Machine Learning Techniques for Ship Performance Predictions in Open Water and Ice
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ABSTRACT

The primary purpose of the work is to explore the practicality of using Artificial Intelligence (AI); specifically, Machine Learning (ML) and Deep Learning (DL), to predict ship performance characteristics based on time-averaged and time-dependent data. Three application cases are studied. The first modelling case is a time-averaged ship propulsor performance dataset, the second and third modelling cases are a time-averaged and time series prediction of forces on a dynamic positioning ship operating in a broken ice-field. An ML-based model was developed to predict various propulsor coefficients of a podded propulsor, given the advance coefficient, cavitation condition, hub geometric variations, pod configurations and the azimuthing angle. The second modelling case involved developing an ML algorithm to predict time-averaged ice forces on DP-controlled ships at the given ranges of ice concentration, floe size, ice thickness, strength, density, drift speeds and direction. The third modelling case involved predicting the time-dependent forces on a DP-controlled ship at specific operating conditions and ice-field parameters. The AI-ML-based predictive models showed reasonable accuracy compared to the corresponding measurements and performed better than conventional regression-based models.

KEY WORDS: Machine learning, deep learning; artificial neural network; marine propulsor; DP-controlled ship.

INTRODUCTION

In recent years, Artificial Intelligence (AI) and Machine Learning (ML) have driven advances in various fields, including medical, financial, research, design, and engineering. From self-driving cars to medical diagnosis, this new technology has changed the way people interact with technology. Given this technological shift, it becomes apparent that investigations into the efficacy of this technology in aiding physical model testing, full-scale measurements, post-processing data analysis and numerical modelling at the Ocean Coastal and River Engineering research centre of the National Research Council (NRC-OCRE) must be investigated.

The primary objective of the current work is to investigate several ML-based models to predict time-averaged and time-series vessel performance characteristics for given sets of vessel, environmental, operational data. The first step in achieving this objective was to conduct a literature review on current ML techniques, a review of open-source platforms for accomplishing this and transferred learning of existing ML model configurations.

The literature reviews carried out involved the popular machine learning techniques, the Artificial Neural Networks (ANNs) developed to solve a variety of ship performance prediction problems. A brief review of applications of a few variations of the popular ANNs techniques, namely, the Feed-Forward Neural Networks (FFNN), Convolutional Neural Networks (CNN), and Recurrent Neural Networks (RNN) for ship performance predictions, is presented below.

The applications of machine learning and deep learning techniques for ship performance predictions have been pursued by many researchers. Anan et al. (2013) at Fujitsu Laboratories in Japan developed an AI tool to predict ships’ fuel consumption. Pedersen and Larsen (2014) developed an ANN to determine the required propulsion power for a given ship using full-scale measurements of the propulsion power, ship speed, wind speed and direction, sea and air temperature. Hou et al. (2017) proposed ship hull parameters in the design phase be determined by the use of an NN instead of traditional model tests or empirical data. Luka et al. (2018) developed a system for monitoring and recording the influence of a running sea on a vessel’s seakeeping performance based on machine learning techniques that relate measured wave parameters (encounter angle, wave height and wave amplitude) with measured motion characteristics of the vessel. Jeon et al. (2018) developed an accurate regression model for the fuel consumption of the main engine by using an artificial neural network (ANN) by big data analysis, including data collection, clustering, compression, and expansion. Liang et al. (2019) utilized AIS (Automatic Identification System) data, ship propulsion power measurements and weather data and applied different machine learning (traditional and deep learning with different architectures) methods to develop improved models to predict ship propulsion power. Kim et al. (2020) proposed several ANN models based on decades of model tests and full-scale datasets for predicting ship resistance in ice.

The application of ANNs in the modelling of hydrodynamic characteristics of marine propulsors is not an entirely new concept, but regardless of the several existing papers (Neocleous and Schim (2002), Roddy et al. (2006), Matulja et al. (2010), Calcagni et al. (2010), and Valčić and Dejhalla (2015), this area is undoubtedly not sufficiently explored. The NN-based model allows for more general modelling of azimuth thruster in usually very complex hydrodynamic propulsion models of the dynamically positioned marine vessel.

Another ML-technique, Convolutional Neural Network (CNN), finds its applications mostly in image processing and classification-related problems. Related to ship performance applications, CNNs have also