Data Informed Model Test Design with Machine Learning – an Example in Nonlinear Wave Load on a Vertical Cylinder

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Abstract

- Introduction of a Bayesian sampling-based model test design strategy for analysing nonlinear wave loading on vertical cylinders in ocean engineering.
- Integration of past experimental results and typical ocean conditions into the design process using a GP-based surrogate model and modified acquisition functions.
- Improvement in experimental design with data-driven methods, offering marginally better performance and interpretable, physically insightful decisions compared to traditional manual approaches.

Objective

A data-driven method that incorporates field data and previous test results to help the experimental design

Our model test: Wave loads on a vertical cylinder

Stokes' type force Coefficient:

$$\Gamma_n = f(kR, kd, kA)$$

Cylinder radius | Water depth | Wave steepness

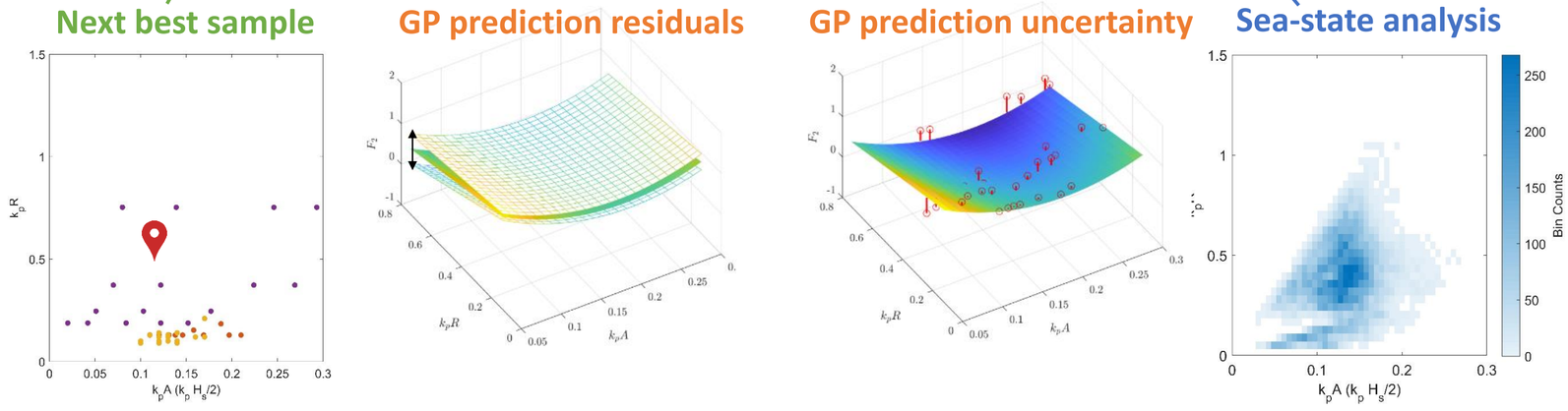
Experimental Facility: Kelvin Hydrodynamics Laboratory

Methods

We modify the likelihood-weighted acquisition functions to both locate the next best sampling point $\boldsymbol{x}^*$ to be the position where the predictive variance achieves a maximum value and also considers conditional statistics calculated from metocean data at 36 locations of UK-based wind farms.

$$\boldsymbol{x}^* = \mathrm{argmax}_{\boldsymbol{x}} \mathrm{std}_{f,g}[\mathbb{P}(S(\boldsymbol{x}, \omega \mid f(\boldsymbol{x}), g(\boldsymbol{x})) > \delta)]\, p_X(\boldsymbol{x})$$

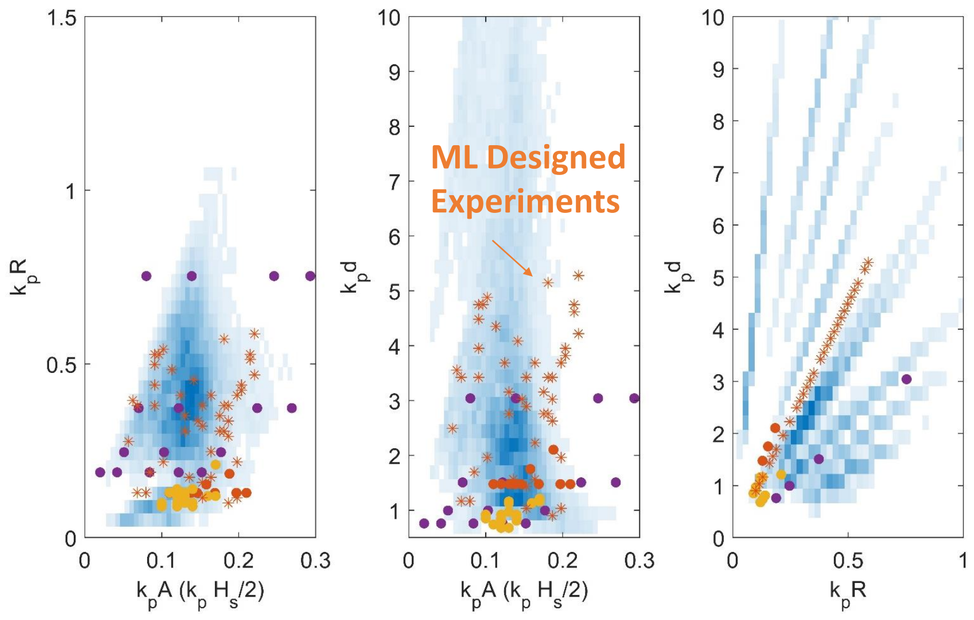
Next best sample | GP prediction residuals | GP prediction uncertainty | Sea-state analysis



Results

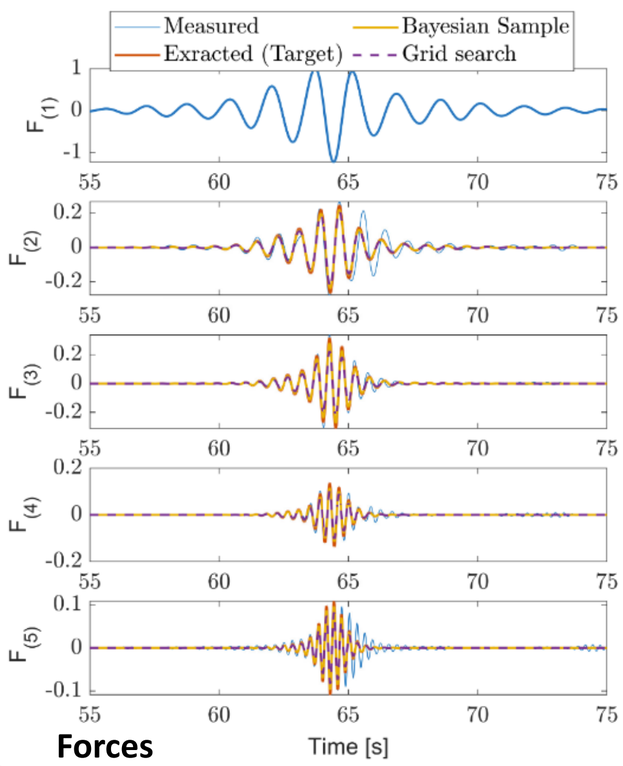
Machine Learning Designed Experiments

We perform a new experiment, which is mainly designed by data-driven methods including several critical parameters such as the size of the cylinder and all the wave conditions. This method is a step forward to a more systematic way of approaching test designs with marginally better performance in capturing the higher-order force coefficients.

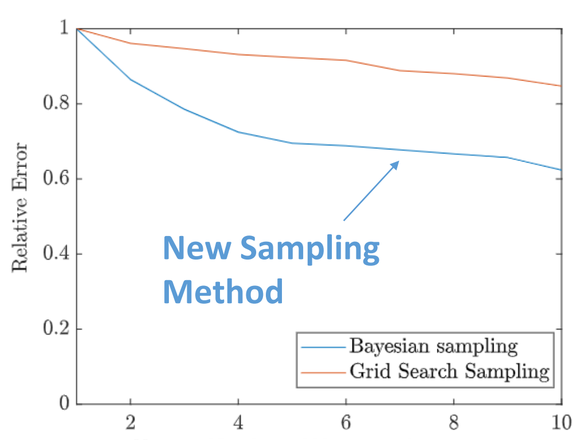


Improvements

The prediction with Bayesian sampling outperforms slightly over the one trained with grid search design. The advantage of using Bayesian sampling is more significant for the nonlinear force components with high frequencies as more noise is expected in these signals.



20% further improvement in the final force prediction accuracy can be achieved following the wave group parameter suggested by the data-driven method.



Advantages and Future Work

- Very first time can incorporate Metocean data in experimental design
- Allows certain freedom in tailoring the acquisition function and improves the experimental design
- Additional advise with physical intuition helps understanding the current model design challenge and provide guidance.

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