Predicting energy consumption of ships in ports using machine learning algorithms

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ABSTRACT: Energy consumption and efficient energy usage is key issue in all developing and developed countries. Energy consumption is a critical issue applicable in almost all domains. Here we are focusing on discussing energy wastage and efficient-optimal consumption at ports. To reduce energy wastage and to consume energy optimally, machine learning algorithms and data analysis methods can be used. In this paper we are discussing different machine learning algorithms in detail. We will also discuss features affecting energy consumptions and compare machine learning algorithms to conclude the most efficient method of all.

Index Terms: Energy consumption, machine learning algorithms, data analysis.

I. INTRODUCTION

Ports are becoming the major consumers of energy in recent years and this emission comes from the ships [1]. The shipping sector is also a major contributor for global carbon emissions and in 2014 the sector contributed about 2.9% of total greenhouse gas emissions. It is expected to get bigger in the future [4][5]. If no action is taken it is assumed that the emission from shipping will increase by 50 to 250% until 2050 [2]. In addition, rising and volatile fuel prices creates a major problem for fuel companies as fuel costs form 60% of the ship operating cost and as a result of that shipping companies are moving towards energy efficient procedures to consume energy and reduce cost [2][3][5]. Recently, the energy and fuel saving applications have been addressed by the International Maritime Organization. The IMO and other societies agreed upon an objective to reduce total gas emission of this sector by 50% as part of continuing path way reduction by 2050 [10]. Nowadays all shipping companies are looking for sustainable methods to consume fuel and energy.

Lim et al. (2018) performed a simulation model which included the “ship motion model” and “electric power consumption model” to predict the electric power consumption of an electric propulsion ship (EPS) [8]. Lai et al. (2018) developed a hydrodynamic model, which combined with parameter learning. To predict energy consumption of propulsion systems Ship speed, engine speed, ship power, trim, draft, wind speed and wind direction are considered as parameters [3]. By collecting large amounts of time series data with the help of electronic equipment based on high acquisition rate sensors has been used in modern ships [7]. We can predict the required propulsion power and monitor the hull resistance due to fouling with the help of plotting accurate speed and fuel consumption curves from relevant operational data [6].

The energy consumption prediction of ships needs to describe the relationship between energy consumption and the uncertain factors like berth allocation, quay crane scheduling, arrival pattern of ships and actual auxiliary power, which can be resolved by machine learning algorithms [1][5][9][10]. Machine learning methods like Gradient Boosting Regression (GBR), Random Forest Regression (RF), BP Network (BP), Linear Regression (LR), K-Nearest Neighbour Regression (KNN), Least Square Support Vector Machine (LSSVM), Multiple Linear Regression etc are used to predict the relationship between energy consumption and factors affecting it. With the help of artificial neural networks, we can make an efficient system for energy consumption. ANN has been used to predict specific fuel consumption and exhaust temperature of a Diesel engine for various injection timings and ANN has been found to be the domain for many successful applications of prediction tasks [2].

II. LITERATURE SURVEY

Yun Peng, Huakun Liu, Xiangda Li, Jian Huang and Wenyuan Wang analyse data of 8019 ships, which are mooring at the birth and there are 30 types of ships at the birth. All types of ships are classified into 11 categories, such as coal category, container category etc. They have applied 5 classification algorithms which are Gradient Boosting Regression

(GBR), Random Forest Regression (RF), BP Network (BP), Liner Regression (LR) and K-Nearest Neighbour Regression (KNN). All the 5 models are employed from the scikit-learn Python library and the default parameter settings are used to train the models and estimate the energy consumption of ships. The result showed that random forest outperforms all other algorithms with the highest accuracy 94.03%. After this, they calculated the feature importance for given 15 features and classified that there are major 4 features which are very important for energy consumption (net tonnage, deadweight tonnage, efficiency of facilities, actual handling volume of handling) [1].

E. Bal Beşikçi , O. Arslan , O. Turan and A.I. Ölçer collected 233 ship noon reports which have covered the sailing of the ship over the 17 months of her operation since it was built. They have developed a decision support system which uses artificial neural networks for ship operators in making decisions concerning the implementation of operational measures considering both the economic and environmental aspects to improve ship energy efficiency. The proposed decision support system provides a strategic approach to ship operators when they have to make decisions based on environmental conditions. In this process artificial neural networks are first used and it outperforms multiple regression with accuracy of 83.4% [2].

Zhihui Hu, Yongxin Jin, Qin Hu, Sukanta Sen, Tianrui Zhou and Mohd Tarmizi Osman collected a data of ship in the time period September 14th, 2017 to September 25th, 2018 and in total 24,386 fuel consumption data is there which includes data acquisition time, ship real-time fuel consumption, engine shaft, ship speed,average draft, trim, current speed, current direction, wind speed,wind direction, wave height, wave direction and so on. They have used Back-Propagation Neural Network (BPNN) and Gaussian Process Regression (GPR) to train the model and with the help of the model they can predict the ship fuel consumption. They used two types of datasets one with marine environment factors and one without marine environment factors and predicted the ship fuel consumption for both datasets in which datasets containing marine environment factors showed greater accuracy. BPNN shows slightly low prediction accuracy than GPR but it is much faster than GPR. So BPNN is more suitable and sustainable for online or real time prediction for ship fuel consumption [9].

Nicolas Bialystocki and Dimitris Konovessis collected 418 noon reports from ship operators and developed an algorithm which performs the fuel consumption prediction. Algorithm uses Ship's draft in the suggested voyage, Weather force, Weather direction, Date of the forthcoming voyage as input parameters. This algorithm is developed to predict fuel consumption and speed curve.

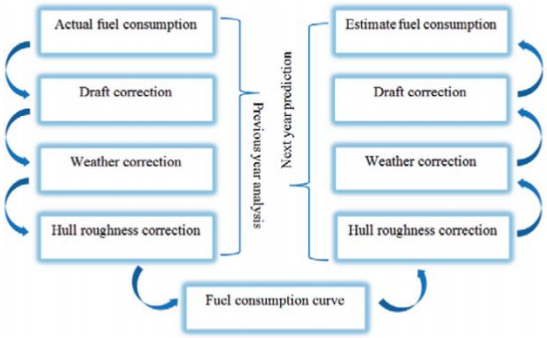

Fig 1. Procedure for fuel consumption curve prediction [6]

Operators have more information than noon reports so with help of this raw data we can create a feasible algorithm which is simple and accurate. With help of this algorithm we can reduce fuel consumption and get a significant amount of accuracy [6].

Chae-og Lim, Jeong-hoon Bae, Byeong-cheol Park and Sung-chul Shin proposed an electric power consumption model which is different from mechanical models like diesel engine or steam turbine. They created a ship motion model and electric propulsion model based on required shipping and power. To verify the electric propulsion system, they created a simulated modeling design. When Marine environment changes with place and time the wave spectrum also changes so they have used the standard wave spectrum for measurement.

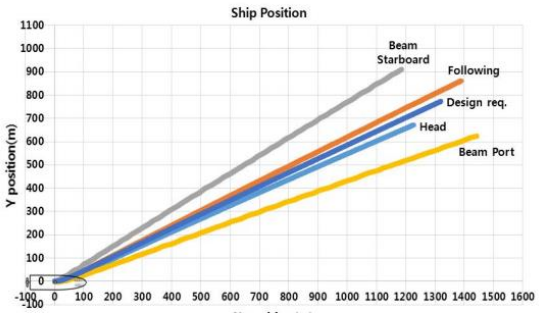

Fig 2. Routes of the ship position for each scenario [8]

By maintaining the heading angle and propulsion we can easily predict the power consumption. This research provides a base data or decision support

system for electric propulsion systems like generators and motors.

The comparison between results for various Machine Learning Algorithms used papers is shown in Table 1.

TABLE 1. Review of Machine Learning Algorithm and Approaches

Title	Methodology	Results
Machine learning method for energy consumption prediction of ships in port considering green ports [1].	Gradient Boosting Regression (GBR), Random Forest Regression (RF), BP Network (BP), Liner Regression (LR), K-Nearest Neighbour Regression (KNN)	The result showed that random forest outperforms all other algorithms with the highest accuracy 94.03%.
An artificial neural network-based decision support system for energy efficient ship operations [2].	Artificial neural network (ANN) and multiple regression analysis (MR)	Artificial neural network provides better prediction results compared to multiple regression.
An integrated physical based and parameter learning method for ship energy prediction under varying operating condition [3].	Model-based approach: 1.Kalman Filter (KF) and Particle Filter (PF) and collaborative filtering. Data-driven approach: 1.Least Square Support Vector Machine (LSSVM) 2.Extreme Learning method 3.Artificial neural network (Ann)	By analysing 177 points physical based learning model outperforms artificial neural network with 13% reduction in mean square error.
Ship Energy Consumption Prediction with Gaussian Process Metamodel [4].	Gaussian process model: $ff(xx)$~GP ($mm(xx)$, kk (xx, xx')) where $ff(xx)$ is a function of variable x, $mm(xx)$ is a mean function, and kk (xx, xx') is a covariance function	Weather conditions are also an important part for predicting ship fuel consumption and speed reduction of 10% can save fuel consumption by 19%.
Predicting dynamic fuel oil consumption on ships with automated machine learning [5].	Least absolute shrinkage and selector operator (LASSO) regression, support vector machines (SVR), artificial neural networks (ANN), Gaussian process regression (GP)	We can use this model with existing decision tool systems at both a reduced cost and complexity.
Prediction of Ship Fuel Consumption Based on Broad Learning System [7].	Support Vector Regression (SVR), Artificial Neural Network (ANN) and Broad Learning System (BLS)	The time consumption for Broad Learning System is 12% less than Artificial neural network and BLS is more accurate than ANN.
Prediction of Fuel Consumption for Enroot Ship Based on Machine Learning [9].	The Back-Propagation Neural Network (BPNN) and Gaussian Process Regression (GPR)	BPNN achieves slightly lower prediction accuracy than GPR but it is faster than GPR so it outperforms GPR.
Ship Fuel Consumption Prediction with Machine Learning [10]	Multiple Linear Regression Method and Artificial Intelligence Method	Data which is generated with the help of machine leaning are compared with original data. With comparison the graph shows not much difference between them.

III. CONCLUSION

As discussed in this survey, prediction of energy consumption has been greatest challenge for world. We cannot accurately predict the factors affecting energy consumption but with help of machine learning algorithms we can create a way to find optimal solution. Machine learning algorithms such as SVM, LR, GBR, BPNN, ANN, GP, BP, RF, KNN etc are widely used in this process but random forest (RF) outperforms all the algorithms with highest accuracy. By combining any algorithm with artificial neural network, we can create a model which can give us very accurate result. In addition, we cannot neglect the weather conditions because it makes a heavy impact on energy consumption.

IV. REFERENCES

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