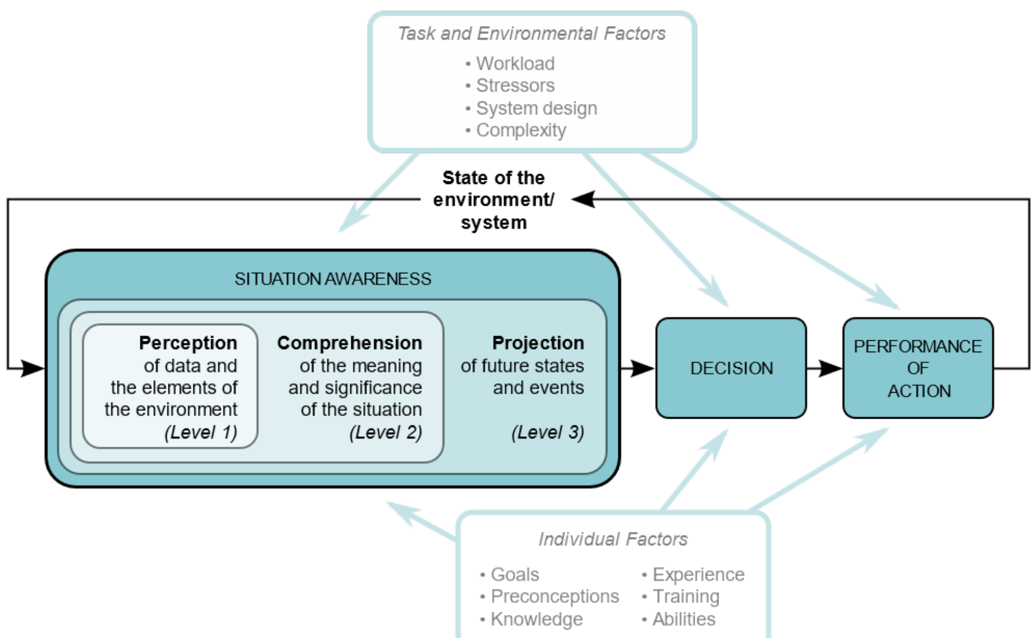

Figure 2: Endsley model for Situation awareness

To explain why someone predicts a future state that will occur, it is important to get insight in the mental model of the crew. The mental model is the mechanism which describes elements in the environment within a volume of space and time. Giving explanations of system functioning, observed system states, and predictions of future system states. Done for a specific representation of the real system, for only selected concepts and relationships [8]. The selected concepts and relationships are based on the background of the person. This is the reason why an economist and an engineer will have completely different mental models when looking at a ship. Where the economist sees it as an investment with related cost and returns. Will the engineer focus more on the way how it sails, propels itself and stays upright. The focus of the crew will be on the state of the vessel and the environment. Does the machinery work, what is the operational status of the vessel, what is the speed of the vessel, what is the wind and current speed, will they encounter bad weather, are there other vessels, does the vessel follow the planned route, etc. This means that a well designed bridge and a high quality planning are needed, to be able to understand the risks and know which information is desired when. When this does not happen loss of situation awareness occurs. This is according to Sandhaland, based on accidents at the north sea caused by: inadequate design, planning failure, communications failure, distracting elements and insufficient training. The consequences have been failure in monitoring the vessels status. For example if the steering was on auto-pilot or manual, detecting obstacles during bad visibility, or not receiving the right thruster status. In some cases it went a level deeper in situation awareness, where the crew received the information. But did not make the right decisions based on this. This was often because the crew was not aware of the risk involved and the effect of operating with the system configured in a specific way. For example when a thruster was deselected, lowering the redundancy [9].

http://www.imo.org/en/OurWork/HumanElement/Pages/Default.aspx

Captain/crew learns to sail a ship. Do this based on rules from for example IMO, but also based on experience. Experience helps to create an image of the world around them. This is also known as situation awareness. There are different levels of situation awareness (show picture). Last level is predicting. This is used to make decision. Can be rational and logical. Under stress this changes, therefore do they train. Well trained people have predictable mental models. Thus there choices can be transformed into a model. In case of captain/crew they ask themselves the following questions.

2.1 Situation Awareness

2.2 Decision making and behaviour

2.2.1 Normal situation

2.2.2 Under stress

2.3 Mental models

2.3.1 Theories

2.3.2 Questions by crew

3 Tool

As mentioned in previous chapter does the crew make decisions based on situation awareness, created by the information given. This information they do receive at the bridge.

From rules is given an bridge is equiped with .... screen, sensors, etc.

This has been so far mostly an evolution, with putting more equipment up. Leading to a possible information overlead.

There are projects at allewijnse/alphatron/praxis/Damen? who work on new bridge designs. This is the user interface of the ship.

Looking at design choices which can be made for an user interface you can find amount of screens, buttons/touch, offshore the demands are different. Thus should be changed.

This is higly related to information overlead and decision making under stress

3.1 Bridge design

3.2 User interface

3.3 Processable information

In the cases where the crew was not able to monitor properly, often the right information was somewhere on the displays. But as that

4 Model

4.1 Physical models

4.1.1 Manoeuvrability

How does the inertia of ship work, and movements due to props and rudder.

Abkowitz defined in 1964 a simple model where position (X, Y) and rotation (N) depends on speed, accelation and rudder angles. Including hydrodynamic forces and moments. This is needed to calculate the path.

4.1.2 Environmental forces

How are we going to model the wind, wave and current forces

4.2 Route planning

What are key issues in optimizing the route

4.3 Cost function

4.4 Monitoring

4.4.1 Environment

4.4.2 Ship

Conclusion

Wrap-up

write the scope of the project

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