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Effect of a movable trailing edge flap on the performance of a crossflow turbine

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Abstract

In recent years, there's been an increasing focus on utilizing wind energy as a sustainable means to address the growing global energy needs. While Horizontal Axis Wind Turbines (HAWTs) have traditionally dominated the wind power landscape due to their efficiency, they also bring notable challenges like extended wake effects and higher operational and maintenance expenses. Consequently, there's been a notable surge in research dedicated to exploring Crossflow Turbines (CFTs) as an alternative option for generating wind energy, both onshore and offshore.

This two-dimensional Computational Fluid Dynamics (CFD) study aims to improve the power performance of a Crossflow turbine (CFT) through the implementation of an active flow control technique.Inspired by the adept flight control mechanisms observed in nature's flyers and swimmers, the study focuses on utilizing blades with sinusoidally actuated trailing edge flaps to alter the turbine's efficiency. The research is focused on the analysis of the variation in blade loads and power performance as a function of the blade's trailing edge flap angle. The CFD model uses a three-bladed crossflow turbine based on NACA 0015 airfoil profile with a trailing edge flap. The turbine has a diameter of 0.750 m with a chord-to-radius ratio of 0.16. Various flap angles are investigated using the Unsteady Reynolds-Averaged Navier-Stokes (URANS) simulations at a fixed diameter-based Reynolds number . Prior to the simulations, the developed computational methodology was validated against the available numerical and experimental data in terms of turbine power coefficient and flow fields. The results show that the performance of the turbine is highly sensitive to the applied flap swept angle, that can result substantial changes in the power coefficient of the turbine, if compared to the case of conventional blades. The flap control effectively mitigates flow separation on the blades, maintaining the blade angle of attack near the stall angle region, thereby enhancing lift.

Keywords: CFD; Crossflow turbine; Blade aerodynamics; Flapangle; Bio-inspired blade; Trailing edge.

Analysis of Carbon Footprint and Cost along the Maritime Logistics Chain: The Influencing Role of Ports and Short-sea Shipping

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Abstract

Ports and short-sea shipping are key components in the end-to-end maritime logistics chain and account for a disproportionate share of emissions. The role and potential contribution of ports and short-sea shipping are quite significant in the context of efforts to decarbonise maritime logistics. Thus, this research focuses on container movement and handling in ports and short-sea shipping. Carbon footprint and cost are essential indicators in assessing the effectiveness of the decarbonisation measures for short-sea shipping and ports. However, existing studies often provide partial estimations, focusing only on either cost or downstream fuel consumed (tank-to-wake/wheel – TTW) emissions, and are limited to specific legs such as ports or short-sea shipping. To address this gap, this research develops a holistic model that comprehensively calculates the cost and carbon footprint of container handling and movement in ports and short-sea shipping. The model is being developed using case studies at the Port of Tyne, UK and Semarang Port, Indonesia, collecting data on container vessels, including AIS signals, ship specifications, charter rates, bunker prices, and port charges. Port-related data concerning port facilities specifications and port operations were also gathered. While the short sea shipping analysis is still ongoing, findings from the ports analysis show container ships' operations in the port emerge as the primary contributor to both carbon footprint and cost. This is followed by container handling and heavy goods vehicle operations within the terminal area. Conversely, pilot boats and refrigerated container service contributed the lowest carbon footprints and costs. These findings highlight the need to select and prioritise appropriate decarbonisation efforts in ports.

Quantitative sustainability assessment of freeports: Hybrid model evidence from the UK

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Abstract

Freeports, and special economic zones in general, aim to boost national economic prosperity, yet sustainability concerns linked to them are often overlooked. Current research on freeport performance is largely fragmented, with a predominant focus on economic metrics specific to individual cases. To address this research gap, this study introduces a novel methodology for holistically assessing freeport sustainability using a hybrid Bayesian Network and Evidential Reasoning (BNER) model. This model can process both qualitative and quantitative performance data, and integrate different key performance indicators (KPIs) to generate a comprehensive index. New contributions of this paper include a unique framework evaluating freeport sustainability across economic, environmental, and social dimensions and synthesising them into a singular index; prioritising all relevant KPIs from multiple stakeholder perspectives; a new BNER model dealing with data uncertainty and interdependent factors in the performance assessment; a real UK freeport case study demonstrating the applicability of the developed model and offering practical insights.

Keywords: Freeport, Free trade zone, Sustainability assessment, Performance assessment, Evidential reasoning, Bayesian network

Route to 2050: Decarbonising the Greek Ferry Industry

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Abstract

With the aim to decarbonise all shipping activities by 2050, as set by MEPC 80, it is expected that a significant change throughout vessel designs must take place. The utilisation of alternative fuels and powertrains is inevitable, in hopes of eliminating dependence upon fossil fuels and resulting Green House Gas emissions. Many of the proposed alternative fuels within the marine industry appear as ideal solutions when applying a typical Tank to Wake assessment, however, when a complete lifecycle evaluation is employed (Well-to-Wake), results show this may not be the case. In this study, a "Wind-to Wake" approach is proposed, where the candidate fuelling propositions are compared in terms of their total renewable energy input requirement, over the energy required to carry out voyages, as well as their resulting emissions footprint. The propulsion system propositions investigated are LNG, ammonia and methanol combustion scenarios, diesel combustion whilst employing carbon capturing & storage onboard and hydrogen fuel cells with batteries, with the vessel case study being based on data acquired from a Greek passenger ferry carrying out trips in the Mediterranean during summer's peak tourist season. Results show that hydrogen exhibits the highest overall efficiency in terms of renewable energy utilisation, requiring 30% less compared to the next closest e-fuel alternative, achieving zero carbon emissions transport work during "peak season. Future work includes comparison amongst these alternatives in terms of cost.

Digitised Dockyard: Optimising Network Infrastructure for Ship-to-Shore Communication

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Abstract

HMNB Devonport is a military dockyard with over four miles of waterfront and is home to many Royal Navy vessels for alongside services and maintenance; additionally, the dockyard also receives ships from other Royal Navy flotillas, as well as international and merchant navy vessels. The Royal Navy is committed to providing welfare services to military personnel, including sailors living aboard when the ship is alongside a shore base, such as HMNB Devonport; these welfare services must allow sailors to communicate with family and friends and be entertained whilst onboard. The easiest way for the Royal Navy to meet these two requirements is to provide sailors with a stable Bring-Your-Own Devices (BYOD) wireless network. This service facilitates communication through messaging, video and audio calling, and social media, while entertainment is accessible via media such as eBooks, streaming services, gaming and surfing the internet. Currently, many berths at HMNB Devonport do not have a wired connection and rely on expensive 4G wireless connections. This presentation reviews the use of optimisation to implement a wired solution across the site to reduce operational costs for the Royal Navy.

Fostering Skills and Expertise in Robotics at UCL: Student Engagement in Virtual RobotX 2023 Competition

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Abstract

Benefiting from developments in the fields of control, computer science and mechanics, the field of robotics has been experiencing a significant and steady growth trajectory. As essential tools in the robotics ecosystem, ROS and Gazebo provide developers with a powerful and convenient framework to build, simulate and test robotic systems. Field Robotics and Learning Group in UCL Mechanical Engineering has arrange a challenge for students to participate in the Virtual RobotX 2023 Competition, which leads students to master how to interact with the Marine Robot in the Gazebo simulation environment and complete the low-level control and upper-level algorithm deployment of the robot.

Through the competition, the team successfully implemented a NMPC controller on the marine robot in Gazebo simulator to achieve the control allocation for four propulsion motors and four rudders. Additionally, the open3d based on point clouds is used to predict distances to the objects in the environment and estimate the robot location fusing with the GPS and sonar feedback. Furthermore, the open3d is used to detect the colour and shape of the buoy and determine the distance between the robot and the buoy.

Overall, participating students benefited from a hands-on learning experience, skill development, problem-solving opportunities, technical proficiency enhancement, collaborative learning, and real-world application of knowledge, all of which are invaluable for their future careers in robotics and engineering.

Robotic Welding for Manufacturing Operations in Marine Buildings

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Abstract

The application of robots in manufacturing and production has grown dramatically over the last few decades, and the marine sector is no exception. Automated systems have been developed and implemented for a wide range of marine applications, from shipbuilding to repair. As a complicated structure, ships are usually constructed by human labour. Situations that are not desirable are often attributed to human mistake. On the other hand, welding robot is highly accurate and effective in complex structures like shipbuilding. As a result, the primary goal of this research is to offer a technical and economic analysis of the use of welding robot during ship construction. The technical part concerns the optimisation technique for designing ship structures to facilitate automated (robot-based) manufacture. Furthermore, the economic component is connected to the cost-benefit analysis of automated (robot-based) production for enhancing the competitiveness, efficiency, and safety of ship design and production. The simulation of the ship's block panel assembly process with robotic welding demonstrates the potential for cost reductions. The analysis demonstrates a considerable difference in operational costs, emphasizing the efficiency and cost effectiveness of welding robot over traditional methods.

Keywords: Robotic Welding; Ship Manufacturing; Ship Structure; Automated Production, Production Cost.

Introduction

Ship construction, being a complicated structure, is certainly a human-driven activity. When operations do not proceed as planned, 'human error' is frequently stated as the cause. Due to its confined design, ship productions experience high summer temperatures between 40 and 50 degrees, and even during the day, it is frequently too dark to perform operations without restriction. However, this welding procedure is now carried out by welder, who operates inside the enclosed area that is encircled by the girders, the top and bottom shells, and the area where the transverse web floors are located [1]. In the shipbuilding industry, one of the most challenging and dangerous jobs for human workers is the manual welding procedure within the closed block [2]. Using robotic welding, this study addresses the obstacles of working in complex and confined structures in the marine building and proposes innovative solutions for efficient and safe welding processes [3].

Numerous benefits come with robotic welding, including enhanced quality, productivity, compliance to regulatory requirements, adaptability to hazardous and confined environments, and facilitation of creative construction methods [4]. The utilization of automated robotics in the welding process results in consistently high-quality welds, which enhances structural integrity and reduces the requirement for post-weld repairs [5]. Furthermore, the integration of welding robot systems has promise for enhancing productivity by minimising dependence on human labour, reducing the total production time, and highlighting prospects for cost reduction [6]. To fully realise the prospective of automated welding in the marine sector, a number of obstacles and constraints still need to be overcome.

According to the problems, the widely used idea of design for production must be updated to become a design for automated (robot-based) manufacturing. This research examines the role of robots in ship production and their potential to improve efficiency, reduce costs, and enhance safety. It then explores various approaches for ship structural optimization, including topology optimization, shape optimization, and size optimization, and how these techniques can be integrated into robot-based ship production to improve the quality and performance of ships.

Methodology

The procedures for carrying out this research include observation and data collection, offering a method to optimize the ship construction in support of automated (robot-based) manufacturing, carrying out numerical modelling, choosing the best design, and doing cost-benefit analysis. Robotic welding is predicted to be technically and financially feasible for the manufacturing of ships after achieving the ideal structure, which will also result in lower production costs and higher productivity.

In order to conduct literature review, a systematic review-based strategy was utilised. The existing literature on a given topic is thoroughly and rigorously analysed in a systematic literature review (SLR). Data were taken from the selected articles, including information like authors, title, year of publication, study aims, techniques, major results, and the type of welding robot technology used [7]. Through the organisation and synthesis of the information gathered from the articles, as well as the examination of the consequences and possible future directions recommended by the reviewed literature, common themes, trends, and research gaps, were made possible by the data extraction process [8]. The data were summarised and examined descriptively to discover trends, developments, and limitations associated with welding robot in maritime operations. The comprehensive literature review findings were organised and presented coherently, adhering to the framework of the research article.

The application of welding robot to a ship's double-bottom construction was simulated and evaluated on the basis of both technical and economic results. The purpose was to discover areas for process improvement and cost savings. The simulation compares robotic welding to traditional welding in the assembly of complicated ship constructions, such as double-bottom structures. This is accomplished by implementing the most efficient method of building complicated ship structures. In the following stage, a simulation is run to evaluate the welding robot procedure for the double-bottom stiffeners. This simulation focuses on evaluating how easily the robot arm can reach under the unique parameters of the baseline robot, which is set up at the level of the double-bottom construction. Given the structure's complexity, a detailed 3D simulation is used to properly determine the sections accessible to the robot arm.

Results and Discussion

Extensive research has examined the use of welding coupled with robotic equipment to better maritime constructions and industrial processes including GMAW, FCAW, GTAW, SAW, laser welding, HLAW (hybrid laser-arc welding), and WAAM (wire arc additive manufacturing). Robotic welding is complicated by the variety of materials and joint types used in maritime applications. These variances necessitate flexibility and adaptability in robotic welding technologies in order to modify welding settings and procedures accordingly. Appropriate process development, parameter optimisation, and sensor-based control mechanisms are required to solve material and joint variability issues. The method utilized to control the robotic systems allows for the classification of referenced welding robot into three primary classes. These classifications comprise totally autonomous, remotely controlled, and human-operated robots. The task's particular needs and the intended amount of human intervention determine which control mechanism is the best. Progress in robotic systems and their applications in a variety of industries, such as manufacturing, welding, and shipbuilding, may result from more research and development in these fields.

Robotic welding offers various advantages, including higher efficiency, improved quality, compliance with industrial standards, adaptability for limited and dangerous situations, and the possibility to enable new building approaches. Despite its merits, robotic welding in maritime applications has various obstacles relating to practical data, structural integrity, uniformity, and controllability [4]. However, the high starting costs and maintenance expenses are substantial impediments to the adoption of these technologies, particularly among small and medium-sized businesses.

The simulation shows that welding robot is around 3.85 times quicker than traditional welding [6]. These findings highlight the substantial time savings achieved through robotic welding over the conventional technique. As a result, the considerable cost difference demonstrates the efficiency and economic benefits of deploying robots for welding activities. The decreased cost of energy and man-hours in welding robot leads to considerable savings throughout the welding process.

Conclusion

The systematic literature review undertaken in this study thoroughly investigated welding robot techniques in the context of maritime constructions and industrial processes. Future study should look at welding problems and optimisation procedures to ensure compatibility with welding robot processes. The early findings demonstrate that robotic welding can lower expenses, perhaps leading to improved revenues for businesses. By overcoming the obstacles given by some of these research gaps, it is predicted that the use of welding robot will become a widely adopted, dependable, and practical technology for the growth of the global marine sector.

References

[1] Y. B. Jeon and S. B. Kim, "Modeling and motion control of mobile robot for lattice type welding," *KSME Int. J.*, vol. 16, no. 1, pp. 83–93, 2002, doi: 10.1007/BF03185158.

[2] D. Lee, N. Ku, T. W. Kim, J. Kim, K. Y. Lee, and Y. S. Son, "Development and application of an intelligent welding robot system for shipbuilding," *Robot. Comput. Integr. Manuf.*, vol. 27, no. 2, pp. 377–388, Apr. 2011, doi: 10.1016/j.rcim.2010.08.006.

[3] S. I. Wahidi, T. W. Pribadi, W. S. Rajasa, and M. S. Arif, "Virtual Reality Based Application for Safety Training at Shipyards," in *IOP Conference Series: Earth and Environmental Science*, Jan. 2022, vol. 972, no. 1, p. 012025. doi: 10.1088/1755-1315/972/1/012025.

[4] S. I. Wahidi, S. Oterkus, and E. Oterkus, "Robotic welding techniques in marine structures and production processes: A systematic literature review," *Mar. Struct.*, vol. 95, no. May 2024, p. 103608, 2024, doi: 10.1016/j.marstruc.2024.103608.

[5] A. G. Dharmawan, A. A. Vibhute, S. Foong, G. S. Soh, and K. Otto, "A survey of platform designs for portable robotic welding in large scale structures," in *2014 13th International Conference on Control Automation Robotics and Vision, ICARCV 2014*, 2014, pp. 1683–1688. doi: 10.1109/ICARCV.2014.7064569.

[6] S. I. Wahidi, S. Oterkus, and E. Oterkus, "Simulation of a Ship's Block Panel Assembly Process: Optimizing Production Processes and Costs through Welding Robots," *J. Mar. Sci. Eng.*, vol. 11, no. 8, p. 1506, Jul. 2023, doi: 10.3390/JMSE11081506.

[7] M. Gharbia, A. Chang-Richards, Y. Lu, R. Y. Zhong, and H. Li, "Robotic technologies for on-site building construction: A systematic review," *J. Build. Eng.*, vol. 32, no. August, p. 101584, 2020, doi: 10.1016/j.jobe.2020.101584.

[8] M. J. Page *et al.*, "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews," *BMJ*, vol. 372, 2021, doi: 10.1136/bmj.n71.

Design of Passive Fault-Tolerant Augmented Neural Lyapunov Control Laws for Autonomous Maritime Vehicles

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Abstract

The development of long-term missions employing Autonomous Underwater Vehicles (AUVs) and Underwater Gliders is hindered by the unstructured nature of the maritime domain. Unpredictable events, such as collisions with other vehicles or with drifting debris might cause damages to the vehicles and to the protruding actuators, such as thrusters and control surfaces. Fault Tolerant Control (FTC) strategies can be developed to cope with such occurrences of faults. Passive FTC methods entail using fixed-gain control laws to cope with both the nominal and the faultless modes, without needing to monitor the health status of the actuators, reducing vehicle costs and power requirements. Passive FTC methods currently available entail linearising highly nonlinear dynamics and cannot easily account for nonlinear effects.

In this work, a machine-learning technique is devised to automatically synthesise nonlinear Passive FTC laws without compromising on formal closed-loop stability certificates. Stability certificates are provided via Control Lyapunov Functions (CLFs), synthesised via Artificial Neural Networks. The formal correctness of the control laws and CLFs is in turn provided via automated reasoning tools. The method is demonstrated capable to compute control solutions in the case of AUVs and UGs with partial and total loss of actuator functionality. This work provides methods and tools supporting the increasing need to enhance the reliability of a growing plethora of maritime vehicles operating in challenging environments, while reducing the need for dedicated monitoring sensors or algorithms.

Extended Abstracts

Ocean observing technologies such as Remotely Operating Vehicles, Autonomous Underwater Vehicles (AUVs) and Underwater Gliders (UGs) are routinely deployed worldwide to record real-time in-situ data. The unstructured nature of the maritime environment poses challenges to the development of long term over-the-horizon missions, during which the maritime vehicles can be exposed to unpredictable and unforeseen events, such as collision with drifting debris or other vessels, or attacks by marine predators. Possible damage to an autonomous vehicles' structure and the exposed control surfaces can be addressed by employing Fault Tolerant Control (FTC) systems.

The standard solution comprises the use of Active FTC methods, which rely on monitoring the health status of the actuators using sensors or fault-detection algorithms. The design and tuning of Active FTC techniques typically result in higher control performance following the occurrence of a fault, with the downside of being computationally more expensive, requiring extra costs and energy consumed to power the monitoring sensors. On the other hand, Passive FTC methods employ fixed-gain controllers that can maintain closed-loop stability without requiring confirmatory data on the occurrence and status of faults, but result in more conservative performance in the nominal faultless scenario. AUVs represent a category of exceptionally expensive vehicles operating in highly uncertain conditions, where reliability and safety are often preferred to higher performance, and where Passive FTC techniques find application. Passive FTC methods, encompassing robust control methods as in H_2/H_∞ suffer two main drawbacks: first, controllers are usually designed based on linearised approximations of nonlinear dynamic; second, nonlinear effects, such as actuator saturations, cannot easily be kept into account. These issues are of paramount importance given the highly coupled and nonlinear dynamics characterising the underwater vehicles domain, where linearisation techniques often bear excessive simplification. Recent advancements in computer-aided control techniques, e.g. Artificial Neural Networks (ANNs), offer great potential to support the design of control laws for dynamical systems without leveraging linear approximations, but require dedicated assessment to verify the closed-loop stability.

Within this context, the *Neural Lyapunov Control* (NLC) method [1], a machine-learning technique encompassing two ANNs, is selected as the most promising candidate method. A key advantage of using the NLC method over other machine-learning approaches lies in the closed-loop stability certificates that can be provided: even if the training is carried out on a finite-size sample set, the formal certificate of stability can be provided over the domain of the reals. Such formal verification is obtained by means of automated reasoning tools designed for theorem proving, such as the Satisfiability Modulo Theory solvers. An *Augmented NLC* (ANLC) method is devised [2], allowing to systematically synthesise nonlinear control laws for nonlinear dynamical systems, with limited user inputs and requiring minimal computational resources. ANLC is tailored to tune two ANNs to embody a) a stabilising controller and b) a Control Lyapunov Function (CLF) to certify the closed-loop stability. During the training, the weight and bias of the ANNs are updated by backpropagating a loss function devised according to the Lyapunov stability theory, with the control architecture outlined in Fig.1.

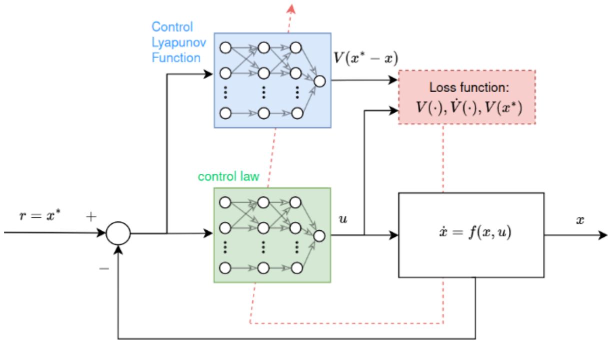

Figure 1: Augmented Neural Lyapunov Control architecture during the training stage, with the Control Lyapunov Function ANN (blue), the control law ANN (green), and the Lyapunov-based optimisation criterion backpropagated (red).

To train the ANNs and return a stabilising controller, the ANLC method exploits a loop between two main modules, the *Learner* and the *Falsifier*. The Learner is tasked with training the two ANNs starting from a finite set of initial samples (sparse), based on a Counter Example-Guided Inductive Synthesis (CEGIS) approach [3], as depicted in Fig. 2.

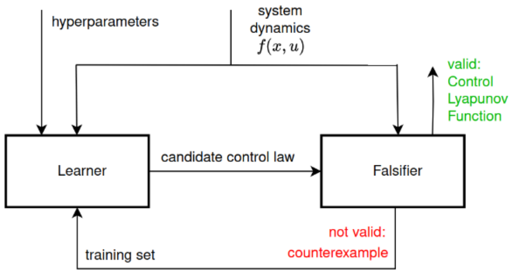

Figure 2: Counter Example-Guided Inductive Synthesis for learning control laws and Control Lyapunov Functions with formal verification of correctness.

The Learner trains the CLF and the control gains by iteratively minimising a loss function, expression of the three theoretical Lyapunov conditions, namely the CLF being positive-definite with its Lie derivative negative-definite, and being zero at the equilibrium. Given an initial finite sample of datapoints, the learning endures until the loss function reaches zero, guaranteeing that, on the sample set, all points respect the theoretical stability conditions. At this stage, the CLF is passed to the Falsifier, where the Lyapunov stability conditions are formally evaluated over a (bounded) domain of real numbers. Following this, either the CLF is verified to be valid and the procedure is terminated, or counterexamples are generated. In the latter case, the counterexamples are added to the dataset, which is fed back to the Learner, which restarts the training procedure. Both ANNs are recurrently updated during the training stage, but serve different purposes. While, upon successful completion of the training, the control law is deployed in the standard closed-loop scheme, the CLF is used during the learning phase to ensure that the closed-loop system is stable. An example of the training evolution of a CLF can be viewed at https://github.com/grande-dev/Augmented-Neural-Lyapunov-Control/blob/master/ANLC_v2/documentation/images/CLF_training.gif, altogether with the software tool, released open source.

Next, the ANLC method is extended to the automatic synthesis of Passive FTC laws for dynamical systems affected by multiple faults. The adapted method, defined as *passive Fault-Tolerant ANLC* (pFT-ANLC) encompasses two key methodological elements: a) the definition of a set of dynamics capturing the nominal and faulty systems and b) the rendering of all the associated Lie derivatives negative definite. The solution is then searched by formulating a simultaneous stabilisation problem for a range of dynamics, where one unique control gain shall guarantee to stabilise the system under several operating conditions. The method is showcased in different scenarios, encompassing both partial and total loss of actuator efficiency for a range of AUV and UG platforms. As an example, the effectiveness of the method is presented in Fig. 3, illustrating an example of planar navigation of an AUV mounting three fixed thrusters, each one capable of generating force both in the positive and negative direction.

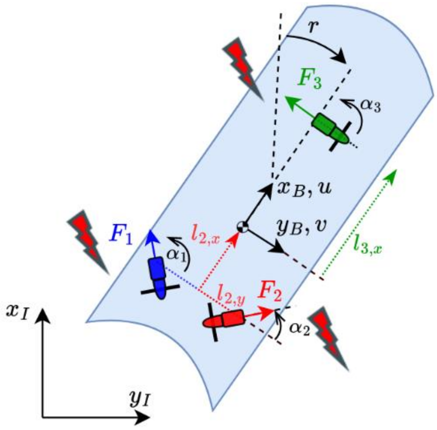

Figure 3: AUV with three fixed thrusters, each one possibly affected by one fault (at most one at any given time).

The goal of the presented study is to synthesise a unique control law to maintain the AUV moving forward at prescribed target speed of x_1* = 0.5 [m/s]. Ten different optimisation runs are executed with random initial control gain parameter, of which 9 successfully converge within 39 [s]. As it can be appreciated in Fig. 4, the method guarantees prescribed performance degradation whilst demonstrating the capability to systematically synthesise control laws within a few minutes of computational time on an unassuming office laptop.

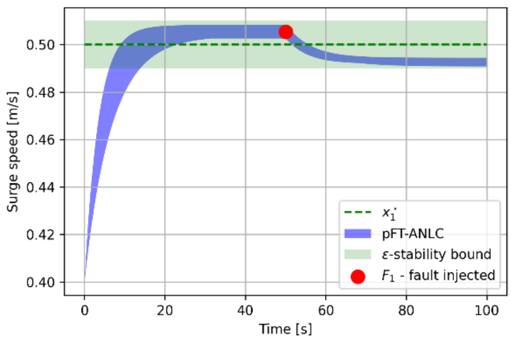

Figure 4: Closed-loop test AUV system: range of surge dynamics associated to 9 synthesised controllers (blue interval) — fault on the fault thruster injected at t=50 [s], with the dynamics remaining within prescribed bounds.

The method demonstrates the capability to compute control solutions in the case of autonomous underwater and surface vehicles with partial degradation of actuator efficiency or with complete loss of functionality. As the integration of artificial intelligence in marine application is becoming ubiquitous, novel control designs can be devised to guarantee desirable dynamical behaviours, without compromising on formal stability guarantees. This work provides methods and tools supporting the increasing need to enhance the reliability and autonomy of a growing plethora of maritime vehicles operating in remote and challenging environments, while reducing the need for dedicated monitoring sensors or algorithms, reducing vehicle costs and power requirements.

[1] Chang Y. et al. "Neural lyapunov control." *Advances in neural information processing systems* 32 (2019).

[2] Grande D. et al. "Augmented Neural Lyapunov Control." *IEEE Access* (2023).

[3] Solar-Lezama, A., et al. "Combinatorial sketching for finite programs". *International conference on Architectural support for programming languages and operating systems (*2006).

[4] Grande D. et al. "Passive Fault-Tolerant Augmented Neural Lyapunov Control: a method to synthesise control functions for marine vehicles affected by actuators faults". *Control Engineering Practice* (2024).

Advanced Powertrain Design and Optimisation for Maritime Vessels

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Abstract

Clean powertrain design is a complex topic that requires a balance between meeting engineering performance requirements, and costs. For instance, lithium batteries have a relatively low up-front capital cost and low operational costs but poor energy density, thus more weight and volume requirements. Hydrogen fuel cells on the other hand, though more expensive to buy, benefit from the higher energy density of hydrogen, giving vessels operating with the fuel a greater endurance. This presentation explores a new method for designing top-level powertrains using a powertrain simulation model. It uses a database of components to generate large numbers of powertrains capable of delivering a specified duty cycle. It then tests them under a real operating profile, measured directly from the vessel's prop shaft. The powertrains are then optimised for cost, mass, volume, or other objectives using multi-objective optimisation to find the best option. It results in information for vessel owners and operators on powertrain design, infrastructure requirements, skills requirements, and vessel performance. So far, the model has been used to design multiple powertrains, including for a hydrogen-based retrofit of a research vessel, Prince Madog, as well as to inform the business cases of many other operators.

Measurement of Power in Vessels for Decarbonisation

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Abstract

Clean powertrains for vessels suffer in comparison with fossil fuel powertrains in terms of energy density, potentially affecting their endurance and speed. As other major industries pivot towards alternative fuels, it is vital for the marine sector that there is a strategy in place to ensure that the operations of these vessels are not effected negatively in the transition.

This presentation documents the approach of CFCM (Centre for Future Clean Mobility), that guides companies and businesses though the route of decarbonisation to a low or no emission vessel by the design of purpose built clean powertrains. The accurate and efficient measuring of useful power output from vessels currently running traditional diesel powertrains will be highlighted. CFCM have developed multiple methods for the measurement of duty cycles on operational vessels. Methods which must take into account the real-world power demands of prime movers and hotel loads of vessels in both typical and demanding conditions.

This will provide an introduction into; the methods used for power measurement, the way in which this data is subsequently analysed to be used as part of the powertrain design process, how it is used to optimise the powertrain selection process to reduce cost and maximise efficiency, then used to drive the testing of prototype powertrains on an engine dynamometer. Thus, completing the sequence of powertrain development.

Methanol and hydrogen combustion in marine diesel engines.

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Abstract

The maritime industry is at a critical juncture, facing mounting pressure to reduce CO2 emissions and embrace sustainable energy solutions. This publication delves into the exploration of methanol and hydrogen as alternative fuels for marine diesel engines, aiming to address the environmental challenges while ensuring operational efficiency. Methanol and hydrogen combustion, showcasing significant environmental benefits pertinent to diesel. The present study examines different combustion methods, injection parameters and engine modifications to allow for stable combustion of methanol and hydrogen at different shares in marine diesel engines. The examined engine is a 4-stroke 10.5 MW one, with 460mm x 580mm bore and stroke respectively. For methanol combustion, relative studies resulted that under port injection, 50% methanol energy fraction can be utilised, whereas for direct injection this number increases to 95%. According to a parametric optimisation and considering combustion and emissions objectives, it is suitable to inject methanol early during the compression stroke whereas the pilot diesel fuel close to TDC. For low load, where the quenching effect of methanol fuel turns important, multi-injection strategies allow for increased combustion efficiency and NOx reduction. Finally, the concept of variable compression ratio engine between loads proves beneficial for engine efficiency. Regarding hydrogen combustion, compression ratio reduction allows for knock-free combustion when hydrogen is port injected at the intake manifold. Conversely, significant measures are required to improve combustion efficiency.
By providing a detailed understanding of methanol and hydrogen combustion in marine engines, this research contributes to the ongoing efforts to foster sustainable maritime transportation practices. Through innovative fuel solutions and technological advancements, this study aims to support the industry in transitioning towards decarbonisation, ultimately mitigating the environmental impact of maritime activities and aligning with global sustainability goals.

Key Words: methanol combustion, hydrogen combustion, marine dual fuel engine, CFD modelling

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Abstract

Approximately 1000 workboats of various sizes operate in UK waters, nearly all of which use diesel fuel, and therefore emit considerable amounts of COx, SOx , NOx and particulates. They may not comply with potential future regulations. This presentation showcases how the Centre for Future Clean Mobility (CFCM) undergoes the process of retrofitting work vessels with low and zero-emission powertrains, specifically the Prince Madog (operating from Port Madog, North Wales). By measuring and analysing the vessel's operational profile, a duty cycle of the vessel's existing powertrain was constructed. The duty cycle was then used with a powertrain simulation model which provided the most feasible powertrain configurations ranked on performance and/or costs. The most optimal powertrain was then selected and simulated using a bespoke control strategy. The components of the powertrain are then sourced, and a prototype will be tested using the dynamometer at CFCM. Using these tools, CFCM is able to design and implement a powertrain optimised for minimal capital expenditure and operating expenditure that is capable of delivering against requirements for power, range, and operating conditions. The selected final powertrain is then fully designed, sourced, bench tested, and is currently being installed on the vessel. These tools can be used to retrofit other vessels of different shapes and sizes with clean powertrains and can also be used for the same applications in the road and rail sector.

Research into Low-Frequency Surge Underpredictions of Floating Offshore Wind Turbines

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Abstract

To meet the growing demand for renewable energy and net zero carbon emission targets set by the government, offshore wind is looking to move into deeper waters using floating offshore wind turbines (FOWTs) to capture the more consistent winds and expand the area available for energy capture. This has presented the challenge of being able to accurately model FOWTs allowing for the design of cost-effective and reliable structures. In recent years, code comparison studies have revealed that current modelling tools and design techniques used in the industry yield a significant underprediction in low-frequency surge motion compared to experimental results.

This project investigated this low-frequency underprediction by incorporating various theories and correction factors into the simulations in multiple environmental conditions, it was found that these correction factors reduced the underprediction when compared to experimental results but further studies with different vessels are required before using any corrections with confidence. Furthermore, an investigation into the potential consequences of this underprediction and the effects it could have on FOWT design was undertaken, and a fatigue analysis assessment of the power cable found that this underprediction could cause an increase in fatigue damage up to 13% higher than expected. Finally, an investigation into how low-frequency forces are calculated through quadratic transfer functions (QTFs) and a comparison of QTFs obtained theoretically through potential theory compared to those obtained through experimental means is made.

Performance Sports Engineering: Improving Knowledge of Human Underwater Undulatory Swimming

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Abstract

Underwater Undulatory Swimming (UUS), performed fully submerged following a dive or push from the wall in swimming, can be exploited to gain a competitive advantage in races. Athletes can travel underwater for up to 30 % of the race while performing an undulatory motion, benefitting from a reduction of resistive forces. The undulatory motion consists of a wave which propagates along the body, from the fingertips to the toes. As this wave moves along the body its amplitude increases, accelerating the fluid downstream to generate propulsive forces which propel the swimmer forward. This swimming technique mimics the locomotion of marine mammals. This collaborative presentation highlights the work undertaken during two closely related UK Sports Institute funded PhD projects. The kinematic data acquisition process using three-dimensional optoelectronic motion capture will be presented, along with the joint centre reconstruction methods. A novel two-dimensional implicit-LES computational fluid dynamics methodology will also be introduced. Examples of applications given by the speakers will include an estimation of error within the kinematic capture domain, the efficacy of training practices in UUS skill development, and a case study on the impact of kinematic modification on UUS force generation of a regional-level swimmer.

Experimental Investigation on Flow-Induced Vibration of Non-Circular Cylinders under Turbulent Flows

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Abstract

With the growing demand of clean and sustainable energy, research into energy extraction from flow-induced vibration (FIV) has gained momentum in both small and large-scale applications. FIV energy extractors offer the advantage of operating effectively in relatively slow flow speeds without causing harm to the ecosystem. There is a limited experimental study on FIV of non-circular cylinders, particularly in the context of freestream turbulence flow, which may be useful for real-world ocean current responses. In this study, we experimentally investigate the effect of FIV on the two-degree-of-freedom (2-DoF) responses of square and semi-circular rigid cylinder under freestream turbulence flow condition. The experiment is conducted in the water flume of Newcastle University, utilizing pivoted rigid cylinders with an elastically mounted pendulum and universal joint setup. The flume can generate flow turbulence intensities of up to 14%. This experimental system facilitates free movement of the vertical cylinder in two degrees of freedom, with horizontal springs attached to the in-line (X) and crossflow (Y) directions. The maximum reduced velocity reaches 20, associated with the Reynolds number of about 12,000. The cylinder X-Y motions and the influence of cylinder inclination during FIV are captured using the Qualisys cameras. The effects of flow turbulence are observed through the measured response time histories and fluctuating frequencies, particularly in the in-line responses and at higher flow velocities. Depending on the angle of incidence and cross-section of cylinder, 2:1 and 1:1 (X:Y) dual frequency responses are observed. The experimentally observed chaotic 2-DoF responses in free-stream turbulent flow offer some fundamental valuable insights into the impact of random flow environments on the development of FIV energy harnessing devices for utilization within the ocean/sea currents. Our ongoing studies involve the development of numerical models to predict combined galloping-VIV features using the quasi-steady theory in conjunction with nonlinear wake oscillators.

The influence of human error on machine learning coral cover predictions

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Abstract

Seabed cover estimates are an internationally recognised Essential Ocean Variable (EOV) for assessing the health of marine environments (Levin et al., 2019). They can be derived from non-destructive seabed image surveys by drawing around the observed objects of interest with a mask, a process known as instance segmentation. Manual instance segmentation is time-consuming and subject to human error (Curtis et al. 2024). Instance segmentation can be automated using supervised machine learning, but the performance of trained networks is impacted by the quantity and quality of the manually created training data.

We demonstrate the impact of training data quality on the instance segmentation of cold-water coral colonies from seafloor images collected from the Darwin Mounds Marine Protected Area (MPA) in 2019 with the autonomous underwater vehicle Autosub6000 carrying the BioCam imaging system (Thornton et al., 2021).

Eleven users annotated the same 96 seafloor images for living cold-water coral colonies. We found that annotators exhibited size selectivity bias, leading to omission of masks for small colonies and inconsistent colony delineation. Using different user annotations to train Mask R-CNN instance segmentation (He et al. 2020) produced different coral colony predictions, with model performance inversely correlating with annotator size selectivity bias. To reduce bias in our training data, we tested several methods: (i) generating missing colony masks, and (ii) combining multiple user annotations to create new training data, both with (a) average masks, and (b) heatmap masks.

Generating masks with a modelled colony size based on users' drawn masks significantly improved model detection success. Annotator variability in size selectivity bias and mask quality was reduced by combining user masks to create new training datasets, generally improving trained model performance. We used the average consensus masks of all 11 users to create a reference dataset and to infer live coral cover over the full 29-hectare extent of the western Darwin Mounds survey area (20,281 individual seafloor images). The potential for fully autonomous surveys of the site and the automated generation of cold-water coral seabed cover EOV data offers an effective and efficient means to monitor the status of this and other offshore MPAs.

Acknowledgements

Many thanks to the captain and crew of RRS Discovery cruise DY108-109 and the Autosub6000 engineering team. We also thank the members of the University of Southampton and the National Oceanography Centre who provided the image annotations for this study. This research was funded by the following UK Natural Environment Research Council programmes: Climate Linked Atlantic Sector Science (NE/R015953/1) and Oceanids (NE/P020887/1, NE/P020739/1, NE/S007210/1, NE/R015953/1).

References

Curtis, E.J., Durden, J.M., Bett, B.J., Huvenne, V.A.I., Piechaud, N., Walker, J., Albrecht, J., Massot-Campos, M., Yamada, T., Bodenmann, A., Cappelletto, J., Strong, J.A., Thornton, B. (2024). Improving coral monitoring by reducing variability and bias in cover estimates from seabed images. Prog. Oceanogr. 222, 103214.

He, K., Gkioxari, G., Dollar, P. & Girshick, R. (2020). Mask R-CNN. IEEE Trans. Pattern Anal. Mach. Intell. 42, 386–397.

Huvenne, V. A. I., Bett, B. J., Masson, D. G., Le Bas, T. P. & Wheeler, A. J. (2016). Effectiveness of a deep-sea cold-water coral Marine Protected Area, following eight years of fisheries closure. Biological Conservation 200, 60-69.

Levin, L. A., Bett, B. J., Gates, A. R., Heimbach, P., Howe, B. M., Janssen, F., McCurdy, A., Ruhl, H. A., et al. (2019). Global Observing Needs in the Deep Ocean. Frontiers in Marine Science 6.

Thornton, B., Bodenmann, A., Yamada, T., Stanley, D., Massot-Campos, M., Huvenne, V., Durden, J. M., Bett, B. J., et al. (2021). Visualising multi-hectare seafloor habitats with BioCam. Oceanography 34, 92-93.

Automatic Detection of Underwater Boulders from Side Scan Sonar using Machine Learning

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Abstract

Detection of small objects in side scan sonar imagery is a challenging task due to the size of the targets and the quality of the data. Boulders are very small objects that look similar to other elements of the seafloor environment. Manual annotation of the targets is a time-consuming process, especially considering that the number of boulders in some areas may reach the thousands. In this study, we experiment with deep learning models for the automatic detection of boulders. It is found that the use of smaller images helps in the reduction of false positive detections and increases detection of actual boulders. The best-trained model, YOLOv8, detects 66% of the boulders during inference; however, it produces a significant number of potential false positive detections. The results demonstrate that the use of deep learning automated target detection systems is promising and can be used as a form of an initial filter to save time. However, their results should be verified by the expert annotator to confirm if the detections are correct. It is unlikely that the process of annotating underwater targets can be fully automated, but for more practical usage, the models require training on a significantly larger dataset.

Enhancing Maritime Environment Perception with 3D LiDAR: A Novel Framework for Robust Detection and Tracking of Floating Objects by Unmanned Surface Vehicles

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Abstract

Environment perception is crucial for Unmanned Surface Vehicles (USVs) to effectively perform various tasks in complex environments. Most existing methods for water surface object detection rely on camera-based methods, which are sensitive to environmental conditions and cannot provide spatial location information for detected targets. This study proposes an LiDAR-based object detection framework focused on high-traffic marine zones, aimed at performing robust and accurate detection of floating objects. This framework consists of two functional modules: object detection and multi-object tracking. For object detection, a Convolutional Neural Network (CNN)-based method is used to address the issue that clustering methods in crowded docking scenarios can easily result in different objects being incorrectly grouped within the threshold. The specific network selected is PointPillar, as it offers an efficient approach to convert 3D point cloud data into 2D pseudo-images, thereby reducing the inference time compared to other networks. A Kalman Filter-based multi-object tracking is implemented, unlike other approaches that fuse detection results with other measurements like AIS. Only detection results are used as input to compensate for missing detections, enabling robust tracking performance in areas that cannot receive related measurements. The proposed framework is tested in a simulated port environment and demonstrates robust performance and potential for real-world applications.

Extended Abstracts

1. Introduction

Unmanned Surface Vehicles (USVs), serving as intelligent robots in the maritime domain, have attracted significant attention owing to their lower development and operational costs. Particularly notable is their enhanced flexibility and autonomy in complex and hazardous environments, along with their advantages in repetitive tasks [1]. To enable USVs to execute diverse tasks in various environments, a robust environmental perception capability is crucial for planning operations and safely implementing tasks through control units. In recent years, there has been notable progress in environmental perception technology within the Unmanned Ground Vehicles (UGVs) domain. However, advancements in the USVs domain have exhibited a comparatively slower pace. This disparity is primarily attributed to the unique challenges posed by maritime environments, such as the impact of wind, waves, and ocean currents on ship movement, along with challenges from sea fog and water reflection affecting sensor performance [1], [2]. Furthermore, maritime traffic lacks strict lane restrictions, and floating objects at sea exhibit a wide range of sizes, from small buoys less than a meter to large tankers exceeding hundreds of meters.

Most existing methods for water surface object detection rely on cameras installed onboard to capture environmental images. These methods utilize semantic information from images and related algorithms to detect objects on the water's surface. However, these methods face numerous limitations in practical applications, such as changes in lighting due to water reflection and image blurring caused by sea fog [2]. Furthermore, image-based methods cannot provide real-world position information for detected targets, restricting their application in planning systems. In contrast, LiDAR is a feasible alternative sensor for perception tasks, thanks to its robustness under various weather and lighting conditions [3]. It generates detailed point clouds data that including precise spatial locations. Such capabilities make LiDAR more effective sensor than cameras for detecting floating objects in marine environment. Despite these advantages, there's still limited research in this field. A significant challenge is the complexity of processing point cloud data compared to images. Point clouds, being 3D and filled with more semantic information than 2D images, demand higher computational resources for processing, consequently impacting the processing time and the ability of real-time navigation and obstacle avoidance, especially in busy areas. Besides, data collection from both cameras and LiDAR is heavily influenced by the motion of USVs. This constraint can result in missed detections at certain moments, resulting in discontinuities in the detection sequence [3], [7].

Being aware of the advantages of LiDAR-based detection over traditional image-based methods, the aim of this project is to develop a framework that uses LiDAR as the primary sensor for conducting perception tasks, with a focus on port areas due to their complexity as high-traffic marine zones. To address the challenges associated with processing 3D point cloud data and accurately detecting floating objects on the water surface, we propose a Convolutional Neural Network (CNN)-based method, specifically the PointPillar approach. To address the issue of discontinuous detection caused by the motion of USVs, we introduce an object tracking algorithm that combines the Kalman Filter (KF) with the Hungarian matching algorithm to compensate for missed detections. Experimental results demonstrate the effectiveness of our proposed framework, proving it to be robust in achieving continuous detection in a sequence of point cloud data-based detections.

Related Work

In the limited research of using LiDAR for open water detection applications, most studies have relied on Euclidean or DBSCAN clustering [5], [6] to group target objects. Xiao et al. [3] proposed a segmentation method using a lightweight network, LiSeg, demonstrating that deep learning-based segmentation methods are more competitive than traditional approaches. Nonetheless, they still rely on Euclidean clustering for grouping the two-dimensional point cloud into multiple objects in post-processing. These clustering methods can become unstable, especially in crowded docking scenarios, as heavily reliance on Euclidean distance for clustering can easily result in different objects being incorrectly grouped within the threshold [7]. Besides using clustering methods to detect objects, deep learning-based algorithms have proven more effective, with their enhanced performance evidenced in ground vehicle applications. LiDAR-based deep learning features two main approaches: the Bird's Eye View (BEV) map and the Voxel grid method. Typically, the Voxel grid method requires a higher computational resource than the BEV map because it requires the use of 3D CNNs to process the data, whereas the BEV map leverages 2D CNNs. Various methods have been developed based on these approaches, with PointPillar being renowned for converting 3D point cloud data into BEV maps, and SECOND being well-known for its use of Voxel grids.

The work of Lin et al. [7] is of particular interest to this project. They simulated a series of maritime point cloud data using ROS to identify multiple targets of interest, including ships, containers, and buoys. They utilized PointPillar as their base network for object detection and integrated the detected object results with AIS data for tracking objects using an EKF. However, AIS data are not always available, such as under bridges or for small boats and buoys that do not transmit AIS signals. Thus, this project is inspired by their framework, employing PointPillar to detect water surface targets, with a focus on ships and buoys of various sizes. An improved object tracking solution is proposed, utilizing only the detection results to track potential missing detections, aiming to enhance robustness for broader application.

Methodology

The proposed framework integrates object detection and tracking, as illustrated in Figure 1. Initially, the point cloud data is fed forward to the PointPillar, which identifies target objects and their oriented bounding boxes (Obbxs). However, the dynamics of maritime environments significantly affect USVs, leading to incomplete point cloud data and, consequently, gaps in target detection. To address these discontinuities, the framework employs a KF-based multiple objects tracking approach, augmented with the Hungarian Matching algorithm, to compensate for the impact of missing detections.

The PointPillar is designed to process point cloud data for the precise estimation of 3D Obbxs, targeting maritime objects including but not limited to various classes of boats and buoys. This process unfolds in three methodical stages, as shown in Figure 1, beginning with a feature encoder network that transforms 3D point cloud data into a streamlined 2D pseudo-image. This pseudo-image then refined by a 2D convolutional backbone, yielding a high-level representation. The last step of this process is finished through a detection head, which is responsible for classifying objects and regressing their 3D Obbxs.

The proposed framework's second component integrates a Kalman Filter (KF)-based multi-object detection mechanism with the Hungarian algorithm. This combination effectively addresses data association challenges in multi-object tracking scenarios. The Hungarian algorithm plays a crucial role in correlating detections across frames, with the KF tracking historical detections and current data.

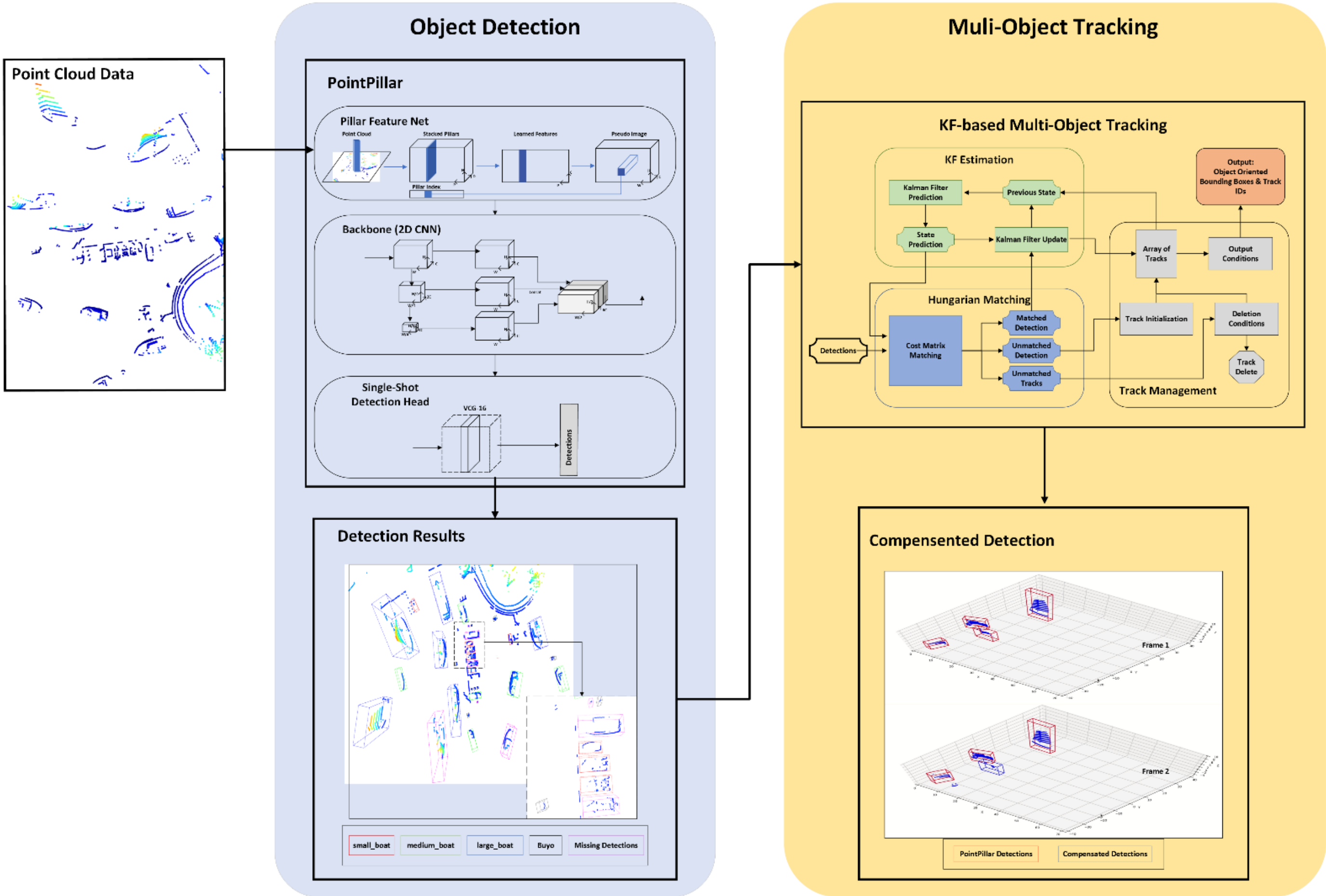

Figure 1: Framework for proposed maritime environment perceptions

Multi-object tracking process begins by pairing new detections with those from the previous frame using the Hungarian algorithm, relying on the Euclidean distance between object pairs for matching. Following steps include assigning unique identifiers to newly detected objects and initializing their tracking using a KF model, denoted as $Kalman_p(x, y, \theta, \dot{x}, \dot{y}, \dot{z})$. Here, (x, y, θ) represents the centre and orientation of the Obbxs, while $(\dot{x}, \dot{y}, \dot{z})$ indicates their velocities. The employed KF model is based on a constant velocity framework. For previously detected objects that match with current frame detections, the KF is utilized to adjust the prior frame's predictive model with the latest measurements. Additionally, for objects not detected in the current frame but observed in earlier frames, predictions from the last frame are used to compensate for these absences. Objects undetected for more than five frames are excluded from tracking. This methodology provides a robust framework for tracking objects across sequences of frames, effectively managing the challenges posed by object detection continuity in dynamic maritime environments.

Conclusion

In this study, we introduce a 3D LiDAR-based approach for the accurate and robust detection of floating objects on water surfaces. Our framework includes: 1) employing the deep learning network, PointPillar, for direct processing of LiDAR point clouds and detection of target objects; 2) deploying a Kalman Filter for tracking detected objects using only detection input, enabling continuous and robust detection. Experiments conducted in a port area simulated using ROS demonstrate that our proposed method achieves commendable performance.

References

[1] Liu, Z., Zhang, Y., Yu, X., & Yuan, C. (2016). Unmanned surface vehicles: An overview of developments and challenges. Annual Reviews in Control, 41, 71–93. https://doi.org/10.1016/j.arcontrol.2016.04.018

[2] Cao, X., Gao, S., Chen, L., & Wang, Y. (2020). Ship recognition method combined with image segmentation and deep learning feature extraction in video surveillance. Multimedia Tools and Applications, 79(13–14), 9177–9192. https://doi.org/10.1007/s11042-018-7138-3

[3] Shan, Y., Yao, X., Lin, H., Zou, X., & Huang, K. (2021). Lidar-Based Stable Navigable Region Detection for Unmanned Surface Vehicles. IEEE Transactions on Instrumentation and Measurement, 70, 1–13. https://doi.org/10.1109/TIM.2021.3056643

[4] Yao, L., Kanoulas, D., Ji, Z., & Liu, Y. (2021). ShorelineNet: An Efficient Deep Learning Approach for Shoreline Semantic Segmentation for Unmanned Surface Vehicles. 2021 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 5403–5409. https://doi.org/10.1109/IROS51168.2021.9636614

[5] Lin, J., Koch, K., Koch, M. Kurowski, J. -J. Gehrt, D. Abel and R. Zweigel. (2020). Environment Perception and Object Tracking for Autonomous Vehicles in a Harbor Scenario. 2020 IEEE 23rd International Conference on Intelligent Transportation Systems (ITSC), pp. 1-6, doi: 10.1109/ITSC45102.2020.9294618

[6] Stanislas, L., & Dunbabin, M. (2019). Multimodal Sensor Fusion for Robust Obstacle Detection and Classification in the Maritime RobotX Challenge. IEEE Journal of Oceanic Engineering, 44(2), 343–351. https://doi.org/10.1109/JOE.2018.2868488

[7] Lin, J., Diekmann, P., Framing, C.-E., Zweigel, R., & Abel, D. (2022). Maritime Environment Perception Based on Deep Learning. IEEE Transactions on Intelligent Transportation Systems, 23(9), 15487–15497. https://doi.org/10.1109/TITS.2022.3140933

List of Posters

Frederick Ebili	University of Strathclyde	Safe Liquid and Gas Energy Transport Amid Decarbonisations
Hyeong-Jin Kim	UCL	Digital healthcare engineering system for ageing containership in rough seastates
Insik Hwang	University of Strathclyde	Establishing safety zone for ammonia bunkering operations: a quantitative risk assessment
Jamie Hawkins-Dady	SOTON	Dynamics of a wave-propelled autonomous surface vessel
Mohammad sholikhan Arif	University of Strathclyde	State of the art simulation in the shipyard (Shipbuilding, ship recycling, ship repair)
Molly Phillips	SOTON	Autonomous Droplet Microfluidic Sensor for Highly Variable Ocean Alkalinity
Nathan Smith	Newcastle University	Digital Technology to support artisanal fishing boats in East Africa
SHIBO ZHAO	Newcastle University	Development of a Decision Support System for Ship Energy Efficiency considering Energy/Exergy Assessment
Song Ma	UCL	Active planning for unmanned surface vehicles in marine pollution surveying
William Cooper	SOTON	Data Driven Modelling of the Global Maritime Transport Network as a Complex System
Yasin Burak Kurt	University of Strathclyde	Integrating Human Factors and Cybersecurity in Maritime Operations: Pathways to Safer and Smarter Shipping
Fei Geng	Newcastle University	Research on the Scour of Offshore Wind Turbine Monopile Foundations in Oscillatory Flow
Sarath Chandran Sivaji	Newcastle University	OPTIMISATION OF SUSTAINABLE HYDROGEN PRODUCTION FOR MARITIME APPLICATIONS
Muhammad Iqal	University of Strathclyde	Fisherman Safety from Onboard Fish Deployment Perspective

#100 AM

Safe Liquid and Gas Energy Transport Amid Decarbonisation Transition

Department of Naval Architecture, Ocean and Marine Engineering (NAOME)

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No.1

Research Background

Three Key Pipeline Operational Phases Over Lifecycle:
- Design
- Construction
- Operation

The offshore natural gas pipelines are the best means of energy transport. However, it encounters different design and operational failure modes that need urgent attention to keep the marine environment stable before the emergence and stability of the proposed alternative.

The Architectural Formulation of this Research Poster is Anchored on Numerical Simulation and Validated with Analytical Process

Methodology

A numerical method is employed to critically investigate the burst pressure strength of the X70 gas pipeline and validated analytically (Appendix File). The mechanical APDL branch of the ANSYS commercial software is robustly utilised for the computational analysis of the burst pressure level within a tolerance-designed value. Also, a tested metal plate with the 'A' result contour plot verified the bilinear behaviour of the material.

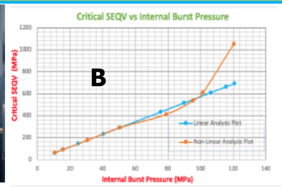
Statistical data of natural gas pipelines worldwide as of January 2022 by project status: **World Atlas-Energy Minute.**

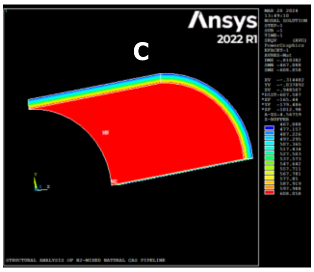
No. of pipeline	Project Status
1608	In operation
339	Proposed
145	U-construction
89	Cancelled
66	Shelved
8	Retired
6	Mothballed

Externally reinforced pipe for offshore pipelay-Nord Stream.

FEA Application in ANSYS

Deepwater Horizon Pipeline Explosion, Gulf of Mexico 2010.



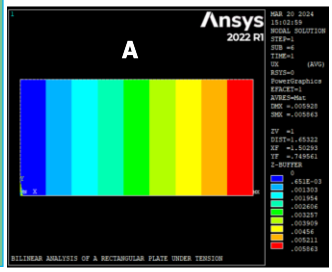


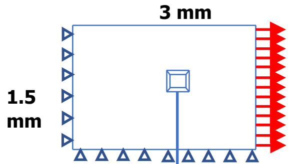
Aim

The study aims to holistically improve the structural performance of an offshore gas pipeline by ensuring critical analysis to evaluate and predict its structural stability and integrity amid the decarbonisation transition.

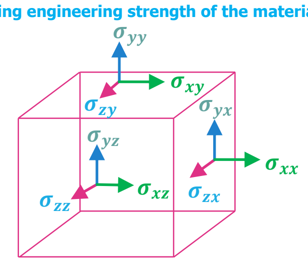
Objectives

- To utilise the capability of FEA for flawed and unflawed offshore carbon steel natural gas pipeline simulation for failure prediction.
- To implement the robustness of the analytical method against the computationally simulated results of the natural gas pipelines for validatory purposes.





A schematic of a piece of a rectangular plate: testing engineering strength of the material.



Both normal and shear stresses are possible at any part of the plate.

$$\sigma_{vm} = \sqrt{\frac{(\sigma_{xx}-\sigma_{yy})^2 + (\sigma_{yy}-\sigma_{zz})^2 + (\sigma_{zz}-\sigma_{xx})^2 + 6(\sigma_{xy}^2+\sigma_{yz}^2+\sigma_{zx}^2)}{2}}$$

Results

- The generated ABC results from ANSYS commercial software suggest a good agreement with the implemented analytical solution (Appendix File).
- 'A' is the contour plot from the verification test of a plate material under tension.
- 'B' is the graphical solution from the linear and non-linear analysis of the verification test.
- 'C' is a contour plot of a quarter section of a pipeline geometry under internal pressure loading.

Discussion

- The von Mises stress criterion suggests that the yield point of a material begins to occur when the distortion energy density reaches a critical value.
- The rectangular plate material behaviour under tension was a validation test for the pipeline analysis.
- The high-stress regions (red-yellow) zones indicate a high propensity for material failure.
- The bilinear (Plot B) graphical solution convergence behaviour starts to move apart at 608.058 MPa when the material begins to behave plastically (unsafe zone).

Conclusion

To Keep the Natural Ecosystem Working.

- Potential pressure threats to an offshore pipeline under immense loading conditions need proper analysis before deployment.
- Accurate design specifications and Standard Operating Procedure (SOP) are paramount to pipeline lifespan targets.
- The simulated results of an unflawed natural gas pipeline under internal pressure in ANSYS Mechanical APDL for the linear and nonlinear analysis are to prevent burst pressure collapse and ensure high efficiency and integrity in operation.

Prospects

The research's future work prognostications:

- Scale up the research value to propose an equation for burst pressure calculation for a liquid or green gas energy pipelines.
- Introduce a novel approach for offshore pipeline analysis to increase efficiency, stability, and integrity.
- Analyse Functionally Graded Materials (FGMs) for offshore green gas energy pipeline transport with PeriDynamics approach.

References

[1] Aftermath Gas Pipeline Explosion, San Bruno Calif, 2010 - Google Search [2] Deepwater Horizon oil spill | Summary, Effects, Cause, Clean Up, & Facts | Britannica [3] Huang, X., Cheng, B., Zha, 174, p.109148. ng, D., and Yu, Y., 2021. A unified theoretical solution of plastic limit load for the thin-walled pipeline with an incomplete welding defect. International Journal of Pressure Vessels and Piping, 191, p.104358. 11 [4] Mondal, B.C., Dhar, A.S. and Hafiz, H.I., 2022. Burst pressure assessment of pipe bend/elbow for transmission pipelines. Thin-Walled Structures [5] Sudula, P. and Sai, V., 2020. Bilinear Isotropic and Bilinear Kinematic Hardening of AZ31 Magnesium Alloy. International Journal of Advanced Research in Engineering and Technology, 11(8). [6] Vazouras, P., Karamanos, S.A. and Dakoulas, P., 2010. Finite element analysis of buried steel pipelines under strike-slip fault displacements. *Soil Dynamics and Earthquake Engineering*, *30* (11), pp.1361-1376.

Digital Healthcare Engineering System for Ageing Ship Hull Structures

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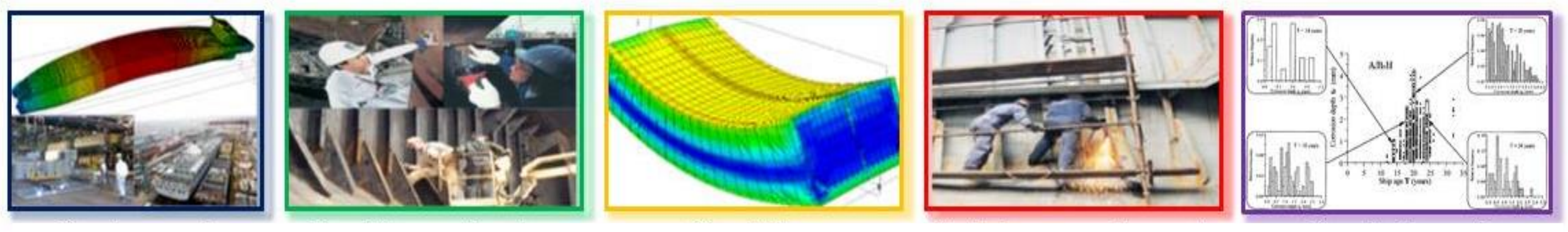
BACKGROUND

As engineering structures and infrastructure get old, they suffer from age-related degradation such as corrosion wastage, fatigue cracking and mechanical denting. Under hostile conditions of the ocean environment, aging ships and offshore structures operating in remote areas can fail leading to catastrophic impacts associated with casualties, property damage and marine pollution. Prof. J.K. Paik firstly proposed a concept of Digital Healthcare Engineering (DHE) to efficiently and effectively manage such catastrophes by taking advantage of digital and communication technologies, where digital twins are used in association with in-situ measurements of health parameters, transmission of measured data, data analytics and visualisation, health condition assessment, diagnostics and remedial actions, and predictions of likely future health conditions. This project develops a DHE system for aging ship hull structures.

Human Bodies

Birth | Health Monitoring (Medical Examination) | Health Condition Assessment | Medication or Surgery | Prediction of Future Health Condition

Engineering Structures



Design and Construction | Health Monitoring (Inspection) | Health Condition Assessment | Repair or Renewal | Prediction of Future Structure Condition

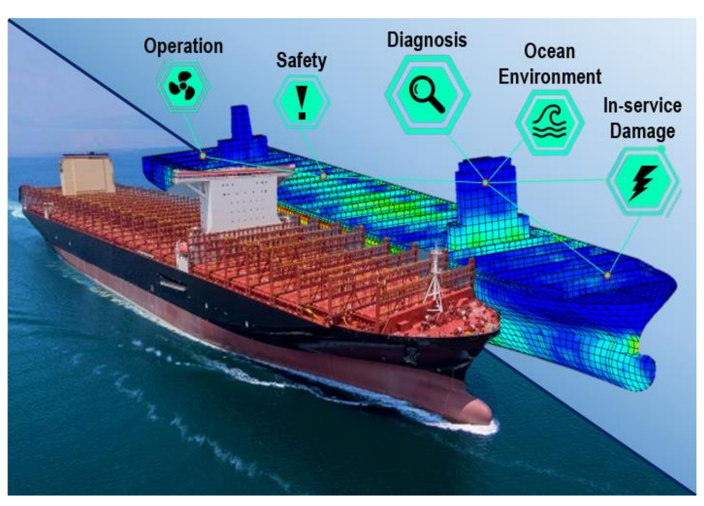
Age-Related Degradation | **Hostile Ocean Environments**

Corrosion Wastage | Fatigue Cracking | Mechanical Denting | Waves

Loss of Hull Girder Strength

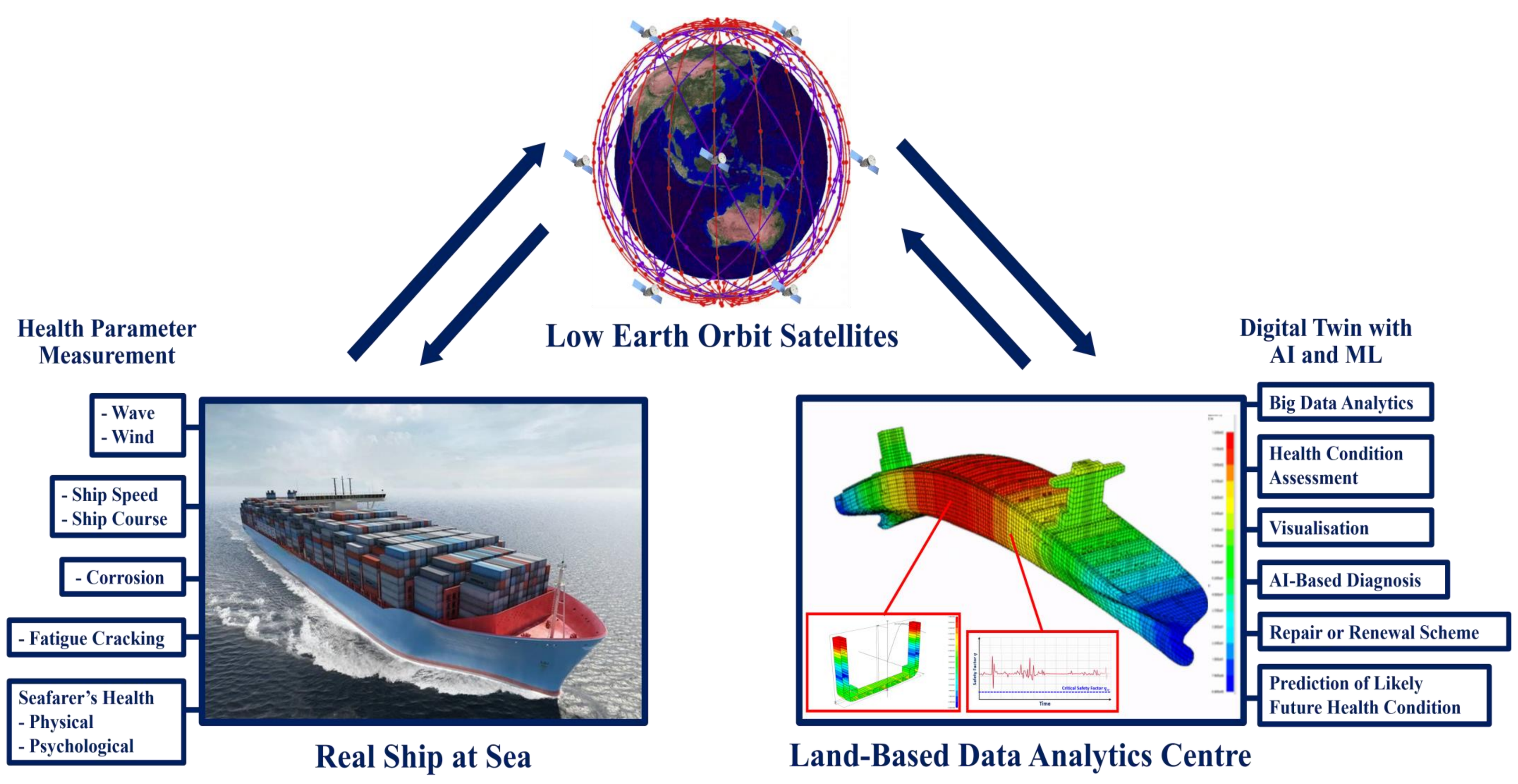
Hull Girder Collapse

DIGITAL HEALTHCARE ENGINEERING SYSTEM



The research tasks of the Digital Healthcare Engineering (DHE) system under development are classified into five groups: (1) in-situ measurements of health parameters (e.g., sea states and in-service damage), (2) measured data transmission, (3) data analytics and visualisation, (4) AI-based diagnoses and remedial actions, and (5) predictions of likely future health conditions.

DHE System Framework



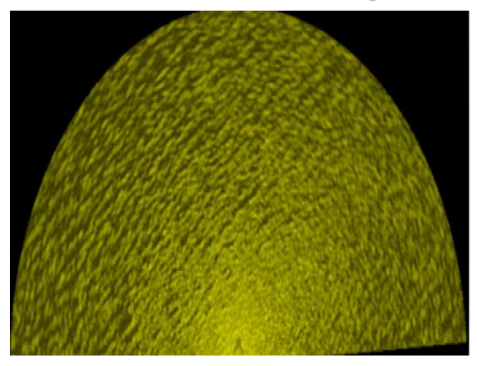
METHODOLOGY

In-Situ Measurement of Health Parameters

Health parameters, such as ocean environmental conditions, in-service damages, and operational conditions, are collected through in-situ measurement. X-band radar will be used to measure wave height, wave duration, and wave angle in real time. In-service damages (e.g., corrosion wastage, fatigue cracking, and mechanical denting) will be detected and measured through visual examination aided by portable devices on weekly, monthly, or quarterly basis rather than an annual and biannual basis.

X-Band Radar

X-Band Radar Image



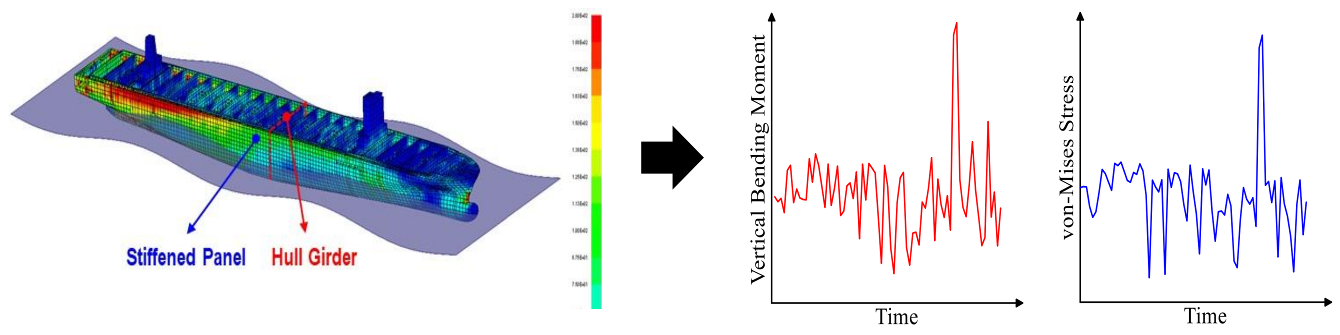
Portable Ultrasonic Sensor

Measured Data Transmission

The measured data of health parameters are recorded in onboard data loggers and transmitted to a land-based data analytics centre utilising advanced communication technologies. WiFi will be used for onboard networking, while close-orbit satellites will be used for data transmission between a ship and land-based analytics centre.

Data Analytics and Visualisation

The transmitted data are analysed to quantify the health parameters and compute the loads and load effects on the hull structures. Computational Fluid Dynamics (CFD) will be used for calculating ocean environmental loads, while residual strength of hull structures will be estimated using Finite Element Method (FEM). The loads and load effects will be visualised based on the analysis outcomes as a form of colour-coded contour and plots.



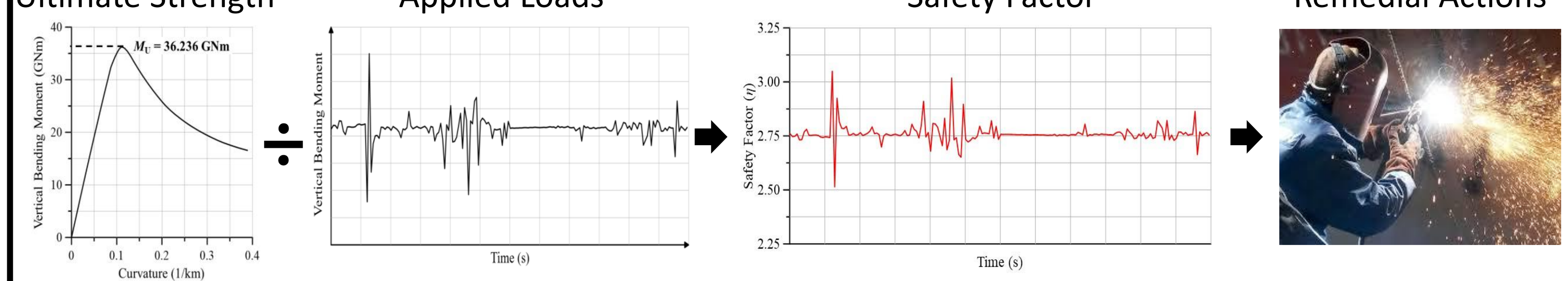
AI-based Diagnoses and Remedial Actions

The health conditions of ship hull structures are assessed by a structural safety index (i.e., safety factor) as defined in the following equation. Repair or renewal schemes are prepared based on the results of health condition assessments with AI techniques.

$$\eta = \frac{C}{D} > \eta_{cr}$$

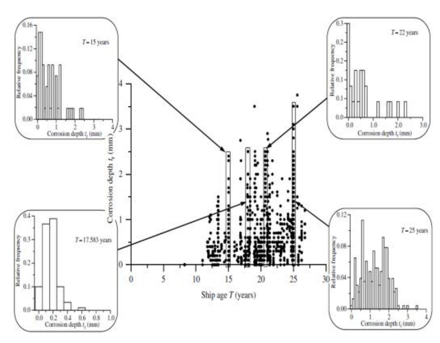
where C is the maximum load-carrying capacity (i.e., ultimate strength), D is the applied loads, η is the safety factor, and η_{cr} is the critical safety factor. η should always be greater than η_{cr} to ensure the safety of the target structures.

Ultimate Strength | Applied Loads | Safety Factor | Remedial Actions



Predictions of Likely Future Health Conditions

Historical data of in-service damages measured from physical model is useful in predicting likely future health conditions. For example, the growth of in-service damages and reduction of residual ultimate strength can be predicted using time-variant mathematical models.



FUTURE WORKS

To complete the project, the following research tasks will be undertaken in the future:

- System set-up for in-situ measurement of health parameters (e.g., wave profile, in-service damage) with sensors and devices
- System set-up for data transmission via WiFi and close-orbit satellite
- Software coding for data analytics, visualisation, and computational modelling
- Digital twins for health condition assessment and management of aging ship hull structures
- Physical testing with real ships for verification of the developed DHE system

Title: Development of a Decision Support System for Ship Energy Efficiency considering Energy/Exergy Assessment

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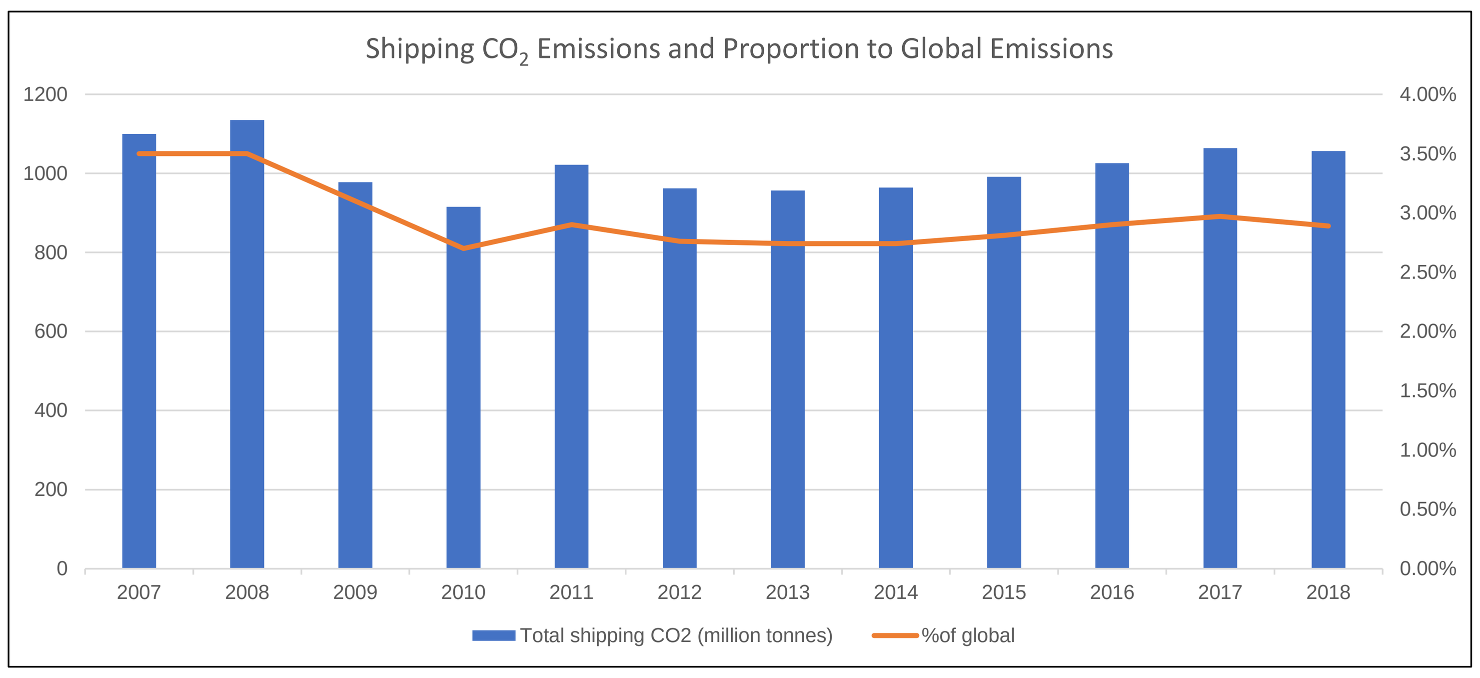
Supervisors: Dr Kayvan Pazouki, Dr Rose Norman

Background

Greenhouse Gas Emissions



It can be seen that from 2007 to 2018, the total annual shipping CO_2 emissions have exceeded 915 million tonnes, accounting for more than 2.6% of the global total CO_2 emissions. If it continues to develop, by 2050, the annual increase in CO_2 emissions in the shipping industry are projected to increase between 50% and 250% (IMO, 2020).

Aim and Objectives

Aim

The overall aim of this research is to develop a ship energy efficiency decision support system considering energy/exergy assessment to assess applicability of different energy efficiency improvement technologies at various operational conditions.

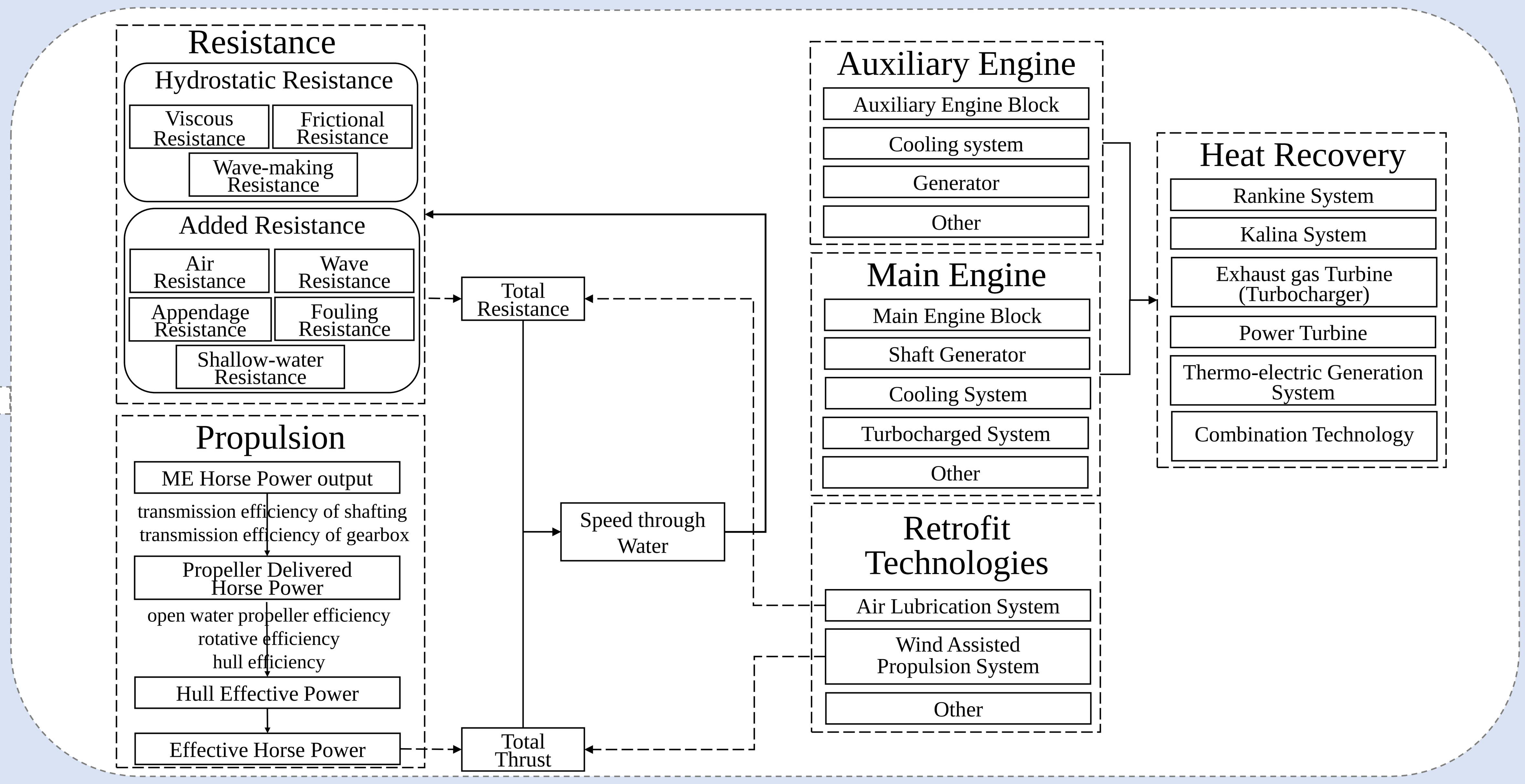
Objectives

The objectives of this research are:

- To analyse the requirements of energy efficiency assessment technology in ship energy efficiency decision support system.
- To develop a ship energy efficiency model and auxiliary energy efficiency improvement technologies, and verification of model using published data.
- To assess the potential of energy efficiency improvement using developed model.
- To develop a ship energy efficiency decision support system considering energy/exergy assessment.

Methodology

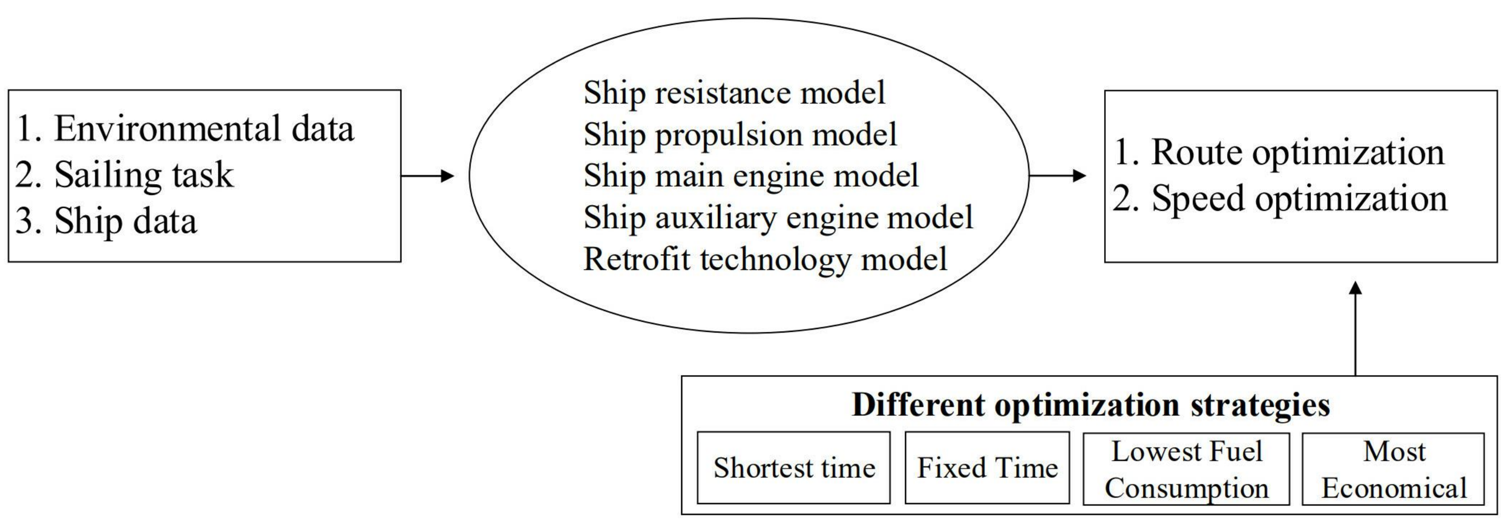
1. Analyse and summarise the energy efficiency assessment technology in the current ship energy efficiency decision support system.
2. Build model of ship energy efficiency and auxiliary energy efficiency improvement technologies, and then verify the established model.
3. Relevant simulation is carried out to verify the potential of different technologies in energy efficiency improvement under different navigational conditions.



Preliminary Findings

1. Each technology, like wind rotors and air lubrication systems, has specific conditions affecting its efficiency.
2. Waste heat recovery systems' effectiveness depends on main engine power.
3. Considering actual navigational conditions is essential for optimal decision-making.

These findings emphasize the need for a tailored decision support system to optimize ship energy efficiency.



Future work

- Construct new energy engine models and databases for alternative fuel types, including liquefied natural gas (LNG), liquefied petroleum gas (LPG), hydrogen, ammonia, and fuel cell, based on the established diesel engine energy model and database.
- Develop an optimization algorithm to maximize vessel energy efficiency and minimize environmental impact by selecting the retrofit technology combination for navigation under different environmental conditions.

References

Baldi, F., Ahlgren, F., Nguyen, T. V., Thern, M., & Andersson, K. (2018). Energy and exergy analysis of a cruise ship. *Energies*, 11(10), 2508-1-41.

He, Y., Yan, X., Fan, A. & Wang, Z. (2021). Development status and prospects of ship intelligent energy efficiency management technology. *Journal of Harbin Engineering University*, 42(3), 317-324.

IMO. (2020). 'Fourth IMO Greenhouse Gas Study 2020'. International Maritime Organization (IMO).

Sun, C., Wang, H., Liu, C., & Zhao, Y. (2021). Real time Energy Efficiency Operational Indicator: Simulation research from the perspective of life cycle assessment. *Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment*, *235*(3), 763-772.

Acknowledgments

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