Development of Drilling Data Acquisition System and Attempt of Anomaly Detection from Drilling Data with Machine Learning

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The drilling operations of the Chikyu are generally conducted using the Drilling Control and Instrumentation System (DCIS). Each drilling equipment has a programmable logic controller (PLC) that controls the equipment and monitors sensors on the equipment. PLCs of all the drilling equipment are linked by means of a network. A feature of DCIS is an additional PLC called “smart drilling instrument” PLC (SDI PLC) in the network link for integrated control and monitoring by receiving drilling data from the equipment PLCs. We developed a data acquisition system to connect with the DCIS via a virtual server established inside the SDI PLC server for security reason. We have so far analyzed the acquired data for evaluating performance of drilling equipment and also for estimating the sediment properties such as shear stress. This study attempted anomaly detection of drilling operations, in particular anomaly condition of drilling torque, from the surface drilling data with machine learning and deep learning approaches.

Training data were prepared using surface drilling data acquired with the developed data acquisition system during the operations of the Chikyu. The first requisite of preparing the training data is to determine the features of explanatory variables sourced from the surface drilling data. Fundamental data analysis including outlier investigation with autoregressive model, Fourier transform and spectrogram analysis were conducted. As a consequence, 2762 training data with normal condition and 352 training data with anomaly condition including dummy anomaly data with 17-dimensional feature vectors were generated.
A detection models were generated from machine learning approaches with the training data. Some algorithms were used for machine learning such as logistic regression, support vector machine, and Gaussian mixture model. The labeled training data were divided at random into ten groups with respect to each label. Nine blocks were combined and used for machine learning and the other block was used for simulation of anomaly detection. During machine learning, four-fold cross validation was applied. The labeled training data were divided into four groups at random. Three blocks were used for machine learning, and the other block of data was used for calculating the F1 score, which uses both the precision and recall for validation.

A similar level of F1 score was obtained in all cases, except for the Gaussian mixture model with eight clusters. Simulations of anomaly detection were then conducted using the detection models that give the highest F1 scores. As a result, we demonstrated that the normal condition could be identified and the anomaly condition could be detected. However, the results reveal that the dummy anomaly condition could not be detected successfully, and also suggest the need for an increase in the volume of training data including anomaly conditions. In addition we attempt deep learning approached for training data that is image data obtained from spectrogram analysis of torque data. Detection model with deep learning consists of 4 layers of convolutional neural network and batch normalization, and the fully connected layer. The results also indicated above.

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