ICMASS 2023 Abstracts

Title: Regulatory scoping exercise for the future adoption of autonomous inland ships in Europe

Paper Id: 1

Authors: Sophie Orzechowski, Institute of International Transport Law;

Abstract:

Title: Regulatory scoping exercise for the future adoption of autonomous inland ships in Europe

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Authors: Sophie Orzechowski, Institute of International Transport Law;

Abstract: Shipping is a heavily regulated sector, and autonomous ships will by no means be able to escape the public regulator's agenda. More specifically, autonomous ships are not permitted under current laws and regulations. The main reason why existing laws and regulations need to be adapted for autonomous ships is that these are unmanned, thereby opposing provisions requiring crew on board for navigation, safety and security purposes as well as environmental protection duties. Another important reason is that autonomous shipping presents a disruptive technology whose consequences when being implemented are not yet entirely assessed and are expected to change even over time following further technological developments. Nevertheless, the benefits gained from implementing autonomous shipping at a wide scale in Europe seem to outweigh potential risks and uncertainties and have, therefore, urged the legislator to take action. In maritime shipping, the International Maritime Organisation (IMO) has already achieved considerable work regarding regulatory adaptation in this context and is expected to adopt a non-mandatory code for autonomous seagoing ships in the second half of 2024. However, in inland shipping, apart from national ad hoc experimental legislation such as the one adopted in Flanders to allow the exceptional operation of unmanned but remotely controlled vessels for study purposes, a similar development cannot be observed, albeit several institutions have started to include autonomous inland shipping in their future agendas. Therefore, regulatory work on the topic at the international level remains very limited. The cause for this relatively slow process is the very different public regulatory institutional structure present in inland shipping: In contrast to its maritime counterpart, where the IMO constitutes the main public regulator, the inland shipping sector consists of a multi-levelled regulatory landscape with different supra-national, regional and national authorities involved in the adoption of binding and non-binding rules, which diverge in their geographical scope of application and hierarchical importance throughout Europe. This also means that unification of rules and regulations is less present in inland shipping and, consequently, makes a harmonised approach to the regulation of autonomous inland ships generally more onerous. Existing literature on regulatory adaptation for autonomous inland shipping is also limited and restricted in scope, resulting in a fragmented research landscape on regulatory obstacles hindering the introduction of autonomous inland ships. Moreover, previous research focuses on either analysing particular issues, including safety or security requirements, or the applicability of specific legal instruments in a particular location, such as the area where the autonomous inland ship experiment was performed. Notably, a comprehensive regulatory scoping exercise of all existing regulations as to their compatibility with autonomous inland ships similar to the one performed by the IMO with respect to maritime regulations is missing in the current research landscape. This paper, therefore, aims to analyse the existing rules and regulations in European inland shipping as to their compatibility with autonomous inland ships and to identify the different types of provisions contained therein which need to be adapted in a harmonised manner to pave the way for a uniform regulation of autonomous inland shipping in Europe. It further discusses existing possibilities for the exceptional operation of autonomous inland ships under current European Union legislation and investigates whether, and if so, how technological developments, in general, are being dealt with as a principle of European Union law. In addition, the paper explores the

latest policy directions taken by the European legislator to speed up the process of regulatory work on the disruptive technology of autonomous inland shipping. The research leading to the results presented in this paper has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Grant Agreement No. 955768 (MSCA ETN AUTOBarge).

Title: A Structured Scenario Set for Assessing Automated Collision and Grounding Avoidance Systems

Paper Id: 3

Authors: Tom Arne Pedersen, DNV; Chanjei Vasanthan, DNV AS; Øystein Engelhardtsen, DNV AS; Kristian Bertheussen Karolius, DNV; Koen Pieter Houweling, DNV;

Abstract: The road towards the realization of fully autonomous ships has indeed been longer than first anticipated. Several concepts and projects have materialized over the years, although most are still relying on the onboard crew to be operated safely. It appears there has been a shift in ambition level from completely unmanned ships towards maintained reliance on humans in a supervisory role; either onboard or remote, or providing the onboard crew with sophisticated decision support systems. Nonetheless, there is a clear consensus in the maritime industry that ships, both conventional and with automated Collision and Grounding Avoidance (CAGA) systems, shall be navigated following the Convention on the International Regulations for Preventing Collisions at Sea (COLREG). This ensures a level playing field and a common understanding of the responsibilities between conventional and autonomous ships, allowing safe co-existence in the waterways. The use of simulation-based testing to explore and document safety and the ability to adhere to the COLREG are expected to play an important role, as it allows for rigorous testing of performance and failure handling also before the software is installed on the ship. It can be applied both for supplier in-house testing and verification by an authorized independent third party. Many terms in the COLREG used to specify acceptable behavior, are of a qualitative nature, such as "ample time" and "apparent maneuver". Hence, they need to be viewed in light of a specific situation in order to be applied in practice. To enable this, a specific navigational scenario is typically set up in a simulated environment and then executed to evaluate the behavior of the automated collision avoidance system in that particular scenario. As the COLREG includes a large set of obligations specific to different types of situations, a significant number of scenarios spread out across the different aspects of the regulations will be necessary to enable any judgments about the overall ability to adhere to these rules. Hence, careful selection is required to enable such an assessment most effectively. This paper describes a set of scenarios that have been carefully designed to allow a systematic assessment of basic COLREG compliance using simulations. Each scenario is created to trigger specific parts of COLREG. The set consists of scenarios with increasing complexity, starting with very basic cases, and progressing through scenarios with increasing complexity, including both single- and multi-vessel encounters and scenarios where multiple encounters trigger conflicting parts of COLREG in sequence enabling a systematic assessment of different aspects of the regulations. In addition, land areas and shallow water are also included in the scenario set. The intended use of the scenario set is to enable a rapid and effective assessment of the ability to adhere to the basic principles of COLREG. The scenario set is made freely available to vendors, students, or any other actors involved in the development or assurance of algorithms for automated collision avoidance systems.

Title: Master of autonomous inland vessel: Contradictio in adjecto?

Paper Id: 4

Authors: Igor Bačkalov, Entwicklungszentrum fur Schiffstechnik und Transportsysteme eV; Mohan Sai Krishna Illuri, Entwicklungszentrum fur Schiffstechnik und Transportsysteme eV; Thomas Kerkmann, Entwicklungszentrum fur Schiffstechnik und Transportsysteme eV;

Abstract: This paper focuses on the definition of Master as found in the present regulations for inland navigation in Europe. An analysis of the applicable regulatory framework indicates that the definition of Master is one of the major obstacles to implementation of autonomous inland shipping. The paper dissects

the definition of Master as given in the “European Code for Inland Waterways” (CEVNI) and German national inland waterways regulations “Binnenschifffahrtsstraßen-Ordnung” (BinSchStrO), and identifies the obstacles to unmanned and/or remotely-controlled shipping created by this definition. The paper also pins down the rules of CEVNI and BinSchStrO which are affected by the definition of Master, and therefore present the obstacles to autonomous shipping themselves. Furthermore, the obstacles found in the rules are classified with respect to the level of autonomy which they hinder, whereby the vessel automation taxonomy put forward by the Central Commission for the Navigation of the Rhine is used. Consequently, the recommendations are given on how to modify the definition of the Master depending on the targeted autonomy level. The paper argues that redefining the Master, and adapting the notion of the Master to the present tendencies in technological development would considerably facilitate the introduction of autonomous ships on inland waterways. Even though the underlying research primarily concerns inland navigation, it is deemed that the considerations presented in the paper may have a wider significance and could be applicable to regulatory framework for autonomous shipping in general. The paper presents the outcomes of a part of the research done within the framework of project SAFEBin (Methoden zur sicheren Ausgestaltung der Automatisierung und Fernüberwachung in der Binnenschifffahrt) funded by the German Federal Ministry of Digital Affairs and Transport, and coordinated by DST.

Title: Data-Driven Time Series Forecasting of Energy Load for Model Predictive Control of Marine Systems

Paper Id: 5

Authors: Esma Özdemir, Technische Universiteit Delft; Andrea Coraddu, Technische Universiteit Delft; Rudy Negenborn, Technische Universiteit Delft;

Abstract: To ensure future autonomous surface ships sail in the most sustainable way, it is essential to optimize the design of the energy and power management system. Marine energy and power management systems are complex systems that coordinate various distributed energy resources, energy storage systems, and power grids to ensure reliable and safe power delivery. Traditional control methods for these systems are limited in their ability to evaluate processes over a certain time horizon and/or learn from experiences gained from earlier journeys. We propose the adoption of Model Predictive Control (MPC) for energy and power management, a promising control method that considers predicted future system responses over a time horizon to determine the best control input, benefitting from energy profiles learned based on past experiences. This presentation addresses the problem of learning energy profiles. An approach is discussed subsequently based on data-driven time series forecasting to predict the energy load, which can be subsequently used as a reference for a Model Predictive Power Controller. In this way, historical and real-time operational data can be leveraged. The proposed approach employs state-of-the-art machine learning methods (e.g. regression, kernel, and ensemble methods) to identify the best-performing algorithm considering accuracy and computational requirements. In fact, the further the forecasts happen in time, the lower the accuracy is. Therefore, two new hyper-parameters need to be learnt: the optimal amount of historical data to include in the learning phase and the maximum horizon that can be predicted without compromising accuracy. The potential of the proposed approach is illustrated using operational data from a real vessel. The results indicate a negligible loss in accuracy with a minimal computational burden for energy load forecasting in the context of the Model Predictive Control framework.

Title: Some Port state Control considerations for autonomous vessels

Paper Id: 6

Authors: CHRISTOPHER BALLS, Maritime Authority of Cayman Islands;

Abstract: Some Port State Control Considerations for Autonomous Vessels. C. Balls, MEng. CEng. FRINA, AFNI, Principal Surveyor, Cayman Islands Ship Registry. Topic; Regulatory & legal frameworks Unit 1, Breezy Castle, 125 Owen Roberts Drive, P.O. Box 2256, George Town, Grand Cayman, Cayman Islands. christopher.balls@cishipping.com Objective; To highlight some of the considerations that need to

be given to enable effective Port State Control (PSC) inspections of autonomous vessels. Methodology; i) Give a brief overview of the role of PSC and the types of inspection undertaken mainly in the context of the Caribbean Memorandum of Understanding on Port State Control. ii) Outline the importance of PSC in ensuring compliance with environmental legislation which in turn improves the industries sustainability. iii) Give a general view on some of the challenges increasing autonomy brings to the conduct of effective PSC and the challenges faced by PSC Officers who are faced with ever evolving ship types, with autonomous systems and vessels being merely a continuation of that evolution. The control of such vessels should not be any more, or less, stringent than with conventional vessels. iv) Present some of the considerations when encountering higher levels of autonomy on vessels – giving an example of likely issues with respect to inspecting as vessel where the bridge is located in an unconventional position. v) Present some of the considerations when inspecting a remotely operated ship and how to achieve the equivalent level of confidence in the satisfactory outcome of ensuring compliance with international statutory requirements to ensure safe navigation with minimal environmental damage. Expected Results; It is anticipated that the paper will show that it is possible to conduct PSC on autonomous vessels to a similar level to that on conventional vessels provided suitable accessibility to related systems is provided by operators.

Title: Nautical safety contours in port areas. A case study in the Port of Rotterdam

Paper Id: 7

Authors: Harmen van Dorsser, Havenbedrijf Rotterdam NV; Jolien Baak, Havenbedrijf Rotterdam NV;

Abstract: Autonomous shipping has advantages but it also brings new challenges such as the interaction with other ships on the waterway. For safe navigation, a human captain needs to be able to predict the behavior of autonomous ships, autopilot tracks need to be at a certain distance from each other, and VTS operators need to know at what distance some sort of intervention is needed. All this prompts the question of when a particular situation is regarded as safe. This research aims to develop a model that determines a “safety distance contour” around a vessel, depending on parameters like vessel length and speed. This model can then be used in Intent Sharing, the planning of autopilot tracks, and possibly also by VTS operators. To determine this, two concepts and their relation to each other are explored, using the Port of Rotterdam as a case study. The first concept is the ship domain. The ship domain is defined as “The effective area around a ship which a navigator would like to keep free with respect to other ships and stationary obstacles” (Goodwin, 1975). Port areas are notoriously complicated due to the high activity, high variation in ships and the limited space on the waterway, which makes many existing ship domain theories inapplicable. By looking at historical behavior of captains, the ship domain within the port of Rotterdam can be found and modelled. This research uses AIS data to determine the distance between vessels at every moment in time. The distances are related to a particular vessel parameter and accumulated in an intensity plot. The evaluated parameters are, amongst others: vessel length, width and speed. The results are also sorted, based on the encounter type between vessels. 📷📷 Figure 1: First plots of ship domain. (a) All points, (b) All points divided by ship length, (c) All points, divided by speed and desired time accuracy. The second concept is that of Moving Havens (Porathe, 2020). By claiming a piece of the nautical waterway (a Haven) at each moment in time during its intended track, a vessel’s intentions of route and timing are crystal clear to others (ships, VTSO, etc). The Moving Haven would simply follow a vessel’s route with a certain speed and the vessel only has to stay inside the Moving Haven. Safety would be guaranteed (as long as all vessels stay within their Haven). The size and distances between Havens is derived from the ship domain as explored in the first concept. Combining the two concepts leads to a model that determines the required safety distance contour within a port area. It is a dynamic contour that depends on parameters found in AIS data. This can then be used for the planning of autopilot tracks, by VTS operators and further automatization of shipping. 📷 Figure 2: Example of Moving Haven. References Goodwin, E. M. (1975). A statistical study of ship domains. The Journal of Navigation, 28(3), 328–344. Porathe, T. (2020). Moving havens: An application of the e-navigation service route exchange. Proceedings of the International Conference on Human Factors, 19-20 February 2020, The Royal Institution of Naval Architects, London.

Title: Creating silent VTS at the Port of Rotterdam. Impact analyses of digitalizing VHF communications

Paper Id: 8

Authors: Harmen van Dorsser, Havenbedrijf Rotterdam NV;

Abstract: As part of the Future VTS program, the port authority is investigating the impact of digitization and automation on the future of Vessel Traffic Services (VTS) in Rotterdam. Based on the assumption that digitization and information exchange between systems will take place more and more and verbal exchange will ultimately remain limited, it has started investigating the VHF communications for VTS within Rotterdam VTS monitors the vessels in ports and provide the ship masters with the required information to ensure the safety and efficiency of the vessel traffic in the port. Information is communicated using very high frequency (VHF) radios on the corresponding VHF-channels of the sectors. In busy sectors in the port, these VHF-channels are crowded, which results in unclear situations and high workloads for the VTS. Based on a “Silent VTS” concept The Rotterdam Port Authority is currently investigating measures to reduce VHF-traffic. 📷 Figure 1: average amount of minutes of communication registered per hour for the Thursdays in 2021 In order to determine which and to what extent communication elements can make a major contribution to the intended goal, further research is carried out. Port of Rotterdam concluded that about 80% of the communication contains three of the five indicated categories. Namely: ship announcement (35% - 45%), the sharing intentions (20% - 30%) and sharing the traffic image for (15% - 25%) and simulator tests with concepts for digital transmission of information about attentions and intended / predicted routes shows that the verbal communication via VHF radio can be reduced by more than 70%. 📷 📷📷 Figure 2: Information elements within the VHF communication With all efforts on MASS and Artifical Inteligent systems on board and in line with the prospects that systems will become more complex and connected, technologies will become more advanced and the role for supporttools in increase , digital exchange of VTS services will be needed. Further research on the impact of digital VTS services should give a solution to the discussion on how to be sure of a Common Situational Awareness and understanding of intended actions are created without a verbal confirmation. The presentation of information in a clear manner will be key and to eliminate the risk of missing crucial information it will be likely that some kind of a conformation that a master has noticed the added attentions should be created. To create more digital Aid to Navigation (ATON), incl the provision of VTS, a communication strategy on digital services will be needed. References Allersma, S. (2021). Digitalization of Vessel Traffic Management in Port Areas. Delft: TU Delft. Bongaertz, e. A. (2022). META STUDIE INFORMATIE HAVENGEBIED. Rotterdam: Minor thesis, STC Rotterdam Mainport Insitute. BUMICON. (2021). Phonetic analyses VHF Rotterdam. Dorsser, H. (2020). VTM Innovation: Maritime Autonomous Surface Ships and the future on Vessel Traffic Management. . Ulsan: ICMASS. Hoeve, R., & Dorsser, H. (2021). Impact of MASS on Marine Aids to Navigation. Den Haag. Hoeve, R., & Dorsser, H. v. (2021). Impact of MASS on Marine Aids to Navigation including VTS. Den Haag: The Netherlands; Singapore. IALA Future VTS woring group . (2022). WP TASK 1.4.3 Future VTS Discussion Paper. Weijers, D. (2021). The digitalization of verbal exchanged information. Rotterdam: Rotterdam University of Applied Sciences.

Title: A fault diagnosis scheme for multiple sensor faults affecting the navigation of autonomous surface vessels

Paper Id: 9

Authors: Abhishek Dhyani, Technische Universiteit Delft; Rudy Negenborn, Technische Universiteit Delft; Vasso Reppa, Technische Universiteit Delft;

Abstract: Autonomous surface vessels (ASVs) will perform various safety-critical operations on the open sea and inland waterways using a large number of sensors for the vessel's state estimation, environmental perception, and situational awareness. This will make their navigation more sensitive to faults occurring in these sensors. A fault in one or more sensors could result in serious consequences, such as damage to the

vessel or infrastructure, environmental impact or human injury. Therefore, a fault in the navigational sensors must be identified and mitigated as soon as possible. The current research on the model-based fault diagnosis of ASVs mainly focuses on the diagnosis of actuator faults while assuming the occurrence of a single fault. However, the sensor fault detection and isolation problem is equally crucial, owing to the harsh marine environment which may additionally contribute to the sensor degradation, for instance, due to the presence of salt spray and moisture. In this work, we propose a model-based two-level scheme for detecting and isolating multiple sensor faults occurring in an ASV. In the proposed approach, the health of sensors is monitored and their monitoring is first decomposed into multiple local (possibly overlapping) sensor sets, to facilitate the isolation of multiple faults. A local monitoring module is dedicated to each local sensor set and consists of a nonlinear observer which can estimate the vessel's state (e.g. position, heading, etc.) under healthy conditions. Further, residual signals are computed for detecting the occurrence of a fault, by comparing them to adaptive thresholds, that are designed for bounding the residuals under healthy conditions. In addition, the adaptive thresholds ensure that no false detections occur. For isolating the faulty sensor(s), an aggregation module is employed, which inputs the decisions of each of the local monitoring modules and computes a set of the possible faulty sensor(s), based on a combinatorial decision logic. We consider a 3 DOF hydrodynamic model to describe the dynamics of an ASV. The vessel is considered to be equipped with multiple sensors, including a GPS/GNSS sensor for the measurement of the vessel's position, an IMU sensor- constituting of a gyrocompass and accelerometer, for measuring the vessel's heading and velocity, an anemometer for measuring the wind speed and a weather vane for measuring the wind direction. The proposed scheme is verified through a numerical example for an inland waterway scenario with a model vessel equipped with multiple sensors to track a desired trajectory.

Title: The Value Proposition of MASS in Short Sea Transport

Paper Id: 10

Authors: Julius Kuechle, Fraunhofer-Gesellschaft zur Forderung der angewandten Forschung eV; Hans-Christoph Burmeister, Fraunhofer-Gesellschaft zur Forderung der angewandten Forschung eV;

Abstract: As the technological readiness of Maritime Autonomous Surface Ships (MASS) is inching closer to maturity, the question of its expected impacts on logistical processes and supply chains arises. Preliminary studies suggest that, given a sufficiently large fleet, MASS offers significant cost advantages for carriers as it directly affects newbuilt-prices, personnel cost, and insurance premiums. These effects are especially pronounced in those transportation services, where crew sizes are large in relation to the transport capacity, i.e. in feeder or short-sea liner services. However, MASS do not only address costs, but it’s also claimed that MASS facilitates more competitive transport services. To build on this, the unique value proposition of MASS in short sea cargo transportation for shippers is explored. The underlying hypothesis is, that the value of incorporating MASS in maritime supply chains goes beyond transportation cost: MASS and its associated technology umbrella offers the means for greater reliability and higher frequencies, which in turn lowers and stabilizes throughput times even with constant travel times. This leads to an increase in overall supply chain performance by facilitating higher service levels and flexibility at reduced overall inventories. Historically, international premium liner services promising higher speed and schedule reliability are not new, the readiness to pay for the associated premiums was however always limited, leading to either the deployment of smaller vessels to reach feasible utilization rates (e.g. APLs Eagle Express operating with 2000 TEU vessels) or the outright failure of the service – like in the case of Daily Maersk. As an inherent strength of waterborne transport are economies of scale, such premium services were rarely envisioned for short sea transport with its generally already smaller ships, since transport volumes are often too low to achieve profitability with large vessels at high frequencies while at the same time fixed costs made employing a fleet of small vessels cost prohibitive. However, economies of scale also impacted short sea shipping, with increasing short sea vessel sizes, resulting in lower frequencies and more intermediate port calls for the cargo. The cost structure of MASS now enables the use of smaller vessels as it directly impacts fixed costs. This presents the opportunity to revisit the idea of higher frequency services in a short sea context. The paper will encompass a comparative analysis and sensitivity analysis of two theoretical case studies pertaining bulk cargo as well

as container transport in the Baltic to show how MASS can be used to offer high frequency premium services at lower costs and how such services can impact overall supply chain performance. Further, it will show how more regular port calls and turnaround times achieved through MASS will increase the attractiveness of waterborne transport for shorter distances and therefore promote modal shift. Finally, a theoretical exploration of carrier selection criteria will be conducted and the potential impacts of MASS on these KPIs will be discussed to further define the competitive advantage autonomous shipping entails.

Title: Collision avoidance of autonomous ships in inland waterways – A survey and open research problems

Paper Id: 11

Authors: Hoang Anh Tran, Norges teknisk-naturvitenskapelige universitet; Tor Arne Johansen, Norges teknisk-naturvitenskapelige universitet; Rudy Negenborn, Technische Universiteit Delft;

Abstract: Promoting autonomous surface ships in inland waterway traffic (IWT) is a potential solution to reduce road traffic and emission footprint. There is growing research on autonomous ships for open waters. However, applying this research to the inland waterways domain is not straightforward. The IWT, due to its confined waterways, poses a different challenge than the open sea case. Due to the confined waterways, inland ships face several hydrodynamic phenomena that they rarely encounter in the open sea, such as shallow water, bank, or ship-to-ship effects. Furthermore, the higher traffic density and alternative sets of waterway navigation regulations in inland waterways also require a different approach for sensing and control systems. This paper offers an overview of the current developments in collision avoidance for autonomous ships operating in inland waterways. The overview covers different aspects, including sensor systems, manoeuvring systems, and autonomous collision avoidance solutions, as well as relevant regulatory contexts. A short analysis is presented to highlight the strength and weaknesses of each approach. We also discuss the current research gap and research directions to enable the future operation of inland autonomous ships.

Title: ASHIP – a safe test environment for innovations in autonomous navigation : case studies

Paper Id: 12

Authors: Thibaut Van Zwijnsvoorde, Vlaamse Overheid; Hongwei He, Universiteit Gent; Jeroen Verwilligen , Flanders Hydraulics; Guillaume Delefortrie, Ghent University;

Abstract: Many promising innovations in autonomous shipping are being developed, some of them in actual operational environments; however the most challenging navigational conditions such as narrow waterways, locks, interactions, are often omitted. Under these circumstances the control algorithms are tested to their limits because of dramatically changing hydrodynamic ship responses in shallow and confined (S&C) water compared to the open and deep water situation. The latter are typical conditions used to calibrate or model the control systems. In case of an unsuccessful event, the direct and indirect damages are immense. ASHIP or Autonomous SHip Innovation Platform – of Flanders Hydraulics (FH) fills this gap by offering a controlled test environment for demonstrating autonomous technologies, focusing on S&C conditions. Within this platform, the benefits of scale model testing and the use of manoeuvring simulators are combined. A state-of-the-art test basin has been created in the Towing Tank for Manoeuvres in Shallow Water (est. 2022), complementary to the captive and free running operation in the Towing Tank for Manoeuvres in Confined Water. The manoeuvring simulator – with dedicated mathematical manoeuvring models for S&C water – allows to extend the number of scenarios which can be tested. The ship manoeuvring simulators of FH allow both for real-time (full mission bridge) and fast-time simulations. In real-time simulations, up to eight simulators can be combined in multiplayer mode. During fast-time simulations the ship is steered based on a variety of integrated control algorithms [1][2]. The ASHIP concept is illustrated by presenting a selection of the studies which have been executed within the ASHIP framework: · Development and validation of autonomous algorithms – PhD research dr. Changyuan Chen (2017-2021) and Msc. Hongwei He (2021 – present) · Investigation of the effect of sedimentation on nautical accessibility for the Western-Scheldt by simulating autonomously steered

container ship. · Nautical assessment of larger ship dimensions on the Ghent-Terneuzen Canal based on advanced model predictive controllers in a ship manoeuvring simulator. We invite research organisations, consortia and other third party companies, to discover the ASHIP environment and further develop its capabilities with us. Our manoeuvring simulators provide an API allowing integration of external software products for testing. [1] Lataire, E.; Vantorre, M.; Candries, M.; Eloot, K.; Verwilligen, J.; Delefortrie, G.; Chen, C.; Mansuy, M. (2018). Systematic techniques for fairway evaluation based on ship manoeuvering simulations, in: (2018). 34th PIANC World Congress: Panama City, Panama. [2] Chen, C.; Verwilligen, J.; Mansuy, M.; Eloot, K.; Lataire, E.; Delefortrie, G. (2021). Tracking controller for ship manoeuvring in a shallow or confined fairway: Design, comparison and application. Appl. Ocean Res. 115: 102823.

Title: Interaction between COLREG-compliant collision avoidance systems in a multiple MASS scenario

Paper Id: 14

Authors: Raphael Zaccone, Universita degli Studi di Genova; Michele Martelli, Universita degli Studi di Genova;

Abstract: The transportation systems are heading towards increasing autonomy in all domains, and the maritime field makes no exception. The International Maritime Organization has been working on releasing a regulatory framework for Maritime Autonomous Surface Ships (MASS) to keep pace with the technological developments in the field. IMO already defined four degrees of autonomy: Degree One, meaning a crewed ship with automated processes and decision support; Degree Two, a remotely controlled ship with seafarers on board; Degree Three, a remotely controlled ship without seafarers on board; Degree Four, a fully autonomous ship. Autonomous shipping forces the researcher and the designers to face a wide range of scientific challenges, such as navigation decision support systems, collision avoidance algorithms, path planning, navigation and control, sensor data processing and fusion, remote control, and communication, with the final utopian intent of achieving a fully integrated Degree-Four worldwide maritime transportation system. In a complete automation and artificial intelligence-driven perspective, a collaborative conflict resolution layer based on information sharing could potentially retire the COLREGs, since there would be no need for a human-centric set of rules in an entirely human-less loop. However, the maritime sector will first face a transition period where traditional ships will share the seas and interact with heterogeneous MASS with various IMO Degrees. Then, for an undefined time, seafarers will cross their routes with human-crewed vessels equipped with decision support systems to enhance their navigation capabilities, remotely operated ships, and even some full-autonomous Degree-Four MASS, each powered by their proprietary systems, with different and currently incompatible communication protocols. In such a scenario, the old but gold COLREGs will still play a primary role in helping the collision avoidance systems resolve conflicts and limiting the degrees of freedom. This paper aims to study the interaction among multiple vessels with autonomous collision avoidance capabilities operating in a crowded navigation scenario. The ships operate according to a COLREG-compliant collision avoidance algorithm. The paper relies on numerical simulation to systematically investigate different scenarios, including two or more vessels, both in the open sea and in the presence of fixed obstacles. Results are presented and critically discussed. The paper is part of the Safer Navigation (SafeNav) project, funded by the European Union: The SafeNav Project aims to develop a state-of-the-art Maritime technology to improve real-time decision-making, aid collision avoidance, and enhance overall safer navigation while moving towards autonomous and remote operation.

Title: The Application of 5G Wireless Communication in Maritime Environment

Paper Id: 15

Authors: Wu jianming, Zhejiang Ocean University;

Abstract: Recently, 5G wireless communication have been rapidly used for maritime applications. As a result, significant progress has been made in the ocean digitalization. 5G features with low latency, high reliability, and a large bandwidth, which satisfies the requirements of maritime applications. Due to

significant difference between land and marine radio propagation environments, the maritime communication experiences a large challenge for providing maritime users with reliable data communication service. In order to solve the abovementioned challenge, we designed a maritime 5G terminal and tested it on an unmanned surface vehicle (USV) in the Lake Lanyue of Zhejiang Ocean University. The test data were collected, and the corresponding data analysis are presented, which includes signal strength, signal reception quality, upload and download data rate. The received signal level (RSL) and transmission data rate obtained by the maritime 5G terminals demonstrate great potential of meeting the communication requirements of the maritime users. It is also can be found that the RSL and the data transmission rate of the maritime 5G can be used for the remote control of the unmanned ships.

Title: Deep Reinforcement Learning for Multi-Ship Collision Avoidance in Heavy Traffic Regions

Paper Id: 16

Authors: Keramat Hasani, National University of Singapore;

Abstract: COLREGs navigational rules do not fully accommodate situations such as multiple vessels converging and vessels with different degrees of manoeuvrability. These situations are prevalent in heavy traffic regions and confined areas, which makes resolving conflicts based solely on COLREGs Rules 13-17 insufficient. These rules have been in place for nearly half a century, but they were originally intended for 1-on-1 situations, and in cases where there are multiple ships requiring both the need to take avoiding action (give-way ship) and maintain course and speed (stand-on ship), it can be legally and operationally awkward. Currently, many ship pilots and masters rely on inter-ship communications or personal experience when dealing with these situations, which are subjective and risky. This study aims to reduce the possibility of human error and miscommunications in common close-encounter situations in heavy traffic regions where COLREGs rules may need clarification by proposing practical navigational rules and inter-ship communication protocols for optimal multi-ship conflict resolution. To achieve this goal, a COLREGs compliance evaluation method for multi-ship conflict situations is developed. Additionally, the decision-making processes of pilots and shipmasters are analysed and modelled. Based on the developed models, a multi-ship collision avoidance policy is proposed which is powered by a cutting-edge multi-agent deep reinforcement learning (DRL) model. The DRL model has the capability to derive optimal solutions for complex conflict situations by leveraging its ability to learn from experience and adapt to changing circumstances. The model has been rigorously trained and tested on a sophisticated simulator that replicates real-life multi-ship scenarios, accurately reflecting the diverse range of vessel types commonly found in Singapore waters. This approach ensures that the developed collision avoidance policy is robust and can be trusted to perform effectively in the challenging conditions of heavy traffic regions and confined areas. By addressing this critical safety issue, this study represents a significant contribution to the maritime industry, with the potential to reduce the likelihood of maritime collisions and casualties caused by human error. It can improve safety in heavy traffic regions and confined areas, where such situations are prevalent.

Title: Demonstration of autonomous sailing in the Autoship project

Paper Id: 17

Authors: Vidar Helgås, Kongsberg Gruppen;

Abstract: Abstract. Autship is a EU Horizon2020 project that started in 2019 and will end in 2023. The main objectives for the project is to demonstrate autonomous technology that enables moving transport of goods from roads to waterways. The project have 2 use cases. One use case on short sea shipping and one use case on inland waterways. The short sea shipping use case is demonstrated on the west coast of Norway using the Eidsvaag Pioneer fish feed vessel. The inland waterways use case is demonstrated in the Wintam/Klein-Willebroek area between Brussels and Antwerpen using the Zulu 4 barge. Both usecases are scheduled for live testing and demonstration in May/June 2023. The partners in the project are Zulu associates, Eidsvaag as, Sintef Ocean as, University of Strathclyde, Bureau Veritas, De Vlaamse Waterweg, PNO group, Kongsberg Maritime, Kongsberg Digital and Kongsberg Norcontrol. This

presentation will focus on the testing and demonstration of the key enabling technologies for autonomous sailing that has been developed by Kongsberg and tested and demonstrated in both virtual and real life environments. The presentation will cover safety evaluation, AI and control, Shore control, autonomy in Inland shipping and test areas and labs.

Title: A system architecture definition for remote operations of passenger vessels

Paper Id: 18

Authors: Lars Andreas Lien Wennersberg, SINTEF Ocean; Even Ambros Holte, SINTEF Ocean; Erik Aleksander Veitch, Norwegian University of Science and Technology;

Abstract: Why remote operations? Autonomous ships are collaborative systems that are likely to depend on some form of remote operations for the foreseeable future [1], [2]. Ship owners might be reluctant to leave the ships to manage themselves as they are high-value assets. It might not be cost-effective to design ships to manage all operational conditions. At the same time, it might not be possible, or prove too demanding of us, to require technology to solve all operational issues in a safe and efficient manner. Lack of means to understand the intentions of other ships in a mixed traffic situation, and problems with machine interpretations of COLREGs adds onto this problem [3]. A viable solution to overcome these challenges is to assist the ship automation systems with remote operations by humans that reside in a remote control centre. In this paper, we propose a definition of a system architecture for remote operations of autonomous passenger vessels. What are remote operations? There is no general consensus on what remote operations are comprised by, including the architecture of the remote control centre and the tasks, roles and responsibilities of the remote operators. The Maritime Safety Committee in IMO is currently working on a goal based definition of remote operations for the maritime domain. This work item is part of the development of the voluntary code for Maritime Autonomous Surface Ships (MASS) [4], and the remote operation definition is expected to be restricted to hardware and software issues. ISO's vocabulary on MASS [5] refers to remote control services as functions that previously were performed by crew in addition to automatic control functions within the remote control centre that can control ship processes. Some of the proposed schemas for levels or degrees of autonomy (ISO [5], IMO [6], CCNR [7],) offers expectations to when remote operations are expected to be carried out. However, none of the above will in any case provide details as to what remote operations are comprised of. Definition of the remote operation system architecture The remote operation system architecture definition in this paper is derived based on a methodology [8] and a framework [9] for description of autonomous ship systems that has been applied to analyse two use cases: The first use case is a concept for an constrained autonomous and remotely controlled high speed ferry operating in sheltered waters with a crew of one person. The second use-case is a concept for a shuttle boat operating autonomously across a small harbour basin [10]. The resulting system architecture definition of the remote operation consists of four building blocks: The remote operation objective, the system description with actors, a communication architecture with proposed carriers and content, and finally a classification of the remote operator's main functions and tasks. Analysis of system definition relevance and applicability to other domains Several definitions or objectives have been proposed for remote control centres [11], [12]. We argue that the objective of the remote control centre is to (1) provide the necessary navigational support to the ships to ensure safe operations as required by the authorities, and (2) contribute to timely and regular operations as defined by the contract with the client and as expected by passengers. With this in mind, we propose a structure of actors and systems that together constitutes a collaborative remote control centre for the two use-cases, and we show that the responsibilities of the remote operator can be summarised by the following task categories: (1) communication and message exchanges, (2) scheduled tasks, (3) non-scheduled tasks, (4) tactical adjustments, and (5) operational interventions. Through our analysis of the remote operation system architecture definition, we discuss how the distribution of tasks within these categories is closely related to the maturity level of the autonomous technology. We propose a schema for the relationship between the remote operator and the ship automation given this increased technological maturity level of the ship automation systems, and we argue how this system structure improves our ability to account for out-of-the-loop situational awareness [13]. Finally, as the results are based on a case study, we discuss the transferability of the system architecture definition to other domains such as cargo transport, short sea

shipping and inland waterways transport. References [1] Ø. J. Rødseth, L. A. L. Wennersberg, and H. Nordahl, 'Levels of autonomy for ships', J. Phys.: Conf. Ser., vol. 2311, no. 1, p. 012018, Jul. 2022, doi: 10.1088/1742-6596/2311/1/012018. [2] E. Veitch and O. Andreas Alsos, 'A systematic review of human-AI interaction in autonomous ship systems', Safety Science, vol. 152, p. 105778, Aug. 2022, doi: 10.1016/j.ssci.2022.105778. [3] Ø. J. Rødseth, L. A. L. Wennersberg, and H. Nordahl, 'Improving safety of interactions between conventional and autonomous ships', p. 9, 2021. [4] IMO, 'Development of a goal-based instrument for Maritime Autonomous Surface Ships (MASS)', IMO, MSC105/WP.8, 2022. [5] ISO, 'Ships and marine technology Vocabulary related to autonomous ship systems', ISO/TS23860, May 2022. [6] IMO, 'Report of the Maritime Safety Committee on its one hundredth session (MSC 100/20), Annex 2 Framework for the Regulatory Scoping Exercise for the use of Maritime Autonomous Surface Ships (MASS)'. Dec. 12, 2018. [7] CCNR, 'International definition of levels of automation in inland navigation'. CCNR, 2022. [8] M. Hagaseth, Ø. J. Rødseth, P. H. Meland, E. Wille, P. Meling, and B. Murray, 'Methodology for Approval of Autonomous Ship System CONOPS'. COMPIT 2022, 2022. [9] L. A. L. Wennersberg, H. Nordahl, Ø. J. Rødseth, K. Fjørtoft, and E. A. Holte, 'A framework for description of autonomous ship systems and operations', IOP Conf. Ser.: Mater. Sci. Eng., vol. 929, no. 1, p. 012004, Nov. 2020, doi: 10.1088/1757-899X/929/1/012004. [10] L. A. L. Wennersberg and E. A. Holte, 'Shore Control Centre', SINTEF Ocean, L3.1, 2022. [11] H. Dybvik, E. Veitch, and M. Steinert, 'Exploring challenges with designing and developing shore cotnrol centers (SCC) for autonomous ships.', Proc. Des. Soc.: Des. Conf., vol. 1, pp. 847–856, May 2020, doi: 10.1017/dsd.2020.131. [12] Andreas Luedtke, 'The drafting of a study on the definition and organisation of a Remote Control Centre (RCC) with a view to its CERTification', FPS Federal Public Service Mobility and Transport – DG Shipping, RCC-CERT, 2023. [13] M. R. Endsley, 'From here to autonomy: lessons learned from human–automation research', Human factors, vol. 59, no. 1, pp. 5–27, 2017.

Title: Use Case Remote Pilotage – Technology overview

Paper Id: 19

Authors: Robert Grundmann, Fraunhofer-Gesellschaft zur Forderung der angewandten Forschung eV; Jonathan Weisheit, Fraunhofer-Gesellschaft zur Forderung der angewandten Forschung eV; Arbresh Ujkani, Fraunhofer CML; Jedi Seppänen, Novia; Hans-Christoph Burmeister, Fraunhofer-Gesellschaft zur Forderung der angewandten Forschung eV;

Abstract: Pilotage transfer is a dangerous task, especially in harsh weather. But this is when pilot services are needed the most. A variety of incidents and accidents, especially related to improper pilotage ladder equipment have been reported over the last years, including severe injuries and death of pilots. Furthermore, pilot transfer – regardless of whether by pilot vessel or helicopter – is generally fossil-fueled and therefore has an impact on maritime transport sustainability. Thus, there is a twofold motivation for realizing remote pilotage: safety and sustainability. Remote Pilotage offer the possibility to save pilot transfers and protect pilots from dangerous working environments without compromising the service they have to offer. During the act of a remote pilotage a trusting relationship between pilot and officer on watch, psychological elements are crucial, in addition to the reliability of the technical equipment, the seamless connectivity and the meaningful presentation of the navigational data are key. In the Sea 4 Value Fairway(S4VF) project a remote pilotage was already demonstrated. The remote pilot used PC monitors to support pilotage and gain situational awareness operating from an ashore location. In that setup the only interaction was a two-way audio connection between the remote pilotage center and the vessel, supported by a video stream. Based on the project Remote Pilotage – Operational, innovative and Manageable Alternatives for Navigation routines (RePO MAN), a minimum viable product is being developed and tested using XR (Extended Reality) Technologies to fulfill pilotage requirements. The approach presented here differs from previous systems for shoreside support of incoming vessels and their navigators. This paper explains in detail the shore side and ship side XR technologies applied and investigates their interaction realized by two user interfaces (UI). The Shore UI supports the pilot with a VR (Virtual Reality) system combined with hand tracking, provided with a live video feed originating from a 360-degree camera installed on the ship. To enhance the immersive and interactive experience, the video information is combined with other sensory data, e.g., vessel information, traffic symbols, environmental

information, or additional information on the expected route. Onboard of the ship the Ship UI, an AR HMD (Augmented Reality Head-Mounted Display) is used to present the pilot's advice. The Ship UI allows to see a variety of visualizations, including the route ahead, pilot's instructions, information about the ship's position and movement, or environmental information visualized by the glasses in combination with what is visible to the navigator's eyes. For RePO MAN, the focus is on human-centered XR to create a support system that is user-friendly and intuitive. Without neglecting information necessary for the interaction between pilot and navigator. Starting from a short study on pilotage transfers in terms of safety and sustainability as a motivation, this paper will then outline trust requirements from pilots and navigators to remote based systems, before the capabilities of XR for these requirements are highlighted. This is followed by outlining the technical approach used within RePO Man. The technical implementation within the context of the individual use cases is explained and a consolidation of these use cases within the framework of RePO Man and the possibility of adaptation in further field tests up to implementation is considered. Finally, limitations and deficits of remote pilot concepts will be outlined using the example of RePO Man and merged with the results of the Sea4Value project.

Title: Autonomous Ships: Terms of reference for rule development

Paper Id: 20

Authors: Marko Rahikainen, Already burdened with a reputation for lack of transparency, shipping’s sector-specific terminology often creates an additional barrier to engagement. As an industry, specialized language, acronyms, and abbreviations can be so pervasive that new employees entering the professions sometimes absorb terms into usage without being able to explain their meaning, let alone their derivation. Citing its responsibility for carrying 90% of world trade, shipping often complains that its voice is not heard, or that public attention only comes its way ‘when things go wrong’. Whether or not this is so, to merit a fair hearing, the shipping industry itself must take responsibility for speaking in clear terms. Few issues in shipping’s recent past have generated such an urgent need for clarity as the autonomous ship. Driven by rapid progress, autonomous ship technology has required immediate regulatory attention, even before the stakeholders have agreed to common terms of reference. The increasing use of autonomous ship technologies and the prospect of supporting functionality ashore - including elements of control - have far-reaching consequences for operating ships, but also for surrounding ships, insurers and the wider public. In May 2021, an International Maritime Organization intersessional working group submitted its ‘regulatory scoping exercise’ report to the Maritime Safety Committee and since a roadmap for the creation of a goal-based code for maritime autonomous surface ships (MASS) has been established. While progressive, the report and subsequent roadmap distilled the scale of the task ahead. It highlighted how much the maritime safety regulations are based on the human presence onboard. In addition, the RSE pointed out that the definitions for the “degrees” of autonomous ship operation have not been agreed, causing trouble for the development of new safety rules. This paper presents the industry proposal for a scale for determining automation in shipping, by describing six ’levels’ which can be applied to various ship operations or an entire ship. It also suggests that levels of automation should be defined on a scale based on the need for human attention/attendance rather than mixing the definition with manning levels on board a ship. One Sea companies are of the opinion that remote monitoring or operation should not be confused with automation. The location of the human operator in the loop is not relevant for the taxonomy of automation and autonomy. Human operators can be situated in various locations - on the ship, on board another ship or on shore. Remote operations can also be performed on ships of various levels of automation, hence the need for separate definitions. The ISWG on MASS concluded that legal provisions such as SOLAS would need to be revisited to consider crewing definitions. Where automation and automated systems interface with those working at sea today, the following general statements appear self-evidently true: · Conditions: the lower the level of automation, the greater will be the need for more continuous human attendance/attention, even during ‘easy’ conditions. · Situation: the lower the level of automation, the greater will be the need for more continuous human attendance/attention, even for ‘simple’ situations. · Time: lower levels of automation either cannot work safely without continuous human attention/attendance or can do so only for a short time. The task at hand therefore involves fitting generalities on human attendance/attention coherently together with accepted functional standards covering automation/autonomy. Work by the main technology companies involved in developing,

verifying, and trialling autonomous ship technologies has included an evolving understanding of the regulatory instruments and challenges facing their adoption. The work, which went on before, during and after IMO's formative scoping exercise, is based on experiences involving autonomous technologies on board real-life ships, owners, and crews, operating in actual sea conditions. As a general principle One Sea members urge caution against combining deliberations over crewing with levels of technology. Crewing principles are in general not affected directly by automation, for example: to avoid unnecessary complications, the two matters should be considered separately. Following two years of work, One Sea has derived a different approach to 'degrees' of autonomy to that created during IMO's preliminary work. The framework is a scale of equivalence based on a modified version of the SAE levels of automation by the Society of Automotive Engineers. The definitions apply to different ship systems or operations or - in extreme cases - an entire ship. The development of international regulations for MASS is the top priority for One Sea, and discrepancies in terminology being used is one of the main obstacles that must be overcome. Its formulation for levels of automation has been approved by all companies within One Sea and summarized for consideration by regulators. The purpose of this paper is to provide clarity and assist rule development and standard definitions which can be easily applied across the industry going forward. Regulations cannot be successfully developed if different definitions and interpretations of how to categorise levels of automation persist.;

Abstract: Sinikka Hartonen

Title: "Market-uptake Accelerators for Autonomous Surface Ships"

Paper Id: 21

Authors: Engelbert Cornelis Kreukniet, Expertise- en Innovatie Centrum Binnenvaart;

Abstract: In February of 2023, the Joint EU Smart Shipping & Logistics Platform held its semi-annual meeting. Interesting discussions took place on the roll-out phase and market uptake of innovative solutions for the Waterborne Transport sector. As a next step, the Platform proposes to hold a dedicated session during ICMASS in Rotterdam and involve a broader audience on this important topic. The goal of the session is to share best practices on the acceleration of market uptake of innovative autonomous surface ship outcomes of (EU-funded) research projects, discussing lessons learned and identifying (shared or unique) bottlenecks towards implementation. Structured as a poster-session, participating projects will present one or two innovative highlight outcomes of their work. Secondly, they will describe the steps foreseen to be taken and the barriers encountered to market uptake and (potentially) the scale-up phase of the innovation. Alternatively, projects can showcase success stories where innovative outcomes were able to reach the market as commercial products and share lessons learned. The presentations are followed by a moderated discussion between participants and the audience. A small team of JESSL Platform members will elaborate on a first and original step-by-step Roadmap for R&D project outputs, containing key elements to consider and anticipate on while travelling the pathway to becoming commercially viable products. The session will end with a brief presentation of this draft roadmap and the invitation to deliver feedback on it by email. Attendees can leave their contact details and are invited for the follow-up session at next year's TRA in Dublin, Ireland. Audience: Open to all. Invitations through ICMASS channels; platform members will also be informed through respective channels. Duration: 2 hours Note: The proposal can be adapted to fit the wants and needs of ICMASS organisers.

Title: Validation of an autonomous, short sea shipping feeder-loop service through advanced simulations

Paper Id: 22

Authors: Espen Johansen Tangstad, SINTEF; Odd Erik Mørkrid, SINTEF Ocean AS; Håvard Nordahl, SINTEF; Stefan Krause, Institut für Strukturleichtbau und Energieeffizienz gGmbH; Kenneth Johanson, North Sea Container line;

Abstract: For the past 3 years the AEGIS consortium has worked together to develop a new, disruptive

short sea shipping feeder-loop service [1]. Traditionally, container-freight being shipped from central Europe to the coast of Norway has been transported either by road, or by larger containerships to central ports. The hypothesis is that introducing smaller, autonomous, battery-powered vessels into the fjords of Norway would open new business areas, being able to access remote regions not previously viable. This would allow shipping companies to take on cargo that could not previously be transported by water. These small green daughter-vessels could serve the larger motherships with additional cargo, potentially moving larger cargo-volumes away from roads and onto sea. This implies a need for transshipment-terminals for interaction between ships. Such a transport system has the potential of reducing cost, GHG emissions and external costs, while increasing frequency of service and the waterborne cargo volume in Europe. One of the main challenges of the mother-daughter logistic system is how transshipment affects defined key performance indicators (KPIs). For this purpose, the Logistic Analysis tool (LA-tool) was developed in the H2020 projects AEGIS and AUTOSHIP. The tool allows for rapid iterations of maritime logistic systems through discrete event scheduling. To run a simulation requires a set of ships, terminals, and cargo-flow for the simulation. Through production and consumption of cargo traveling on the ships between locations in the simulation, we can evaluate KPIs of the system, compare it to historical data, or other, competing transport systems modelled in the tool. Once a transport system satisfied the requirements set by relevant stakeholders, a voyage analysis of the ships performance in the system can give further insight into the cost, emission, and externalities through the sister-simulator Maritime Autonomous Surface Ships (MASS) analysis tool (MA-tool). The MA-tool relies on an extended ship-model including autonomy-level, energy-systems, and hydrodynamic models to sail designated shipments along the routes designed through LA-tool. Statistical weather profiles can be attached to the routes to further improve the accuracy of the ship's energy-efficiency and other KPIs for different ship-concepts. This paper will present methodologies and results from a case-study on different transport systems using the abovementioned simulation tools. An important prerequisite for comparing the new mother-daughter transport system is to define a proper baseline case. Such baseline cases include transportation by truck and traditional short sea container shipping. The mother-daughter transport systems include autonomous daughter-ships of different sizes, subject to a given cargo-flow in a region. The LA-tool is used to simulate the performance of the transport system. Achieving a stable system is done through iterating over different control-parameters such as ship-size, sailing-speed, sailing schedule, routes etc. A system is considered stable if the amount of cargo at all terminals does not exceed terminal storage capacity. Once the logistic system is adequately stable, the ships, routes and cargo-flow are transferred to MA-tool. The concepts are validated through cost and environmental KPIs presented in [1], in addition to external costs based on the European handbook on the external costs of transport [2]. Results from the case-studies indicate that transport systems including green daughter-vessels have the potential of lowering GHG emissions compared to the baseline transportation systems. Evaluating cost-KPIs of non-existing transport systems is complex because it may require new business model. Investments into autonomy, while creating new transport opportunities, also indicate a shift in costs, while crew-less daughter ships reduce the yearly operating expenses overall. References [1] S. Krause et al. 2022, Development of an advanced, efficient and green intermodal system with autonomous inland and short sea shipping – AEGIS, J. Phys.: Conf. Ser. 2311 012031 [2] European Commission, Directorate-General for Mobility and Transport, Essen, H., Fiorello, D., El Beyrouty, K., et al., Handbook on the external costs of transport : version 2019 – 1.1, Publications Office, 2020, https://data.europa.eu/doi/10.2832/51388

Title: Formalizing Good Seamanship- Transforming skills to measurable quantities

Paper Id: 23

Authors: Robert Grundmann, Fraunhofer-Gesellschaft zur Forderung der angewandten Forschung eV; Franklin Nyairo, Yrkeshogskolan Novia; Arbresh Ujkani, Fraunhofer CML; Manfred Constapel, Fraunhofer Center for Maritime Logistics and Services;

Abstract: Navigators, possessing adequate nautical craftmanship, have been long admired for their ability to safely guide ships and their crews into port. This skill set is often referred to as good seamanship. However, good seamanship is more than the ability to resolve a dangerous traffic situation quickly and effectively as outlined in the Convention on the International Regulations for Preventing Collisions at Sea

(COLREGs). It involves the ability to apply complex rules from pre-learned knowledge, taking factors into account such as the behavioural characteristics of ship, its operational status, the traffic situation, the sailing area, the cargo and stability status of the ship, and current as well as future meteorological and environmental conditions. Currently, navigators' competence is tested through written exams, practical tests, and simulations on realistic replicas of ship bridges and their subsystems. Experienced navigators are responsible for assessing and rating their performance. Introducing the conceptual framework of the i-Master project, our paper provides an objective basis for expert rating by transforming nautical knowledge and competencies into measurable quantities and formalizing them as necessary functions of a system. The approach will enable the comparison of different skills via their associated quantities, setting thresholds for quantities, and finally, the creation of a map for nautical knowledge assessment. Our paper concludes the insights from the I-Master project, specifically from the use case of creation of the navigation competency mapping. Based on those results, selected skill definitions of navigators will be analyzed and transformed to support the formalization. Based on the formalization utilizing a rule-based engine to enable for a flat and readable hierarchy of COLEGs for traffic situation assessment in the B ZERO project, our method of formalization and the creation of relations between skills and the usage of data for calculations are explored and described in detail. Finally, we aim to show the approach as a way of measuring non-measurable values on the one hand, and to strive for new considerations for testing nautical knowledge on the other hand.

Title: A multi-sensor indoor tracking system for autonomous marine model-scale vehicles

Paper Id: 24

Authors: Filippo Ponzini, Universita degli Studi di Genova; Raphael Zaccone, Universita degli Studi di Genova; Michele Martelli, Universita degli Studi di Genova;

Abstract: Attitude estimation is a popular topic in marine engineering and robotics; in fact, the position and orientation of a vehicle are required as feedback from several algorithms to achieve autonomous navigation capabilities, such as dynamic positioning, track keeping, and autodocking. Typically, position and heading angles are provided by the Global Positioning System and compass. Usually, during the development and testing, the experiments are performed in a controlled environment, such as an indoor test tank, using self-propelled scale vessels. And unfortunately, Global Positioning System systems can be unreliable due to non-negligible model scale errors or simply the absence of line-of-sight with the satellites. For this reason, this article presents an experimental tracking system setup suitable for indoor testing facilities based on cameras and LiDAR sensors. In particular, the paper presents a tracking system based on a GigE camera and ArUco markers detection providing the position and heading angle of a model vessel with a high frame rate. Specifically, a set of ArUco markers from the original series are placed on the scale model; the system detects the markers in the camera frames, and data are processed to obtain the marker's reference frame. The pinhole camera model handles the calibration and pose estimation process, relating the marker's points to the world reference system. Moreover, the paper proposes a LiDAR-based tracking system using a 3D mechanical LiDAR sensor to virtualize the test environment into a point cloud. The point cloud is then analyzed with unsupervised machine learning techniques, providing information on the degrees of freedom of the model-scale vessel. The MQTT broker-based publish/subscribe message-queuing protocol achieves real-time data communication and sharing. The proposed system was developed, installed, and tested in the COMPASS laboratory (University of Genoa), where a test tank oriented to Guidance, Navigation, and Control experiments is available. The two tracking systems' outcomes have been compared while detecting moving targets in the testing tank. Eventually, an accuracy analysis was performed by comparing the results to the ground truth in purpose-built experiments. The proposed approach can estimate the degrees of freedom of a model-scale vessel in an indoor testing facility. Moreover, no active or powered markers are required, and the information is acquired and shared with multiple entities in real time at a high frame rate.

Title: Supporting Remote Operation Centres for Unmanned Ships Through Machine Learning-Based Route Prediction

Paper Id: 25

Authors: Brian Murray, SINTEF Ocean; Pauline Røstum Bellingmo, SINTEF Ocean AS; Marianne Hagaseth, SINTEF Ocean; Thorbjørn Tønnesen Lied, Kongsberg Norcontrol;

Abstract: Work towards realizing autonomous shipping is progressing at a rapid pace, with multiple full-scale projects underway. Safety is of primary focus, as the level of risk associated with autonomous ships should be no greater than that of conventional vessels. This has opened the door for leveraging many emerging technologies e.g., Artificial Intelligence (AI). Collisions with surrounding maritime traffic is considered one of the primary sources of risk with respect to ship operations. To facilitate collision avoidance, AI is viewed as a potential facilitator of the look-out functionality of a navigator due to its state-of-the-art performance with respect to object detection and classification. If effective, AI can automatically detect target ships, and conduct collision avoidance actions in accordance with the Convention on the International Regulations for Preventing Collisions at Sea (COLREGs). Ship traffic will be mixed between manned and unmanned vessels in the foreseeable future. In most two-vessel encounter situations, the COLREGs can be interpreted properly, allowing for safe collision avoidance actions. However, in complex multi-vessel encounter situations, the COLREGs rely on good seamanship which is not directly interpretable or programmable for an autonomous vessel. Such situations will likely be outside of the operational envelope (Rødseth et al., 2021) of the automation system responsible for controlling the autonomous ship. To handle such situations, many actors plan to utilize Remote Operation Centres (ROC). Human operators in such centres will be able to take control of the autonomous vessel in high-risk situations e.g., complex encounter situations that rely on the concept of good seamanship to resolve. In some cases, the operators will be responsible for multiple vessels, and will not be able to maintain adequate situation awareness at all times. As such, the automation system must be capable of identifying when its limitations are approaching and allow for a safe and timely handover to a human operator. Operators will rely heavily on the ability of decision support systems in the ROC to provide them with a high level of situation awareness in a short period of time. To achieve this, future encounter situations will need to be identified in a timely manner. Currently, the primary focus of such systems is on providing operators with what is considered by Endsley (1995) to be Level 1 situation awareness e.g., object detection and classification. Collision risk is then estimated based on linear extrapolations using the observed position and velocity vector of detected target vessels or objects. Such predictions are, however, limited to the next manoeuvre of the vessel, inherently restricting how early an operator can be notified of a potential conflict. This study investigates recent advances in AI to forecast surrounding maritime traffic beyond the next manoeuvre, thereby identifying potential close-encounter situations far in advance. ROC operators can then be notified in a timely manner, allowing them to gain adequate situation awareness to handle high-risk situations. Furthermore, by forecasting future traffic, the route of an autonomous vessel can be re-optimized to minimize future risk of collision, e.g. via minor speed or course alterations. To facilitate accurate route predictions, this study will investigate recent developments in AI e.g., transformer-based (Vaswani et al., 2017) models that have demonstrated ground-breaking performance in Natural Language Processing (NLP). As opposed to training on a corpus of text, however, such models will be trained on historical ship behaviour. This is made available via historical Automatic Identification System (AIS) data. Using a live AIS stream, a ship's future trajectory can be predicted by sending its current behavior as input to the model. Furthermore, simplification of the historical trajectories in the AIS dataset via the Douglas-Peucker algorithm (Douglas & Peucker, 1973) will be investigated to improve the performance of the transformer-based models. Results from a case study will be presented related to the unmanned ASKO Maritime vessels crossing the Oslo fjord in Norway between the ports of Horten and Moss. Historical AIS data form the Oslo fjord will, therefore, be utilized to train transformer-based route prediction models. The accuracy of the predictions will be evaluated based on a test set from the historical data. Massterly is currently finalizing the development of their ROC in Horten, where Kongberg Norcontrol has installed their solutions for maritime surveillance. The developed route prediction models will, therefore, also be evaluated in terms of integration into their maritime surveillance solution.
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Title: Understanding Inland Shipowners' Intention towards Autonomous Shipping

Paper Id: 26

Authors: Dhaneswara Al Amien, Nord universitet; Roberto Rivas Hermann, Nord university; Terje Andreas Mathisen, Nord University;

Abstract: There is an emerging trend of innovations research in inland waterways transport, including environmentally friendly/green technology, information and technology-based initiatives, scrubbers installation, digitalization, and autonomation. Multiple stakeholders introduce automation and digitalization to increase inland shipping attractiveness in Europe. One example is the European Green Deal initiative, which aims to shift 75% of road transport to railways and inland shipping and railways. Understanding what factors drive autonomous inland shipping adoption intention is crucial to determine its success. Despite their essential role in innovation adoption, there are limited references to inland shipowners' perspectives.This paper investigates how European inland shipowners develop an intention toward autonomous shipping innovation. This paper uses the Theory of Planned Behavior (TPB) to explain the inland shipowners' intention toward autonomous shipping innovation. We collect the primary data from European dry bulk shipowners through surveys. In a previous study, we found the variables affecting the adoption rate of autonomous inland shipping innovation. Therefore, by combining previous literature and primary data, we expect to understand what constructs the inland shipowners' intentions. Moreover, we propose the Rhine River region inland shipowners' grouping based on relevant variables. The results show how different variables affect the shipowners' autonomous inland shipping adoption rate. This paper will enrich the literature by providing lieu of theorieson inland shipping, autonomous shipping, and innovation studies. The results would also benefit the stakeholders in the industry, including policymakers, regulatory bodies, financial institutions, and others, by providing insight into which necessary actions are needed to promote the technology more effectively. The author is affiliated with the AUTOBarge project as an Early-Stage Researcher (ESR). This project has received funding from the European Union's EU Framework Programme for Research and Innovation Horizon 2020 under Grant Agreement No. 955768.

Title: Mind the kayak: An evaluation of safe coexistence of autonomous urban ferries and the surrounding vulnerable traffic

Paper Id: 27

Authors: Ole Andreas Alsos, Norwegian University of Science and Technology; Mina Saghafian, Norwegian University of Science and Technology; Taufik Akbar Sitompul, Norwegian University of Science and Technology; Felix-Marcel Petermann, Norwegian University of Science and Technology; Erik Aleksander Veitch, Norwegian University of Science and Technology;

Abstract: Abstract. Background Urban autonomous passenger ferries can move traffic from the streets to under-utilized urban waterways and, in that way, change transport systems in cities. However, little research has been done on how passengers perceive safety and trust onboard such ferries, and in particular how the self-driving ferries can co-exist with other traffic, including vulnerable water traffic users such as kayaks Method During a three-week trial operation of milliAmpere2 – one of the first urban autonomous passenger ferries ever put in operation open to the public – we conducted nearly 500 trips in autonomous mode with more than 1500 passengers. When other traffic in the canal, such as nearby boats and kayaks, interrupted the self-driving ferry, we observed the passengers’ reactions and interviewed them about the experience. For 20 of the trips, we deliberately and unexpectedly caused the ferry to stop with a close encounter with an intercepting kayak controlled by a researcher. Immediately after the trip, we

interviewed passengers (N=43) about the experience and analyzed the interviews using thematic analysis. Further, we triangulated these findings with the ferry's system log and the logbook kept by the onboard technicians who monitored the system performance to see if the ferry could see the kayaker and avoid a collision. Findings We found that the ferry performed as expected and successfully detected the kayaker and avoided a collision in all the interceptions. Further, based on the information provided in the passenger interviews, we found that the participants had a generally positive experience with the self-driving ferry and did not change their mind about it after trying it. We also found that the participants were not worried for themselves or for the person in the kayak during the incident, that they thought it was plenty of space between the ferry and the kayak, and that the ferry had good maneuverability. Getting sufficiently informed about the ferry's operation was considered important for passengers to feel safe onboard the ferry, especially in the absence of an onboard safety host.

Title: New BUREAU VERITAS additional Class notations for Digital Systems

Paper Id: 28

Authors: Jerome FAIVRE, Wendel SA;

Abstract: As an introduction, the framework built by Bureau Veritas Marine & Offshore for developing the new additional Class notations for Digital Systems will be shortly explained. After that, details about the 3 notations that have been recently released will be presented, covering the following topics: the Data Infrastructure, the Asynchronous Communication, and the Condition-Based Maintenance (CBM). To structure our notations development for digital systems, Bureau Veritas Marine & Offshore has defined a framework composed in four groups: The first group, called « Computer based ships », covers the functional safety of computer-based systems and digital solutions generating data on-board. The second group, called « Connected ships », covers the ship-to-shore data transfers, the means of collection and remote access to ship's data, also called "data infrastructure". This group also includes cyber security requirements. The third group, called « Augmented ships » covers the data driven operating models from shore, including the ship monitoring, the remote support and the optimization of ship's efficiency for operational and environmental performance. Although we include in this third group the capability to monitor the ship remotely, we exclude the capability to operate the ship remotely. These advanced capabilities are considered in the last group, called « Remotely Controlled & Autonomous ships » or "MASS" = Maritime Autonomous Surface Ships as called by IMO. These four groups are used as a backbone of development for our new notations for digital systems. Indeed, the new revision of the NR467 released in January 2023 includes these three new notations: Firstly, the notation DATA-INFRA may be assigned to ships fitted with a data infrastructure, which ensure, for a list of on-board data, the collection, transmission, storage, control, sharing and availability of data to end data consumer. The second one, ASYNC-COM may be assigned to ships equipped with asynchronous communication systems which can ensure transfer of data between the ship and the shore. This notation supersedes the old notation SYS-COM. The third one, CBM, is an additional service feature and is assigned to ships where a Planned Maintenance Survey system for machinery (PMS) is implemented and on which at least one machinery item is to be surveyed under a Condition Based Maintenance scheme. All these new notations are only one more step in our digital journey. We have an ambitious roadmap of developments for 2023 & 2024. We will focus our next regulations development on several topics such as the Data-Centric Evaluation and the Data Quality.

Title: A distributed diagnosis framework for sensor and process faults in marine propulsion plants

Paper Id: 29

Authors: Nikos Kougiatsos, Technische Universiteit Delft; Vasso Reppa, Technische Universiteit Delft;

Abstract: Maritime safety is a prerequisite for modern vessels and a basic pillar for the development of future autonomous ships. However, recent statistics from the European Maritime Safety Agency suggest that 28 % of maritime casualties for 2019 were attributed to loss of propulsion, a situation that can leave a ship ungoverned in the uncertain sea environment. The propulsion system of the vessel is indeed crucial

for operational safety and like every other system, it can be affected by faults. Towards ensuring safety on-board vessels, the detection and isolation of faults affecting the sensors and the systems of the vessel through the use of dedicated monitoring agents is an important task. In current literature though, most papers discuss about process faults while sensor faults are disregarded. Moreover, there is a small amount of papers that deal with a combination of sensor and process faults and distinguishing between the two of them. In this paper, a novel fault diagnosis framework for marine propulsion systems is proposed, considering multiple process and sensor faults affecting the respective automation systems for the power and propulsion. The detection of faults is realised based on residuals generated using nonlinear Differential Algebraic estimators combined with adaptive thresholds. The isolation of faults is, then, realised in two levels; local sensor fault detection and isolation agents are designed to monitor specific sensor sets and aim to detect faults in these sets and reason for their type (e.g. sensor or process fault); and a global decision logic is designed to isolate multiple faults that may be propagated between the local monitoring agents. In addition, the optimisation of the fault detectability and isolability is proposed in this work, balancing the use of hardware and analytical redundancy in the system. Finally, simulation results are used to illustrate the application of this method and its efficiency.

Title: Semantically enhanced design and operation of marine vessels for changeability and re-configurability

Paper Id: 30

Authors: Nikos Kougiatsos, Technische Universiteit Delft; Jesper Zwaginga, Technische Universiteit Delft; Jeroen Pruyn, Delft University of Technology; Vasso Reppa, Technische Universiteit Delft;

Abstract: Nowadays, the maritime industry faces two main challenges; the energy transition towards greener and more sustainable fuels and increasing the level of autonomy. Consequently, the regulatory framework behind vessel design and operation is expected to gradually be adjusted to allow and promote novelties against these challenges. At the same time, marine vessel systems will have to be modified or even redesigned with new system and automation technologies in mind (i.e. methanol engines, IoT sensors etc.). A ship can be considered as a network of many interconnected systems, from different manufacturers, which together provide the target functionality. Despite vessel control systems being designed taking into consideration digital twin representations of the installed systems and their physical interconnections, the layout design and control perspectives are typically disconnected both in literature and in practice. Currently, control of marine vessel systems is designed based on a monolithic version of the system layout without taking into consideration that systems might be added, removed or even replaced in future iterations of the design. As a result, both the on-board system configuration and control need to be redesigned from scratch every time an equipment modification occurs. Moreover, multiple vulnerabilities can be exposed during the vessel operation phase and lead to automation malfunctions , such as faults and cyberattacks. Thus, novel algorithms and tools are needed in order to allow for online reconfiguration of marine vessel automation systems and maintain both stability and performance. In this work we propose a semantically enhanced algorithm to assist during ship design and operation. To integrate the design process, the use of a semantic representation for all vessel system and automation components is proposed to be used during the system and automation design steps. A “pool” of considered systems are correlated, visualised and connected by an automated graph-making tool, based on their semantic representations. Using the information about the system interconnections, feasible system layouts can be synthesized. These layouts are then assessed based on their re-configurability, which results in a specific system layout. The automation design step then takes into account the sematic representations of the systems in the chosen layout and enhances the semantic information with that of other associated automation components (e.g. sensors, controllers etc.). The automated graph tool is then used to create the automation interconnection graphs, from where we can ”reason” for the synthesis of feasible closed-loop control architectures. An intelligent agent then determines the loops that are active based on multiple performance and operational criteria . The necessary automation components are then activated by utilizing the stored semantic information. The active loops can consequently be reconfigured online in case of vulnerabilities that affect the on-board automation systems. The applicability and efficiency of the proposed multi-level semantic method are shown using a case study of marine propulsion.

Title: Trust-affected Decision-making for Maritime Autonomous Surface Ships with Human Supervision

Paper Id: 31

Authors: Rongxin Song, Technische Universiteit Delft; E Papadimitriou, ; Rudy Negenborn, Technische Universiteit Delft; Pieter van Gelder, Delft University of Technology;

Abstract: It is likely that maritime autonomous surface ships (MASS) will in the future navigate under the supervision of human operators. A MASS is expected to operate autonomously where possible, with minimal intervention from human operators in its decision-making process, reducing human effort and increasing operational efficiency. However, achieving this requires modelling and incorporating human trust, which is uncertain in the decision-making process of MASS. This paper proposes an approach for taking into account trust in autonomous ship decision making based on a Partially Observable Markov Decision Processes (POMDP) representation. We refer to this approach as trust-POMDP. The approach utilizes the POMDP representation to model the decision-making problem under uncertainty. Human trust is modelled as an unobservable state that can be indirectly observed by monitoring human operator intervention. The proposed approach is applied to a case study of a MASS navigating in the presence of other vessels, with a human operator remotely monitoring the MASS's decision making and intervening when necessary to ensure trustworthiness. The results indicate that the trust-POMDP framework can be effective in modelling human trust and improving collision avoidance performance. The case study illustrates the potential of the trust-POMDP framework to address challenges in MASS decision-making.

Title: Study on autonomous ship enhancement by optimizing the object detecting algorithms

Paper Id: 32

Authors: 仉欣慧, Zhejiang Ocean University; Xue Jiang, Zhejiang Ocean University;

Abstract: Traditional target detection algorithms often encounter issues such as missed detections and false alarms, which can greatly affect the safety and efficiency of ship automatic navigation. To improve ship automatic navigation safety, this study aims to optimize the key process of ship object detection through the adoption of deep learning technology.Based on a ship dataset, this paper proposes an improved model for the traditional YOLOv5 algorithm, which incorporates a series of attention mechanisms according to ship object characteristics. The attention mechanism can make the model pay more attention to the important feature areas of the target, reduce the influence of background interference, and improve the accuracy and recall rate of ship target detection.The attention mechanisms added in this paper include SE, CBAM, SimAM, ECA and CrissCross Attention. By comparing the effects of these attention mechanisms, the optimal attention mechanism is selected for ship target detection. The experimental results show that the performance of the algorithm is significantly improved after incorporating attention mechanisms. Among them, the CrissCross Attention performs the best, effectively improving the accuracy and recall rate of object detection.According to the experimental results, we can conclude that the YOLOv5 model with CrissCrossAttention is an effective target detection method, which improves the safety of ship automatic driving. In the future, it can be applied to the field of ship automatic driving, which not only improves people 's travel safety, but also promotes the development of society.

Title: Application of the EAST-BL method on a MASS system for Hazard Identification and Risk Assessment

Paper Id: 33

Authors: Alexandros Koimtzoglou, Ethniko Metsobio Polytechneio; Nikolaos P. Ventikos, National Technical University of Athens; Panagiotis Siokouros, National Technical University of Athens;

Abstract: As can be seen through the continuous research on the Marine Autonomous Surface Ships

(MASS) in recent years, several positive as well as optimistic results have been emerged, along with several concerns. Maritime industry is investing in the development of autonomous ships and in general in the utilisation of automation. The main goal is that the safety of the autonomous ships should be ensured at levels at least equal to the conventional ships. However, the risk analysis process regarding MASS faces many difficulties as the lack of respective data may lead the estimation of probability or frequency to be extremely uncertain or even biased. To this end, the application of risk informed approaches, that are based on the traditional definition of risk, can be quite misleading. Furthermore, the role as well as the interaction of human within the MASS model (e.g., in the loop, on the loop, etc.) may alter the dependencies and create emerging risks that traditional risk identification methods (e.g., HAZard and OPerability Analysis (HAZOP), Failure Mode and Effects Analysis (FMEA), Fault Tree Analysis (FTA), etc.) cannot capture. Consequently, various system-based methods like System-Theoretic Process Analysis (STPA), Event Analysis of Systemic Teamwork - Broken Links (EAST-BL) and NETworked Hazard Analysis and Risk Management System (NET-Harms) have been developed. However, in the maritime domain only STPA has been mainly applied compared to the rest of methods that are considered quite innovative, and they still have not applied in the maritime industry. The EAST-BL is a qualitative system thinking risk assessment methodology that combines the output of three different networks (i.e., task, social and information) for human and non-human agents of a system to identify potential failures in the communication and information transfer, along with the related risks, among the systems agents. Social network, task and information networks are developed individually, and they are combined to create a complete social work-information network diagram, which represents all the links and information flows (i.e., distributed knowledge) within a network of networks. EAST-BL consists of an extension of EAST methodology, which incorporates the identification of risks by “Breaking the Links” (BL) within all the networks and proposes risk mitigation measures for the identified risks, based on the knowledge of the researcher. The research presented in this paper, deals with two main aspects. The first is regarding the application of the EAST-BL in a MASS system, which is one of the first attempts to utilise the specific method in the risk identification process for a MASS system. The purpose of this application is to assess the results as well as the applicability of the EAST-BL and exploit its utilisation in the hazard identification process of autonomous marine systems. Whereas the second, is an effort to combine EAST-BL outcomes with the risk model proposed in the European Maritime Safety Agency (EMSA) Risk Based Assessment Tool study along with expert judgement to assess the risk level for the various fallback states of a MASS. Fallback state is a predefined system condition, outside the operational envelope of the MASS system, that can be used when it is not possible the system to remain within its operational limits. The above-mentioned methodology is applied on a case study of a feeder container vessel of a class A3-B1, according the DNV’s scale of autonomy, navigating in congested waters. In that way the effectiveness as well the applicability of EAST-BL to identify emerging risks on a MASS system, by modelling and analysing interactions at the Socio-Technical System (STS) level is tested. In particular, the operators of the vessel are assumed to be onboard the vessel and they are informed by the system only in a case of emergency or when the MASS system needs to enter a fallback state. The paper concludes with insights regarding the application of EAST-BL as well as the way that system-based methods can be utilised to enhance the hazard identification and risk assessment processes for MASS. Furthermore, the future steps of the research are highlighted.

Title: How Do Incumbent Firms Introduce Short Sea Autonomous Shipping and Cargo Operations into Their Offerings?

Paper Id: 34

Authors: Pål Brennhovd, SINTEF;

Abstract: Short sea autonomous transport of goods is promised to increase social, environmental and economic impacts by replacing diesel-driven trailer transport with emission-free sea transport. How do incumbent firms introduce short sea autonomous shipping and cargo operations into their offerings? To gain insight into this emerging phenomenon, this paper takes an exploratory approach with a single case study. The case study is the Yara Birkeland and ASKO Maritime projects and the prospected effects of a network of small, autonomous emission-free ships. This study takes a business model innovation

perspective of an emerging business ecosystem—digital transformation in maritime and logistic industries. All three incumbent firms subject to the investigation have made efficiency innovations in their business models when digital transformation was introduced into their offerings. However, digital transformation has potential to disrupt the way values are created, delivered and captured. Another finding suggests that digital transformation increases the degree of complexity and dependencies among the involved actors. This is the main reason for observing an emerging business ecosystem among incumbent firms in traditional industries that have a value proposition for which one of the actors cannot deliver the value alone. Uncertainties about two interrelated fungibilities—choice of interface standards between port facilities and ships and choice of digital logistic system—explain why an ecosystem is emerging and has not yet been fully established. These fungibilities cause uncertainties about the possibility of scaling up services to replace road transport with sea transport. Extant research suggests that the key aspect of business models and business model innovation is complementary between activities underlying the mechanisms of a firm's value creation, delivery and capture. This study suggests that complementarity can also be a way to describe the interdependencies between firms' business models in an ecosystem by including a modified framework of value cocreation, co-delivery and co-capture at the network (meso) and societal (macro) levels. This expansion provides the possibility to make use of a modified ecosystem theory to describe how the innovation of firms' business models affects how they create, deliver and capture values together.

Title: Structured Description of Autonomous Inland Waterway Barge Operations

Paper Id: 35

Authors: Marianne Hagaseth, SINTEF Ocean; Per Håkon Meland, SINTEF; Egil Wille, SINTEF;

Abstract: Autonomous and unmanned ships must be at least as safe and secure as conventional ships. To ensure this, the ship's operational profile (CONOPS – Concept of Operations) must be described for each of its areas of operation and for its intended usage. Currently, few formalities exist on how to ensure that all aspects of the operations regarding autonomous, supervised, and manual operations are covered. In this paper, we will use the methodology from the Seatonomy[1]project and the AEGIS[2] project to formalize the description of operations of an autonomous IWW barge sailing between Rotterdam and Ghent. This is an interesting case to analyse for several reasons: · This is an inland waterway route passing through a number of locks and bridges. · The route goes from one country to another (Netherlands - Belgium). · The waterways have varying degrees of traffic and the geography of the canals and rivers vary. · Blocking or congestions may introduce serious delays both to vessels, ports, and hinterland operations. · The barges operating along these routes are heavy and slow-moving. · It is easy for a threat agent to be in the physical vicinity on the vessels even from ashore. The same applies for the landside infrastructure. The methodology starts with a textual and high-level description of the mission, in our case the voyage on the canals and rivers between Rotterdam and Ghent for an autonomous barge. Further, more details are added by defining the context (the external entities and systems), the internal actors in the ship system, and also the various mission phases that the mission consists of. Examples of mission phases are passing of the specific locks, passing the specific bridges en route, and performing IWW sailing on the various canals and rivers. Also, some of the ship particulars must be described to be able to further cover the actual ship processes that the autonomous ship system must handle. Examples of ship processes are navigation, cargo handling and energy production. Each mission phase will be generalised into a mission phase pattern. This may be an iterative process, meaning that the initial definition of the mission phase may need to be changed after the mission phase pattern has been defined.Typical mission phase patterns in this case include Passing Manual Lock, Passing Automatic Lock, Passing Remotely Connected Lock, Bridge passing, Complex IWW Sailing, and Simple IWW Sailing. When the patterns have been defined, the System Control Tasks (SCTs) and their prose definitions are developed, again with a possibility that one need to revise the patterns. Examples of SCTs in this IWW case are the navigation of the barge through locks and under bridges, and cargo handling both inside and outside regular terminals. Finally, some of the SCT definitions are converted to UML diagrams, and the context diagram and actors can be converted into suitable UML constructs. In this work, we argue that it is useful to formalize the description of SCTs by using different types of UML diagrams, for instance, UML activity diagrams, UML state diagrams,

UML sequence diagrams, UML collaboration diagrams, UML class diagrams, and UML use case diagrams. Lastly, we argue that we can use the resulting UML diagrams to perform safety and security analysis. Our experience with this methodology is that it allows for a smooth transition from the autonomous ship system design phase to the assessment of the same system using the same UML notation. We believe that the same methodology can be easily applied to the other use cases and similar systems elsewhere. [1] https://www.sintef.no/en/projects/2013/seatonomy/ [2] https://aegis.autonomous-ship.org/

Title: Energy Efficient Adaptive Speed Control for Autonomous Inland Waterway Vessels with Conventional and Alternative Power Systems

Paper Id: 37

Authors: Man Jiang, Technische Universiteit Delft; Simeon Slagter, Technische Universiteit Delft; Rudy Negenborn, Technische Universiteit Delft; Yusong Pang, ; Klaas Visser, ; Mark van Koningsveld, Technische Universiteit Delft;

Abstract: To comply with the European Green Deal and the Sustainable and Smart Mobility Strategy (SSMS), efforts towards energy efficiency of Inland waterway transport (IWT) are required. Additionally, due to the varying inland navigation conditions at different geo-locations, times and the corresponding uncertainties, conventional inland sailing operation is not sufficient for achieving energy efficiency. Automated speed control of vessels on inland waterway systems is needed to adapt more deftly to the dynamic operating conditions and to achieve optimal energy efficiency. Besides operational solutions, alternative power systems for inland vessels with higher energy conversion efficiency should also be considered. Therefore, in this paper, taking into account both the alternative power system and the dynamic navigation conditions, we demonstrate the energy efficient sailing speed control for autonomous inland vessels by two scenarios below. OpenTNSim-Energy simulator is used for quantifying the ship energy use, emissions and optimal speed ranges in the scenarios. Scenario 1 illustrates an autonomous inland vessel, using a conventional diesel-powered internal combustion engine, that sails upstream and downstream trips with real world navigation data where the water depth and current speed vary per waterway stretch. The optimal sailing speed range is selected accordingly with the energy efficiency related indicators, e.g. the amount of emissions (CO2, PM10, NOx), energy consumption, diesel fuel use, fuel cost, with transport time constraints. Scenario 2 presents an autonomous inland vessel with the same vessel type and sailing task as Scenario 1, but using an alternative power system: Proton Exchange Membrane Fuel Cell (PEMFC) powered by green hydrogen. The optimal sailing speed range is selected according to the desired green hydrogen consumption and fuel cost, with transport time constraints. The two scenarios with energy efficient adaptive speed control are compared with the outcomes of conventional operation by conventional inland vessels. In addition to the adaptive speed control which prioritises energy efficiency and fuel consumption, we've also discussed adopting logistical and safety factors to the adaptive speed control problem formulation. Recommendations on further research and technology development of autonomous inland vessels for green and resilient IWT are provided.

Title: Real-time 360 degree bird's eye view of milliAmpere2

Paper Id: 38

Authors: Mathias Thoresen Paasche, Norges teknisk-naturvitenskapelige universitet; Edmund Brekke, Norwegian University of Science and Technology; Øystein Helgesen, Zeabuz;

Abstract: Abstract in PDF format with figure sent to papers@icmass2023.org Abstract. Objective: In recent years, there has been a growing demand for sustainable transportation in cities. In cities with rivers and canals, electric autonomous passenger ferries have received a lot of attention as a cost-effective, environmentally friendlyand flexible transport alternative. However, with passenger transportation, a high safety standard is required. Therefore, the primary objective of this paper is to present a method for increasing the safety of these ferries, particularly in scenarios where a human operator must take control of the vessel, either locally or remotely, due to autonomous system failure. Furthermore, this paper

presents different code optimizations to achieve real-time processing to make the method possible to use in a real-world application. The system is tested on the full-scale autonomous personnel ferry milliAmpere2, as a part of the Autoferry project. Methodology: The primary method used in this paper is inverse perspective mapping (IPM). IPM is a technique that transforms images from the perspective view created by a camera to a bird's eye view. The image processing pipeline in the paper consists of several steps, among them: capturing of images using the 8 optical cameras installed on milliAmpere2, undistortion of the images, IPM, image stitching and bi-linear interpolation. The images are processed locally on the computer installed on milliAmpere2. The goal of this research was to achieve real-time execution of the system, defined as processing time of less than 200ms.However, since the system needs to process 8 images at a rate of 5Hz, code optimization was an essential part of the research. To optimize performance and meet the 200ms-goal, several strategies were employed, including lowering the resolution of IPM-images and using more efficient Python-functions. In particular, pre-calculating pixel weights utilized in the interpolation algorithm was a key improvement. Results: The research consists of two stages. In the first stage, the goal of achieving a processing time of less than 200ms was pursued. To develop, document and test this, the system was run using pre-recorded video footage from a previous experiment with milliAmpere2. Initially, the processing time was 34s per IPM-image, but after multiple rounds of optimization, a final processing time 179ms was achieved. In the second stage, the system is tested in real-time on milliAmpere 2. Its suitability as a decision support tool for docking at the pier is being investigated. Future research: There are a lot of potentials for future work. First and foremost, rewriting the code to utilize GPU instead of CPU. This would make it possible to process images at much higher rate than 5Hz. Secondly, make a system that combines the sea map and IPM-image, by overlaying valuable information from the map onto the IPM-image. Lastly, it can be used in a larger system to aid autonomous navigation close to objects.

Title: Extracontractual liability issues for autonomous inland shipping in the Netherlands and Belgium

Paper Id: 39

Authors: Camilla Domenighini, Universiteit Antwerpen;

Abstract: Inland waterways transport (IWT) is considered one of the most sustainable means of transport in relation to accidents, noise pollution, energy efficiency, and congestion (Al Enezy, van Hassel, Sys, & Vanelslander, 2017; Hofbauer & Putz, 2020; Sys, Van de Voorde, Vanelslander, & van Hassel, 2020), for this reason, the European Union, in the context of the Green Deal (2019) and Sustainable and Smart Mobility Strategy (2020) is promoting the modal shift from road hauling to inland shipping and railways transport. These policy goals have found application in the NAIADES III (2021), the action plan of the European Commission to boost the shift of cargo on inland waterways. Under this plan, digital development is considered pivotal to improve the efficiency of IWT, to integrate it into the multimodal transport chain and thus the attractiveness of the sector for shippers. In this context, research activities are carried out also to test technologies for autonomous navigation, while remote operations are already in place in Belgium, and tests are carried out in the Netherlands and Germany. In Flanders, the Decree of the Flemish Government n. 2019/13067 allows waterways and port authorities to issue permissions to carry out experiments with innovative technologies within the area they manage. The authority required an application from the interested party which consists, inter alia, of a Concept of Operations, a gap analysis of the River police regulations and a risk analysis (Waterschoot, 2022). In 2022 the Central Commission for the Navigation of the Rhine (CCNR) issued similar guidelines regarding the possibility to carry out remote-controlled operations along the Rhine. Legal experts advising the Dutch government have also proposed a system of exemptions granted on a case-by-case basis for the early-stage introduction of autonomous and remote-controlled barges (Smeele & Stevens, 2019). The request for gaps and risks analysis is a kind of legal experimentations which allows the public body to gain insights with the perspective to regulate the operations based on the data collected. However, this determines additional costs for the investors and in the long term could be detrimental. Although autonomous technologies are deemed to be safer than conventional operations, the possibility of accidents happening cannot be ruled out completely. Moreover, as a matter of fact, once the master and crew are replaced onboard by AI

algorithms which take decisions based on data collected on board by sensors and cameras, or provided by third parties, new actors join the IWT ecosystems, namely the technology providers, and this may interfere with traditional actors' obligations, duties and liabilities (Domenighini, 2022). The current legal framework was not designed to accommodate autonomous inland shipping operations, which raises concerns about legal uncertainties and imbalances in risk distribution when applying inland shipping law provisions. Such gaps, uncertainties, and shifts in the exposure to risks could impede the adoption of autonomous barges, as they increase transaction costs. For instance, ambiguity regarding legal responsibility for accidents and the potential for the responsible party to limit liability exposure could render the business uninsurable or very expensive to insure. Therefore, it is necessary to conduct a legal analysis of collision law and limitation of liability regimes in inland shipping with respect to autonomous ships. This aims to investigate whether the current collision law and limitation of liability regimes in Belgium and the Netherlands are applicable to autonomous inland vessels. Moreover, it will assess whether applying the existing provisions would result in legal uncertainties or unbalanced risk distribution. Additionally, it will explore, from a comparative perspective, the similarities and differences between the two legal systems analysed with the purpose to evaluate whether solutions already found in one system could be a path to follow in the other. It is necessary to consider not only jurisprudence but also the fact that the main convention on inland collision law has not been ratified by Belgium. Additionally, it's important to note that the legislators of the two countries have adopted different approaches in transposing the CLNI regime. The paper will focus on Belgium and the Netherlands since inland shipping has a significant modal split in these countries, 11.5% and 41.9% respectively, the European average is 5.6% (Eurostat, 2023). Furthermore, Belgium is a pioneer in testing and operating semi-autonomous technologies. While contractual arrangements such as the transport contract and technology provider service contract are relevant to risk distribution assessment, this paper will solely focus on extracontractual liability, specifically collision law, and liability limitation regimes. The traditional legal analysis will focus on the liability systems outlined in Book 8 of the Dutch Civil Code and the Belgian Shipping Code. The inland shipping law will be the main focus, but domestic maritime law will be examined where the legislator refers to it to regulate inland waterway transport. The analysis will identify gaps and potential obstacles, by describing and evaluating the relevant provisions, which adopt traditional concepts such as fault of the vessel or reckless behaviour, supplied by landmark cases in each jurisdiction. The focus will be on the liability regime, the likelihood of fair compensation for the damaged parties, the distribution of the burden of proof, and the statutory defenses. Additionally, the analysis will consider the role of the technology provider and relevant aspects of its business, such as the limitation of liability. The results of this analysis will provide a clear understanding of the legal challenges posed by the introduction of autonomous inland vessels in Belgium and the Netherlands from a risk distribution perspective. This analysis aims to be useful for IWT stakeholders considering investing in autonomous technologies, legislators who will regulate these technologies, and legal scholars focusing on inland shipping law. However, this paper may also be relevant outside the field given the entwined relationship between maritime law and inland shipping law and the similar legal challenges that other transport modes may face when implementing autonomous technologies. Al Enezy, O., van Hassel, E., Sys, C., & Vanelslander, T. (2017). Developing a cost calculation model for inland navigation. Research in Transportation Business & Management, 23, 64–74. https://doi.org/10.1016/j.rtbm.2017.02.006 Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions Naiades Iii: Boosting future-proof European inland waterway transport. , (2021). Domenighini, C. (2022). 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(2022). Een toekomst voor onbemand varen in de Vlaamse binnenwateren. Tijdschrift Vervoer & Recht, (6).

Title: Inattentional blindness in supervisory control of autonomous vessels

Paper Id: 40

Authors: Erik Aleksander Veitch, Norwegian University of Science and Technology;

Abstract: Abstract When focused on a task, unexpected visual stimuli can go by unnoticed. Inattentional blindness is problematic for supervisory controllers of autonomous vessels, because this role specifically relies on identifying unexpected stimuli in case preventative action is needed. In a simulation-based experiment (n = 32), we show that 50% of participants did not perceive an unexpected visual stimulus (a gorilla passenger) when assigned the task of supervisory controller of an autonomous ferry. This replicates findings from previous studies and suggests inattentional blindness may influence supervisory control. Additionally, eye-tracking showed that 12 of the 16 players who did not identify the gorilla gazed directly at it. Results also showed no correlation to expertise (gamer or navigator). We discuss the implications for supervisory control of remotely operated and autonomous vehicles. Introduction Inattentional blindness describes an inability to perceive things that we do not consciously attend, even if those things are in our visual field [1]. Inattentional blindness appears to be a natural part of being human and may even be necessary to balance conscious perception with attentional resources. However, it may be problematic if one's task is specifically to look for objects or events that are out-of-the ordinary. This is precisely the prescribed role of supervisory controllers, a job that will emerge with the implementation of autonomous ships. Even the most advanced navigation algorithms rely on humans for supervision and back-up. Preventative action most often takes the form of manual intervention in the case of an unexpected event. Given the propensity for humans to be inattentively blind to unexpected events, however, to what extent can we rely on screen-based interaction for safety-critical navigation? Does inattentional blindness play a significant role even for an operator whose role it is to look out of unexpected events? Moreover, is the ability to perceive unexpected events in this context related to experience and skillsets? We explore these questions in an original empirical study. Method We used a custom-made simulator based on the Gemini platform [2] to test how volunteer participants reacted to an unexpected stimulus during a simulation of highly automated ferry operations. This simulator is available for download (https://github.com/mikael-rh/ScenarioBuilder/tree/development). We recruited two skills groups: gamers (n=16) and licensed maritime navigators (n=16). The participants were told that they were "shore control center operators" whose job it was to ensure that passengers boarded and deboarded safely. At some point in the simulator, an event occurred requiring manual intervention. Participants completed two scenarios: in the first, an alarm appears warning of a system failure in the Autopilot ("handover"); in the second, the player must avoid a collision with a small boat ("takeover"). Before the critical event occurs in each scenario: an animated gorilla boards the ferry, directly in sight of the supervisory controllers. Inspired by the famous "gorillas in our midst" experiment [3], the gorilla was specifically used to check for inattentional blindness. After completing the scenarios, the participants were asked whether they noticed the gorilla, and in which scenario(s). Eye-tracking data was used to confirm which participants gazed directly at it. Results Half of the participants (n = 16) reported that they did not see the gorilla in the first scenario. Of these, 75% (n = 12) gazed directly at the gorilla according to eye-tracking data. Interestingly, almost all reported seeing the gorilla in the second scenario. Using eye-tracking data, we found that of the 12 participants that gazed directly at the gorilla without perceiving it, 10 of them reported seeing it in the second trial. Even among those who had the gorilla only in their peripheral vision, 75% (3 out of 4) reported seeing it in the second trial. This indicated that simply having the gorilla in the field of view (whether in direct gaze or peripherally) was a strong predicter of whether the gorilla is perceived in the repeated trial. Discussion and Conclusion The results replicated the classic study on inattentional blindness [3] in the context of supervisory control of autonomous vessels. Even when operators were expressly told to be aware of unexpected events as part of their supervisory role, the effects of inattentional blindness were still present. Possessing different skills (gaming or maritime navigation) made no difference. The results indicated that second exposure of the stimulus greatly increased the chances of perception. This may have implications for simulation training for supervisory controllers, because simple visual exposure to critical events in a simulator may help to identify them when they occur in real life. Since the role of a supervisory controller is predicated on an attentive operator who can identify events that may require preventative action (including "unknown unknowns"), the results point to

inattentional blindness as an overlooked hazard in supervisory control. However, its risks may be mitigated with teamed operators and with simulation training focused on exposure to critical events. References [1] A. Mack and I. Rock, Inattentional blindness. Cambridge, MA, US: The MIT Press, 1998. [2] K. Vasstein, “A high fidelity digital twin framework for testing exteroceptive perception of autonomous vessels,” ICMASS, 2021. [3] D. J. Simons and C. F. Chabris, “Gorillas in our midst: Sustained inattentional blindness for dynamic events,” Perception, vol. 28, no. 9, 1999.

Title: Towards the decision support system for MASS collision avoidance taking into account intact stability

Paper Id: 41

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Abstract: Worldwide scientific and industrial communities have been steadily progressing towards wider implementation of Maritime Autonomous Surface Ships (MASS) by researching various aspects of MASS design and operation. Among these aspects are: human factors involved, algorithms for collision avoidance, and stability issues. However, these are frequently studied in separation from one another, and a holistic approach to MASS safety requires a massive effort and resources. With the current international R&D project, we address both collision avoidance and intact stability by application of innovative methods including Collision Avoidance Dynamic Critical Area (CADCA), neural networks for real-time stability calculations, and ground-augmented precise navigation. Through the application of the above, a Decision Support System in line with IMO Degree of Autonomy 1 will be developed and implemented onboard two research vessels to test its feasibility.

Title: Data interface for an interactable ship bridge towards MASS at human-in-the-loop levels

Paper Id: 42

Authors: Baiheng Wu, Norges teknisk-naturvitenskapelige universitet; Lars Ivar Hatledal, Norwegian University of Science and Technology; Tongtong Wang, Norwegian University of Science and Technology; Andreas Brandsæter, Norwegian University of Science and Technology;

Abstract: In recent years, there has been significant advancement in the development of Maritime Autonomous Surface Ships (MASS) in both academic and industrial domains, including technical solutions and legal regulations. According to the International Maritime Organization (IMO), human navigators will still play varying degrees of roles in ship navigation, and manual navigation will continue to be predominant at least in the MASS I-III levels. The IMO plans to enhance the development and application of MASS between 2024-2028, with the application of MASS estimated to occur gradually between 2030-2060, signifying a period of coexistence and collaboration between human navigators and machine intelligence. Relative to the self-driving car field, research on MASS lags behind in terms of technology development and application, mainly due to the unique characteristics of the maritime traffic industry. MASS are mainly used in the transport industry and public transportation sector, which results in higher single accident losses and a cautious approach towards autonomous technology. However, caution does not imply conservatism, but rather respect for human life safety and responsibility for global economic and trade security. Thus, phased development and application of MASS are necessary, starting from fully manual navigation to onboard decision support, partial automatic navigation system assistance, human remote control, and finally, fully autonomous navigation and operation. This process requires a thorough study, modeling, and evaluation of human navigators' navigation modes to inspire the development of autonomous navigation functions and ensure maritime traffic safety in future hybrid and

quasi-intelligent traffic systems. Data collection on human navigators currently comes from real ship bridges and simulators, but neither has data interfaces for decision support systems (DSS) and autonomous navigation systems (ANS) functionality. Therefore, this research focuses on developing a set of data interfaces suitable for Human-in-the-Loop (HITL) level MASS for DSS and ANS development, testing, and evaluation. This article proposes a data interface solution based on a commercial bridge simulator, with a simulator server named Sim-PC set up as a service station to receive unidirectional broadcast NMEA data based on the UDP protocol from the bridge simulator. Data interaction of control instructions registers is achieved through TCP/IP protocol in another bidirectional channel. Bidirectional downstream data is transmitted between Sim-PC and the user end, including NMEA and registers from the upstream, achieved by building WebSockets on Sim-PC. This enables DSS and ANS systems to access the bridge simulator. After implementing the solution, testing was conducted on existing DSS and ANS systems. While some technical issues exist, the solution effectively connects the target system to the bridge simulator for testing purposes. The refinement of technical details will be continued in future work, along with batch testing on developing DSS and ANS functions for feedback, to enhance the solution's practical application.

Title: Risk assessment method for autonomous ship systems: Case study of Electronic Lookout

Paper Id: 43

Authors: Meriam Chaal, Aalto-yliopisto; Victor Bolbot, Aalto-yliopisto; Axel Berres, Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren;

Abstract: The development of new technologies for autonomous ship navigation is currently underway, including advanced perception systems and automatic collision avoidance systems. Meanwhile, the integration of these technologies into existing and future autonomous ships poses significant challenges and may also introduce new risks. Therefore, it is essential to evaluate system safety during the design phase. However, the safety assurance of autonomous ship enablers still requires transparent and systematic procedure of risk assessment, which can support the development of qualitative and quantitative safety requirements for different autonomous ships systems and enablers. To address this issue, a comprehensive risk assessment method is proposed in this study. The method makes use of the aviation industry safety practices and risk assessment procedures. The method is demonstrated on the case of the Electronic Lookout, one of the enabling technologies for future autonomous navigation, which is being developed as part of the ECAMARIS research project together with maritime regulators in Finland. The results provide explicit safety requirements for the design nd integration of ship Electronic Lookout system.

Title: How to analyse the market and design introduction strategies for radically new technological innovations? The case of Autonomous Shipping

Paper Id: 45

Authors: Mariah Kurtinaitis Joukes, Technische Universiteit Delft; Roland Ortt, Delft University of Technology; Mark de Bruijne, Delft University of Technology; Linda Kamp, Delta State University;

Abstract: Organizations involved with the development, application and commercialization of radically new technological innovations face an upcoming market that is turbulent and hard to analyse with standard market research instruments. Turbulence means that the market situation can change quickly and erratically. Prolonged periods of stagnation can alternate with periods in which pilots are planned, investments spur and specific versions of the technology are introduced in niche applications. In this turbulent situation of an upcoming market for a radically new technological innovation, organizations struggle how to analyse the market and derive possible introduction strategies. The current article provides perspective by indicating how to analyse the wider technological innovation system (TIS) around the upcoming market of Maritime Autonomous Surface Ships (MASS) and how to derive strategies to introduce this breakthrough technology. Radically new technological innovations represent either an advance in technology that is so significant that price/performance ratios are altered dramatically, or that

entirely new kinds of applications are made possible (Tushman and Anderson, 1986; Garcia and Calantone, 2002). Such innovations seldomly start diffusing smoothly in an existing market. After the first introduction, an erratic process of introducing and withdrawing specific versions of the innovation in niche markets can be witnessed. It is remarkable how long it takes before radically new technological innovations start diffusing on a large scale (Schnaars, 1989; Agarwal and Bayus, 2002; Ortt, 2010). This erratic process is often caused by a market that is incomplete at best and mostly full of barriers to large-scale diffusion. Radically new technological innovations may represent a significant advance in technology that may enable new types of applications, but that most often entails new complementary products and services, new customer groups and adapted institutional arrangements. This means that a new market arrangement must emerge for large-scale diffusion of a radically new technological innovation. The ultimate market arrangement is often unknown early on, because of uncertain progress in development of technologies, complex and unpredictable patterns of competition between old and other new technologies. The resulting market turbulence makes it hard to analyse the market using standard market research instruments. The current article will focus on MASS and use it as a case to illustrate how to analyse the wider system around an upcoming market and derive introduction strategies into that market. The current article takes the work of two previous articles as a starting point. In a first article, we carefully defined MASS and described its status in the process of technology development and diffusion, concluding that the diffusion of MASS is now hampered by several barriers and it is thus applied in small scale niche applications only, such as survey and ferry transport. So, MASS has not yet started to diffuse on a large scale (Kurtinaitis Joukes et al., 2023). In a second article, we analysed the wider sociotechnical system around the upcoming market for MASS. We created a special Technological Innovation System (TIS) framework that can be used by maritime managers and researchers. This framework combines technological, economic, institutional and social aspects relevant for strategy formulation. In doing so we described seven TIS Building Blocks of the socio-technical system from which new markets emerge (Kurtinaitis Joukes et al., 2023) and concluded that some important Building Blocks are still fully or partially absent for the large scale diffusion of MASS. The current article extends the previous work by showing how several underlying conditions influence the status of these Building Blocks. We will show how insight into the status of the TIS Building Blocks and the influencing conditions can be used to derive strategies to spur the diffusion of MASS. We focus on the application of MASS in commercial shipping rather than pleasure craft. Research questions 1. RQ1: What is the combination of influencing conditions and Building Blocks that together form a Technological Innovation System (TIS) around MASS? 2. RQ2: How can potential (niche introduction) strategies be derived from the analysis of the TIS around MASS? We used a combination of literature research and two rounds of interviews with MASS researchers and practitioners methodologically to underpin our results. The unstructured and semi-structured interviews gave a broad perspective of the barriers and a detailed view of the barriers and their underlying influencing conditions respectively. As a result, the Building Blocks Model was adapted to MASS TIS, forming an industry specific TIS. From the previous article (Kurtinaitis Joukes et al) it was already determined that Safety is a very important building block for MASS TIS, which is not part of the original framework. Another aspect from the original Building Block Model was the Price factor, which appeared to be not a relevant Building Block for MAS. In the context of MASS development and large-scale diffusion the cost-benefit is more important than the price itself. Our results show that, from the analysed Building Blocks, the majority of them was deemed partially present by the interviewees. The exceptions were cost-benefit, considered absent and production system, considered fully present. The Building Block complementary services was not considered important enough to drive adoption but serves as an influencing factor to the cost-benefit., which was also found to be a hampering factor to large-scale diffusion. Regarding the influencing factors, the interviewees mentioned operational aspects, which are factors that influence the regular operation of autonomous vessels, such as maintenance of the engines, cargo inspections, communication with other vessels and port facilities. These aspects influence the operation of unmanned vessels in general, but not much of autonomous vessel that still have crew members onboard. They currently do not hamper the diffusion of MASS but will act as hampering factors to further diffusion when (if) operation of the vessels is moved to Ship Control Centres (SCC) or vessels become fully unmanned. Natural, human and financial resources, as well as accidents and events are seen as encouraging factors to the diffusion of MASS by our interviewees, while the other influencing factors were considered partial barriers, meaning that they are partially present in the system, but not on a scale that could encourage the adoption and consequent diffusion of MASS. The analysis of MASS Building

Blocks and Influencing factors in comparison with the Breakthrough technologies Building Block Framework (BBF) proposed by Ortt & Kamp (2021) has shown that the majority of the BBF suits the MASS TIS. Despite the small modifications made to the Building Blocks to ensure full compatibility with MASS, the essence of the framework applies to this developing technology. On the practical perspective, the overview of the MASS TIS shows that the adoption of this technology is not straightforward, safety enhancement is not yet guaranteed, and the return on investment in MASS is not clear cut for most shipowners if the crew size remains unchanged . The crew reduction needs to be, at least, approved by the national authorities to ensure return on the investment to MASS. The cost-benefit, therefore, is only straightforward for most shipowners if MASS is recognized by the regulation authorities. While some national governments and the International Maritime Organization (IMO) discuss MASS regulation, the technology is not yet recognized and certified. Given the size of the IMO and the differences between the goals of its members, expectations that international regulations will be changed soon are very low. Based on the shown MASS TIS, the adoption and regulation of MASS is a multi-faceted issue that comprises market decisions on upgrading expensive assets, risks on the safety effects of the use of technology, as well as regulatory matters that include harbour infrastructure investments, legislation review and significant changes in the maritime education system. The presented niche strategies which include the Geographic, Lead User and Educate Niche strategies, to address the Cost-benefit, Innovation Specific Institutions and Safety building blocks respectivelshow that not a single strategy can be used to address MASS TIS and encourage diffusion, since some of the strategies work against each other. In this context, a combined pathway of different niche strategies and a policy change would be necessary to ensure a TIS in which MASS can diffuse.

Title: Comparing Multiple Extended Object Tracking with point based Multi object tracking for LiDAR in a maritime context

Paper Id: 46

Authors: Martin Baerveldt, Norges teknisk-naturvitenskapelige universitet; Audun Gullikstad Hem, Norges teknisk-naturvitenskapelige universitet;

Abstract: In this paper, we compare a recently developed Multiple Extended Object Tracking method with a point-based tracker for maritime applications based on both real LiDAR data and simulated LiDAR data. Situational awareness is a key property of an autonomous system since autonomous operation requires an understanding of the surrounding environment, of which other vessels are a key component. To estimate the states of other vessels based on a set of measurements, target tracking methods are commonly used, since the origin of a particular measurement is unknown. This is the problem of multi-object tracking [1]. Traditionally, Multi-object tracking uses the point approximation to simplify the target tracking problem, meaning that an object is assumed to only generate a single measurement. With recent advances in sensor technology, such as LiDAR and high-resolution Radar with which a target generates several measurements, this approximation is no longer valid. Therefore, to continue using methods built on the point approximation, the use of a clustering method is needed such that several measurements are combined to form a single target detection. This use of clustering can introduce further errors [2]. Multiple Extended Object Tracking instead makes use of Extended Object Tracking methods, where the extent of a target is estimated using all available measurements, enabling an estimation of the extent of a target in addition to the kinematic states [3]. However, the target models used in extended object tracking are by necessity more complex since the model also needs to be able to estimate the extent. For the sake of comparison, we use a newly developed Poisson Multi Bernoulli Mixture filter based on the Gaussian Process target model, which can estimate an arbitrary ship shape [4]. We will compare a simple traditional point multi-object tracker known as the JIPDA with a recently developed Poisson Multi Bernoulli Mixture filter based on the Gaussian Process target model. We will study the performance of both methods on real and simulated LiDAR data which was used in a previous paper, where the tracked targets were small ships. The real data was gathered on multiple occasions in a canal in Trondheim [5]. As performance metrics, we use the GOSPA score as well as the Root mean squared error (RMSE) of the position and velocity. We will also compare the Intersect over Union (IoU) of both methods to determine if extended object tracking can reduce the margin of error by producing a more accurate estimate. We expect the

extended object tracking method to produce an accurate extent estimate and a more accurate positional estimate since the Gaussian process model can model contour-generated measurements. In addition, the multiple extended object tracking method should have better GOSPA performance. However, experiments on real data have previously shown that effects such as wake clutter have an outsized effect on the extended object tracking model, showing that more research is needed for more accurate modeling of these effects. Funding Acknowledgement: The research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 955.768 (MSCA-ETN AUTOBarge). This publication reflects only the authors' view, exempting the European Union from any liability. Project website: http://etn-autobarge.eu/.
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Title: Design and Build of an Autonomous Catamaran Urban Cargo Vessel

Paper Id: 47

Authors: Yan-Yun Zhang, Katholieke Universiteit Leuven; Jiangtao Shuai, Katholieke Universiteit Leuven; Jef Billet, Katholieke Universiteit Leuven; Peter Slaets, Katholieke Universiteit Leuven;

Abstract: According to the European Commission, freight transport is projected to increase over 58% by 2050 or 1.2% each year, necessitating improvements in the capacity of the transportation system. However, most freight is currently carried by road, which incurs high and escalating external costs, such as accidents, air pollution, climate change, noise and congestion. For instance, road congestion already accounts for 1 to 2% of Europe's Gross Domestic Product (GDP). Urban areas are even more congested, and many cities have implemented car banning policies in their centres. Furthermore, to limit climate change to 2°C by 2050, reducing greenhouse gas emissions by 80–95% below 1990 levels is critical. Given these challenges, increasing road transport is not a viable solution to the rising demand for freight transport. Thus, Europe needs to explore alternative modes of urban freight transport. The massive under-exploitation of inland waterways (IWW) in Europe, especially in and around urban areas, represents a significant opportunity. According to The European Inland Waterway Transport Platform (IWT), the average external cost for inland waterway transport is 3.9 €cent/tonne-kilometre (tkm) when considering congestion, compared to road transport, which is 70% higher. Furthermore, transporting goods via waterways is regarded as the most environmentally friendly mode of transport: with 1 litre of fuel capable of transporting 1 tonne of cargo up to 180 km by waterways, compared to a maximum of 15 km by road or 45 km by rail. In cities with dense, widespread waterway networks, a considerable portion of freight transport can shift from road to water, resulting in a significant reduction in external costs and greenhouse gas emissions. Small vessels (CEMT I-II) that can operate in narrow urban environments account for 15% of the total inland vessel capacity and transport 21,084 million tonnes of freight per year, representing 2.5% of the total European inland cargo flow. Despite their potential, these small vessels are currently not economically viable, with over 12% of them being demolished in the last decade. Current negative investment climate is attributed to various factors, including high crew cost (which can be up to 60% of the total shipping cost), a declining number of young skippers, high entry and exit barriers, and a lack of technological advancements. These issues can be resolved if machine is able to replace part of men's job, reducing the dependency on highly skilled helmsmen and significantly lowering the crew cost. Therefore,

increased automation is critical to ensuring a sustainable and economically viable future for this scale of inland cargo vessels. To this end, an autonomous urban cargo vessel, Maverick, has been designed and built as a prototype, with the goal of developing, testing, and evaluating suitable technologies. The hull form of Maverick was selected to be a catamaran, as it offers several advantages, including a large open deck area, high transverse stability, and excellent manoeuvrability at low speeds. Maverick is equipped with two 360-degrees-steerable azimuth thrusters, one at bow and one at stern. This configuration makes Maverick over-actuated, and offers more advanced motion control possibilities compared to conventional rudder-propeller actuated vessels. Maverick incorporates hardware and software modules, devised in a modular system with a robust and flexible interface, enables it to accommodate diverse control terminals for future developments. It consists of three subsystems: the actuation control subsystem, the battery subsystem, and the autonomy subsystem. This modular system can operate independently or integrate with external devices to function under various control strategies, such as onboard operator controlled, man-in-loop remote controlled, or fully autonomous controlled. The adaptability and versatility of this modular system allows Maverick to meet different operational requirements and seamlessly embed into a larger autonomous framework. Furthermore, to demonstrate the feasibility of Maverick within an urban context, a pilot test was conducted. This test involved a full cycle of cargo uploading and offloading, as well as setting sail, tracking waypoints, and berthing. The pilot test aimed to showcase the practicality of using Maverick for urban freight transportation. The first author Yanyun Zhang is a researcher funded by the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No955.768 (MSCA-ETN AUTOBarge). This publication reflects only the authors’ view, exempting the European Union from any liability .Project website: http://etn-autobarge.eu/.

Title: Development and operation of the autonomous urban passenger ferry milliAmpere2

Paper Id: 48

Authors: Egil S. Eide, Norges teknisk-naturvitenskapelige universitet; Morten Breivik, ; Edmund Brekke, Norwegian University of Science and Technology; Bjørn-Olav H ERIKSEN, ; Erik F WILTHIL, ; Emil Thyri, Zeabuz AS; Erik Veitch, Norwegian University of Science and Technology; Ole A ALSOS, ; Øystein K HELGESEN, ; Tor Arne Johansen, Norges teknisk-naturvitenskapelige universitet;

Abstract: This paper describes the development and trial operations of the autonomous and electric urban passenger ferry “milliAmpere2” at the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway. This ferry has been developed by employees and students at NTNU together with industry partners in the period between 2019 and 2021. The development was based on the experiences made from the first prototype ferry “milliAmpere1”, which was launched in 2017. The “milliAmpere2” is a result of a multi-disciplinary design process that brought together the NTNU departments of electronic systems, design, engineering cybernetics, marine technology, and information security and communication technology. In autumn 2022, the ferry underwent public field trials, successfully transporting 1500 travellers across a 100-meter canal and demonstrating the viability of autonomous transport in urban waterways. It is the world’s first autonomous urban passenger ferry which has been used for actual public transportation. The ferry is 8.6 meters long and 3.5 meters wide, with an aluminium monohull with a total displacement of 6 tons, see Figure 1. It is equipped with four 10-kW electric thrusters which are connected to a DP2-class dynamic positioning system, which makes the ferry fully actuated. The ferry hosts a maximum of 12 passengers and is designed to accommodate bicycles, wheelchairs, and other modes of personal transportation. Passengers can initiate the crossing using a button, analogous to the functionality of an elevator. Figure 1: The “milliAmpere2” during trial operation in the Trondheim City Canal in September 2022, while “milliAmpere1” is docked in the background. Lacking design guidelines for autonomous vessels, a multidisciplinary design approach was taken that adopted elements of risk-based design and human-centred design. The former involved goal-based design oriented towards functional requirements of safety controls (e.g., redundancy of thrusters, network, and batteries); the latter involved drawing up design requirement from across disciplines early in the design process (e.g., workshops, model-scale prototyping) with a focus on user needs and user experience. Even if the “milliAmpere2” is operated in a canal inside the harbour area, it will often have to operate in a maritime traffic scenario characterized by kayaks, small and medium sized leisure boats, and commercial

vessels operating in a congested area. Therefore, the autonomy system must detect and track a variety of targets and ensure that the collision avoidance algorithms always operate safely and reliably. The situational awareness (SITAW) system used on board the “milliAmpere2” is based on two lidars, eight electro-optical machine vision cameras, four infrared cameras, and a standard X-band marine radar. Inputs from these sensors are used, together with data from a real-time kinematic (RTK) GNSS system and an IMU. The SITAW system tracks and provides estimates of obstacles in the vicinity of the ferry, which the motion planning system uses to adjust the ferry speed to avoid collisions. Since the ferry will be used for passenger transport, safety requirements must be high. Early in the design process, an extensive list of hazards was drawn up across all involved disciplines and safety controls were suggested. During the trial operation, a safety host was on board the ferry, which main role was to monitor the autonomy system and take over manual control, if necessary. The next stage of the “milliAmpere2” operation involves operation without a safety host onboard. Instead, the role will be transferred to a nearby remote control center hosted by the NTNU Shore Control Lab, a research platform designed to develop supervisory control of autonomous vessels. The control room is connected to the “milliAmpere2” using both a cyber-secure 5G link and a dedicated C-band microwave link for redundancy.

Title: Formation Control and Coordination of Maritime Autonomous Surface Ships: A Multi-Agent Decentralized System Approach using Rigidity Graph Theory and Lyapunov based non-linear control strategy.

Paper Id: 50

Authors: Vittorio Garofano, Technische Universiteit Delft; Yusong Pang, ; Rudy Negenborn, Technische Universiteit Delft;

Abstract: This research paper presents the design, analysis, and implementation of a fleet of Maritime Autonomous Surface Ships (MASS) working together as a multi-agent system. By leveraging recent advances in sensor technology, embedded systems and communication protocols the proposed methodology demonstrates potential for various applications, including environmental monitoring, cooperatively moving large objects, mapping vast water territories, and enhancing logistics for goods transportation in an autonomous and coordinate way. Investigating rigid graph theory, nonlinear systems stability, and Lyapunov based non-linear control strategy, we explore two multi-agent related problems with increasing levels of complexity: formation acquisition and formation manoeuvring. Results demonstrates that the combinations of these strategies are promising towards the implementation of control frameworks for the decentralized coordination of an autonomous fleet of vessels.

Title: Modelling and Simulation of an Over-actuated Autonomous Inland Cargo Vessel

Paper Id: 51

Authors: Yan-Yun Zhang, Katholieke Universiteit Leuven; Rudy Negenborn, Technische Universiteit Delft; Peter Slaets, Katholieke Universiteit Leuven;

Abstract: According to projections by the European Commission, freight transport is expected to increase by 60% by the year 2050. This poses a significant challenge for the transportation industry, which will need to enhance its capacity to accommodate this growth. Inland waterway transportation is a promising mode of transport due to its reliability, energy efficiency, and capacity for increased use, especially given the rich water system in Europe. With crew cost accounting for up to 60% of the total cost, autonomous vessels represent an exciting disruptive technology that can greatly cut the cost and make inland waterway transportation economically competitive. However, realization of autonomous vessels requires the establishment of an accurate ship manoeuvring model. This model is typically built on the basis of physics, using hydrodynamic coefficients to represent the forces acting on the vessel. By predicting how a vessel will respond to control commands, the ship manoeuvring model can facilitate the development of control strategies for autonomous vessels. Inland cargo vessels face unique challenges in navigating through spatially restricted complex waterways. To address these challenges and enable the development of autonomous inland cargo vessels, new vessel designs that with enhanced manoeuvrability are needed.

The European Watertruck+ project is at the forefront of this effort, designing a new generation of inland barges. These barges feature an innovative embedded actuation system, comprising a 360-degrees-rotatable 4-channel thruster at the stern and a 360-degrees-rotatable steering-grid thruster at the bow. As part of this project, KU Leuven has developed a self-propelled scaled model of the Watertruck+ vessel, named Cogge, which serves as an experimental platform for research and development. Cogge is equipped with the same over-actuated propulsion system as the Watertruck+ vessel, thereby enabling the imposition of various combinations of propeller forces and moments in different directions with both bow and stern thrusters. It is important to note that the damping forces acting on Cogge must follow the directions of the total propeller forces. However, existing ship manoeuvring model structures only account for traditional under-actuated vessels and do not offer the ability to align the directions of the damping forces with the total propeller forces. This paper presents a new 3 degrees of freedom (DOF) ship manoeuvring model structure for over-actuated vessels. Taking Cogge as a study object, the model structure is designed follows a modular manner by dividing the forces acting on the vessel into inertial forces, propeller forces and damping forces. The propeller forces are modelled based on the open water towing tank test results of the bow and stern thrusters. A new parameter is introduced into the damping term to act as a direction indicator, specifically for over-actuated vessels. Various manoeuvres are numerically simulated to evaluate the proposed model structure. Results indicate that the proposed manoeuvring model is better suited for over-actuated vessels. The first author Yanyun Zhang is a researcher funded by the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No955.768 (MSCA-ETN AUTOBarge). This publication reflects only the authors' view, exempting the European Union from any liability .Project website: http://etn-autobarge.eu/.

Title: A Multimodal Sensor Box for Inland Waterways: Design, Build, and Experiment

Paper Id: 52

Authors: Jiangtao Shuai, Katholieke Universiteit Leuven; Senne Van Baelen, Katholische Universität Eichstätt; Jef Billet, Katholieke Universiteit Leuven; Thibaut Schamp, Katholieke Universiteit Leuven; Yan-Yun Zhang, Katholieke Universiteit Leuven; Peter Slaets, Katholieke Universiteit Leuven;

Abstract: Inland Waterway Transport (IWT) is acknowledged as an ecologically friendly and energy-efficient transportation mode, but it requires skilled personnel to navigate vessels through complex waterways. Regrettably, the relatively elevated crew expenses, amounting to 60% of the total cost, as well as difficulties in attracting young personnel, restrict the competitiveness and growth prospects of IWT in comparison to alternative transport modes such as roadway and railway. As a result, there is a pressing need to enhance the automation level in IWT by exploiting advanced Guidance, Navigation, and Control (GNC) systems. The fundamental requirements of a GNC system encompass accurate localization concerning the surrounding environment and a predetermined routine, as well as operations of the actuators. Furthermore, perception is a critical subtask when constructing an advanced GNC system. Although learning-based methods have already exhibited their exceptional performance for perception in maritime environments, their applicability for inland waterways is limited by the lack of training datasets. To address the fundamental requirements and advance the GNC system in IWT, this paper introduces a multimodal sensor box for data collection from various sources and implements basic GNC applications using the sensor box in an inland waterway environment. The sensor box is designed as a standalone module with a power supply and can mount on different platforms. In order to perform navigation tasks, the box incorporates Light Detection and Ranging (LiDAR), Global Navigation Satellite System (GNSS), and Inertial Measurement Unit (IMU). To ensure data consistency, LiDAR is synchronized with IMU and GNSS using Pulse-Per-Second (PPS) signal and NMEA (National Marine Electronics Association). The sensor box also comprises an Automatic Identification System (AIS) and a cellular network unit to maintain interface capabilities with existing vessel systems and external systems. All peripheral equipment can communicate with an industry PC located inside the box via a switch or direct cable connection, where it can carry out tasks for the GNC system and data collection. In order to achieve adaptability to different vessels and extensibility for future development aimed at varied research objectives, the architecture of the sensor box system comprises both hardware and software modules that

are designed in a modular system with a flexible and robust interface, allowing for easy integration of third-party components and extensions. To facilitate communication across different software levels concerning various services, a middleware operates on the system in line with the communication architecture's design. Consequently, with its array of cable ports and the cellular network unit, the sensor box can be seamlessly integrated into an existing automation system through wired or wireless communication. Finally, the sensor box is evaluated in an inland waterway environment through a series of tests, which include conducting sensor function tests concerning navigation objectives and operating a vessel to perform basic sailing tasks. The tests aim to demonstrate the sensor box's capabilities as a data collection platform and a GNC system for autopilot.

Title: Path Following Control for a Novel Inland Surface Vessel

Paper Id: 53

Authors: Jef Billet, Katholieke Universiteit Leuven; Yan-Yun Zhang, Katholieke Universiteit Leuven; Jiangtao Shuai, Katholieke Universiteit Leuven; Peter Slaets, Katholieke Universiteit Leuven;

Abstract: Being more sustainable than traditional road-based freight traffic, the Inland Waterway Transport (IWT) sector suffers from financial caveats; smaller-sized inland ships are increasingly out of fashion due to prohibitive costs associated with crewing and (off)loading, which drives the functional neglect of smaller waterways. Such small waterways are common in the West-European hinterland and serve as (inter) urban transport infrastructure. Nowadays, usage has become mainly limited to leisure and tourism activities. Therefore, these waterways have potential to relieve the congested road networks and contribute to, e.g., the transition goals of the European Green Deal. To make small waterways once again a viable alternative for freight traffic, one option is to forgo the need for crew by introducing small and maneuverable Autonomous Surface Vessels (ASVs) operating in and between cities. Small waterways present a constrained operating environment characterized by shallow waters and permanent proximity to obstacles such as canal walls. As such, the maneuverability and flexibility of novel ASVs is important, and can be improved by introducing novel over-actuated propulsion layouts. This work addresses identification and path-following control for an ASV designed for urban waterways by IMP, dubbed Maverick. The Maverick is a rudderless 1-ton catamaran equipped with symmetrically positioned identical bow and stern azimuth thruster as the means of actuation. The Maverick’s design has inter-city transport in mind; pallet-sized cargo fits its deck while it is, thanks to the over-actuated azimuth thrust configuration, capable of performing complex maneuvers in confined environments. As a rudderless and over-actuated vessel, standard identification tests such as zigzag or turning circles that employ a rudder prove inadequate to capture the maneuvering capabilities of the Maverick. Therefore, we utilize modified identification maneuvers such as the Counter Thrust Test (CTT), and the Sine Angle Test (SAT), and present the derived first and second-order Nomoto models. The servo systems of the azimuth propellers are also modelled. All identification experiments are performed on a canal with a depth and width of four and twenty meters, respectively, near Leuven, Belgium. We use the identified (Nomoto) models to develop a velocity and a heading controller based on linear Model Predictive Control (MPC), which have bow propeller RPM and stern angle as control inputs, respectively. These controllers are subsequently benchmarked in i) a heading-keeping scenario, ii) a velocity-keeping scenario, and iii) a waypoint-following scenario using Integral Line of Sight (ILoS) over a 1.2-kilometer canal section against conventional Proportional Integral Derivative (PID) control. The results show effective path following that outperforms the PID benchmark.

Title: Multi-functional and Practical Adaptive Collision Avoidance Decision-making System for Autonomous Ship

Paper Id: 55

Authors: Kangjie Zheng, Dalian Maritime University; Xinyu Zhang, Dalian Martime University China; Zhensheng Liu, Dalian Martime University China; Kwangil Lee, Korea Maritime & Ocean University; Chengbo Wang, Dalian Maritime University of China;

Abstract: With the increasing size and number of ships, maritime safety faces significant navigation challenges such as ship collisions and groundings. Since autonomous ships are seen as the future direction for intelligent ship development, collision avoidance decision-making is considered the brain of autonomous ship navigation systems. However, current decision-making technologies cannot adapt to various encountered scenarios, which limits the theoretical study of navigation systems. Moreover, ship navigation systems rely on comprehensive platforms that use AIS, electronic charts, and radar, where ship drivers confirm navigation situation estimation and avoidance decisions. Although various collision avoidance algorithms have been gradually applied to navigation systems during testing, no system integrates multiple functions such as multimodal display of navigation situation information, navigation warning, trajectory deduction, adaptive collision avoidance decision-making, human-machine interaction, and visualization of decision results in a modular way. This paper presents a multi-functional and practical adaptive collision avoidance decision-making system for autonomous ships. The system integrates and processes information related to navigation safety, including navigation situation information, navigation warning, trajectory deduction, adaptive collision avoidance decision-making, human-machine interaction, and alarms. It displays the own ship's navigation situation on the electronic chart, identifies and shows navigation information around the own ship, calculates the collision risk with object ships under encounter situations, and provides collision avoidance assistance measures such as trajectory deduction, trial operation, and adaptive avoidance decision-making based on the navigation task, ensuring safe navigation. The system consists of three subsystems: the collision avoidance decision-making subsystem, the collision avoidance auxiliary subsystem, and the navigation situation information subsystem. The collision avoidance decision-making subsystem initially constructs a semantic understanding model of the navigation situation based on ontology and divides it into different scenarios. Then, using the bearing-only parameter estimation (BOP) algorithm to calculate real-time parameters such as ship speed, heading, the time to closest point of approach (TCPA), the distance to closest point of approach (DCPA), encounter situation, and collision risk for the own ship and different object ships. Then it constructs a collision avoidance decision-making model and makes adaptive decisions by using algorithms such as B-spline. Finally, big data technology is used to visualize parameters such as DCPA, TCPA, collision avoidance risk, and changes in the distance between ships in the subsystem. The collision avoidance auxiliary subsystem includes functions such as setting collision avoidance scenarios, demonstrating collision avoidance effects, querying navigation aids, and risk alarms based on electronic charts. It also employs a trajectory deduction algorithm built on the trial operation function of human-machine interaction, enabling the deduction of safe trajectories for the next 3-15 minutes of navigation. And a communication service is built in this subsystem using sockets to facilitate information exchange among the three subsystems and display real-time navigation situation information, collision avoidance risks, and alarm information. The navigation situation information subsystem mainly uses JavaScript technology to display comprehensive ship information in real-time through modularized. Ship comprehensive information can be displayed through various forms such as instruments, text, graphics, and sound. In addition, the collision risk solved by the BOP algorithm in the subsystem can be transmitted as an alarm through sound. Furthermore, the multi-functional and practical adaptive collision avoidance decision-making system has been tested on a comprehensive navigation system and found easy to operate with good visualization of navigation situation information. The tests demonstrate the system can calculate collision avoidance decisions in real-time and improve navigation safety. The system integrates multi-functional and practical functions such as navigation situation judgment, trajectory deduction, adaptive collision avoidance decision-making, human-machine interaction, and visualization of decision results, which can better assist autonomous ship navigation.

Title: Smart Ships and implications in Logistics chains – a case study in Zeeuws Vlaanderen-

Paper Id: 57

Authors: Andres Caballero Rosas, Hogeschool Zeeland; Jur Janse, Nederlandse Rijksoverheid;

Abstract: Autonomous shipping is expected to be gradually adopted in the coming years. While many scientific studies in the field have focused on the technological development, recent research has started to explore the effects of the use of this innovation in the transportation industries and shippers who hire

transportation services. This study investigates the economic and other type of incentives that drive logistics and shipper entrepreneurs to adopt tele-operated barges, a specific type of smart shipping, through an in-depth case study of cargo transportation between two companies using roundtrips with trucks and barges. Quantitative results reveal that not only there would be economical and environmental gains when implementing tele-operated barges. More importantly, when faced with the potential decision of adopting smart shipping to enhance and cost-reduce transport operations, company managers, researchers and experts who participated in the study devised different ways to conduct this logistics operation using smaller tele-operated barges. A major conclusion of the study is that smart shipping can deliver economic gains but can also serve as a catalyst for redesigning logistics operations and thereby increasing the supply chain reliability in this flow. This case study contributes to the body of knowledge regarding the impacts of autonomous shipping in the logistics sector, providing valuable insights until larger scale empirical studies can be conducted in the future.

Title: A Simple and Forgiving Automatic Docking System for Underactuated USVs

Paper Id: 58

Authors: Jakob Maximilian Odenwald, Norges teknisk-naturvitenskapelige universitet; Kim Christensen, Norwegian University of Science and Technology;

Abstract: With the aim to support the feasibility of USVs, this paper presents an automatic docking system aimed towards underactuated vessels. The developed hardware, sensor, and control concept was tested using a full-size prototype, with the system able to dock the underactuated test vessel reliably. Based on multiple subsequent alignment steps, the prototype can compensate for high yaw and sway offsets. After presenting corresponding performance data, the paper then discusses potential improvements, the integration of additional automation, and the adaptability to other vessel types. Introduction The integration of uncrewed vessels can prove beneficial to maritime traffic and shipping networks (Peeters et al., 2020), while reducing vessel size and complexity helps to improve their feasibility (Gribkovskaia et al., 2019; Rødseth et al., 2023). Underactuated vessels can perform a variety of tasks using simple and robust propulsion, but can require measures to aid their maneuverability during docking (Naranjo, 2015; Rowe, 2007). Realizing uncrewed maritime operations includes finding solutions for docking vessels without human involvement. Reliable and forgiving automatic docking solutions can increase harbor safety and enable flexible missions at any time, saving energy and resources. Furthermore, they can also enable the automation and augmentation of harbor operation routines such as cargo transfer, charging, maintenance, tug assistance, monitoring, or real-time mapping. While current systems focus on large vessels or demand high levels of maneuverability, underactuated vessels require higher offset tolerances for safe docking. To help counter this issue, the aim of the presented project was to extend the applicability of automatic docking systems to underactuated vessels. The project was executed by developing and testing an automatic docking solution of low complexity and high offset tolerance. Method The method section shows the development process and testing strategies. Taking into account strengths and weaknesses of underactuated vessels regarding maneuverability and accuracy, the scope of the project was set on realizing an automatic solution for stern-to docking. By subsequent prototyping and integration of core functionalities, hardware for aligning and mooring of the vessel was developed, together with corresponding equipment on the vessel. The setup was then equipped with sensors to time and execute the docking process. Through intermediate on-water tests, the individual prototyping stages were put to the test. After testing the alignment and mooring concept with manual controls, the docking system was set to run automatically, utilizing the developed sensor and control system. Findings The project resulted in a functional full-size prototype including a robust sensor and control system, which is demonstrated with on-water proof-of-concept. An overhead view of the prototype can be seen in figure 1. The system can handle significant yaw and sway offsets, which is documented by image and tracking data recorded during the tests. Using the vessel's momentum and propulsion system, the vessel is aligned and arrested quickly, minimizing the period when it is subjected to drift. The system is able to sense the arrival and initiate the docking process automatically as soon as the vessel has reached a stable position. The mooring system proved to function reliably, while also contributing to the alignment process. Evaluating different settings on the prototype also resulted in performance and design data for future versions.

Discussion While only being an early-stage concept and prototype, the system proved to be a reliable docking solution, also in moderate wind and wave conditions. In addition to discussing the concept's application in different operational scenarios, this section considers potential for improving and extending the system. Possible additions involve improving suspension of the docked vessel, and measures to enhance wind and weather resistance. Another topic is the integration of additional technology such as replenishing and cargo transfer, enabling further automation of shipping operations. The section also covers the applicability to other vessel types and layouts, and the potentially automatic adaptation to varying incoming vessels. Conclusion Automatic docking solutions are a key step towards utilizing uncrewed vessels for a variety of tasks, ranging from automatic harbor operations to uncrewed transportation. Additional benefit can be gained from deploying vessels of limited size to increase the positive effect of automation, and underactuated propulsion concepts to reduce complexity. Due to their size and complexity, existing automatic docking solutions are not particularly viable for these vessel types, with high demands regarding maneuverability and accuracy limiting their applicability to underactuated vessels. Aiming to create a simple and reliable automatic docking solution for underactuated vessels, a corresponding docking concept was developed, prototyped, and tested with a catamaran USV. The prototype performed well, able to correct considerable vessel offsets, utilizing a robust sensor and control solution to initiate and terminate the docking process. While there is potential for improvement, the system and concept pose a solid foundation for further development. References Gribkovskaia, V.; Borgen, H.; Holte, E. A.; Lindstad, E.; Nordahl, H. Autonomous ships for coastal and short-sea shipping [Online] 2019. Naranjo, R. J. The art of seamanship. Evolving skills, exploring oceans, and handling wind, waves, and weather; International Marine/McGraw-Hill Education: Camden, Maine, 2015. Peeters, G.; Kotzé, M.; Afzal, M. R.; Catoor, T.; van Baelen, S.; Geenen, P.; Vanierschot, M.; Boonen, R.; Slaets, P. An unmanned inland cargo vessel: Design, build, and experiments. Ocean Engineering 2020, 201, 107056. DOI: 10.1016/j.oceaneng.2020.107056. Rødseth, Ø. J.; Nesheim, D. A.; Rialland, A.; Holte, E. A. The Societal Impacts of Autonomous Ships: The Norwegian Perspective. In Autonomous Vessels in Maritime Affairs; Johansson, T. M., Fernández, J. E., Dalaklis, D., Pastra, A., Skinner, J. A., Eds.; Studies in National Governance and Emerging Technologies; Springer International Publishing: Cham, 2023; pp 357–376. DOI: 10.1007/978-3-031-24740-8_18. Rowe, R. W. The shiphandler's guide for masters and navigating officers, pilots and tug masters, 2nd ed.; Nautical Institute: London, 2007.

Title: Exploring conventional ship interaction with autonomous ships from the conventional ships' officers' point of view: A proposed human factors methodology using full mission simulators.

Paper Id: 59

Authors: Pieter Maes, Hogere Zeevaartschool Antwerpen; Elspeth McMahon, Antwerp Maritime Academy; Rowan Van Schaeren , Antwerp Maritime Academy; Werner Jacobs , Antwerp Maritime Academy; Dirk Van Rooy, Universiteit Antwerpen; Edwin van Hassel, Universiteit Antwerpen; Stijn Verwulgen, University of Antwerp;

Abstract: The use of automation and artificial intelligence in maritime operations has been on the rise over the past decade, mainly as a result of the developments in autonomous and/or unmanned surface vessels. However, this evolution towards maritime autonomy will take time and is not free from its challenges. Moreover, questions have been raised regarding the safety of the interaction between conventional ships and Maritime Autonomous Surface Ships (MASS). This interaction of mixed-traffic environments is of particular concern when researching navigational safety in MASS operations, especially in collision-avoidance processes and their associated risk identification (Kim et al., 2022). Current research recognises the critical role MASS technology plays in the dynamics of the interaction within a mixed environment (Alsos et al., 2022; Porathe & Rødseth, 2019; Vagale et al., 2022). In contrast, limiting studies have examined the role of conventional manned ships and their interaction with MASS. Furthermore, how conventional ship operators' behaviour might be affected during navigation in mixed environments has not been considered by previous studies. Recognising that conventional ship operations in mixed environments can be complex, the main objective of this paper is to investigate these complexities and challenges associated with MASS interactions from the conventional ship's bridge's

perspective. As mixed traffic environments are far from being common in shipping, we recommend the use of Full Mission simulators in order to investigate this objective. This proposed methodology will allow researchers to explore potential changes in operating behaviour and collision avoidance approaches from the perspective of a conventional ship operating in a mixed environment. By doing so, this paper aims to contribute to a better understanding of the impact on the safety of navigation with the introduction of MASS at sea. An overview of related research and prior Full Mission simulator studies is provided first. Second, we dive into the theory of collision avoidance at sea and the associated role of operators' mental models. Next, we derive an overview of the risks associated with collision avoidance in mixed-traffic environments, including target ship prediction problems, communication issues, and the establishment of trust. Lastly, based on the described mixed-traffic risks, we formulate hypothesises to be tested using the conventional ship-based approach. This methodology uses collision scenarios developed and operated in a Full Mission simulator to analyse ship manoeuvres, evaluates the performance of the Officer of the Watch, and uses operators' pre and post-surveys and interviews. We aim to answer vital questions regarding navigational safety, communication, and training by facilitating the above-stated research. By doing so, we will demonstrate how our proposed methodology may help ensure a safer introduction of MASS. This paper is part of the first steps towards validating Full Mission simulators as essential infrastructure for future sea operations development and testing and will bring awareness to the importance of studying mixed traffic interactions. Alsos, O. A., Hodne, P., Skåden, O. K., & Porathe, T. (2022). Maritime Autonomous Surface Ships: Automation Transparency for Nearby Vessels. Journal of Physics: Conference Series, 2311(1). https://doi.org/10.1088/1742-6596/2311/1/012027 Kim, T. eun, Perera, L. P., Sollid, M. P., Batalden, B. M., & Sydnes, A. K. (2022). Safety challenges related to autonomous ships in mixed navigational environments. WMU Journal of Maritime Affairs, 21(2), 141–159. https://doi.org/10.1007/s13437-022-00277-z Porathe, T., & Rødseth, E. J. (2019). Simplifying interactions between autonomous and conventional ships with e-Navigation. Journal of Physics: Conference Series, 1357(1). https://doi.org/10.1088/1742-6596/1357/1/012041 Vagale, A., Osen, O. L., Brandsæter, A., Tannum, M., Hovden, C., & Bye, R. T. (2022). On the use of maritime training simulators with humans in the loop for understanding and evaluating algorithms for autonomous vessels. Journal of Physics: Conference Series, 2311(1). https://doi.org/10.1088/1742-6596/2311/1/012026

Title: Reduced energy consumption in successively automated ship maneuvers

Paper Id: 60

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Abstract: Innovative automation contributes to safer and cleaner shipping. The development of maritime autonomous surface ships (MASS) is one way to drive these innovations. Many of the applied methods can be used to operate conventional vessels more efficiently and cleanly. Currently, the global fleet consists of approximately 119 thousand merchant vessels with an average age of 20 to 30 years. Within the valid legal framework, the assistance and automation systems for these vessels must ensure that the nautical officers can fulfill their responsibilities and take back control of the ship at any time. Therefore, familiar nautical tools should be part of the assistance systems, which are successively extended by automatic functions. Autopilot in general and dynamic positioning (DP) control for specialized vessels are well-established automation systems, but there is still a leak of methods to automate the maneuvering of vessels. In recent years, however, automated industrial solutions have been introduced for maneuvering near structures or in narrow waterways, e.g., for docking and undocking or for collision avoidance in tight maneuvering margins. The focus is on autonomous navigation systems that enable remote control from land and thus unmanned operations. Additional sensor systems are installed onboard to provide situational awareness in real-time and detect obstacles in the planned path. This paper presents an approach that involves the expertise of nautical officers to develop automatic maneuvering. Typical manual maneuvers are analyzed to derive an effective maneuver plan and the characteristic conditions within the different

phases of a specific maneuver. The motion behavior of a specific vessel is characterized by its dimensions, the actuators and maneuverability represented in an aerodynamic and hydrodynamic motion model. Conditions in the various phases include velocity and heading angle ranges and geographic boundaries within the selected sea area. So far, the maneuver plan is designed manually by nautical personnel, taking into account a geographic path and the predicted weather conditions. A maneuver plan consists of a minimum number of points at which one or more actuator commands are changed. In the result, transient machine states are avoided which is a basic prerequisite for saving fuel and reducing emissions. Subsequently, the controller structure and its parametrization is developed based on the nautical valid maneuver plan, phase conditions and safety requirements. For this, the general architecture for guidance, navigation and control (GNC) within the automation module is assumed. Controls and corresponding allocations work with virtual forces derived from a simplified, control-oriented dynamic motion model. For moderate speeds, an in-port transit mode is selected with cascaded trajectory, velocity and heading control. DP control is realized for very low speeds and thus higher influence of the environmental forces on the vessel. An automatic supervisor needs appropriate criteria to switch between the different controls depending on the maneuver phase. The method is applied to a berthing maneuver with the 50 m long research vessel DENEB which has been in operation since 1994. During automatic maneuvering, maneuver plan and motion prediction are displayed in the electronic nautical chart of the maneuver assistance system (MAS) installed above the bridge. Thus, nautical officers can supervise the automatic control and compare the target track with the current track. If necessary, they can resume manual control by moving one of the actuator levers. The energy consumption is estimated from measurements of active power. The control performance is quantified with the cross-track error between the planned and the actual realized path. The results of maneuver plan, manual and automatic controlled maneuvers are compared.

Title: Advancing Maritime Infrastructure Monitoring with Heterogeneous Group of Unmanned Surface Vehicles

Paper Id: 61

Authors: Nico Zantopp, Fraunhofer-Gesellschaft zur Forderung der angewandten Forschung eV; Florian Segor, Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB; Cosmin Delea, Fraunhofer CML; Aleksej Buller, Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB; Wilmuth Müller, Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB; Johannes Oeffner, Fraunhofer-Gesellschaft zur Forderung der angewandten Forschung eV;

Abstract: The growing demand for sustainable and green shipping has prompted the development of innovative solutions to enhance efficiency and protect critical maritime infrastructure. This paper presents an advanced approach to long-term, resource-efficient, and area-wide protection of critical maritime infrastructure using a Heterogeneous Group of Unmanned Surface Vehicles. The system comprises several Maritime Autonomous Surface Ships that collaborate to perform tasks such as inspecting critical infrastructure or performing ship inspections to monitor security-sensitive ports. This research explores the implementation of artificial intelligence (AI) at different levels within the collaborative system. At the higher level, a Planning AI module is responsible for situational planning, resource deployment, autonomous situation analysis, and flexible planning of tasks such as patrol and inspection. At the lower level, a Reactive AI module intelligently onboard controls the heterogeneous collaborative group on a multi-agent basis. The developed system employs autonomous navigation algorithms to guide the heterogeneous team in performing surveillance tasks. Object processing algorithms are utilized to detect, classify, and issue warnings for potentially hazardous vehicles. In cases where not all vehicles are equipped with sensors for 3D environment perception, the system shares LiDAR-based collision avoidance data among the team members, enhancing their collective intelligence. This paper elaborates on the various levels of AI incorporated into the system for Critical Infrastructure Monitoring and demonstrates the results of experiments conducted with a heterogeneous swarm operating in a harbour in Kiel. The paper starts with an overview of the challenges associated with Maritime Infrastructure Monitoring, followed by a review of existing solutions and AI applications in this field. Subsequently, the system architecture is presented, and the Kiel harbor test case is described and examined. The paper

concludes with a discussion of the test results. The findings contribute to the ongoing discussions on autonomy for sustainable and green shipping, safety evaluation, regulatory and legal frameworks, and collaborative systems. The concept has the potential to significantly improve maritime security while reducing the environmental impact and resource consumption of traditional shipping methods.

Title: What are your intentions? Trackpilots providing new opportunities to make inland navigation more efficient and safe

Paper Id: 62

Authors: Colin Guiking, Automation within the shipping industry has a long history in aiding on board navigation. So are trackpilots nowadays providing inland shipping the technology to automatically sail on a predefined track without the need for manual steering or speed control. Because a trackpilot ‘knows’ the predefined track, this can be shared with the surroundings to inform others – this can be defined as sharing navigational intentions. Sharing the navigational intentions with surrounding vessels is currently mostly done on request and proceeded via VHF communication. The request likely follows from the skippers estimation whether traffic may interfere with the own planned route. That estimation is not always correct, nor is the VHF communication about each other's sailing plan. These are common factors in navigational incidents and accidents: having misconceptions or wrong assumptions on the intentions of others. The underlying causes are related to how skippers build up their situational awareness and can be linked to the decision-making process for communicating with surround traffic. Information processing Understanding the whereabouts of other vessels in the surrounding and predicting their future track, is largely based on the skippers past experiences, formal knowledge such as existing traffic rules and limited information about the other vessel itself. The information that is normally available just contain: - The sailed route so far and the current course and speed that it sails right now; - Specifics on the vessel; - Traffic rules and the normal behavior of ships in the specific area; - If available: the destination of the other ship. When using pas experiences in estimating navigational intentions of surrounding traffics, humans tend to use heuristics in familiar situations and seek (too much) for information that confirms a certain assumption instead of exploring alternative possibilities – this is known as the confirmation bias. In some cases this could lead to a wrong assumption and being inactive, which could result in a dangerous navigational situation. These causes of wrong estimations and miscommunication may be tackled with having a better and more accurate understanding of others vessels navigational intentions. Displaying the navigational intentions, or future track, in an electronic navigational chart may help to provide a more accurate (mental) picture of future tracks of vessels and improve the assessment whether intervention is needed such as steering or changing speed. It is highly relevant whether such form of new information and the way it is presented would help overcome known causes of wrong assumptions and miscommunication, in the aim of increasing safety and efficiency of traffic on sea and inland waters. Digitally sharing intentions Over the last years, considerable research on sharing intentions has been carried out in European research projects which focuses coastal and high seas areas. These studies – which included several simulations and real-time tests – indicated that the concept of intent sharing is promising. It provides support that the extra information helps in avoiding close quarter situations and that it is more useful in open seas than in close approaches. An important limitation in the tested concept was that all the captains had to manually enter all waypoints to form the intended sailing route. This is a time-consuming procedure and also prone to human error which makes it less suitable for making changes in close quarters situations. With a trackpilot, nowadays used in inland shipping in Western Europe, no manual input of waypoints is required. This makes it an effective instrument to use for (digitally) sharing navigational intentions. There are three main suppliers of trackpilots in Western-Europe that we are currently aware of: 1. Argonics based in Germany 2. Shipping Technology in The Netherlands 3. Tresco based in Belgium Based on the experiences and recommendations in studies on short sea shipping Rijkswaterstaat decided to ask MARIN to carry out a simulator experiment. The objective of the experiment was to investigate whether efficiency and safety benefit from intention sharing with the focus on inland shipping. The three suppliers of trackpilots were consulted to participate in a simulator study at MARIN to research the potential benefits of Intention sharing on inland waters. All suppliers were enthusiastic and a simulation study was set up with trackpilot systems installed on MARIN simulators. The trackpilot manufacturers had to adapt their product to be able to participate. First, they had to be able to address future positions of the vessel with a

time mark related to these positions, indicating where the vessel will be in time. This data was communicated in a specially and rather quickly designed format making use of a wired data network, to perform the experiment. Secondly, the trackpilot interfaces had to be adapted to show the intention data of the ships in the environment. The experiment took place in September 2022. Two groups of three skippers each participated in the experiment, using scenario's with and without sharing the intentions. By observing the sailing behavior of the skippers, asking them questions and letting them fill in a questionnaire, as well as using an eye-tracking system, data was gathered. MARIN observed that the skippers needed help with the systems in the beginning, but quickly learned to use it in their benefit resulting in more anticipating sailing behavior and less VHF communication. MARIN[1]concluded that Intention sharing could improve safety and efficiency on inland waters, by supporting situational awareness. Intent sharing can be viewed as a new set of eyes, which is most useful in low visibility conditions. However, there are risks as well. Due to the task transfer of sailing from skipper to a (track control) system, there is a risk of lowered situational awareness and out-of-the-loop problems, overreliance on the system, and risk-compensation behavior because skippers are aware that their intended route can be seen by the surrounding traffic. Two types of recommendations were made: 1. There are risks attached to the use of trackpilots, even when no intentions are shared. It is advised to mitigate these risks by improved design and clear operational procedures on how to use the trackpilot. These risks can be identified and assessed when building a safety-case. Drawing guidelines for human-machine control and the interface can help the suppliers of trackpilots making their systems (and the use of it) more safe. 2. When implementing Intention sharing, defining an operational concept and a proper user-interface can help trackpilot suppliers to implement the concept as safe as possible and to reap the full potential of trackpilots. This should be part of the implementation plan. Further work on how to safely implement Intention sharing and reap the potential of using trackpilots is expected to start in spring 2023. We are reaching out to additional partners who share the potential of Intention sharing and would like to use it. [1]Digital Intention sharing, Simulation study on the benefits of intention sharing, MARIN commissioned by Rijkswaterstaat, report number 33281-1-MO-rev.2, December 2022, https://open.rws.nl/overige-publicaties/2022/digital-intention-sharing-simulation/;

Abstract: Patrick Potgraven

Title: A Web-based Shore Service for Operating Collaborative Unmanned Vehicles in Port Infrastructure Inspection Missions

Paper Id: 63

Authors: CHing Nok Au, Fraunhofer-Gesellschaft zur Forderung der angewandten Forschung eV; Cosmin Delea, Fraunhofer CML; Johannes Oeffner, Fraunhofer-Gesellschaft zur Forderung der angewandten Forschung eV;

Abstract: For regular inspection and maintenance on critical infrastructure, lightweight unmanned vehicles not only substitute humans in high-risk environments, their advanced onboard hardware also provide excellent level of inspection details, data bandwidth, and operational range. As the crew size on either port area or ships are decreasing, such tools are necessary to ensure high quality inspection with a constrained workforce. Using autopilot and waypoint following algorithms, an autonomous drone swarm acts as performance multipliers and significantly cut down the operation time. However, this poses collision risks and increases difficulty in mission management. In our work, a Web based service is built to realize a basic U-space, or UTM (Unmanned Traffic Management) system, to explore operating with a swarm of unmanned vehicles for simple inspection use-case. The service provides a planner for swarm missions and a clear overview of the operational theatre in real time. A digital twin model based on ROS and Gazebo is used to demonstrate situational awareness in several collaborative inspection scenarios. Human-in-the-loop is realized by prompts for human interaction in interruption events during the mission. Several scenarios are simulated to demonstrate the situation awareness and conflict detection of the service layer, such as a normal mission without interruption, mission abortion, vehicle malfunction, air traffic intrusion, and sea traffic intrusion. Background Python scripts are used to validate the planned trajectory for collision, and traffic intrusion during real time. Events, warnings, and interrupts are sent to

clients and displayed on the user interface. The mission flow involves basically five roles of users: the client who creates the mission, the planner who allocate resources, the supervisor who oversees the operation, the controller who monitors the operational theatre, and the operator who pilots the drones. These roles can be operated both manually and autonomously. By performing a crack detection use case in a simulated environment, the service demonstrates the situational awareness of the service, minimal human intervention required, and a potential to reduce the time drastically. References U-space blueprint (EU body or agency und SESAR Joint Undertaking, (2017)(SESAR | eATM Portal | Deployment View - U-Space Implementation Map Tool 2022). Au, C. N., Delea, C., Schneider, V. E., Oeffner, J., & Jahn, C. (2021). A Web-oriented Architecture for Deploying Multiple Unmanned Vehicles as a Service. TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation, 15(1).

Title: Ship-to-Ship interaction of multi-autonomous-surface ships moving at different speeds and distance

Paper Id: 64

Authors: Xin Xiong, Technische Universiteit Delft; Yusong Pang, ; Rudy Negenborn, Technische Universiteit Delft;

Abstract: At present, in the field of cooperative control of Maritime Autonomous Surface Ships(MASS), most scholars focused on the cooperative control strategy and the motion control of single ship. However, the majority of the studies have ignored the ship-to-ship interaction where hydrodynamic effects significantly impact ship motions. In the cooperation scenarios, MASS are close to each other especially refer to the cooperative collision avoidance and formation. Ignoring ship-to-ship interaction may lead to control failures. Thus, this paper presents a numerical model of ship-to-ship interaction which can obtain the interaction forces and moments between the ships in real time. The numerical model is built by using Nonlinear-Unsteady-Potential-Flow-Solver(NUPFS) combined with non-linear free surface. NUPFS has more accurate numerical results and faster evaluation of the total drag of ship hulls operating in both wet and dry transom stern conditions. The numerical model can be used to cooperative controller which can make the controller more accurate and stable to improve the cooperative efficiency.

Title: Small autonomous boat with self generative propulsion system as multitask platform

Paper Id: 65

Authors: Javier Busquets-Mataix, Universitat Politecnica de Valencia;

Abstract: Marine autonomous surface vehicles are a growing and promising technology today. Marine autonomous navigation is one of the challenges that should be faced in the near future in all areas where marine human-commanded operations are carried out nowadays. As an example, a small autonomous boat able for carrying up to 6 pax is presented. The Autonomous Surface Vehicle (ASV) has been designed with the aim of serving as a test platform for validating new designs and innovative systems for application in autonomous navigation. This paper aims to show the design and implementation of this multiplatform small autonomous boat, including its locally distributed control system and its multiple power source based on sustainable energy sources. The boat is a 7.5 m fishing boat transformed into a workbench designed to test all the systems and technologies developed. The boat is able to carry up to 6 crewmembers in autonomous mode. The functional systems and remote surveyed parameter control is made through 5G near real-time communication system. Other original innovative solutions are applied to make this boat easy to manoeuver both by humans in the loop HIL and by remote control mode. Finally, another innovative system is described based on renewable energy for extended range operation purposes. Several solutions are applied to the boat to ensure safe navigations both in port protected areas and in open sea. The theoretical base for these innovations and the solutions implemented are presented together with the real trial data obtained in several scenarios where the real prototype has been tested.

Title: Trickle-down strategies: integrating simulations with control loops of autonomous vessels on lab scale.

Paper Id: 66

Authors: Fedor Baart, Deltares; Max Willem van Gijn, Deltares; Bart Boogmans, Delft University of Technology; Marije Wassenaar, Erasmus University Rotterdam; Chris Karman, Digishape; Migena Zagonjolli, Deltares; Jelle Burger, Delft University of Technology; Cem Akilli, Gemeente Rotterdam; Rob Zuidwijk, Rotterdam School of Management; Rudy Negenborn, Technische Universiteit Delft; Mark van Koningsveld, Technische Universiteit Delft;

Abstract: As we work towards reducing climate change and cleaner air, using existing and future energy sources efficiently becomes essential. Fossil fuel sources need to be used more efficiently to reduce emissions. New energy sources, such as batteries, can help reduce emissions but also reduce the range of vessels. It will thus become more important to facilitate ships in their route or engine setting choices. Choosing whether to sail based on minimal emissions, maximum fuel use, or earliest arrival time is a strategic decision. Based on these goals, a ship can change its course or engine order. Depending on route choice and optimal engine settings, a ship can try and follow these, considering currents, other traffic, infrastructure, and tidal windows. If the strategy (reduce emissions) results in operational actions (reducing engine power when possible, steering in a direction that results in less fuel use), the strategy has trickled down into the operation. To be able to decide the optimal engine settings and direction a ship needs more situational information. In this research we pick a common example where a ship has to sail into the port, but as the ship approaches, this berth can be occupied by another ship. A ship then has three options, sail to the berth and wait, sail to another berth first, or reduce speed to arrive with less waiting time. We implemented this use case using autonomous vessels that are enhanced using a digital twin, a virtual copy of the ships involved and a virtual operator that helps to inform the ship approaching the port. In this paper, we (Resilient Delta and Deltares) show the successful integration of strategic decision-making with operational control systems in autonomous shipping, using a digital twin approach in the Research lab Autonomous Shipping (RAS). To demonstrate this integration, we developed new components that were tested in three experiments: - The green routing capability experiment showed the bridge between the control system of the autonomous vessel, operated via Robot Operating System (ROS), to the simulation environment of OpenCLSim. We developed a real-time variant of OpenCLSim and a communication component that could expose the state of the OpenCLSim simulation with the ROS system. This experiment showed that the path provided by the simulation was followed by an autonomous vessel. - The green steaming capability experiment showed that the ship could also adapt its speed based on information from the simulations. We developed an additional communication component capable of providing the vessel with a reference velocity. Together with the green routing capability, this forms the basis for more complex experiments. - The port layout experiment showed a potential use case of the green routing and green steaming capabilities. We created a waypoint layout similar to the port. While a ship is sailing, every five seconds, twelve simulations are computed. The scenarios vary in engine order, route choices, resulting in varying emissions, fuel, and cost. We evaluated the impact of different tactics such as green routing, green steaming, and full-speed sailing on operational behavior like steering and engine order. Our approach, using a real-time version of a Vessel in the OpenCLSim simulation software, enabled predictive simulations to facilitate the chosen tactic based on a given strategy. The integration of simulations to evaluate the optionswith the control systems can develop into a valuable tool for optimizing vessel performance and reducing environmental impact in autonomous shipping operations.

Title: Barriers to commercialization of Autonomous Maritime Surface Ships

Paper Id: 67

Authors: Ziaul Haque Munim, Universitetet i Sorost-Norge; Nils Andreas Pettersen-Hagh, University of South-Eastern Norway ; Olivier FAURY, EM Normandie, Metis Lab.; Veronica Jaramillo Jimenez, University of South-Eastern Norway ; Marius Imset, University of South-Eastern Norway ;

Abstract: This study explores the barriers to commercialization of Autonomous Maritime Surface Ships (MASS). Based on a literature review of published studies, 17 potential barriers were identified, which were grouped into four categories: legislative, technical, economic, and societal barriers. Data were

collected using a structured questionnaire survey from relevant experts in academia and industry. Results indicate that societal barriers are considered as least influencing barriers, whereas legislative ones are the most influencing. The findings are relevant for policymakers in accelerating MASS adoption in commercial shipping.

Title: W-Band Radar: The Future of Marine Autonomy

Paper Id: 71

Authors: Rachael O'Connor, Halma Plc;

Abstract: The paper will introduce Navtech Radar's millimetre wave FMCW 76-77GHz radar technology which provides high resolution detection capability for small targets, giving marine professionals unparalleled situational awareness in all weather and lighting conditions. The marine industry has relied upon radar for years due to its robustness in reduced visibility. However, the modal shift towards autonomy now requires an additional level of sensing capability which high resolution W-band radar can provide. Complementing traditional marine radar, Navtech Radars operate at a higher frequency of 76-77GHz which enables detection of objects as small as buoys, kayaks, and swimmers. This unlocks the ability for vessels to safely navigate congested waterways autonomously. A sensor comparison will be discussed, presenting the extended range, reliability, and high-resolution imaging that FMCW radar technology can offer when compared to both lidar and cameras. This technology is an already proven automation solution being used successfully in the mining industry, delivering in extreme and challenging conditions. Uninterrupted operation can be achieved as these robust sensors have been designed to require minimal maintenance, with a 10-year lifetime and a 5 year service interval. More recently, vessels ranging from passenger ferries, cargo ships and dynamic positioning vessels are evaluating this technology to unlock automation. The presentation will include the latest examples of data from real-world trials onboard vessels which rely upon the fusion of Navtech Radars and cameras for situational awareness and therefore safe automation.

Title: Robust Path Following on Rivers Using Bootstrapped Reinforcement Learning

Paper Id: 73

Authors: Niklas Paulig, Technische Universitat Dresden; Ostap Okhrin, Technische Universitat Dresden;

Abstract: 1 Introduction The Directorate-General for Mobility and Transport (2023) of the European Commission emphasizes the importance of inland waterway traffic and its development due to decreased costs and increased safety in comparison to other modes of transport. To build on this directive, the present study tries solving the path-following problem for underactuated vessels on restricted waterways using deep reinforcement learning (DRL) and under consideration of environmental influences. Breivik and Fossen (2004) stated, that, compared to other automated systems, ships on inland waterways face additional challenges due to their environment (e.g., strong directional currents, shallow banks) and underlying physics (e.g., underactuation, highly non-linear maneuvering models), leading to a highly dynamic and stochastic operational environment. To overcome these hurdles, we incorporate water depth, current direction, and speed into the agent's perception, allowing it to navigate tight river turns safely. 2 Path following for autonomous surface vessels The objective of path-following for ships demands a controller to generate steering commands that enable an underactuated autonomous surface vessel (ASV) to follow a pre-defined path with minimal angular and spatial deviation. The problem formulation for this study will only include rudder angles as control outputs while keeping the engine revolutions constant. To guide the ASV towards, and along the path, this study adapts the Vector Field Guidance approach of Nelson et al. (2007), which uses a global vector field encompassing the path to guide the vessel towards it, independent of the magnitude of deviation. Besides classical analytic control systems like proportional-integral-derivative (PID) controllers or model predictive control, deep reinforcement learning as part of the machine-learning family of algorithms is becoming increasingly popular. Reinforcement learning (RL) is a type of machine learning where an agent learns to make decisions by interacting with an environment. The goal of the agent is to maximize acumulative reward signal received from the environment. In RL, the

agent takes actions based on the current state of the environment and receives feedback in the form of a reward signal indicating how well it is doing in achieving its goal. The agent then uses this feedback to update its decision-making policy, to improve its overall performance over time. One of the key challenges in reinforcement learning is balancing exploration and exploitation, as the agent needs to explore the environment to discover new and poten- tially better strategies, while also exploiting what it has already learned to maximize reward. Therefore, this study uses a bootstrapped Deep Q-Network (DQN) algorithm proposed by Waltz and Okhrin (2022) . 3 Controller design for inland ASVs To be able to sense the environment, and react to it, the agent is provided with several observations from it for every time step (state). It senses its position, heading, rudder angle, velocities, current direction and current speed for the last and the current time step. Given an observation, the agent can respond to it with a single action, which will be a change in rudder angle. There are three possible discrete actions at every time step t: at ∈ {δt−1 − 2◦ , δt−1 , δt−1 + 2◦ }, where δt is the rudder angle at time step t. The admissible rudder range in this study is [−20◦ , 20◦]. The agent's goal is to maximize the reward it receives from the environment. The reward function consists of three components: a reward for the distance to the path, a reward for the heading error as given by the Vector Field Guidance, as well as a penalty for running aground. 4 Environment and training Since restricted waterways in general, and rivers in particular feature a wide variety of widths, lengths, riverbed profiles, water depth distributions and current velocities, a robust agent needs to be trained in an equally diverse training environment. Hence, we developed a versatile segment-based river generator to construct arbitrary-looking rivers, featuring both cus- tomizable directional current fields and randomized location-dependent water depths. For training, the agent-vessel is placed at the out- set of the first segment of the constructed river with a heading equal to the current path heading plus some noise, an initial speed U_0 = 2.0ms−1 , and a fixed propeller rotation rate of 4.0s−1 . During training, random batches of 128 transitions are sampled from a replay buffer of size 106 , gradient updates are performed by the Adam optimizer (Kingma and Ba (2015)) with a learning rate of 5 × 10−4 . Training has been conducted for 3×10^6 steps. 5 Results The policy found from training was simulated on several sections of the lower and middle Rhine as well as on artificial scenarios checking for reactivity under harsh environmental changes. All experiments are en- rolled for the KEBDQN, a reference PID after Paramesh and Rajendran (2021) and a standard DQN approach for comparison. One scenario validates the performance on a near 180◦ degree turn on the lower Rhine close to Düsseldorf harbor (51.22◦ N, 6.73◦ E), as it features one of the tightest turns in the lower Rhine. By analyzing the rudder commands, we observe relative similarity in magnitude and direction, indicating that the DRL agents were able to learn a similar behavior as exerted by the PID controller, however, the DRL controller re- acts quicker, thus being able to achieve a maximum cross-track deviation of 4.36m compared to 26.30m from the PID controller. These results are also reflected in most of the other experiments. To validate the robustness of our approach, we let the agent drive up and down the entire lower- and middle rhine using velocities not seen during training and compared the results to the PID controller. The results, as shown in Figure 1 indicate that the DRL agent is able to robustly adapt to unseen situations, while the PID controller's performance deteriorates significantly, depending on the scenario. Bibliography Breivik, Morten and Thor I Fossen (2004). "Path following of straight lines and circles for marine surface vessels". In: IFAC Proceedings Volumes 37.10, pp. 65–70. Directorate-General for Mobility and Transport (2023). Inland waterways. url: https : / / transport . ec . europa . eu / transport - modes / inland -waterways_en. Kingma, Diederik P. and Jimmy Ba (2015). "Adam: A Method for Stochastic Optimization". In: 3rd Interna- tional Conference on Learning Representations, ICLR 2015, San Diego, CA, USA, May 7-9, 2015, Conference Track Proceedings. Ed. by Yoshua Bengio and YannLeCun. url: http://arxiv.org /abs/1412.6980. Nelson, Derek R et al. (2007). "Vector field path following for miniature air vehicles". In: IEEE Transactions on Robotics 23.3, pp. 519–529. Paramesh, S and Suresh Rajendran (2021). "A unified seakeeping and manoeuvring model with a PID controller for path following of a KVLCC2 tanker in regular waves". In: Applied Ocean Research 116, p. 102860. Waltz, Martin and Ostap Okhrin (2022). "Two-Sample Testing in Reinforcement Learning". In: arXiv preprint arXiv:2201.08078.

Title: The Green and Autonomous Corridor Project; a Collaborative Effort to Realize an Autonomous Shortsea Corridor between Norway and the Netherlands

Paper Id: 74

Authors: Ilse Rodewijk, Netherlands Maritime Technology;

Abstract: In our project, we collaborate with a range of partners representing different stakeholders to create an autonomous corridor between the Netherlands and Norway. Our main goal is to set a clear research agenda and establish the layout of a field lab. We're delving into the business case for autonomous shipping, with a focus on safety, technology, and legal aspects. Knowledge institutes from both countries, along with commercial partners, work closely to ensure a comprehensive approach. Rather than starting from scratch, we leverage existing knowledge and expertise. During this presentation, we'll share our methodology and initial findings and highlighting the project's significance for Netherlands Maritime Technology (NMT). Join us to find out how we put theory into practice and what the outcome of this project can mean for you.