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論　文　内　容　要　旨

報告番号	甲　先　第　412　号	氏　名	ANGGRAINI PUSPITA SARI
学位論文題目	STUDY ON FORECASTING OF WIND SPEED AND DIRECTION USING DEEP NEURAL NETWORK （ディープニューラルネットワークを用いた風速・風向予測に関する研究）		

内容要旨

In this study, we investigate forecasting of wind speed and direction based on deep learning to create an accurate forecasting model that can support the growth of wind power generation. The proposed forecasting model based on a deep neural network (DNN) model which is a type of artificial intelligence (AI) technology.

Proposed DNN is composed of three dimensional convolutional neural network (3DCNN), deep convolutional long short-term memory (DCLSTM), and two dimensional convolutional neural network (2DCNN) which called 3CNN-CLSTM-2CNN. The proposed forecasting model combines the merit of convolutional neural network (CNN) and convolutional long short-term memory (CLSTM) for improving forecasting accuracy of wind speed and direction. The input of the forecasting model is time sequence images of wind speed and direction that represented an image on two dimensional coordinate.

The actual observed data are taken from Automated Meteorological Data Acquisition System (AMeDAS), Japan. The proposed model forecasts one hour ahead and the forecasting accuracy of the proposed model was evaluated by the root mean square error (RMSE) between actual observed data and forecasted data. The proposed model is implemented in four seasons which are the characteristic of Japanese climate. For verifying the effectiveness of the proposed model, the model was compared to fully connected long short-term memory (FC-LSTM), DCLSTM, 3CNN-CLSTM (3DCNN combines DCLSTM) models. It was confirmed that the proposed model is the strongest performance in all models. 3CNN-CLSTM-2CNN model is the highest forecasting accuracy and the forecasting result is approached actual observed data. DCLSTM, 3CNN-CLSTM, and 3CNN-CLSTM-2CNN models can resolve spatio-temporal sequence and improve forecasting accuracy better than the FC-LSTM model. 3CNN-CLSTM-2CNN model improve forecasting accuracy than DCLSTM, and 3CNN-CLSTM models effectively. 3CNN-CLSTM-2CNN model can improve forecasting accuracy more than 10% from DCLSTM model and more than 2% from the 3CNN-CLSTM model both in wind speed and direction.

3CNN-CLSTM-2CNN model is compared in four cities (Tokushima, Takamatsu, Hiketa, and Choshi) to confirm an applicability to different characteristics of wind conditions. 3CNN-CLSTM-2CNN model was evaluated by RMSE, mean absolute error (MAE), and mean absolute percentage error (MAPE) in four cities. RMSE is used for mean forecasting. MAE is used for median forecasting. MAPE is used to measure forecasting accuracy that easily explain and interpret errors in terms of percentage. For calculating MAE is used the absolute value for evaluating forecasting results. Afterward, forecasting

errors have a small variance so that MAE is slightly lower than RMSE. In the forecasting error of MAPE, the lower result of MAPE is good caused the forecasting result is more approaching actual observed data.

The order of fluctuation wind speed and forecasting accuracy of wind speed in four cities are same: Takamatsu (standard deviation (SD) = 0.9167 m/s, RMSE = 0.9755 m/s), Tokushima (SD = 1.0153 m/s, RMSE = 1.0180 m/s), Hiketa (SD = 1.1347 m/s, RMSE = 1.1520 m/s), and Choshi (SD = 1.3513 m/s, RMSE = 1.3969 m/s). The order of fluctuation wind direction and RMSE of wind direction in four cities are same: Choshi (SD = 30.1256°, RMSE = 30.4677°), Tokushima (SD = 45.3046°, RMSE = 43.4435°), Hiketa (SD = 49.7260°, RMSE = 48.4974°), and Takamatsu (SD = 52.9903°, RMSE = 56.0314°). So that, the 3CNN-CLSTM-2CNN model can handle and suitable to apply in four cities although different characteristics of wind speed and direction.

The improvement rate of the 3CNN-CLSTM-2CNN model is obtained by comparison between RMSE of the 3CNN-CLSTM-2CNN model and the persistent model in each city. The lowest improvement rate of forecasting accuracy is Hiketa city in wind speed and Takamatsu city in wind direction. The largest improvement rate of forecasting accuracy is Choshi city both in wind speed and wind direction. Choshi city has lowest MAPE in Choshi city both in wind speed and direction. The highest result of MAPE in Takamatsu city both in wind speed and direction.

3CNN-CLSTM-2CNN and 3CNN-CLSTM models improve forecasting accuracy than DCLSTM due to these models uses CNN that can easier for training and reduce training time. 3CNN-CLSTM-2CNN model can improve accuracy than 3CNN-CLSTM model due to the last process of 3CNN-CLSTM-2CNN model uses 2DCNN that can easier for training and effectively to process sequential time.