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Virtual Wave Buoy

Predicting Wave Heights for Offshore Wind Energy Applications

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Ørsted

Motivation and Goals

Problem: To ensure safe and efficient offshore vessel operations, wave height measurements should be high quality, low-cost, and in real-time

Solution: Create a virtual twin to predict sea state conditions, such as wave height and direction, using machine learning and a distributed network of public buoys

Figure 1: Wave Buoy in the wild

Background

Data is collected around a wind farm using Wave Buoys. (see Fig. 1) Buoys are often made by a wide range of manufacturers and unkempt by an even wider range of owner groups. Depending on the model of buoy, a buoy can collect a variety of data fields like wave height and median wave direction as well as weather related quantities like temperature, wind speed and direction, and atmospheric pressure.

Figure 2: Open source buoy-network sites
Figure 2a: Left - buoys in Martha's Vineyard | Figure 2b: Right - buoys in the Gulf of Maine

Datasets Used and Sites Predicted

Two main data sources were used: Ørsted proprietary data and National Oceanic and Atmospheric Administration's (NOAA) open source National Data Buoy Center (NDBC)

Sites Predicted:

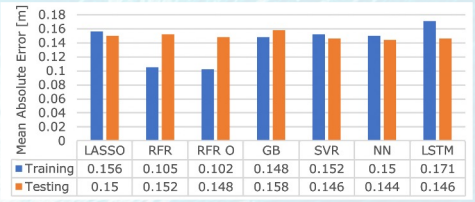
- West Central England/Irish Sea (Ørsted)
- South East England/North Sea (Ørsted)
- Martha's Vineyard - Off the coast of South Massachusetts (NDBC) (Fig. 2a)
- Gulf of Maine - Off the coast of North Massachusetts (NDBC) (Fig. 2b)

Alternative Models

In our research, we have tried many different machine learning models including:

- Random Forest Regression (RFR)
- Lasso Regression
- Super Vector Machine (SVM)
- Long Short-Term Memory (LSTM)
- Gradient Boosting for Regression (GBR)
- Neural Network (NN)

The results from our analysis can be seen in Figure 3



	LASSO	RFR	RFR O	GB	SVR	NN	LSTM
Training	0.156	0.105	0.102	0.148	0.152	0.15	0.171
Testing	0.15	0.152	0.148	0.158	0.146	0.144	0.146

Figure 3: Model Comparison for Gulf of Maine site with median errors between 11.5 cm and 10 cm

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Sensitivity Analysis Performed and Results

In our research, we tested the sensitivity of our results in several ways

- Grid Search Hyperparameter Tuning
- Distance Sensitivity
- Sequential Distance Sensitivity
- Months of Data Trained on
- Range of Wave heights
- Inclusion of Additional Data fields
- Permutations of Buoy Prediction

Conclusions

- The framework was successfully transferred on different sites
- The addition of features like wind speed and period helped the regression accuracy for some of the buoys
- A buoy needs at least 4 months of data and removing the farthest buoy from the predicted buoy does not often significantly affect accuracy
- RFR's performance is the same as alternative models (SVR, GBR, LSTM) and performs better than standard regression
- RFR tends to overfit on the training set

Next Steps

Next steps for this project are largely focused on finishing our last sensitivity analysis and the handoff of our work to Ørsted Engineers.
This work will also be presented at Engineering Mechanics Institute Conference (EMI) Summer 2023!