Research topic presentation

PhD and Postdoc at IHB

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PhD starting in 2016

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PhD Thesis

Knowledge Management of University-Industry Innovation Projects

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Background

The research-based innovation projects between industry and university can amplify competitiveness of industry in the global market, build scientific quality, and develop innovative solutions for society. Anyhow, many of university-industry (UI) innovation projects end up in the so called 'valley of death' when the research results fail to be implemented in real life. Application of new knowledge is a prerogative for innovation and therefore it should be a focus in innovation projects.

Challenge to be investigated

Conflicting objectives of collaboration and different time horizons, where industry is looking for tangible short-term outcomes and academia is interested in publishing is one of the challenges to manage UI projects. The other challenge is differences in innovation approaches. Industrial companies innovate by doing, using and interacting with their stakeholders (DUI). Universities have a long-standing research perspective and use science, technology and innovation (STI) approach, which is based on explicit knowledge. The latest focuses on technological solutions rather than users' needs, so research results often fail to be implemented.

Research goal and objectives

This study aims to contribute to the knowledge management theory by solving the described challenges and answering research questions (1) how to define strategies and objectives to meet both partners' expectations, (2) how to facilitate the projects to amplify knowledge application

Industrial goals

Create practical Knowledge Management tools that will support University and Industry in conducting Innovation projects more effectively and efficiently such they deliver even more innovation.

Research methods

The context for the study are manufacturing companies and NTNU. The study covers so-called, 'User-driven research-based innovation'-type of projects. 'User' is the industrial company, which applies to the Research Council for financial support.

The semi-structured in depth interviews with projects managers on behalf of the industry and university are conducted. Moreover, informal interviews of the university-industry project group-members and observations of ongoing UI projects contribute to the study.

Based on the collected data, the knowledge management model of UI collaboration in the research-based innovation projects is created. For practical use, the model must me transformed in pragmatic form such as project managers of UI projects can use it on a daily bases.

Project managers from industry and university, representatives of the Research Council of Norway will validate the model. For this, the group interview will be conducted.

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PhD Thesis

Robotic cleaning of fish processing plants – Virtual tools, hygienic design and prototyping

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Background

Fish and seafood products are among the most valuable resources when considering ways in which to address the need for sustainable food sources in the future. However, any increase in fish processing production must be implemented in an environmentally sustainable way. The cleaning of fish processing plants and equipment the equipment used in such facilities has been identified as an area in which research has the potential to make significant contributions to the reduction of environmental impact, both in terms of the utilization of chemicals during cleaning and the general water consumption that occurs in the processing of fish and the cleaning of fish processing equipment and facilities.

Challenge to be investigated

Currently, the most commonly used cleaning practices in the fish processing industry involve manual operations, which are both subject to human error and unstable. Furthermore, the cleaning of fish processing plants is a demanding manual operation that is characterized by repetitive and stressful tasks. In addition, cleaning fish processing plants is also very costly; however, it is a necessary final step in the daily process of such facilities to ensure food safety.

Research goal and objectives

The overall research objective is to determine "How can fish processing plants be cleaned more effectively through the use of robotics?". This poses the following research questions (RQs):

1. How can a robotic cleaning system be designed such that it will outperform the manual approach to cleaning currently used in most fish processing plants?
2. How can modern design tools be utilized to enable rapid installation and commission as well as industrial performance on the part of novel fish processing equipment?
3. What are the hygienic design principles for fish processing equipment?

Industrial goals

Testing of a full-scale prototype in a close-to-real environment. The following research objectives (Ros) are set:

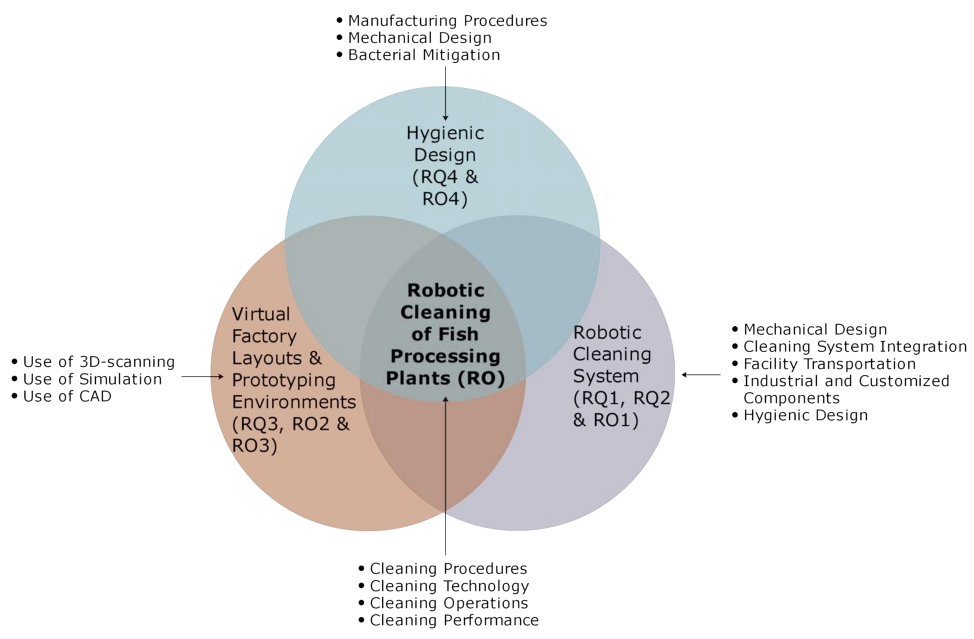
1. The proposal of a robotic cleaning system for fish processing plants that satisfies the requirements identified in this work for such systems;
2. The proposal of a method for enabling retrofit installations of said robotic cleaning system;
3. The proposal of a method to enable rapid installation and commission of such a system; and
4. The proposal of hygienic design principles for fish processing equipment.

Research methods

Prototyping is used extensively as a research method, both virtual and physical prototypes. Physical prototypes are needed as no analytical data which enables simulation of cleaning performance exists.

3D-simulations are also used with regards to virtual prototypes to evaluate reachability, dexterity, flexibility and goodness of cleaning paths.

The physical and virtual prototypes intertwine with each other, and the prototypes will be developed in iterations between virtual concepts and physical



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PhD Thesis

Model-Based Synthesis of Bioreactor Structures: Optimizing Biomethane Generation using Reactor Networks

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Background

Methane bioreactors (MBs) have become increasingly important in sustainable waste management, involving the generation of methane or hydrogen rich biofuels via biological degradation of organic & pathogenic pollutants.

MBs (Fig. 1) have different characteristics often making them more adequate to treat waste of specific characteristics and thus utilizing one reactor in one configuration may limit performance.

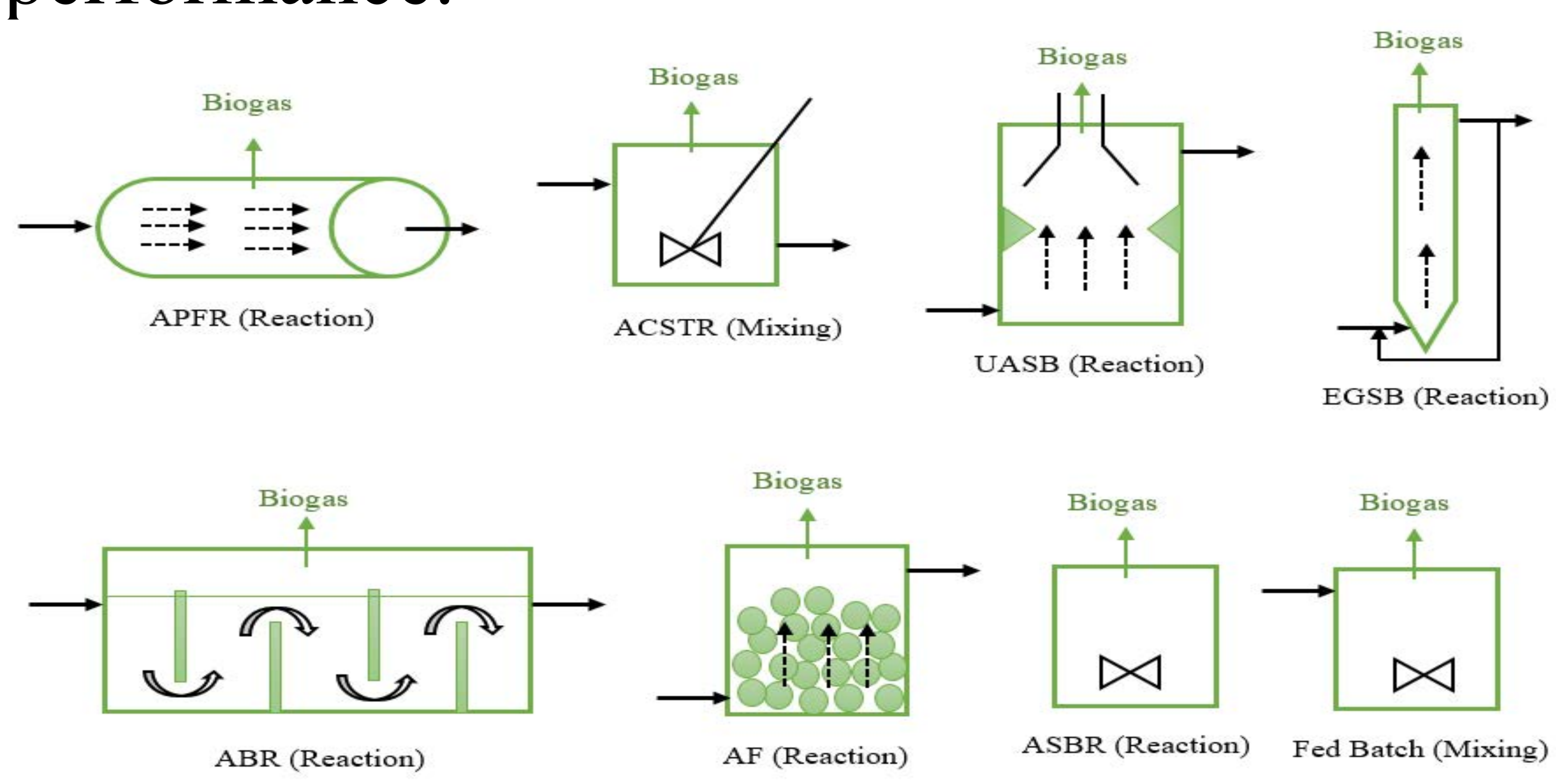

Fig. 1: Characteristics of single methane bioreactors

If designers begin to think about MBs in terms of reactor networks (Fig. 2) as opposed to single reactors (Fig. 1) then more effective designs may be achieved overall

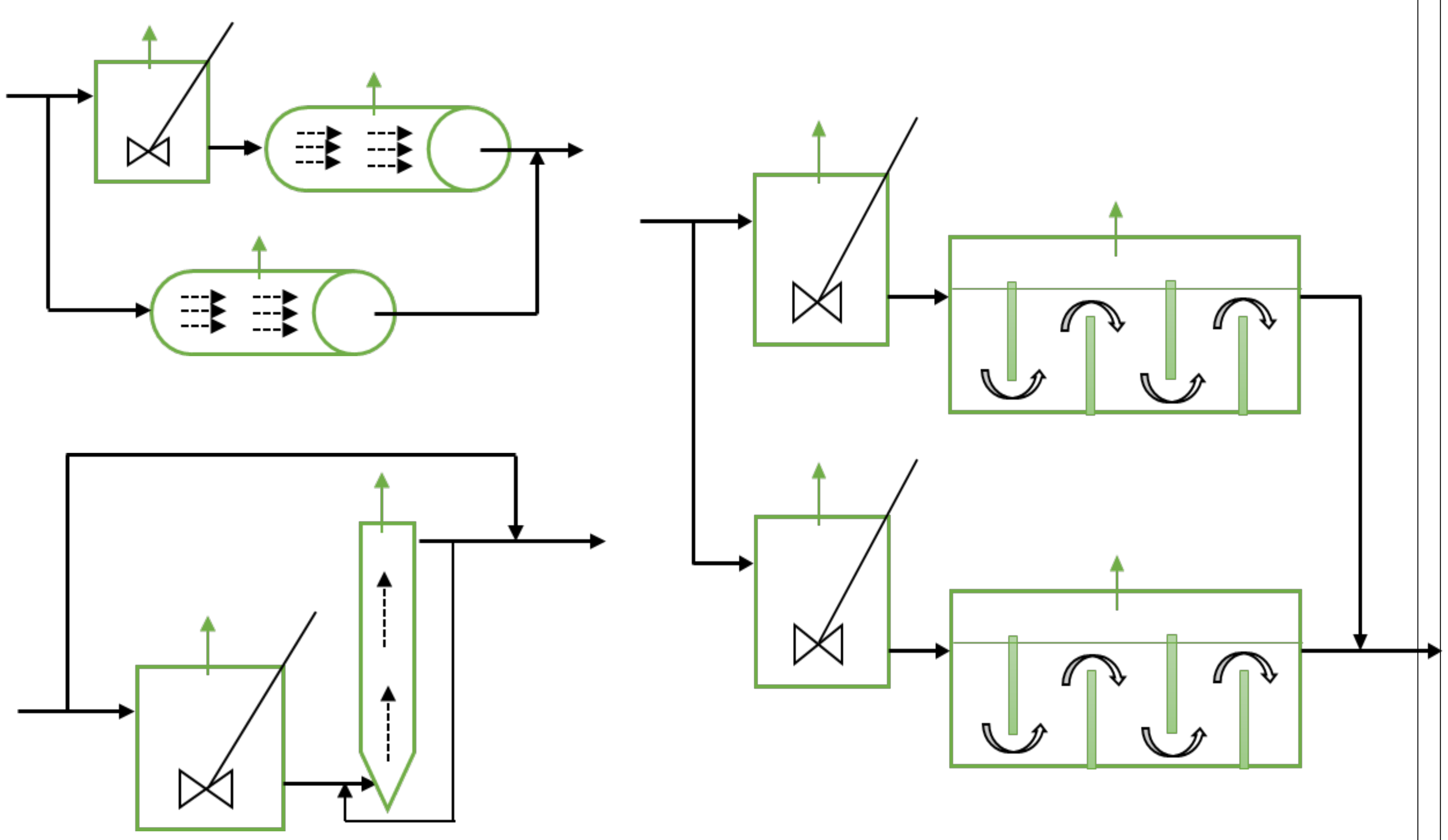

Fig. 2: Conceptual networks of methane bioreactors

Research goal and objectives:

Develop a dynamic model-based framework, which integrates elements of geometry, gradient-based optimization & stochastic simulation for optimal synthesis of methane bioreactor structures, considering both process and economic objectives:

1. Develop and calibrate simplified models of MB
2. Develop a framework for coupling process kinetics and reactor network synthesis with macroeconomic variables
3. Develop a self- optimizing synthesis framework that integrates uncertainty into bioreactor design
4. Develop model-based and decision support systems for synthesis of MB structures

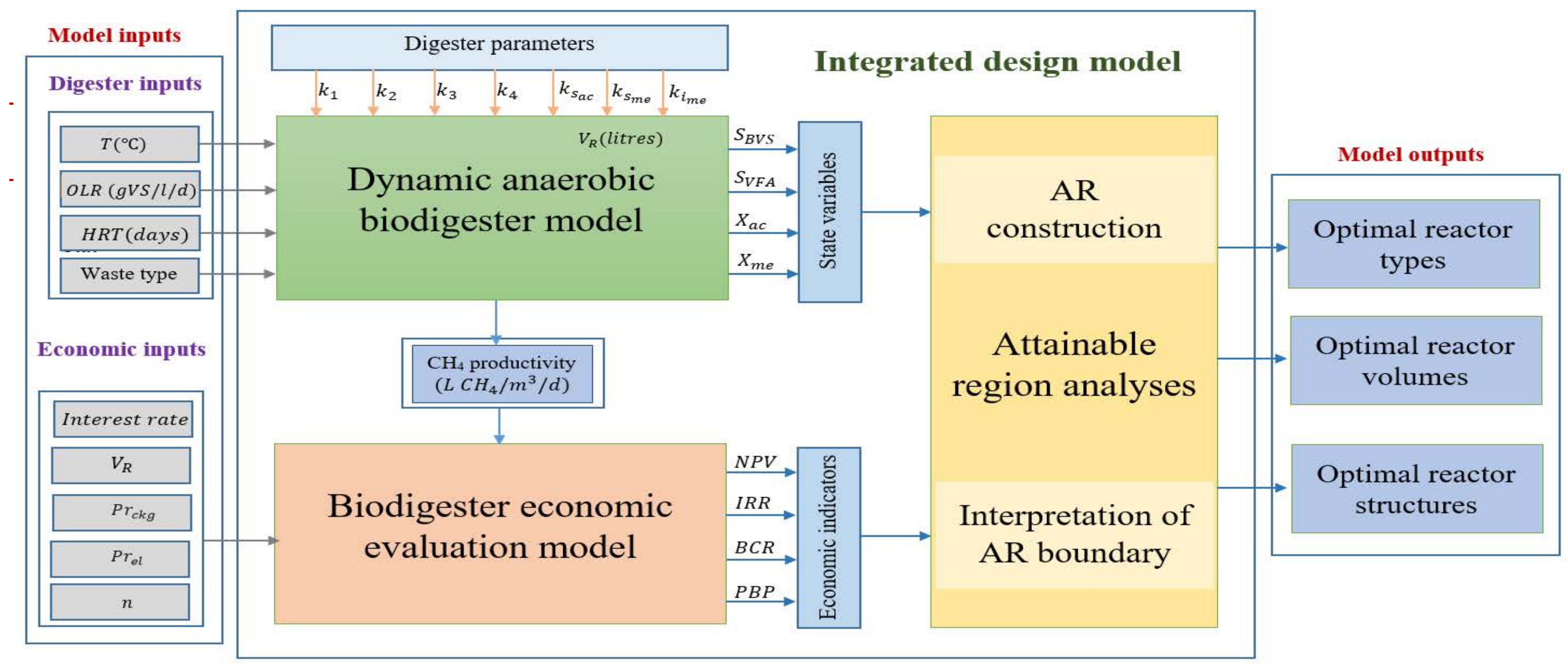

Fig. 3: Framework for optimal synthesis of MBs

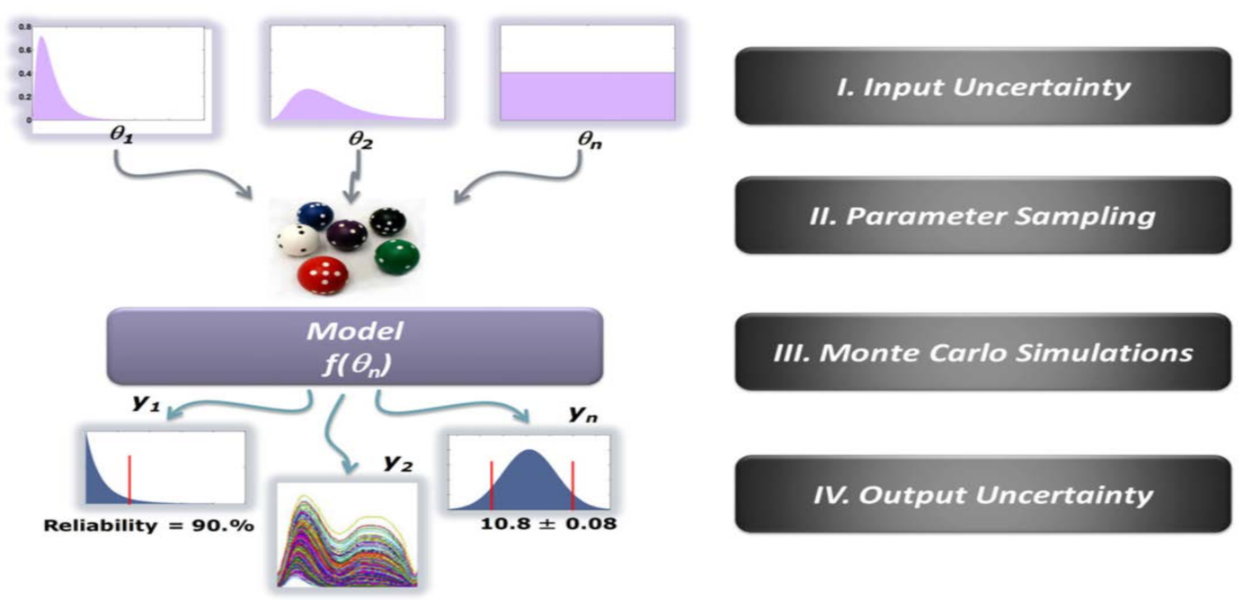

Fig. 4: Stochastic simulation for robust design of MBs

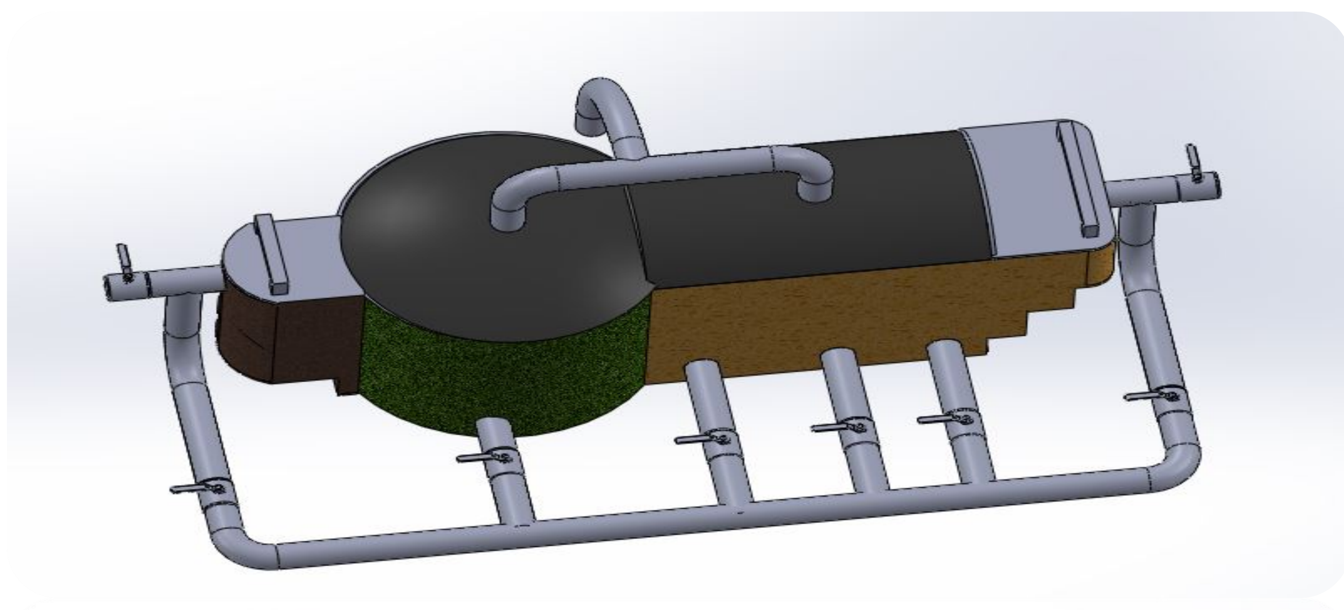

Fig. 5: Concept of optimally synthesized prototype of MB

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PhD starting in 2017

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PhD Thesis

A Systems Approach for Sustainable Management of Cruise Tourism Destinations

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Background

Although the Cruise industry contributes to generating jobs and income in tourism destinations there is a cost through environmental and social impacts.

Challenge to be investigated

Balancing the positive and negative impacts of cruise tourism is a challenging task for port operators and the information available to support decisions when cruise ships call to port are often fragmented and limited. An impact or criteria could also be perceived different in importance or severity between ports and different stakeholders. The issue of sustainability connected to cruise ship operation is made up of more than the cruise ship itself. The cruise ship interacts with its surroundings and is part of processes making up a system. This PhD thesis will hence explore how cruise tourism destinations could use a systems approach to manage impacts to sustainability from cruise ships.

Research goal and objectives

The goal of the project is to develop methods that will enable cruise tourism destinations and stakeholders to assess impacts to sustainability from cruise ships in a more holistic manner.

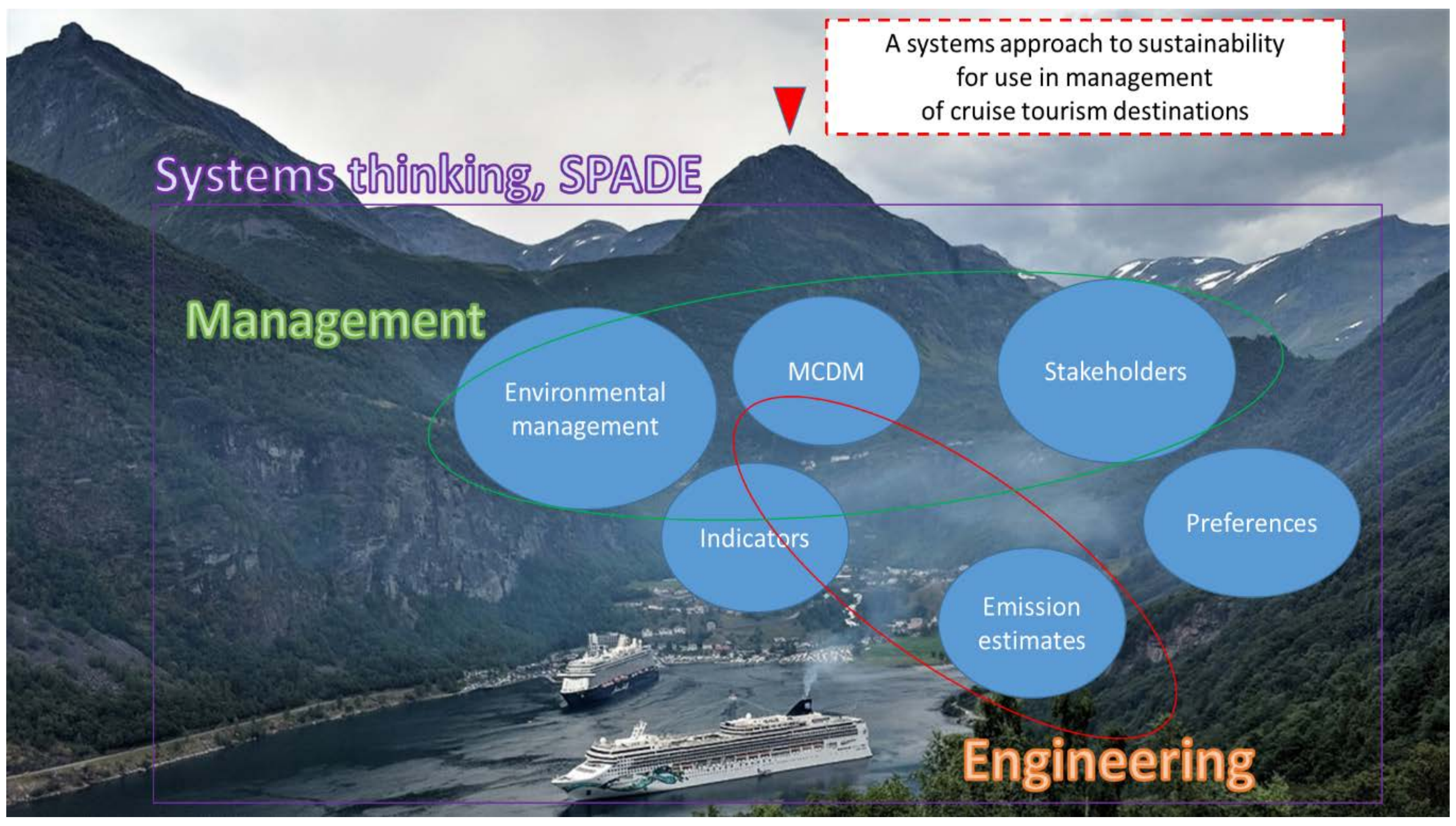
1. Develop a systems thinking based method for management of cruise tourism sustainability impacts from the destinations perspective.
2. Develop sustainability scoring system for cruise ships at tourism destinations
3. Apply models in case studies

Industrial goals

The developed methods will be implemented in a case study and tested for functionality. This will serve as a feasibility study for use in cruise tourism destinations.

Research methods

A multitude of processes and stakeholders are connected to the cruise ship activity. The interactions between the activities of the cruise ship and its impact to the destination can be defined as a system, where systems thinking could prove to be a useful concept to structure, understand and evaluate impacts to sustainability. The SUSTRANS project makes use of the SPADE methodology which also will be the case for this PhD. The acronym SPADE is short for Stakeholders, Problem, Alternatives, Decision-making, Evaluation. The alternatives will be expressed with sustainability criteria and performance. Multi Criteria Decision Making (MCDM) methodology will be used in order to define the desired alternative based on criteria score and weighting.



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PhD Thesis

Data-based Ship Motion Prediction in Offshore Operations

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Background

In offshore operations, safety and efficiency are of key concern. As the complexity of such operations increase, tighter operational constraints are put on the vessel. These constraints may be in terms of position accuracy or collision avoidance capability when operating in a congested or confined area. Motion prediction can aid in this respect by increasing the knowledge about the states of the vessel in the near future.

Challenge to be investigated

When performing machine learning and using such models for prediction, determining the architecture is important to reach a balance between its performance in terms of prediction accuracy and computational speed/model complexity. Furthermore, deciding on which input, among a large set of measurements, to use should be based on information content in relation to a given model output.

Machine learning methods have the benefit of being adaptive and independent of a specific mathematical description of the vessel.

Research goal and objectives

The goal of the project is to develop methods that will enable prediction of ship motion within the near future (< 30 seconds). Machine learning models based on the general methods will support applications for situational awareness, and dead-reckoning.

1. Develop methods for constructing prediction methods based on measured data.
2. Perform validation of methods on real data.

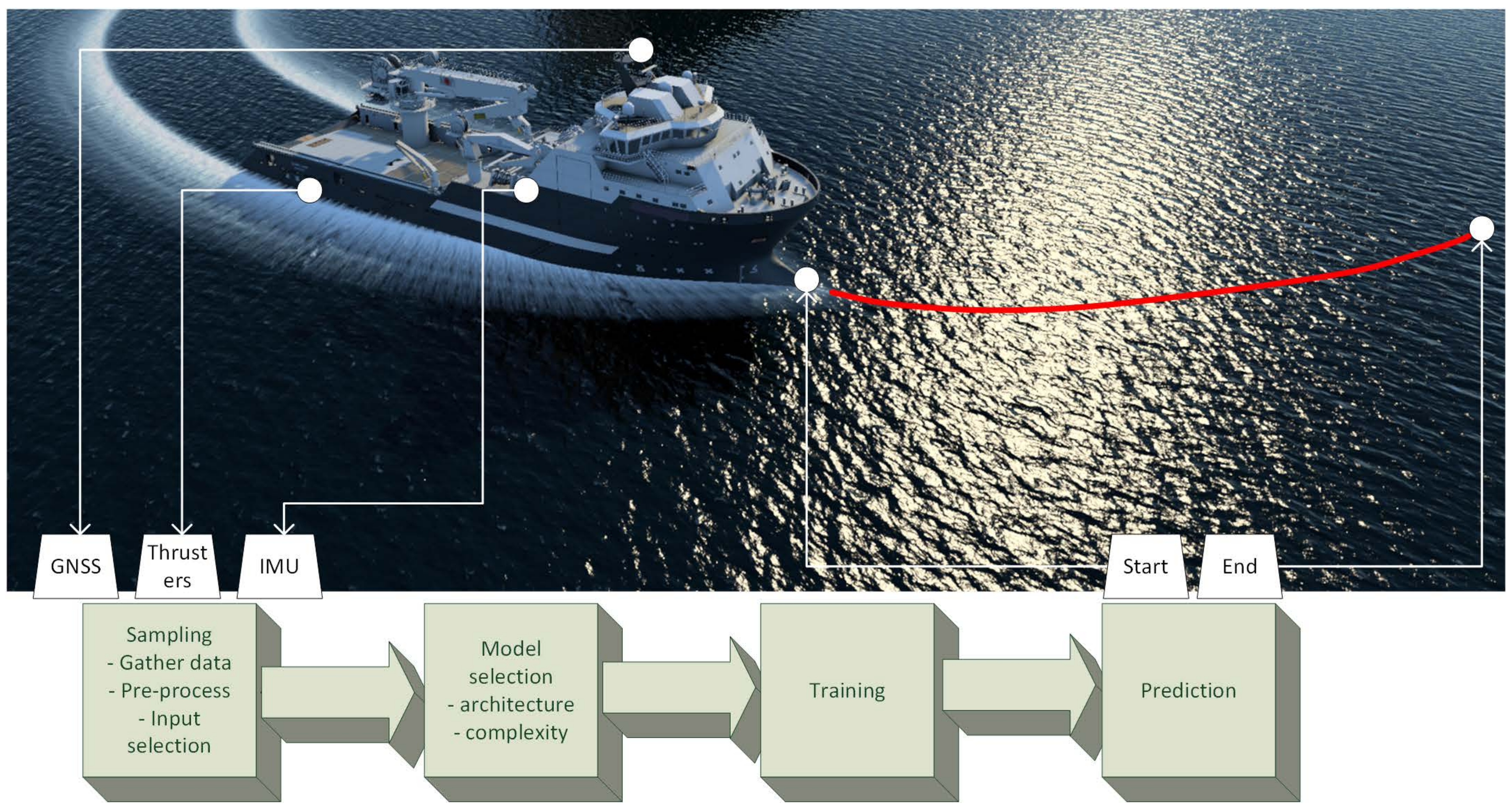
Industrial goals

The developed methods will be implemented in a simulator and tested for functionality. This will serve as a feasibility study for use in marine operations. Examples of applications:

1. Dead-reckoning: maintaining position estimates without GNSS by data-based models
2. Situational awareness: predicting future position and the future vessel motion in general.

Research methods

Through sampling, statistical analysis of data and model assessment, machine learning methods will be evaluated. Important criteria to ensure that the generated prediction models are fit for purpose include real-time operation, adaptability to non-stationary data and accuracy. Simulation studies will be performed to gauge the effectiveness of a given application, while validation will be performed based on sampled data from a real vessel.



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PhD Thesis

Human in the Loop for Remote Ship Operations

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Background

The concept of unmanned ships capable of being controlled remotely is now beyond the idea and will start a revolution in the maritime industry. In this context, remote ship operations refer to processes of controlling the vessels from distance such that operators obtain information from sensors. Thus, the improvement of human interactions can enhance the overall performance of the system. However, there are unknown human-human and human-machine relationships in remote ship operations.

Challenge to be investigated

One of the major challenges of remote operations is human interaction particularly human-machine and human-human interaction, which make complex systems with unpredicted behaviours. In this context, identifying human interactions and developing human interaction frameworks is a paramount question. This is a distinct view compared to today's practices, and it is the main core of the current PhD project that safety and efficiency can be reached by better understanding and analysing human interactions. More important, there is currently a gap between real operation, remote operation and design for remote operations, which is intended to be tackled in this project.

Research goal and objectives

Human operators are key components of the shore control centers (SCCs) and their performance and efficiency directly affect remote ship operations. This implies that study the human-human and human-machine interactions are highly important to implement remote ship operations. Hence, the current project focuses on study the human interactions and underlying mechanisms of human behavior during the remote ship operations, especially within the SCCs.

Industrial goals

Most of the current autonomous forums focus on technological aspects, in this respect, ignoring human behaviour as a critical sub-system in a remote-controlled environment can degrade the overall performance. However, this represents a gap in the conceptualization and operations of a remote ship environment. Hence, the current study focuses on this industrial gap and gained knowledge could be used by designers and engineers in all design phases of SCC.

Research methods

There are different methods and techniques for human factor engineering (HFE) which can help to study human and organizational concerns. In the current project, HFE methods including similar systems analysis and operational analysis are utilized to analyse systems in order to provide data about human performance and human interactions. Besides, the current project focuses on utilizing physiological sensors especially Electroencephalography (EEG) in order to implement human-centered experiments.

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PhD Thesis

Data-driven Prognostics and Health Management Solutions for Autonomous Ships

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Background

The maritime industry widely expects to have autonomous and semi-autonomous ships (autoships) in the near future. Ultimately, autoships will have no maintenance personnel on board ready to perform periodic maintenance when needed. Therefore, autoships demands real-time operational sensor data that will be transferred back to an onshore control center to conduct diagnostics and prognostics of critical systems and components.

Challenges to be investigated

Deep learning (DL) is a potent area for this development, as it is rapidly finding applications in a variety of domains, including both self-driving cars and the aviation industry. Prognostics and Health Management (PHM) is the area of research with the greatest promise to manage maintenance operations for zero-downtime performance of autoships. A data-driven PHM system goes far beyond traditional maintenance approaches, such as reactive maintenance and preventive maintenance, and can use DL algorithms to perform automatic fault detection, fault isolation, fault classification, and associated remaining useful life (RUL) predictions to devise an ideal maintenance schedule that eliminates failures.

Research goal and objectives

Develop a novel data-driven PHM system. The system will include cutting edge diagnostics and prognostics approaches.

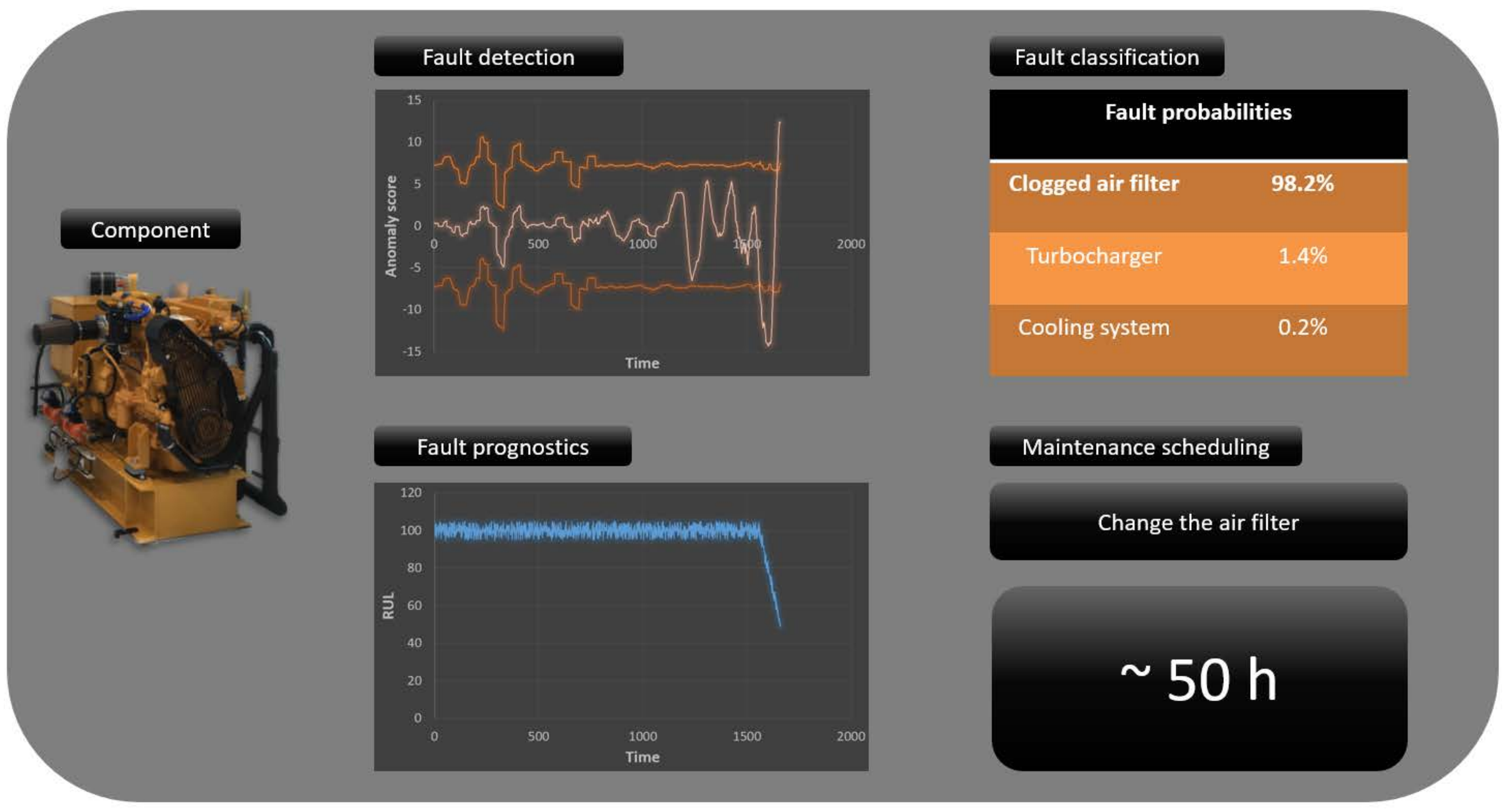
1. Develop fault detection algorithms suitable for autoships.
2. Develop prognostics algorithms to optimize maintenance schedules for autoships.

Industrial goals

The project should bridge and implement the research results into practical demonstrators for the maritime industry. Thus, there will be a strong industry involvement in order to gather real-life sensor data from different ship components. The data will be in focus to
Case A: Use fault detection to provide early warnings and automatically construct run-to-failure targets.
Case B: Predict the remaining useful life (RUL) of different components using DL.
Case C: Perform tests on the hybrid power lab at the NMK2 facilities.

Research methods

First, data gathered from computer simulators and the benchmark publicly available Commercial Modular Aero-Propulsion System Simulation (C-MAPSS) dataset will be used for algorithm development and refinement. Finally, the most appropriate diagnostics and prognostics approaches will be used in case studies where real-life sensor data will be gathered from both the industry and the NMK2 facilities.



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PhD Thesis

Real-Time Simulation of Nautical Operations: The Effect of Ship Dynamics and Control Design Approaches in Guidance, Navigation and Control of Remotely Operated Vessels.

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Background

This popular belief is being challenged: "Unmanning (or autonomy) reduces costs and increases safety, while key supporting technologies are already available in 2018." As we prepare for the future of shipping and ocean operations, development of technology is as crucial as challenging the technology and revealing its limitations.

This thesis considers the man-machine relationship in highly automated ships, where the relationship is broken down to three areas: Hydrodynamics; Control; and Human Factors.

Challenge to be investigated:

The human-machine relationship is investigated through three lenses: First, the performance of hydrodynamic models is investigated and the uncertainties are presented. Second, the effect of hydrodynamic uncertainties in performance of ship controllers. Third, the effect of increased automation on human operators in charge of running safe business.

Research goals and objectives:

The main goal is to communicate the challenges between engineering fields, such as hydrodynamics and control, and nautical science fields such as navigation and human factors.
This will be acheived by help of presenting uncertainties in hydrodynamic models and the propagation of such uncertainties as ship control is delegated more navigational tasks.
Imphesizing the unintended human factors as a result of the automation paradigm shift.

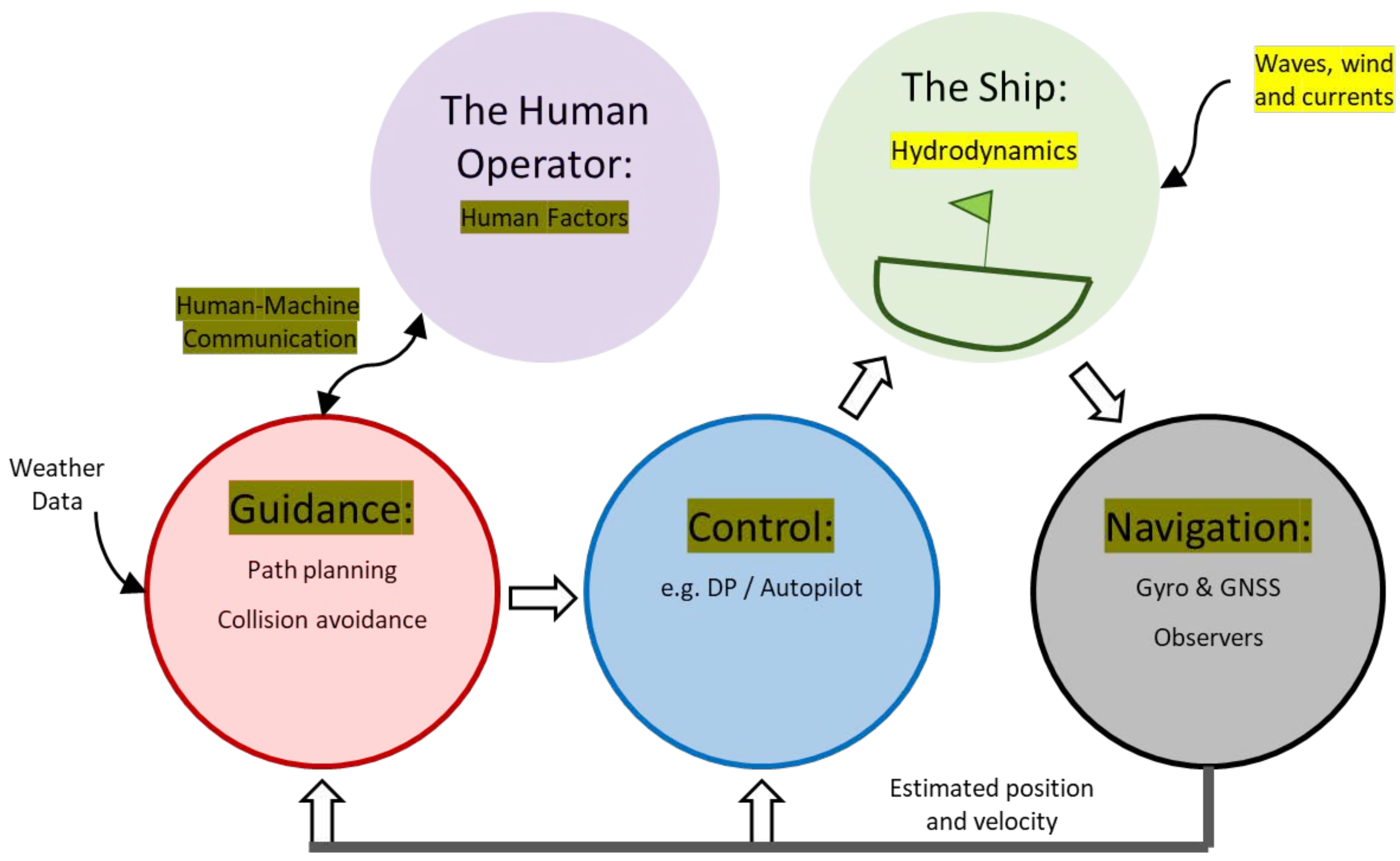
Industrial goals

Industry challenges of today are multidisciplinary non-linear problems and communication among different fields is more important than ever.

1. This thesis serves as communication tool between the engineering and cybernetics fields and the human factors field in the domain of maritime operations.
2. The project allows testing remote control concepts way before manufacturing.

Research methods

This research includes literature reviews in the fields of hydrodynamics, simulations, cybernetics, and human factors.
Experiments involve coding and comparing of state-of-the-art hydrodynamic models.
Experiments involve testing in a simulator and comparing quantitative real-time motion data.
Surveys or interviews involve domain-expertise opinions on tested control strategies.



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PhD Thesis

Data analysis and quality assessment of data-driven models for offshore operations

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Background

Offshore operations are complex and hazardous due to the significant uncertainties and various operating conditions. Operational safety is a major issue and is easily challenged by harsh marine environments, complex geological conditions, human and equipment factors. The conventional model-based solutions require an in-depth knowledge of the offshore operations, which are impractical for complicated offshore operations. With the rapid development of technologies such as data collection, data mining and artificial intelligence, the extraction of useful information has been significantly improved in the offshore operations, which can be used for efficient operational monitoring and improving the mathematical model.

Challenge to be investigated

1) the sensor data to be analyzed are usually too large and high dimensional;

2) the sensor data usually contain measurement-induced noise and redundant information, which makes it difficult to analyze accurately;

3) It is not easy to intuitively interpret the data from multiple sensors. Furthermore, there are many uncertainties in these data, which are influenced by a variety of factors, such as weather conditions, human factors, and so on.

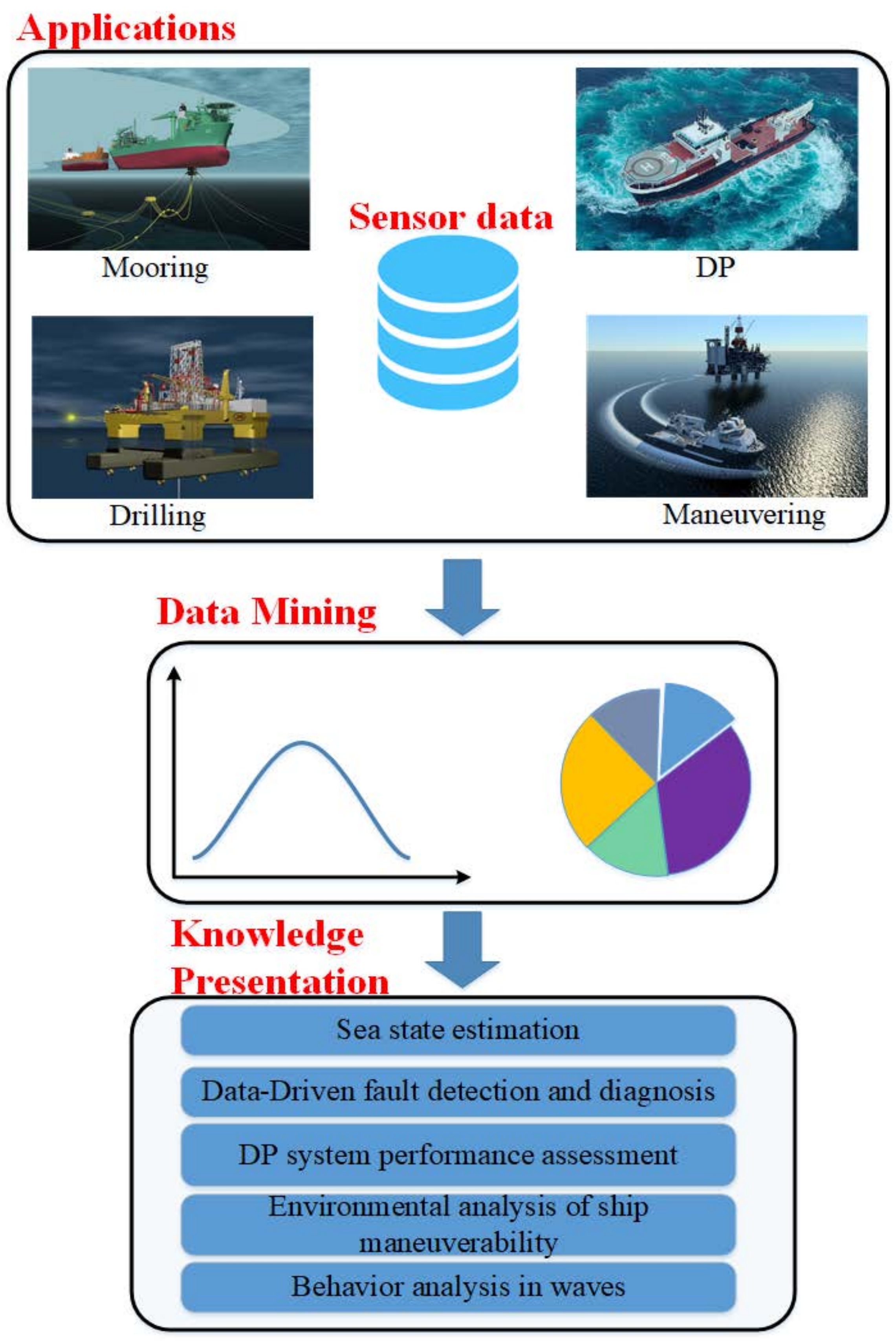
Research goal and objectives

The objective of this PhD project is to increase safety and efficiency of vessels operating at sea by improving the data-driven modeling techniques and analyzing the influence of environmental factors based on the offshore operation data.

1) Develop methods for sensitivity analysis that is able to improve the data-driven models with the sensor data of offshore operations.

2) Develop methods used for analysis of environmental factors to determine their impact through case studies in simulator.

3) Use data gathered from a real vessel to validate the results obtained from running the methods in simulators.



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PhD Thesis

A CROSS-MODAL INTEGRATED SENSOR FUSION SYSTEM FOR FATIGUE AND AWARENESS ASSESSMENT IN DEMANDING MARINE OPERATION

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Background

Marine operations are becoming every day more demanding and their complexity increases even further when the coordination among professionals operating e. g. vessels, cranes, winches and ROV needs to be taken into account.

A number of studies conducted by various maritime organizations reported that more than 75% of ships accidents worldwide are due to human and organizational errors and a majority of human errors (71%) fell under situational awareness challenges.

Challenges to be investigated

Monitoring operators during demanding task in order to assess their mental fatigue state is a very challenging task. Specially regarding the design of a non-invasive and reliable system. So, the appropriate selection of sensors and data channels is the initial challenge to overcome. Machine learning techniques can be used to process the input data and output the assessed mental fatigue level. The correct design and application of the machine learning algorithm is essential for the success of the proposed method.

Research goal and objectives

The main concept consists of a multi-sensor monitoring system that will evaluate human awareness and fatigue and the quality of the marine operations.

The main objectives for this research are:

- Concept design of a cross-modal multi-sensor fusion system for fatigue and awareness assessment in demanding offshore operations;
- Developing the cross-modal cognition algorithm for human fatigue and awareness assessment.

Industrial goals

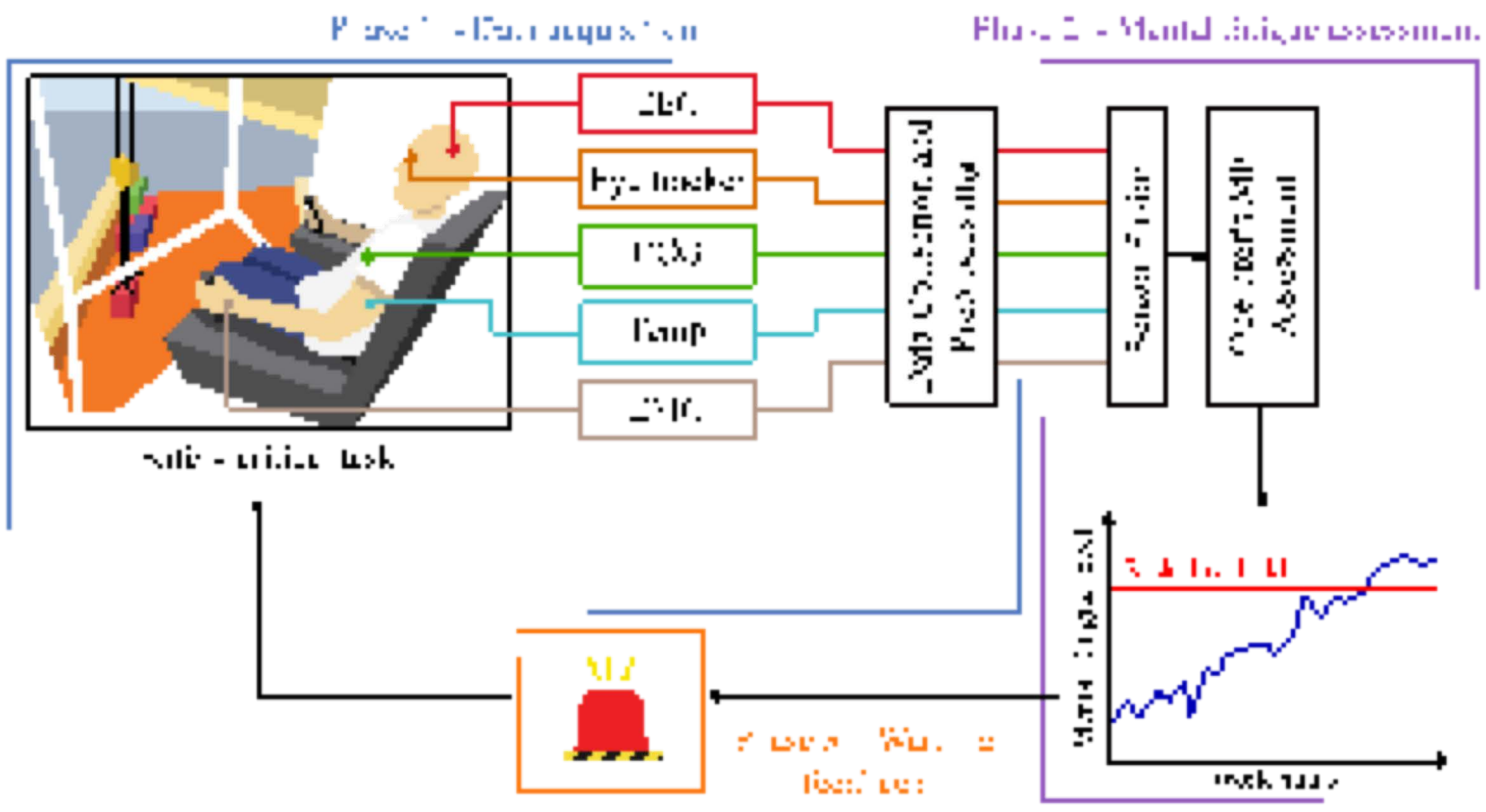
Develop methods and tools that help understanding the operators working conditions with good accuracy, providing:

- More reliable evaluation of fatigue and awareness during demanding maritime operations;
- Means for the industry to improve operational safety and effectiveness.

Research methods

Develop an integrated multiple sensors facility for monitoring different body parts of human operators, where loss of concentration or fatigue can manifest.

The disparate sensory data will be handled using sensor fusion techniques, and data evaluation will be conducted based on physiological studies.



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PhD Thesis

Human-Centred Approach to Maritime Autonomy

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Background

Introducing autonomy in the maritime industry is to a large degree seen as a technology challenge. Even though autonomy imply that it will be less humans on the vessels, it is still a need for humans to supervise and control the operation.

Challenge to be investigated:

An isolated focus on components and technology will fail to identify the safety of the system and collaborating systems

The coexistence of conventional and autonomous vessels in the maritime industry is therefore a complex socio-technical challenge that needs to be understood in a system perspective. The Vessel Traffic Services (VTS) is a control system that will experience new challenges, but could also be one key component for the success of the future Maritime Traffic System.

Research goal and objectives:

The main research question for the project is *"which maritime systems will interact in a future with incremental autonomy, and how can we evaluate the effects of change to these systems?"*

1. Describe the human role in maritime autonomy
2. Identify how VTS-operators cope with complexity
3. Explore a socio-technical perspective on the future VTS
4. Discuss how a future VTS could facilitate for safe coexistence between autonomous and conventional vessels

Industrial goals

The industrial benefits of the project will be:

- Save time and cost for developing future maritime systems with autonomous solutions since changes will be done in an early phase of the development
- By creating a system language the designers, manufacturers, ship owners and regulators could discuss concepts in a unified way
- The system perspective discover and eliminate potential system failures in the design phase and increase the probability for designing systems that are as safe or safer than existing solutions

Research methods

The project will combine systems theory and a human-centred approach to include stakeholders and operators to design future systems to meet the challenges and benefits of autonomy.

The project uses a Cognitive Task Analysis to identify the situation for the VTS-operators. Navigation simulators are used to explore future scenarios. Finally, a human-centred design thinking process is applied to identify the future role of the VTS.

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PhD Thesis

Protocols and standards for co-simulation and simulation

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Background

Simulation tools available in the market today provides little flexibility in terms of integration of models from different sources (other tools/languages, Industrial Internet of Things devices …), and/or coupling with a dynamics engine (AGX Dynamics, Open Dynamics Engine, Bullet , FHsim …).
Furthermore, existing tools tends to be inflexible with respect to how a simulation can be presented or controlled. Interaction and presentation of simulations are typically provided within the constrictions of the software itself, with limited or no options for custom access from the outside.

Challenge to be investigated:

Most frameworks today are focused on modeling behavior and behavior only, like 20Sim, OpenModelica, SimulationX, MATLAB and other typical engineering tools. By separating a model's properties and behavior, simulation scenarios may be re-used with different level of fidelity and allows behaviors to be changed more easily during runtime.

Also, when combining models and/or components from different sources in a co-simulation, main challenges is related to accuracy, data-exchange, stability and the protection of Intellectual property.

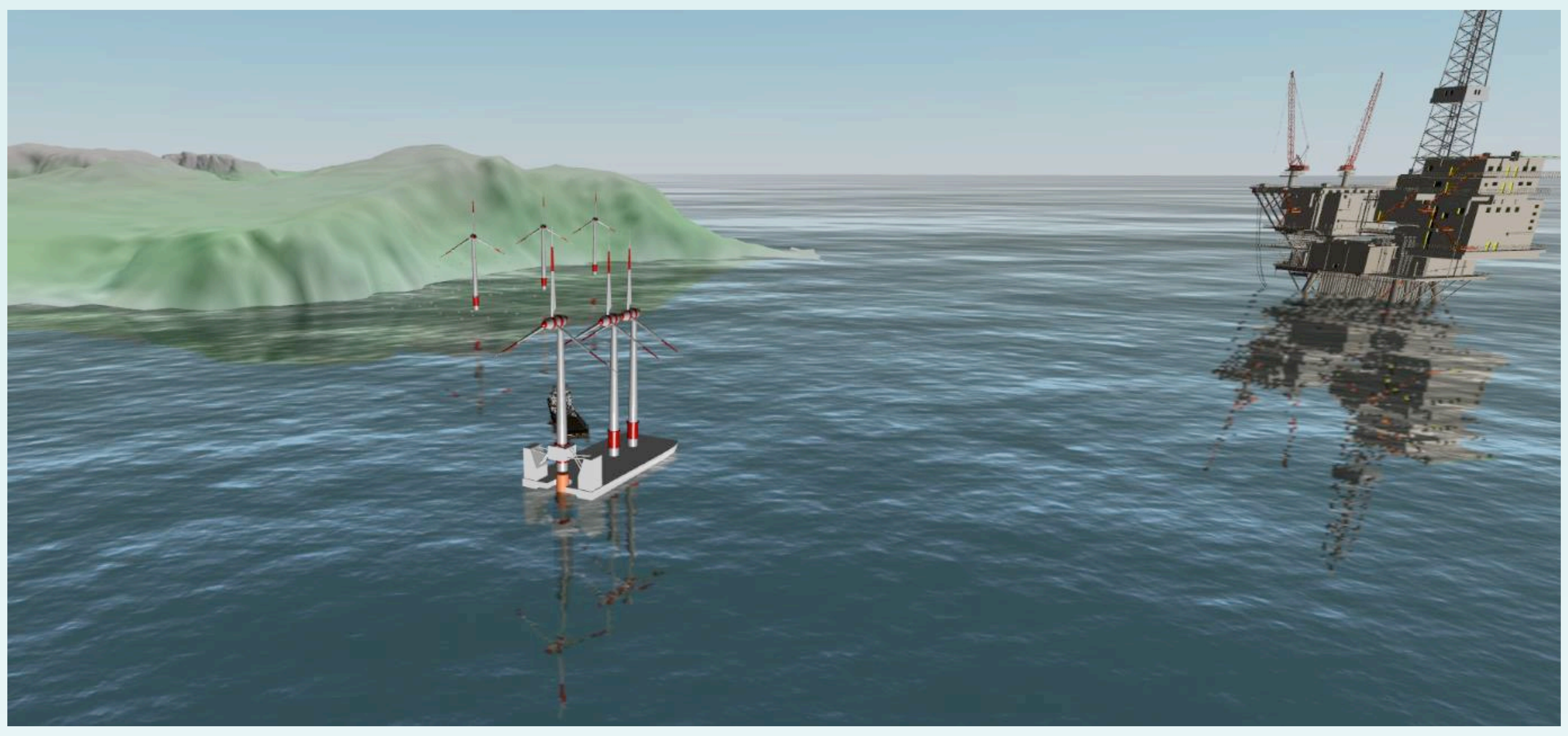

Figure 1: Early simulator prototype

Research goal and objectives:

The goal is to create a generic open-source simulator framework, with a strong focus on maritime use-cases, which can provide flexibility for the user in terms of what to simulate, how to simulate and how to present and control simulations, looking at simulations beyond behavior only. The solution should provide the ability to define simulation scenarios where the user can easily select which behavior models to use prior to execution, and also during run-time.

Some of the project's aim is to:

- Help drive adoption of the Functional Mock-up Interface (FMI) for simulation of heterogenous systems by providing easy to use software packages for local and distributed execution of Functional Mock-up Units (FMUs).
- Help drive adoption of the System Structure & Parameterization (SSP) standard by supporting it in developed software.
- Establish a stable and effective co-simulation environment through investigation and implementation of state-of-the-art master algorithms for co-simulation.
- Contribute to the Open Simulation Platform (OSP) initiative.

Industrial goals

The project should result in open-source software packages for simulation and co-simulation that can be used by the industry in order to facilitate or enhance the use of simulation in the company.

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PhD Thesis
Data-based Models from rapid virtual prototyping

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Background

In the advent of remote operations and autonomous operations, digital twins and virtual prototyping with fast iterative design and engineering process are keys to the success of the Norwegian maritime and offshore industry. Streamlining the creation and refinement of accurate and performant rig, ship, and equipment models is essential in this respect. Other applications include on-board augmented reality: showing tensions, predicting wave or current patterns.

The Functional Mockup Interface (FMI) standard has gained traction to be the co-simullation framework in the maritime industry. Sea trials are a costly task to perform to assess the quality of a delivered ship, but a lot of uncertainty persist due to lack of repeatability of the environment and expensiveness. Virtual Sea Trials can be far less costly if they were trustworthy.

Challenges to be investigated

FMI is perfect for modelling modular design, in which the system is composed on sub-components, but not for modelling the environment which is pervasive and can be potentatially connected to every FMU in the co-simulation.

Benchmarking ship models in virtual see trials is a necessary task for assessing the quality of the simulation and its subsequent predictions. The questions to be answered are not trivial on both the theoretical and the implementation phase.

Research goal and objectives

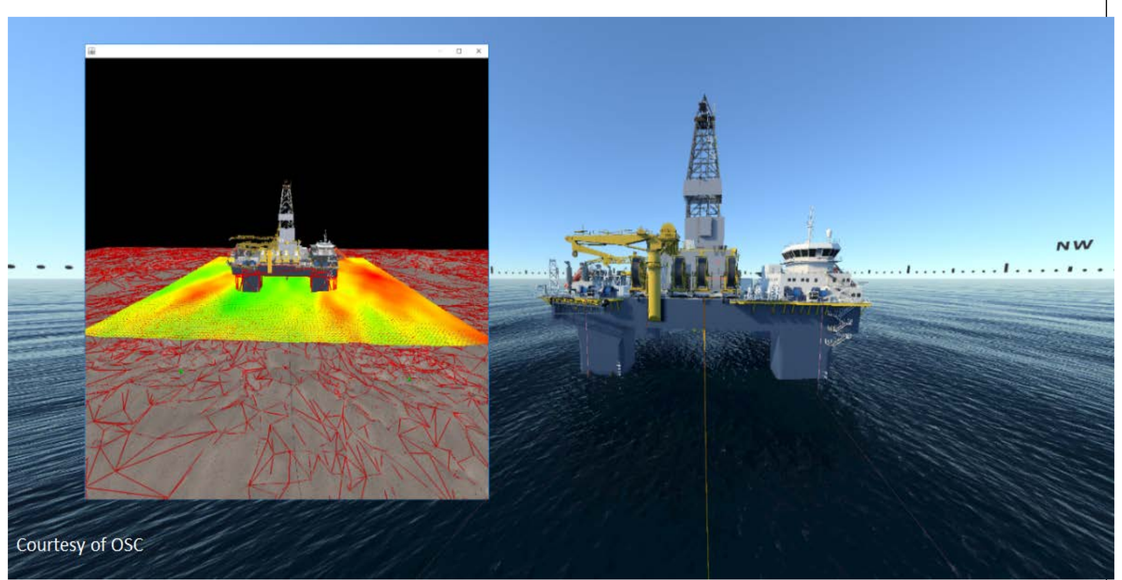
The primary objective is to create a 100% data-driven time domain ship model. The secondary objectives are to build and **an offshore operation sensor fusion in a virtual prototyping simulator, derive a machine learning prediction tool based on the sensor data, develop a model quality assessment model**

Industrial goals

Dramatically shorten the Life-Cycle of product development of maritime systems thanks to the creation a rich library of FMU models for fast virtual prototyping, a standard for sharing the environment, and methodologies for virtual sea trial benchmarking

Research Methods

Develop faster methods to create models
Develop data driven generic FMU models by combining machine learning and IoT
Develop an FMI compatible version of the environment
Develop methods for benchmarking models



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PhD Thesis

Ship Digital Twin - A Standard for Life Cycle Data Format

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Background

Currently, digital processes in the ship life cycle are handled with multiple software tools and data formats. The digital twin aims to improve handling of vessel data by aggregating the digital models of the vessel during earlier stages of the life cycle and simulating the behavior of the vessel as built during operation. The digital twin simulations can be used to support operational decision making and to obtain feedback insight for future designs.

Challenge to be investigated

To assimilate all the models pertaining to a complex system such as a vessel in a consistent manner, a digital twin will require the adoption of standards. The standards would ideally allow the seamless exchange of data among the life cycle processes, translating to a better information flow through the value chain.

However, standardization is a demanding task and previous efforts encountered business challenges that lead to low adoption in the industry.

Research goal and objectives

This project aims to investigate standardization to enable effective data usage during the vessel life cycle with a digital twin. The objectives are to:

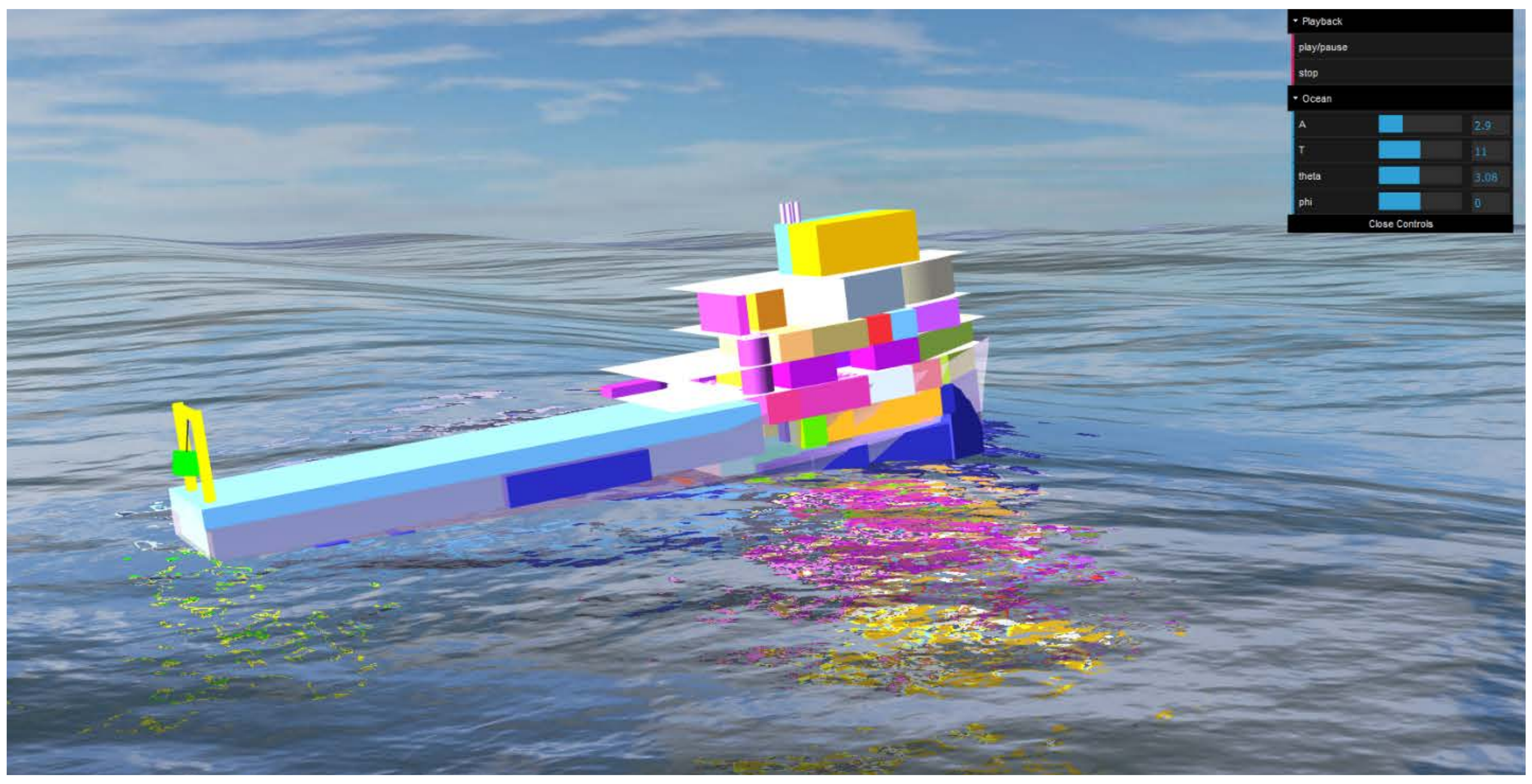
1. Identify the key elements for a ship digital twin standard in the life cycle.
2. Propose standardization methods for the most significant elements identified.
3. Evaluate the effectiveness of the standards with case studies.

Industrial goals

The research follows an open approach, relying on open source libraries to develop software tools which in turn are also shared as open source. Thus, the code can be adapted or modified for suitable industrial applications. The research publications can also be used as discussion papers in standardization efforts for ship digital twins and life cycle data, for example standardization consortia.

Research methods

The project requires combination of computational and experimental methods. The application of product data management principles is necessary to create a ship model for design and manufacturing with data such as CAD geometries and hydrodynamic analyses. On the other hand, the usage of the digital twin to mirror and simulate the model's behavior in real-time will require the realization of experiments.



The research investigates web-simulations as a tool for creation and standardization of ship digital twins.

Supervisors

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PhD starting in 2019

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NN

PhD Thesis

Data Mining of Ship Status for Onboard Supporting

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Background

The scale of the maritime industry in Norway has experienced a noticeable increase in recent years. Ships are of great concern for economical and safety reasons. In general, there are various sensors installed on the ship, some of which are used in real time for maneuvering and related actions, and some of which are placed in sensitive areas like propeller blade to collect the data for future purpose such as system diagnosis. The data on the vessel has been stored for years in huge size.

Challenge to be investigated

Even though the ship industry has saved millions of data for different kind of vessels, the raw data is usually meaningless unless useful information is extracted. Different systems in the vessels usually provide different type of data, the data is needed to be fused together in a systematic way. Data mining and machine learning technique is used for these purposes. Furthermore, deciding on which input to use among a large set of measurements is critical and highly depend on the desired information content needed to be extracted.

Research goal and objectives

The goal of the project is to develop methods that will enable the estimation of current ship status and prediction of future ship. Data mining technique and machine learning models will support applications for fault diagnosis and prognostics, and onboard supporting.

1. Develop methods for estimation and prediction methods based on measured data.
2. Perform validation of methods on real data.

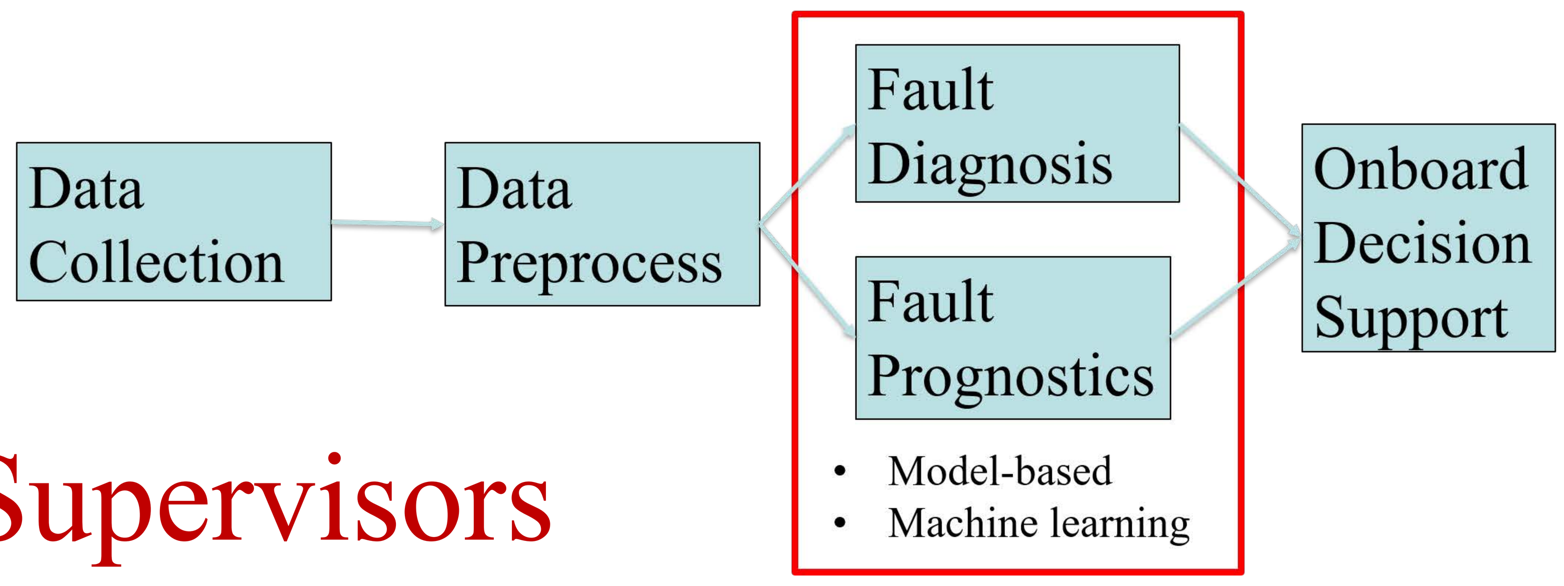
Industrial goals

The developed methods will be implemented in a simulator and tested for functionality. This will serve as a feasibility study for use in marine operations. Examples of applications:

1. Fault diagnosis and prognostics: detect, isolate and identify the faulty component and predict its remaining useful life.
2. Onboard supporting: provide useful information for better onboard decision.

Research methods

Through statistical analysis, data mining technique and machine learning algorithm, the current status of ship will be estimated and future status will be predicted. Important criteria will be set to provide the models with real-time operation, adaptability to non-stationary data and accuracy. Simulation studies will be performed and sampled data from a real vessel will be used to gauge the effectiveness of a given application.



Supervisors

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PhD Thesis

Ship Response Prediction for Manoeuvring in Confined Waters

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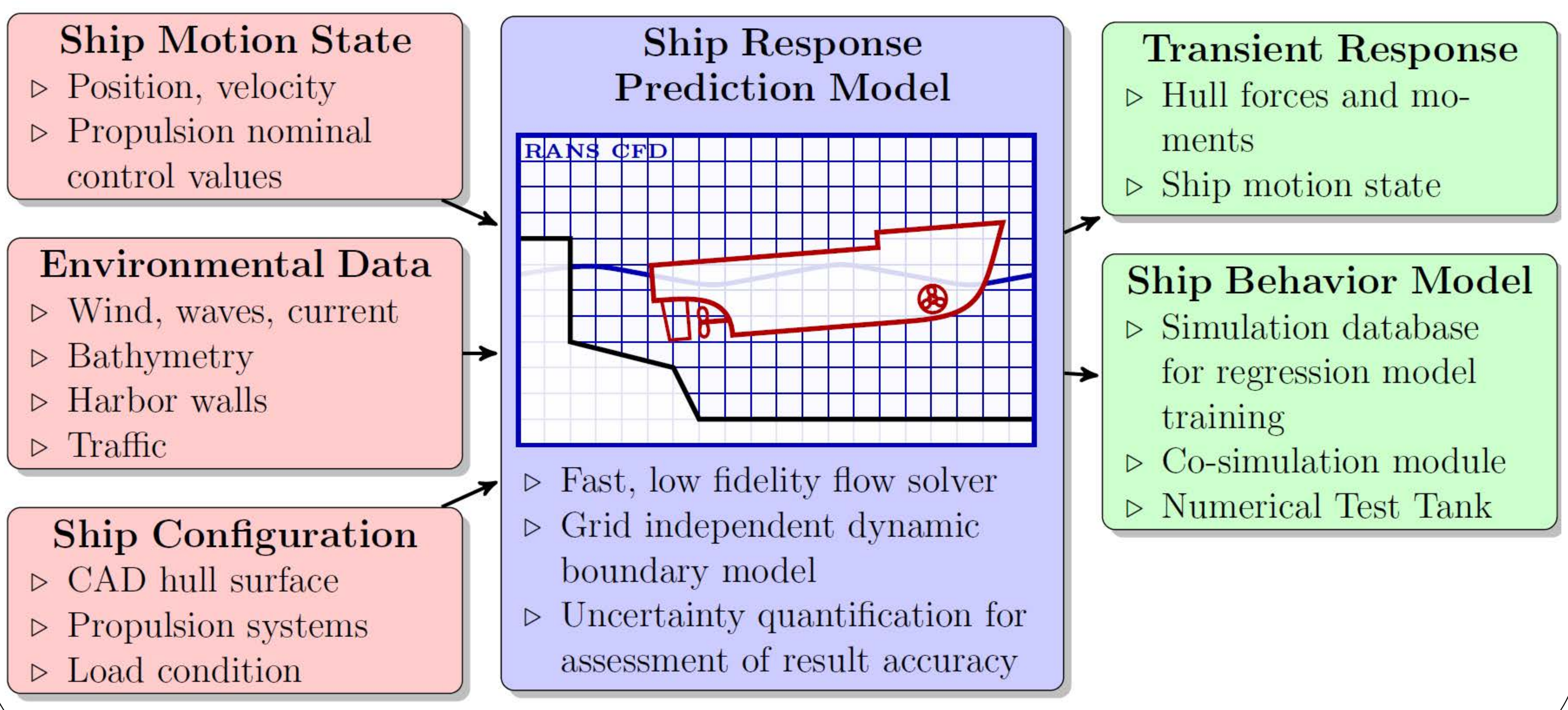
Background

In modern shipping, manoeuvring operations have become increasingly demanding due to increased vessel size, traffic and complex environmental factors. In harbour conditions, especially during docking, these factors are complemented by complex hydrodynamic phenomena caused by confined waterways. A better understanding of the harbour scenario and ship behaviour is the prerequisite for the development of autonomous harbour manoeuvring systems. Development of these systems is the common goal behind the collaboration project between the departments of IHB and IIR.

Challenges to be investigated

While the conventional manoeuvring models (developed for open water conditions) can predict ship resistance and motion with high fidelity, they are not accurate and versatile enough for complex harbour scenarios. The main challenge for this research is the development of a motion prediction model which incorporates the complex dynamic boundary conditions due to shallow water and banking effects. Furthermore, the model should be computationally efficient so it can be coupled with a control system. The following figure shows the main features of this PhD project.



Research goals and objectives

There are three main objectives for this project:

1. Development of fast, low fidelity, ship response prediction method
2. Development of a mesh technique which enables large ship motions in a complex harbour scenario,
3. Uncertainty quantification of the ship flow which facilitates the reduced accuracy requirements.

Industrial goals

This research complements the marine industry's ongoing efforts in the development of autonomous vessels. There is an opportunity to collaborate with NMK as methods developed during this project can contribute to the development of advanced marine operations simulators.

Research methods

Various motion models and mesh techniques will be assessed using Computational Fluid Dynamics (CFD). In addition to the commonly used Finite Volume Method, the suitability of particle methods will be investigated. Verification of the model based on the results of turning/zig-zag tests performed on a real vessel. Different harbour scenarios with different environmental factors and traffic will be evaluated. Finally, we will be looking into methods to extract hydrodynamic coefficients from a CFD simulation. Regression analysis will be performed on the simulation data.

Supervisors

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PhD Thesis

Intelligent and Flexible Domain Models for Digital Twins of Maritime Design and Operation

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Background

The recent years have seen an increasing interest in developing and employing machine learning, cloud computing etc intelligent technology for maritime industry design and operation services.

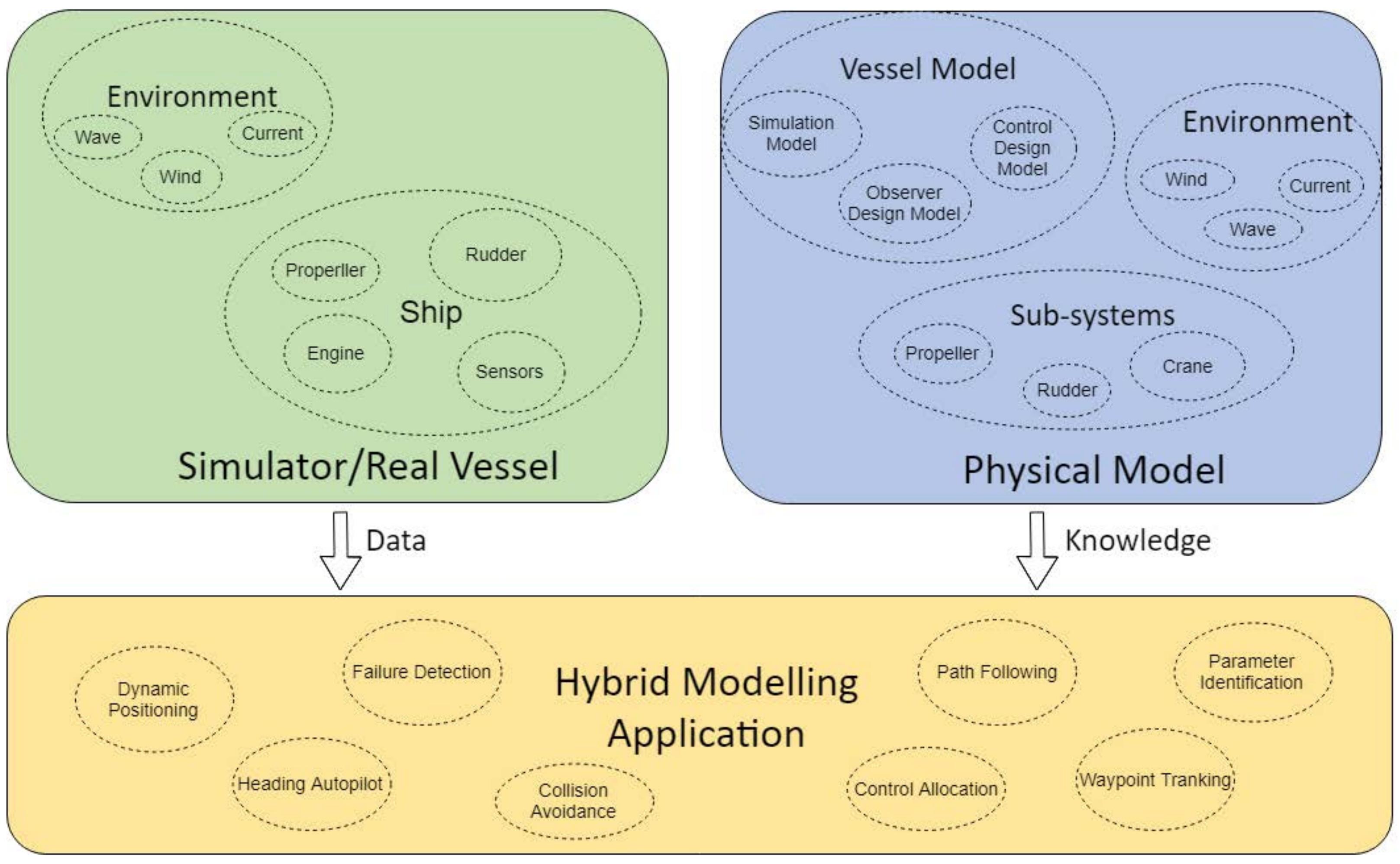
Incresing data storage and computational power enable for new ways of managing vessel's safety and performance. However, data-driven methods need a huge amount of data in the process. Also we have no idea of the inside of the 'black box', which decreases its credibility to some extend in industry.

Therefore, hybrid modeling method, taking advantage of both data driven model and simulation model is proposed for maritime design and operation , by utilizing the intelligence and accuracy of data-driven model to make up the error caused by assumption or simplication of classic theory or empirical formula, as well as increasing interpretability and reducing the data demand of data model.

Challenge to be investigated

When performing hybrid modeling and using such models for on-board support, determining the architecture is of great importance. That is to what extent is enough for data model replacing physical model to reach a optimal performance and least computation load.

Furthermore, combining components from different sources relates to accuracy, timing and stability of simulation, where limited or no support for existing standard is a major challenge. It is of great significance to set up the benchmark for hybrid modeling method. It differs from specific operation or application.



Research goal and objectives

The goal of the project is to develop intelligent and flexible domain models for digital twins of maritime design and operation that will enable take benefits of both machine learning methods and knowledge based methods.

1. Combine machine learning with machinery to provide intelligent hybrid domain models
2. Develop efficient methods to extract and implement proper model data from sources.
3. Perform verification of methods on real data.

Research methods

Simulation studies will be performed to develop vessels and specific sub-system models based on knowledge. Machine learning models based on general methods will be intergrated with given mathematical model through analysis of data from simulator or real vessel experiment to provide on-board support in ship manuvering. Moreover, verification work will be performed on real data.

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PhD Thesis
Data-driven decision support for demanding aquaculture operations

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Background

Autonomous Underwater Vehicles (AUVs) can make operations such as ocean monitoring and exploration efficiently. On the other hand, its long-term use is still limited by the autonomy of the vehicles. Enabling long-term unattended operations would dramatically decrease the cost of operations, making them also more versatile and efficient. Modern artificial intelligence methods could be used to derive new dynamical models for different environmental conditions of interest contributing to long-term autonomous operations, decision-making, mission planning, etc.

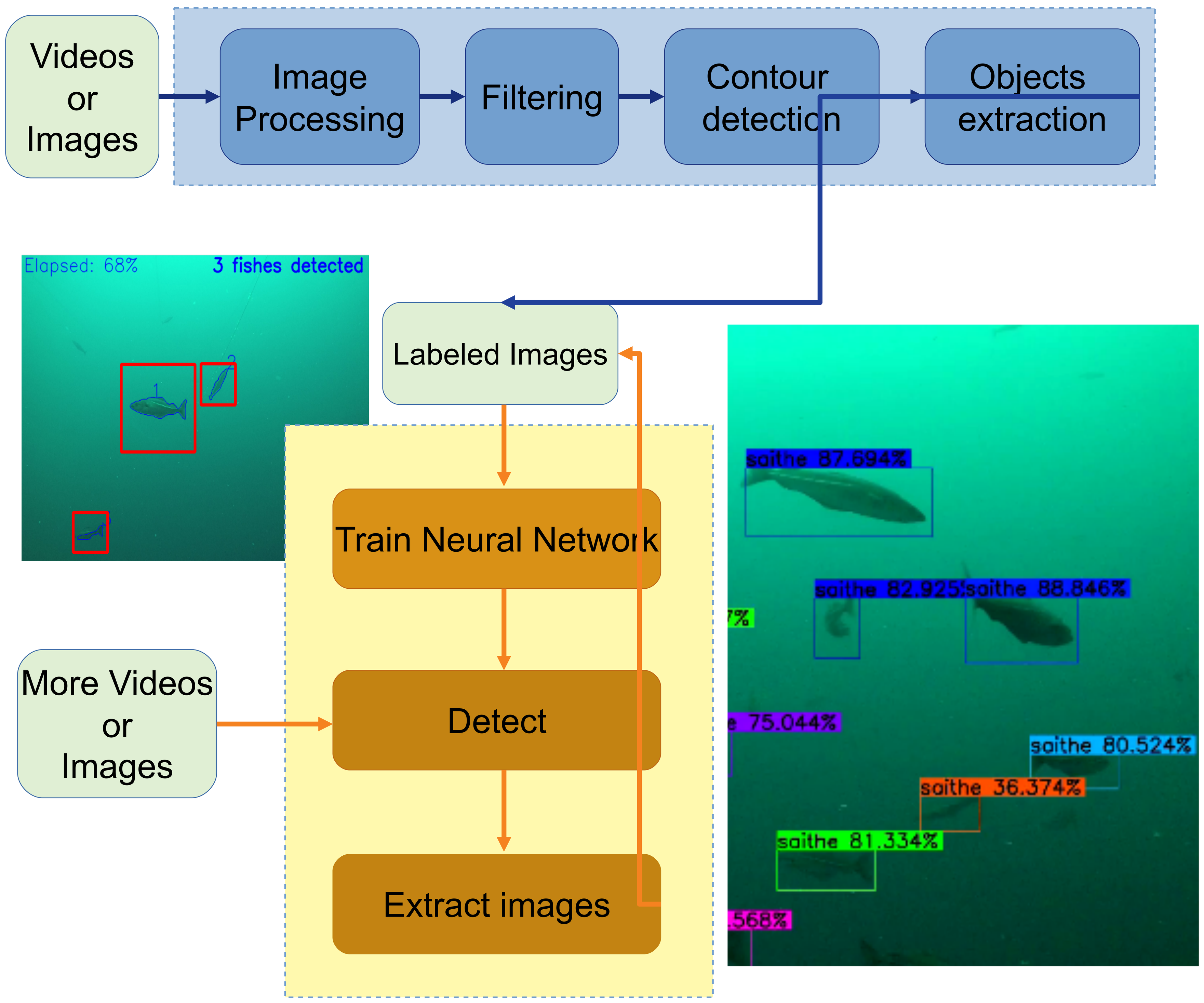
Research goal and objectives

The goal of this project is to collect data from disparate sources in fish farms and their surroundings and analyze it using artificial intelligence to generate environmental models. This will be applied to make predictions in different scenarios supporting the AUV's decision-making on autonomous operations.

1. Collect data from different sources
2. Integrate data
3. Analyze data and build models using artificial intelligence:
   - Study wild fish assemblages
   - Seabed mapping and benthic evaluation
4. Visualization and user interaction of real time data and off-line data.

Research methods

Different methods and tools of artificial intelligence will be explored to analyze the data gathered around fish farms. This will be used for data classification, patterns recognition and the development of models for the aquaculture environment.
At the same time, these models will allow making predictions of different environmental conditions to improve decision-making, and thus increasing the autonomy of operations.
The predictive models will be validated using real-time data and also off-line data.



Supervisors

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PhD Thesis

Virtual Prototyping of Installation of Offshore Power Systems

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Background

The industries, houses, and transportation equipment are producing extensive amounts of emissions and as a result, they are threatening the living species by polluting the planet. In order to reduce emissions and protect the environment, it is required to utilize cleaner sources of energy such as wind energy. Wind turbines are designed to convert wind energy to electricity. Wind turbines can be located both onshore and offshore which each of them has its advantages and disadvantages. The wind velocity is higher and more stable at the sea and it increases the potential of Offshore Wind Turbines (OWTs) while their costs are considerably higher than the inland installations.

Challenge to be investigated

Installation of offshore wind turbines is a challenging operation and that is mainly due to complexities in the environment such as waves, winds and currents. In addition, there are different structures that are involved in the operations such as OWT assembly, lifting vessel, floating spar etc. (depending to the installation arrangement). The response of each of these structures to the environment and interaction between them is cumbersome and increases the complexities in the operation. In this research it will be focused on understanding the underlying physics and the way the competitive advantage of this technology can be increased.

Research goal and objectives

Main research objectives of current project are:

1. Development of the mathematical model for underlying physics of maritime operations that can be integrated into different simulation environments.
2. Development of virtual prototyping environment which is in accordance with Functional Mock-up Interface (FMI) Standard.

Industrial goals

Industries are facing huge amount of difficulties when it comes to floating wind turbines. Installation of Offshore Wind Turbines (OWTs) is one of the major parts of the expenses of these projects. Another complexity is rooted in unpredicted dynamic environment. In the current project it has been tried to solve the industry issues by:

1. Knowledge transfer from offshore oil and gas industry and implement in OWT installations.
2. Developing innovative concepts for OWT installations in order to increase the efficiency of floating turbines installations.
3. Developing a unified simulation tool for the optimized design of the operations.

Research methods

The main research method which will be used in the current PhD project is the quantitative method. Using the theoretical analysis and numerical simulations the research objectives will be reached.

In order to validate the research, the outcomes will be compared to the available literature, laboratory experiments, and industrial reports.

Supervisors

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PhD Thesis

Digital transition in the maritime organizations.
Effects of remote monitoring and power by the hour on organizations and professions

Bjarne Pareliussen
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Background

Digitalization, meaning the use of digital technologies, is transforming the business of industrial companies, service companies and the public sector.
One example of Digitalization in the maritime domain is Kongsberg Maritime's business model, Power by the hour. This business model is using output-based contracts that shift the risk of engine failure from the owner of the vessel to the supplier. Also, the cost of maintenance is included, allowing the owner of the ship to have a concise knowledge of the running cost of the ship. To mitigate the increased financial risk the supplier relies on the knowledge of their engines and information from real-time sensors sent through fast data links from vessel to shore. This allows for real-time monitoring for instance using digital twins and optimized performance of the engines.
This will influence the relationship between supplier, ship and shipowner and have effect on the professions involved with the running of the ship. The aim of this thesis is therefore to investigate the organizational implications by introducing this business model.
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Challenge to be investigated

The aim of the study is to investigate how servitization and remote monitoring, exemplified through the concept of Power by the hour, is changing aspects of the ship as an organization and the professions of the organization members. Also, a review of the relationship between involved organizations like Ship, Shipowner and Supplier is affected by the new technology and business model. This study will explore this issue at the individual, group and system levels. At the individual level the implications for the engineer will be analyzed, at the group level the focus will be on the ship as an organization and at the system level the interorganizational relationship will be analyzed.

Research goal and objectives

The main research question is:

What is the effect on the maritime organizations by introducing Power by the hour and remote monitoring?

Which is broken into two research questions:

How will the ship as an organization be affected by remote monitoring and new business models?
How is relationship between ship, shipowner and supplier changing with the introduction of new technology and new business models?

Industrial goals

1. To identify how new business models will affect the organizations in the maritime industry
2. Investigate the consequences of digitalization on competency and professions in the maritime industry.

Research methods

A case study with a company with two vessels operating with Power by the hour business model. The research will be qualitative with interviews as the primary data collection method. The informants will be from vessel, shipowners office and supplier.

Havila kystruten - latest company using Power by the hour

Supervisors

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- Vilmar Æsøy
- Jann Peter Strand

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PhD Project

Human-in-the-loop control and learning system for autonomous maneuvering

Baiheng WU

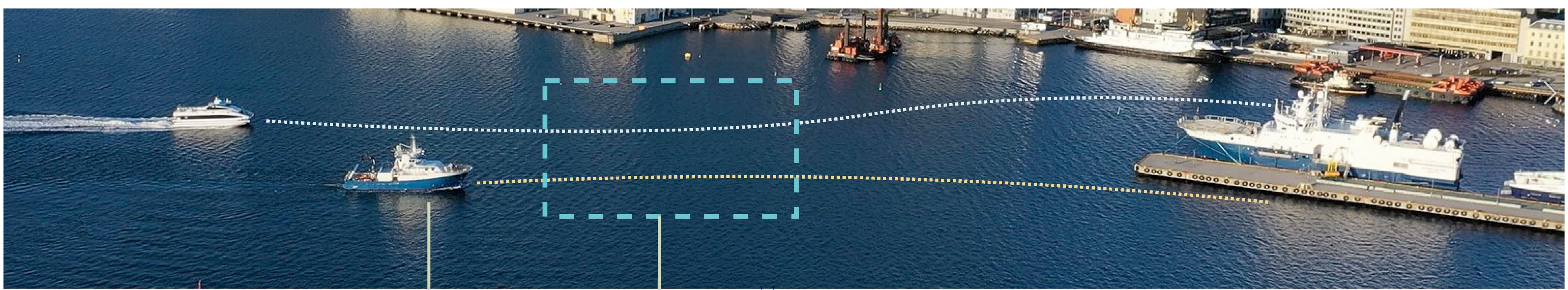
Department of Ocean Operations and Civil Engineering (IHB)

Introduction

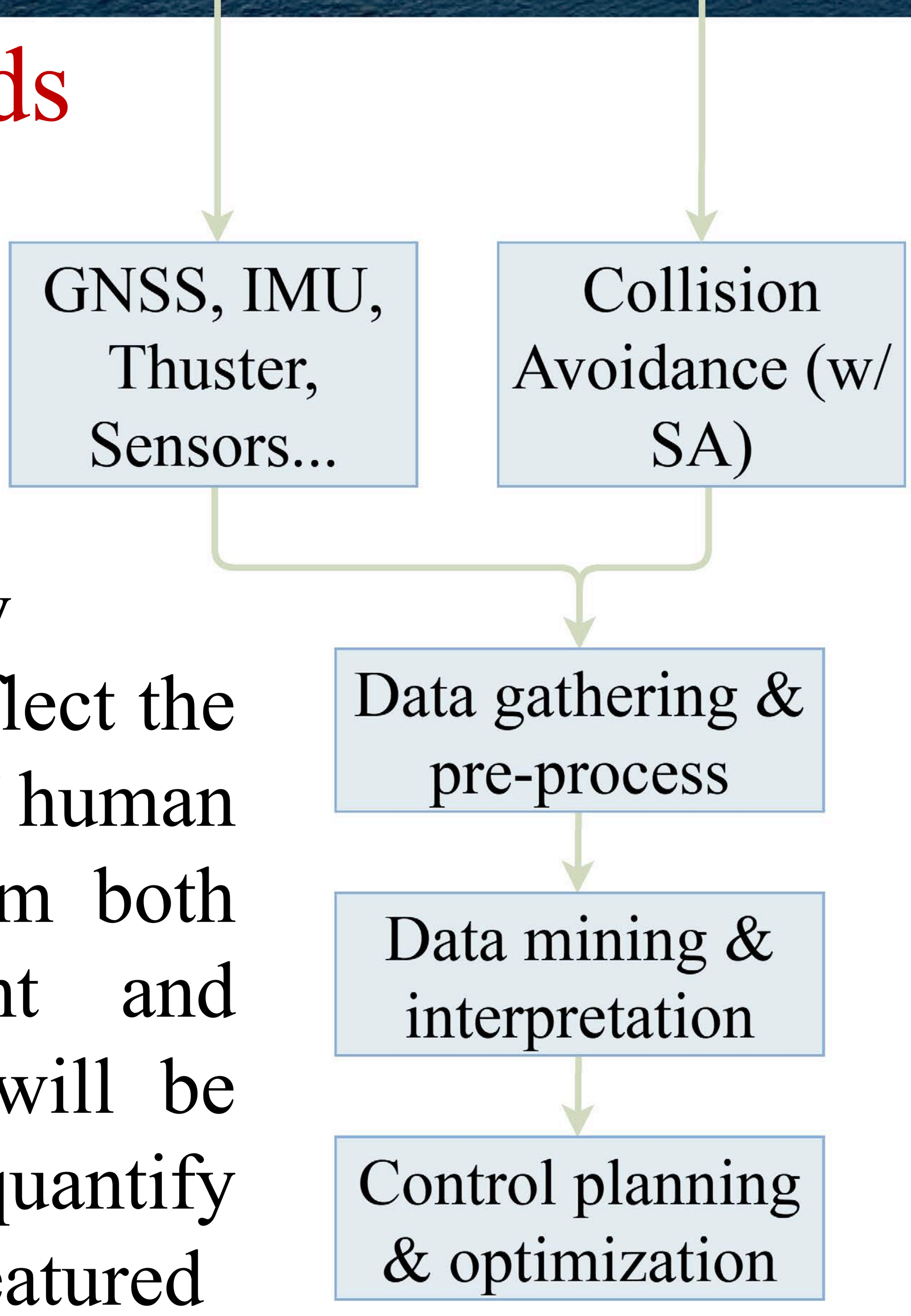
When building up the maritime autonomy, it is of high priority to guarantee the autonomous sailing as safe as human navigation, which is regarded as an inductive paradigm to enhance the intelligence and security of the ship autonomy. Hence, rationally quantifying human response is crucial to setup a reference for the control problem and corresponding optimization objective function. Incorporating with advanced control methods, the ship autonomy is expected to perform humanoid strategies to maneuver the vessel in most nautical scenarios.

Case Study - Autonomous Docking

Docking in the congested water or narrow channels is a challenging operation. The vessel is preferred to be restricted to the planned route, and have fast response to situation awareness. To attain the optimal docking process, multi-factors should be considered, including the safety distance to the strandline, engine efficiency, docking duration, comfortability (affected by acceleration) and so on. An optimal route is generated based on several times human operated docking, and an optimization function is built upon the above factors to supervise the control.



Goals & Methods



The project aims to build the ship autonomy upon human operations as reference. Larger capacity of data will better reflect the trigger and tactics of human operations. Data from both on-site measurement and training simulation will be used to model and quantify human operations. Featured parameters will be selected to setup the objective function to obtain the optimal control. The selection will be initiated intuitively with suggestions from navigators at this stage.

Case Study - Scenario Construction

Obtaining all the data onboard is demanding, but it can be acquired from training simulators. As a supplementary work, a multi-agent route planning system is to be designed to work in both open sea and harbour area. This system renders the ships to occupy the largest percentage of the designated area with their effective coverage on condition that no collision happens. The system for open sea will be initiated offline based on game theory. While in the harbour, marine traffic should be accounted for to make the planned route in accordance with the maritime logic.

Supervisors

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PhD Thesis

Maritime Cyber Security and Risk Management: Understanding Deck Officers' Risk Perception in Cyberspace to Achieve Risk Reduction and Enhance Maritime Safety

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Background

In today's maritime operations there is an increasing reliance on digitalization, integration, automation and networked-based systems. The increase of technology and connectivity makes operations at sea vulnerable to cyber-attacks.

Risk perception plays a vital role in identifying cyber risks and achieving risk awareness. Research into this side of cyber security in the maritime domain is limited, but it can be valuable to identify and understand seafarers' cyber risk perception. By understanding cyber risk perception, we can create targeted education, develop policy to improve behavioral compliance, and design technology more effectively. This study will therefore focus on achieving in-depth understanding of cyber risk perception in the maritime domain.

Research goal and objectives

The main research objective is to investigate how deck officers perceive cyber risks in maritime operations, and how this affects the risk management process. The research objective is divided into three research questions:

1. How can risk perception be understood in the context of maritime cyber security and risk management?
2. How does the deck officer perceive cyber risks in maritime operations?
3. Can simulation contribute to increased understanding of the deck officers cyber risk perception?

Industrial goals

Achieve better understanding of deck officers cyber risk perception, in order to give the maritime industry recommendations on operational cyber training and development of cyber security policies.

Research methods

This study will be divided into stages which coincides with the three research questions. The first stage will consist of a literature review. In the second stage it will be conducted a case study with qualitative data collections. The third stage will consist of quantitative experiments in maritime simulators.

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Close-range Auto-Docking by Combining Sampling-based Planning and Reinforcement Learning

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Background

The development of autonomous ships is becoming increasingly demanded in the maritime domain. Automatic docking is one of the most important components of autonomous ships. However, how to maneuver a ship safely and efficiently under harsh environmental disturbance in various close-range scenarios is still a challenging problem. In the close-range scenarios, such as, urban ports, congested waterways etc., ships should be carefully aware of their surroundings and make decisions by interacting with other vessels. Therefore, an intelligent docking system is needed to increase ship safety and efficiency.

Challenges

For ship docking application, as shown in Fig. 1, we can find that the limited working space, the positioning, and the heading requirements for docking and the marine traffic nearby constitute a complex spatial environment for maneuvering. In addition, environmental disturbances like wind, wave, and current make the docking more complex. Therefore, it is challenging to optimize the trajectories and maneuver the ship in real-time under these situations.

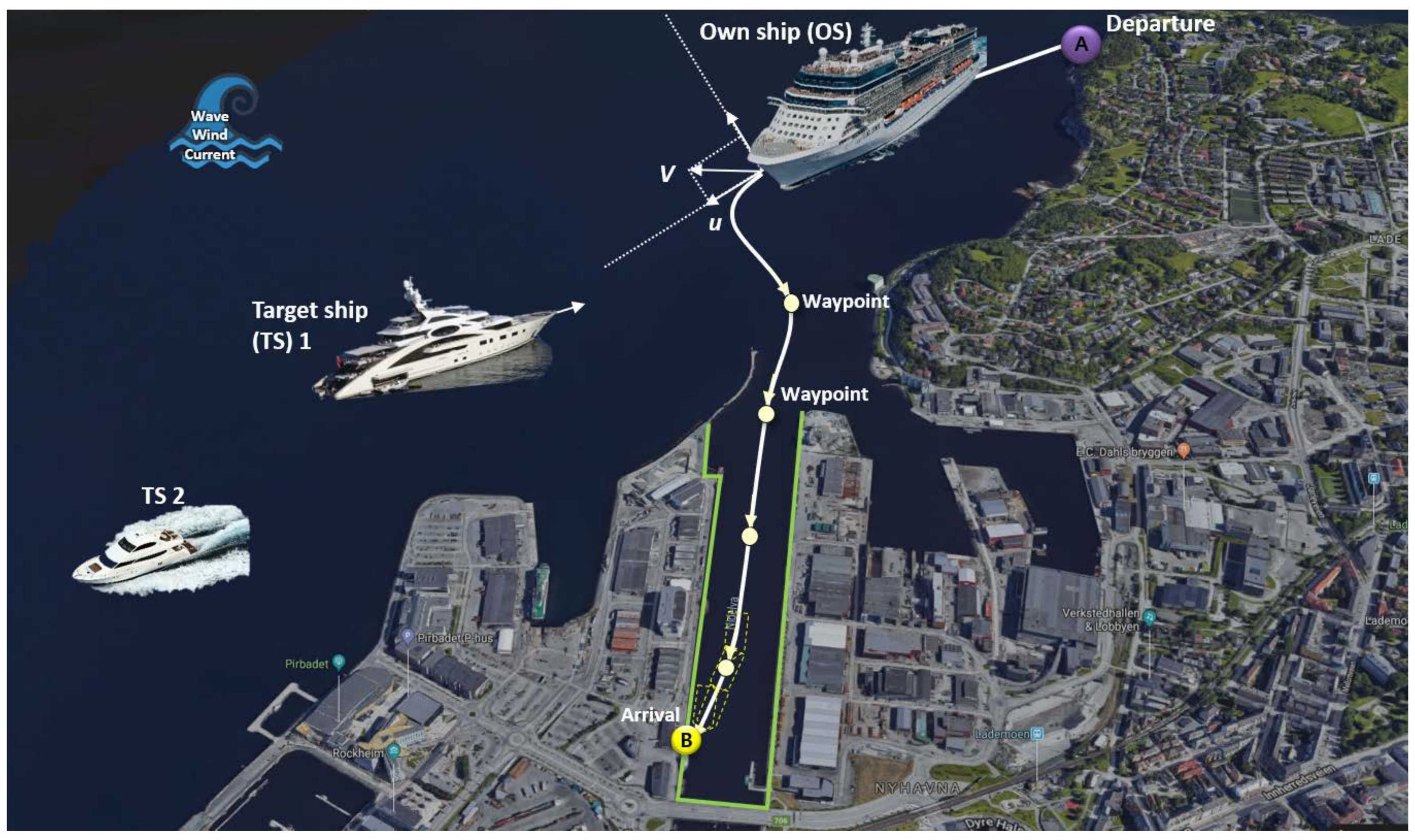


Fig. 1. Schematic diagram of ship docking to Trondheim.

Research and industrial goals

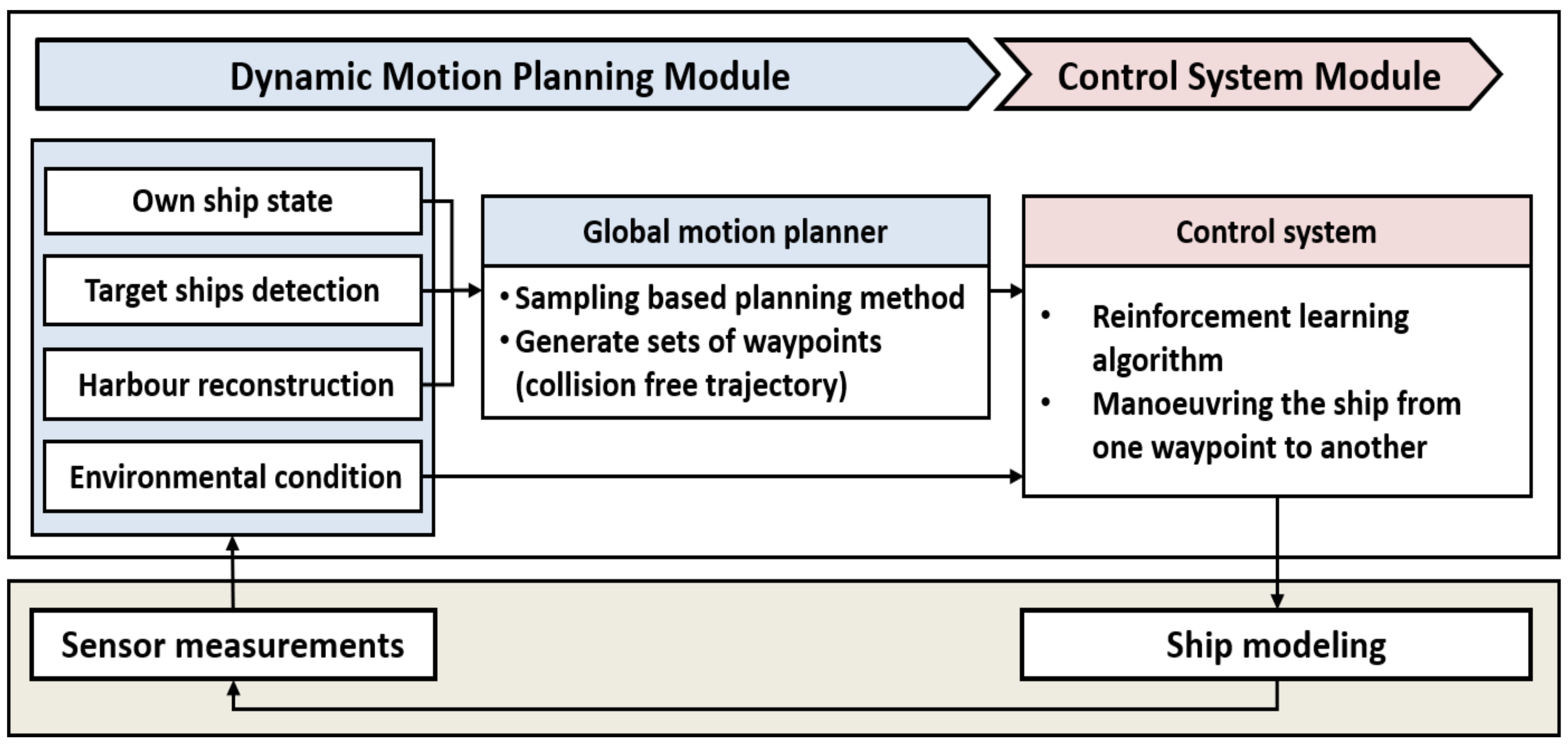
The goal of the project is to develop a robust and efficient auto-docking system that combines sampling-based motion planning with reinforcement learning for on-board supporting for docking operation.

1. Develop a dynamic motion planner which capable of generating collision-free trajectories by taking dynamic models of own ship and target ships, harbor information, and collision regulation into account.
2. Develop a control method to maneuver the ship to perform the docking operation by following the trajectories under various environmental disturbances.

The proposed method aims to solve the difficulties encountered in practical docking operations.

Research methods

Our proposed method consists of two steps as shown follows. Firstly, the sensor inputs are fed into a global motion planner to generate optimal trajectories in real time. Secondly, a local planner is used to manoeuvre the ship along with the trajectory into the harbour under the environmental disturbances.



Supervisors

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Postdoctoral Research

Predictive modelling of microbial pathogens in water: development of an early warning system for the Ålesund water supply system

Hadi Mohammed
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Background

The primary goal of water supply systems is to provide microbiologically safe drinking water to the public. Presence of microbial pathogens, e.g. *E. coli* provides conclusive evidence of direct faecal or sewage contamination from warm-blooded animals. Results of laboratory analysis of raw water currently become ready after raw water has undergone treatment and reached consumers. In cases of waterborne outbreaks, levels of pathogens in drinking water are only investigated after the incidents.

Challenge to be investigated

Unexpected increases in concentrations of the microbial pathogens in raw water sources often lead to waterborne disease outbreaks. However, it is currently difficult to rapidly identify changes in concentrations in water that could challenege treatment processes. To achieve the goal of protecting public health, early detection of microbial organisms in raw water is necessary for proactive optimization of water treatment processes as well as reduction of infection risks due the consumption of treated water.

Research goal and objectives

The goal of the project is to develop an early warning system for real-time monitoring of the microbiological quality of drinking water at the source and distribution stages. Specifically, to:

1. Develop and integrate hydrodynamic and machine-learning models with cloud-based field data transmission
2. Predict changes in water quality in the system in real time

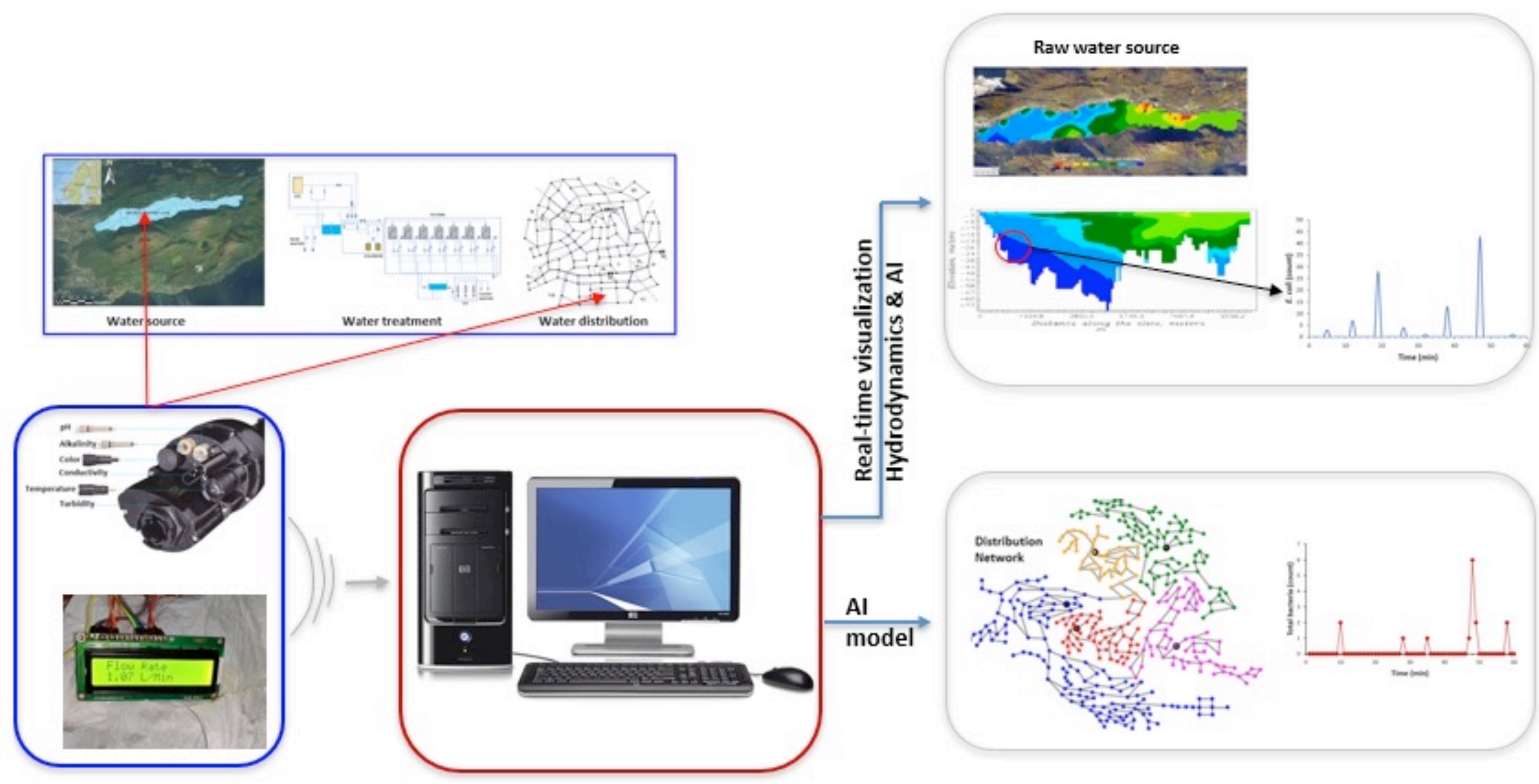
Industrial goals

The monitoring system to be developed is intended for application in the water supply system for the Ålesund Kommune. This is expected to enable:

1. Real-time monitoring of microbiological quality of raw water in the Brusdalsvatnet Lake in response changes in weather, hydrological and water quality in the watershed
2. Communication with water distribution pipes for prompt identification of zones of water quality deterioration in the distribution pipes

Research methods

The method is composed of installation of water quality sensors, flow sensors, and a meteorological station in the Brusdalsvatnet catchment, water distribution pipes, as well as laboratory experimentation. Both historical and new data collected from the sensors would be applied in developing the hydrodynamic and machine-learning models for water quality prediction. Further, cloud-based data transmission will be used to drive the calibrated models for real time visualization of results.



Supervisor

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Postdoc Topic

Flexible Riser Replacement Optimization

Shuai Yuan
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Background

Flexible dynamic risers are vital components for offshore floating oil and gas production. As a critical maintenance for continued operations, the flexible riser replacement involve complex procedures which need to be well optimized and trained for safety and cost effective. Safer operations can be promoted through advanced simulation and prediction tools, such as virtual prototyping.

Challenges

1. Develop and configure realistic flexible riser replacement models within real time frames is a harsh requirement due to nonlinearity of dynamics.
2. There are no mutually adopted simulation frameworks that support total integration including human factors, material, mechanical, control, operational performance etc. for riser replacement.

Research goals

The main goal of the project is to build a framework in order to enable virtual prototyping which are developed for overall riser replacement operation, allowing for concept verification, modelling, simulation and training in a flexible, effective and efficient way. Sub goals includes:

1. Develop generic models for all key structures, parts and sub-units of risers and operations.
2. Develop the framework based on Functional Mockup Interface(FMI) for virtual prototyping of riser replacement operations

Industrial goals

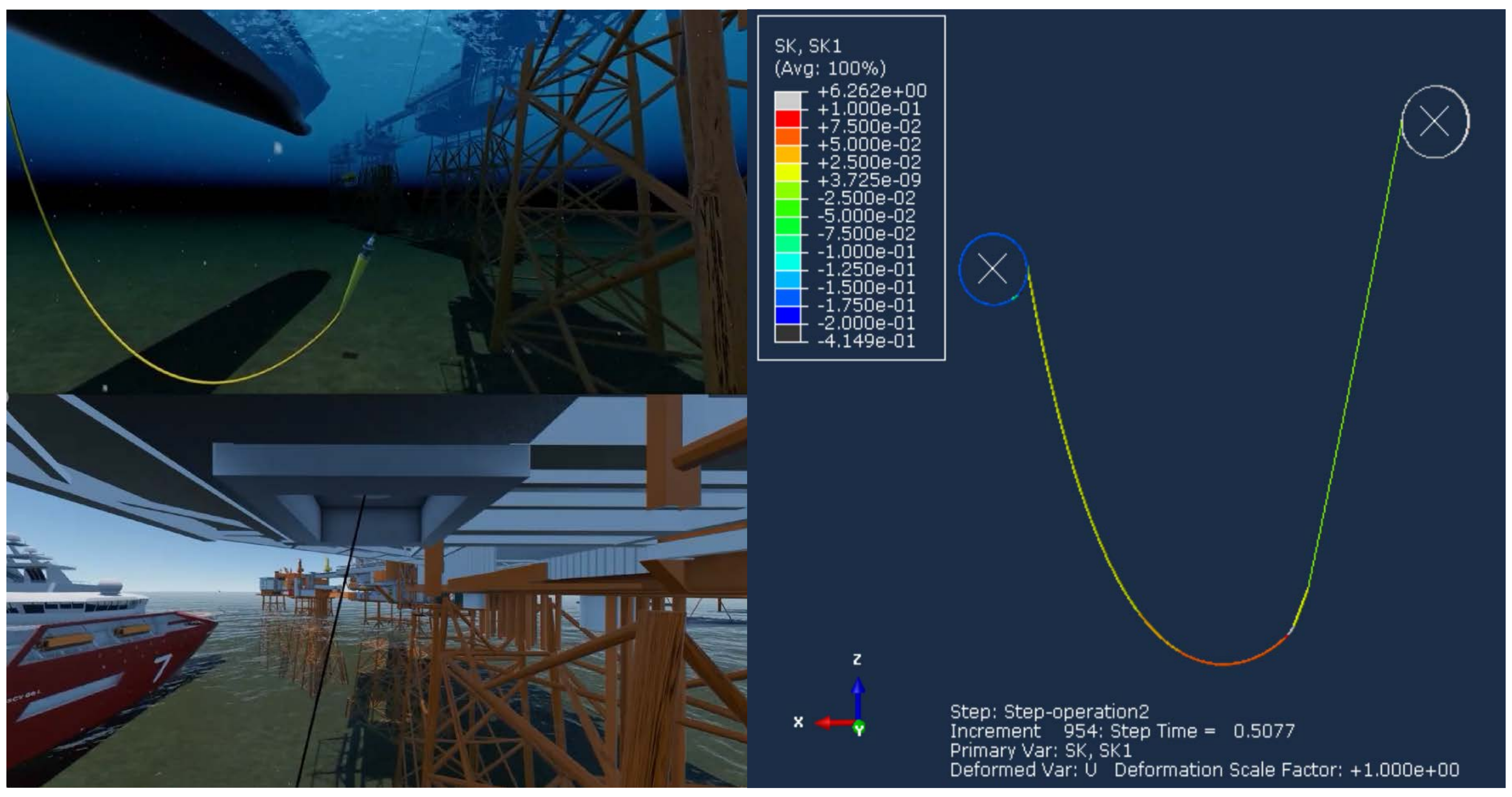
The developed framework can be used for vitual prototypes of riser equipments and to simulate related operations in a short time. It enable the industry to implement simulation-based riser operation planning.

Examples of applications:

1. On-board trainer to educate offshore crews on procedures, dangers, etc.
2. Prediction tool for riser configuration, tension, etc.

Research methods

Detailed finite element method can be adopted as a benchmark for mechanical accuracy of riser operation simulation. Based on the parametric studies for various activities, simplified models are obtained for the physical modelling in virtual prototyping. The developed real time component models will be packaged as Functional Mockup Units and relevant co-simulation for riser operation can be implemented within FMI framework.



Mentor

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Kunnskap for en bedre verden

Developing a Bayesian network model for transportation system decision aid in nature conservation areas

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Background

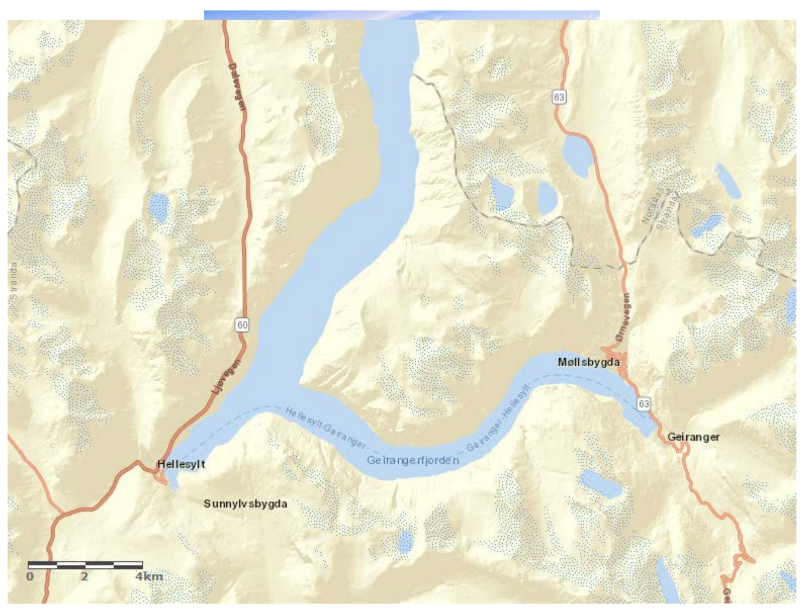
Nature based tourism destinations represent a unique challenge in transportation system planning due to high seasonal fluctuations of visitor loads. These remote but honeypot areas often struggle with limited capacity which may lead to congestion, crowding and environmental degradation. Understanding transportation system dynamics and balancing stakeholder interests is key to successful transportation planning and decision aid.

In the SUSTRANS project, the transportation system in the Geirangerfjord World Heritage Site has been explored using a multi-stage stakeholder involvement process. The first stage output is a preliminary Bayesian network model (BNM) of the transportation system connecting improvement measures (alternatives) and utilities (criteria) through a causal node network. The model permits handling uncertain outcomes, and model outputs may be further utilized in stochastic decision models.

Research goals

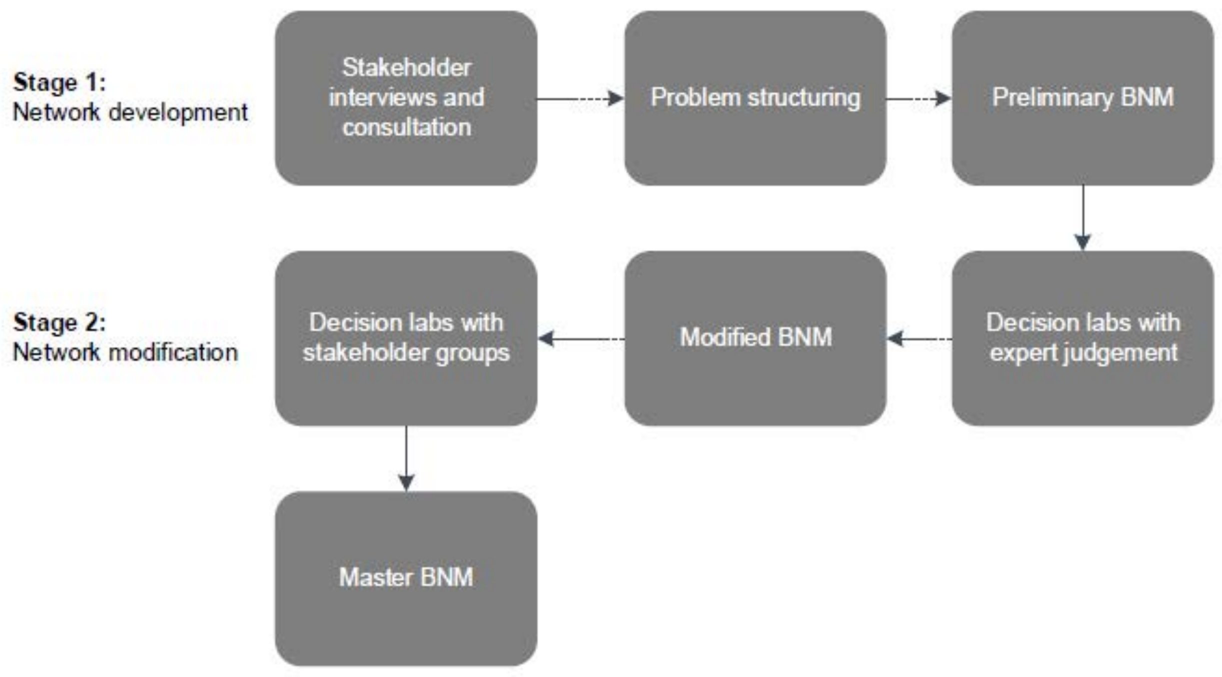
The goal of the post doc project is to develop decision models for transportation planning in nature based tourism destinations. Bayesian network modeling and multi-criteria decision analysis will be developed and connected to comparatively evaluate alternative improvement measures in the transportation system.

1. The Geiranger area



- Located in western Norway
- Added to UNESCO's World Heritage List in 2005
- Third biggest cruise port in Norway – popular tourist destination
- 240 residents – close to 1 million tourists during peak season
- 10% projected annual growth in tourism until 2030
- Challenges related to capacity and environmental degradation

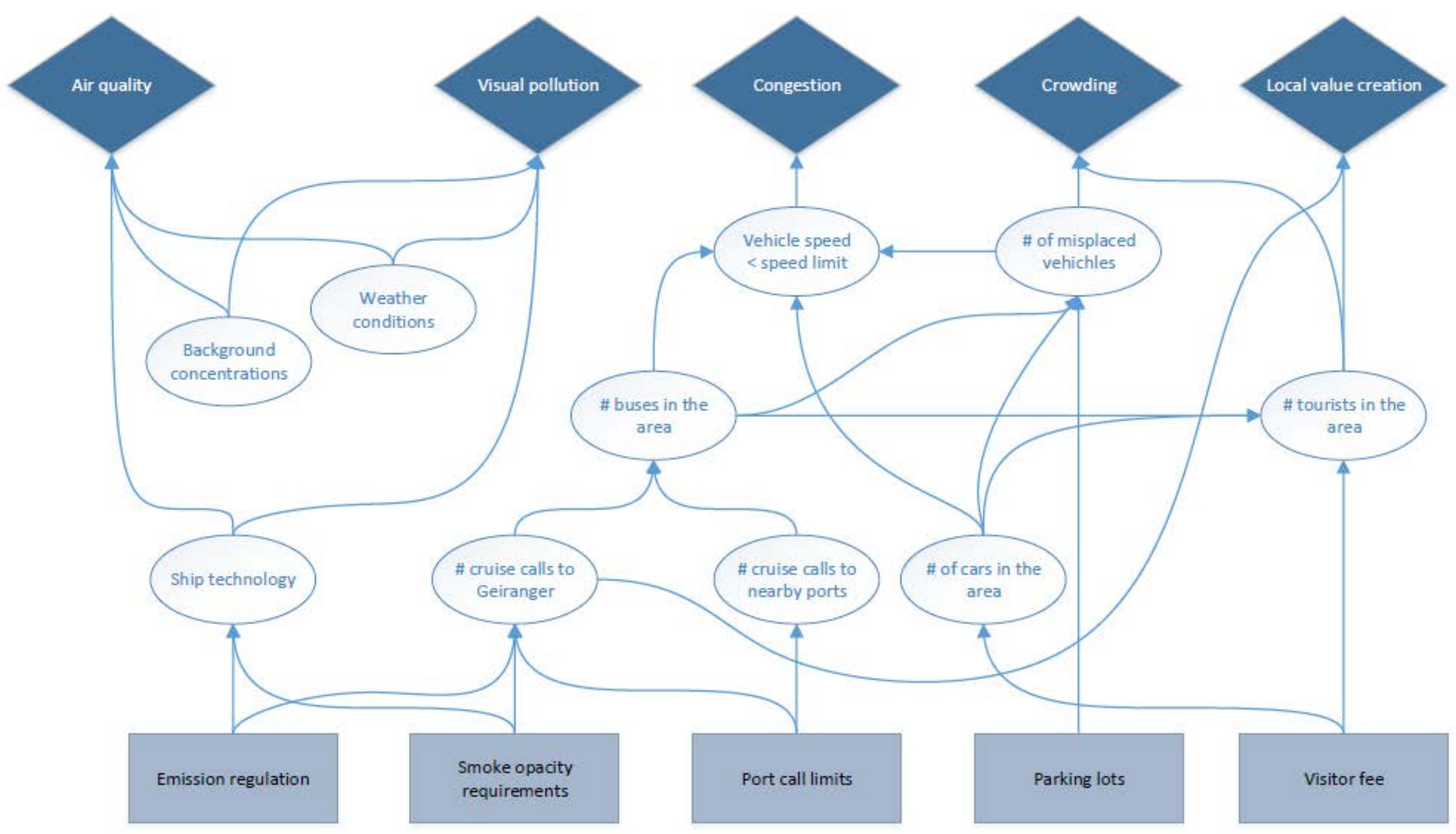
2. A multi-stage stakeholder involvement process



Stakeholder consultations are used to develop and validate the Bayesian network model (BNM). Stage 1 is cmpleted in the SUSTRANS project

3. A preliminary Bayesian network model

The output from stage 1 is a preliminary BNM derived from stakeholder interactions. The network model is a probabilistic directed acyclic graph (DAG) representing the transportation system, important performance metrics and alternative improvement measures.



SkillSea: 'Futureproof Skills' for the Maritime Transport Sector

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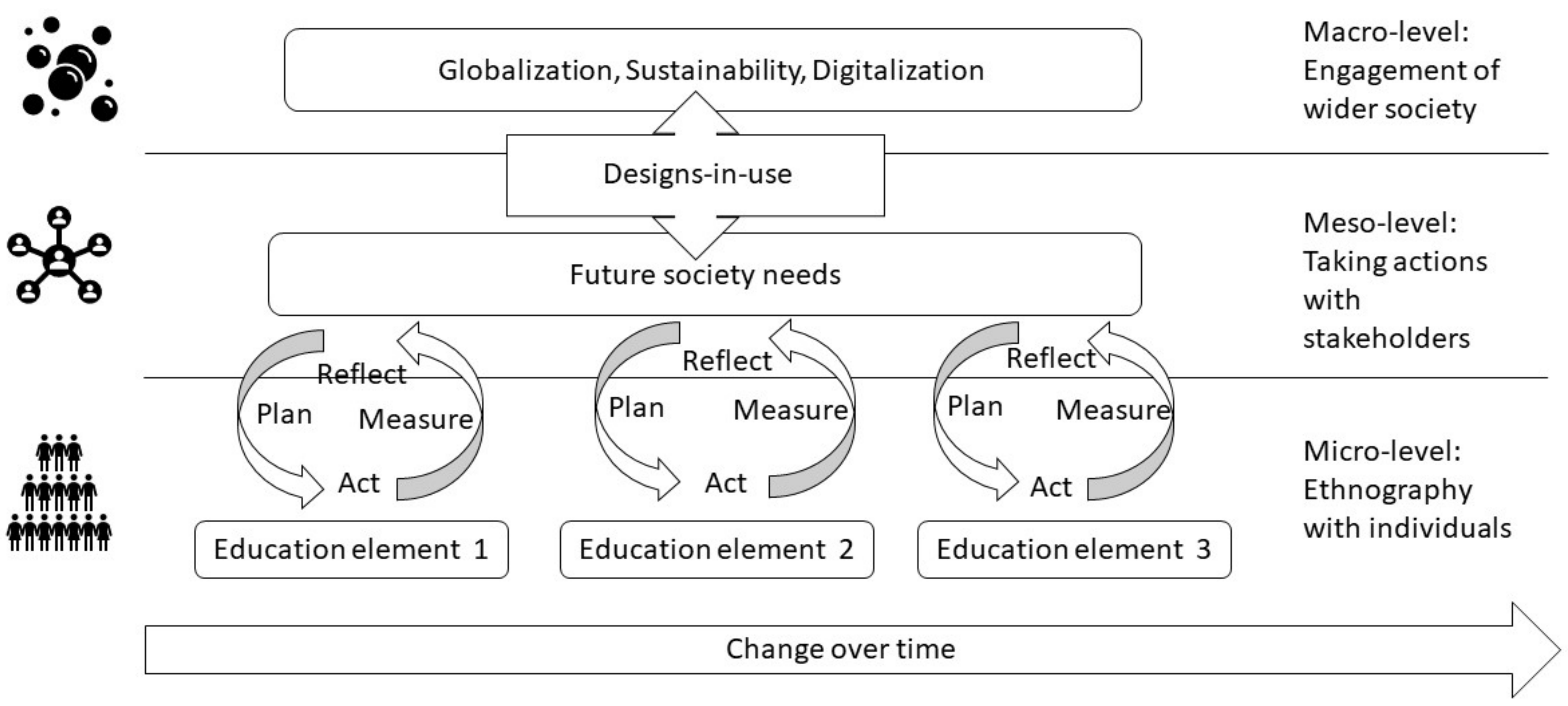
Co-funded by the Erasmus+ Programme of the European Union



Aim and expected results

Providing implementable recommendations for the EU directive 2019-1159 § 16 – Developing ICT-driven Maritime Diplomas of Excellence in Europe.

Background

Digitalization, high-tech equipment and low-carbon solutions are affecting the workplace of the maritime world. The maritime job market needs more tech-based maritime professionals. Seafarers will need to possess new and different kind of skills to 'equip' themselves for the technological changes, which the shipping industry is facing. The growing Artificial Intelligence, Internet of Things and Automation are trends that maritime industry invests regularly. Ships are increasingly using systems that reply on *digitization*, *digitalization*, *integration* and *automation*, which call for new understanding of work practices of seafarers on board and on land. To this end, it is significant to create new learning approaches based on the digitalization changes.

Challenges

The diversity of nautical sciences in Europe makes three challenges in the project, such as the skills needs of the industry and the education provided are different. In addition, the cooperation between education, research, and competence authorities and industry also needs to be improved.

Methodology

We start from an assumption that nautical science and marine technology are thoroughly social activities. They are social in that seafarers and engineers are always members of communities, trained into the practices of those communities and necessarily working within them. Through *design of information systems* perspective, we see those communities as social technical systems and investigate how scientific knowledge and technological artifacts are *constructed*. We pay attention to the ways in which education provider and technological equipment provider attempt to construct stable structures and networks of digital elements for seafarers, often drawing together into one account the variety of resources used in making those structures and networks. The central premise of our methodology is that 'engineers' use the *material* world in their work; it is not merely translated into *knowledge* and *objects* by a mechanical process. We use *qualitative research* to study different stakeholders of the skillsets, including seafarers, classification societies, technology companies, manufactories, workers union, education, and research institutions, and finance companies.