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# Automatic Control and Routing of Marine Vessels

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## 1. Introduction

Due to the intensive development of the global economy, many problems are constantly emerging connected with the safety of ships' motion in the context of increasing marine traffic. These problems seem to be especially significant for the further development of marine transportation services, with the need to considerably increase their efficiency and reliability. One of the commonly used approaches to ensuring safety and efficiency is the wide implementation of various automated systems for guidance and control, including popular systems such as marine autopilots, dynamic positioning systems, speed control systems, automatic routing installations, etc.

This Special Issue is focused on various problems related to the analysis, design, modelling, and operation of the aforementioned systems. The Issue collected ten papers that cover such areas as identification using neural networks, optimal weather routing, sliding mode control, tracking control, logistics and cooperation between seaports and carriers, control of multi-joint autonomous underwater vehicles, path-following control, and collision avoidance systems.

A brief description of each paper is given in the following section.

## 2. Papers Details

Xu et al. [1] proposed using a physics-informed neural network (PINN) to identify the dynamic models of the unmanned surface vehicle (USV). PINN has an advantage of combining the data-driven machine learning and physical models. It is shown how PINN can be adopted to embed the dynamic models of an USV into the loss function. The special tests were carried out in the Qing Huai river to obtain the empirical data. The PINN method was implemented and compared with a tradition neural network. The results of the investigation indicate that the PINN has a better performance in predicting the USV dynamics under a small number of training samples.

González-Prieto et al. [2] investigated the course keeping control problem for a USV in the presence of unknown disturbances and system uncertainties. The authors developed the adaptive integral non-linear controller based on the sliding mode surface with adaptive gains. The mathematical background for the proposed control design approach is provided. Various numerical simulations have been carried out with fixed and time-varying references and different external disturbances. The obtained results show that the developed controller allow to achieve the desired performance of the closed-loop system in course keeping problem.

Lezhnina et al. [3] analyzed the effectiveness of cooperation between ports and carriers in the logistics chain in order to increase profits and reduce costs. Special emphasis is placed on the role of peripheral ports, which give ports an opportunity to increase the level of loading and unloading services, and allows sea routes to receive a stable income from the port's operation. The presented study uses a game-theoretic approach and describes a multi-port game scenario. A mathematical model is built and the algorithm for optimal route search is proposed. Numerical experiments are shown that indicate the effectiveness



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of cooperation in reducing the effects of disruptions as well as reducing overall logistics costs.

Zhao et al. [4] presented a multicriteria ship route planning method based on improved particle swarm optimization–genetic algorithm. This algorithm aims to optimize the meteorological risk, fuel consumption, and navigation time of a ship. The output of the algorithm allows to obtain the minimum-navigation-time route, the minimum-fuel-consumption route, the minimum-navigation-risk route, and the recommended route. The simulation experiments for a container ship are provided. These experiments show the feasibility and effectiveness of the proposed approach.

Yu et al. [5] discussed the problem of modeling and control of multi-joint autonomous underwater vehicles (MJ-AUV). The considered MJ-AUV is a multi-input and multi-output system, where the variation of two joint angles is the input and the pitch and yaw angles of the body is the output. The 3D motion model of the MJ-AUV was established using Newton's second law and the principle of moment balance. In order to design feedback control, the system was decoupled into pitch and yaw subsystems. The linear state observer and LQR design approach was used to obtain optimal control law for each subsystem. The numerical simulation was carried out to verify the obtained mathematical model and to test the effectiveness of the control algorithm.

Volkova et al. [6] analyzed the possibility of using neural networks to predict the coordinates of the vessel during river navigation. This problem is of practical importance, in particular, for autonomously moving vessels. The proposed predicting system can serve as a source of additional information for timely decision-making in case of AIS signal distortion. The real experiment was conducted to collect data, which was used to train neural networks with different activation functions and different structures. A number of simulation experiments were carried out and discussed to assess the reliability of the obtained results for various trajectories of the vessel.

Zhang et al. [7] proposed a new path-following control law. The main innovation is a developed hyperbolic guidance law, which is used to control a marine ship on a straight-line path. The authors have shown that this approach allow to improve the performance characteristics of the closed-loop system in comparison with existing control algorithms. Also, a problem of curved path-following is considered, where the curve is formed as a transition between two adjacent straight-line paths. The modification of the reverse stepping method is proposed to make the system globally asymptotically stable. The simulation experiments are carried out for three different types of ships and the control effect is evaluated and discussed.

Songtao et al. [8] studied the use of fin stabilizers to reduce the rolling and heeling during ship turning. The authors have established the nonlinear mathematical model of a vessel, taking into account forces and moments produced by fin stabilizers, rudders, propellers, and waves. The resulting nonlinear control model has uncertainty due to inaccuracy of parameters and external disturbances. For this reason, the L2-gain based adaptive robust method is proposed to control the fin stabilizers. The controller design process and the proof of the closed-loop system stability are presented in details. The simulation experiments are carried out, where the comparison with the well-tuned PID controller is given and discussed.

Veremey [9] investigated the design of stabilizing feedback control laws for marine vessels moving along initially given trajectories. Unlike the traditional methods, it is proposed to use an optimization approach and implement the optimal damping (OD) concept, previously developed by V.I. Zubov. Essential attention is paid to the practical adaptation of the optimal damping methods for marine control systems. A new method for tracking controllers' design, which ensures the desirable reference motion of the vessel along the forward speed and heading angle is proposed. A new methodology for selecting the functional to be damped is discussed. The choice of this functional influences the properties of the closed-loop system, such as asymptotic stability and the quality of control processes. The important feature is that the developed OD based approach can be implemented in real-time regime of a ship's motion. The practical applicability and effectiveness of the approach is illustrated by a numerical example of tracking control design.

Guan et al. [10] discussed issues related to the problem of preventing collisions of ships. The main purpose of the research is to develop a decision-making system to assist sailors and reduce the number of maritime accidents. The paper proposes a ship domain model, which is based on the fuzzy logics and can combine many factors affecting ship collision risk. These factors are determined by ship own parameters and external environmental factors. The composition fuzzy inference is used to determine the range of the ship domain and, as a consequence, to calculate the collision risk. The simulation experiments were conducted to demonstrate the feasibility and effectiveness of the proposed method.

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**Data Availability Statement:** All relevant data and links to that can be found in the presented papers at https://www.mdpi.com/journal/jmse/special_issues/Evgeny_automatic_control_routing_marine_vessels (accessed on 24 April 2022).

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## References

1. Xu, P.-F.; Han, C.-B.; Cheng, H.-X.; Cheng, C.; Ge, T. A Physics-Informed Neural Network for the Prediction of Unmanned Surface Vehicle Dynamics. *J. Mar. Sci. Eng.* **2022**, *10*, 148. [CrossRef]
2. González-Prieto, J.A.; Pérez-Collazo, C.; Singh, Y. Adaptive Integral Sliding Mode Based Course Keeping Control of Unmanned Surface Vehicle. *J. Mar. Sci. Eng.* **2022**, *10*, 68. [CrossRef]
3. Lezhnina, E.A.; Balykina, Y.E. Cooperation between Sea Ports and Carriers in the Logistics Chain. *J. Mar. Sci. Eng.* **2021**, *9*, 774. [CrossRef]
4. Zhao, W.; Wang, Y.; Zhang, Z.; Wang, H. Multicriteria Ship Route Planning Method Based on Improved Particle Swarm Optimization–Genetic Algorithm. *J. Mar. Sci. Eng.* **2021**, *9*, 357. [CrossRef]
5. Yu, L.; Meng, Q.; Zhang, H. 3-Dimensional Modeling and Attitude Control of Multi-Joint Autonomous Underwater Vehicles. *J. Mar. Sci. Eng.* **2021**, *9*, 307. [CrossRef]
6. Volkova, T.A.; Balykina, Y.E.; Bespalov, A. Predicting Ship Trajectory Based on Neural Networks Using AIS Data. *J. Mar. Sci. Eng.* **2021**, *9*, 254. [CrossRef]
7. Zhang, Z.; Zhao, Y.; Zhao, G.; Wang, H.; Zhao, Y. Path-Following Control Method for Surface Ships Based on a New Guidance Algorithm. *J. Mar. Sci. Eng.* **2021**, *9*, 166. [CrossRef]
8. Songtao, Z.; Peng, Z. L2-Gain Based Adaptive Robust Heel/Roll Reduction Control Using Fin Stabilizer during Ship Turns. *J. Mar. Sci. Eng.* **2021**, *9*, 89. [CrossRef]
9. Veremey, E.I. Optimal Damping Concept Implementation for Marine Vessels' Tracking Control. *J. Mar. Sci. Eng.* **2021**, *9*, 45. [CrossRef]
10. Guan, Z.; Wang, Y.; Zhou, Z.; Wang, H. Research on Early Warning of Ship Danger Based on Composition Fuzzy Inference. *J. Mar. Sci. Eng.* **2020**, *8*, 1002. [CrossRef]