Navigation modes classification using a machine learning method

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Introduction

Icebreaker (IB) assistance operation is vital for the efficiency and sustainability of winter navigation (Valdez Banda et al., 2016). IB helps merchant vessels to break the ice, avoiding getting stuck in ice or causing hull damage (Zhang et al., 2019). However, IB resources are limited. The decision on the need of IB assistance influences the entire traffic flow. Currently, IB's captain decides whether a vessel needs IB assistance. The decision clues rely on navigation regulations and captains' experience (e.g., the attainable ship speed in prevalent ice conditions) (BIM, 2020). The problem is that human-made decisions are ad hoc and subjective regarding decision criteria (Liu et al., 2022). It is difficult to automate the decision-making based on the varied criteria. There is a potential to develop a data-driven model to automatically predict the need of IB assistance by learning knowledge from human-made cases.

Materials and methods

Multiple data sources and a machine learning model are adopted to develop a data-driven method for different navigation modes classification (e.g., IB assistance or independent navigation). Specifically, a logistic regression model is developed to model the IB assistance need as a function of various features. To capture the realistic operational conditions, there are 15 variables learned by the model, including the concentration of level ice, ridge ice, and rafted ice, the thickness of level ice, ridge ice, and rafted ice, air temperature, wind speed, snow thickness, ship length and width, ship deadweight, ship engine power, and ship ice class. Each data point consists of all the above variables, presenting either IB assistance or independent navigation. Finally, 80% of data points are used to train the logistic regression model, and the remaining are reserved for the model prediction performance validation.

Results

The logistic regression model successfully classified navigation modes. The classification accuracy, precision, recall, and the area under the receiver operating characteristic curve (AUC) are used to evaluate the model's performance. The model performs classification with 80.0% accuracy, 80.6% precision, 79.7% recall, and 87.5% AUC. Furthermore, the effectiveness of the assessed variables was compared to the existing knowledge regarding navigation mode determination. The comparison result shows that learning multiple data-presented variables can improve the model's classification performance by at least 9.6%.

Implications on sustainable maritime operation

The proposed model can automatically make operational decisions based on big data. The potential of machine learning techniques to support the development of intelligent decision-support system is highlighted. On the one hand, the model can achieve a good classification performance by interpreting the coupled effect of influencing factors. On the other hand, the explainability of how complex operation conditions affect decision-making can help decision-makers build trust in the intelligent strategy. In the long term, machine learning techniques can be expected to help evaluate the need of IB assistance and optimize the IB resources in the future, contributing to the sustainability of winter navigation.

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