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Study on Prediction Method of Propulsive Performance by means of Gaussian Process Regression for On-board Monitoring Data

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ABSTRACT

Propulsive performance of a ship in actual seas can be comprehended by analyzing on-board monitoring data. In this paper, we propose a way of analyzing on-board monitoring data, for example data cleansing, data visualization, regression of propulsive performance of a ship and a way of the usage results of the regression. We apply Gaussian Process Regression, which is one of machine learning, to regress the on-board monitoring data and calculate propulsive performance of a ship against Beaufort scale as a way of the usage results of the regression.

KEY WORDS: on-board monitoring data; propulsive performance of ship; actual seas; Gaussian Process Regression.

INTRODUCTION

It is expected that analyzing on-board monitoring data and comprehending propulsive performance of ship in actual seas is useful for feedback on shipping schedule or ship hull design. The feedback on shipping schedule contributes to shipping companies, the feedback on ship hull design contributes to ship building companies. On-board monitoring data includes Voyage Data Record (VDR) or engine data logger. On the other hand, communication system between ship and land has been developing recently. Large size of data can be sent between ship and land. Therefore, on-board monitoring data can be observed at ship and land simultaneously (Kimura et al., 2012).

The purpose of this paper is that we propose a way of analyzing on-board monitoring data, for example data cleansing, data visualization, regression of propulsive performance of a ship, and a way of the usage of results of the regression. We show propulsive performance of ship against Beaufort scale (BF) using results of the regression. As a result, it is shown that the performance of a ship in several external conditions can be organized clearly.

Orihara et al., 2018 evaluates performance of a ship in actual seas using on-board monitoring data. He applied physical modeling simulation to analyze on-board monitoring data and evaluate performance of a ship. However, it takes so much time to prepare physical model parameter of ship and calculate external disturbance and simulate physical model. In this paper, performance of ship in actual seas using on-board monitoring data is evaluated by means of machine learning which has lower time than physical modeling simulation. Prediction accuracy of machine learning depends on size of learning data and it is difficult to evaluate the prediction results. Therefore, we applied Gaussian Process Regression (Bishop, 2006, GPy, 2012) to predict performance of ship using on-board monitoring data. Gaussian Process Regression can show reliability of prediction accuracy that described in next section. Furthermore, Gaussian Process Regression is equivalent to the infinite neural network which has one hidden layer, the one hidden layer has finite units (Neal, 1996). It means that Gaussian Process Regression has the expressive ability for data-fitting.

GAUSSIAN PROCESS REGRESSION

Modeling

Gaussian Process Regression (GPR) is a non-parametric stochastic regression model which predicts output y against input vectors $\mathbf{x}$. It is assumed that output y follows the multivariate normal distribution of N. Observed n size data t_n is given by following.

$$t_i = y_i + \varepsilon_i \qquad (i = 1, 2, \cdots, n) \tag{1}$$

Where $y_i = y_i(\boldsymbol{x}_i)$, ε_i is a random noise variable which follows the normal distribution of N. As $\boldsymbol{t} = (t_{1,\ldots,}t_n)^T$, simultaneous distribution of $\boldsymbol{t}$ is derived from the simultaneous distribution of y as follows.

$$p(\boldsymbol{t}) = \int p(\boldsymbol{t}|\boldsymbol{y})p(\boldsymbol{y})\,d\boldsymbol{y} = N(\boldsymbol{t}|\boldsymbol{0}, \boldsymbol{C}_n) \tag{2}$$

Where $\boldsymbol{C}_n = \boldsymbol{K} + \boldsymbol{\beta}^{\mathbf{1}}\boldsymbol{I}_n$, $\boldsymbol{\beta}$ is called accuracy parameter and $\boldsymbol{K}$ is called Gram matrix. When observing n data, $\boldsymbol{K}$ is denoted by the following