Ocean Wave Forecasting for Wave Energy Converters

Ming Ge

Dr Eric Kerrigan

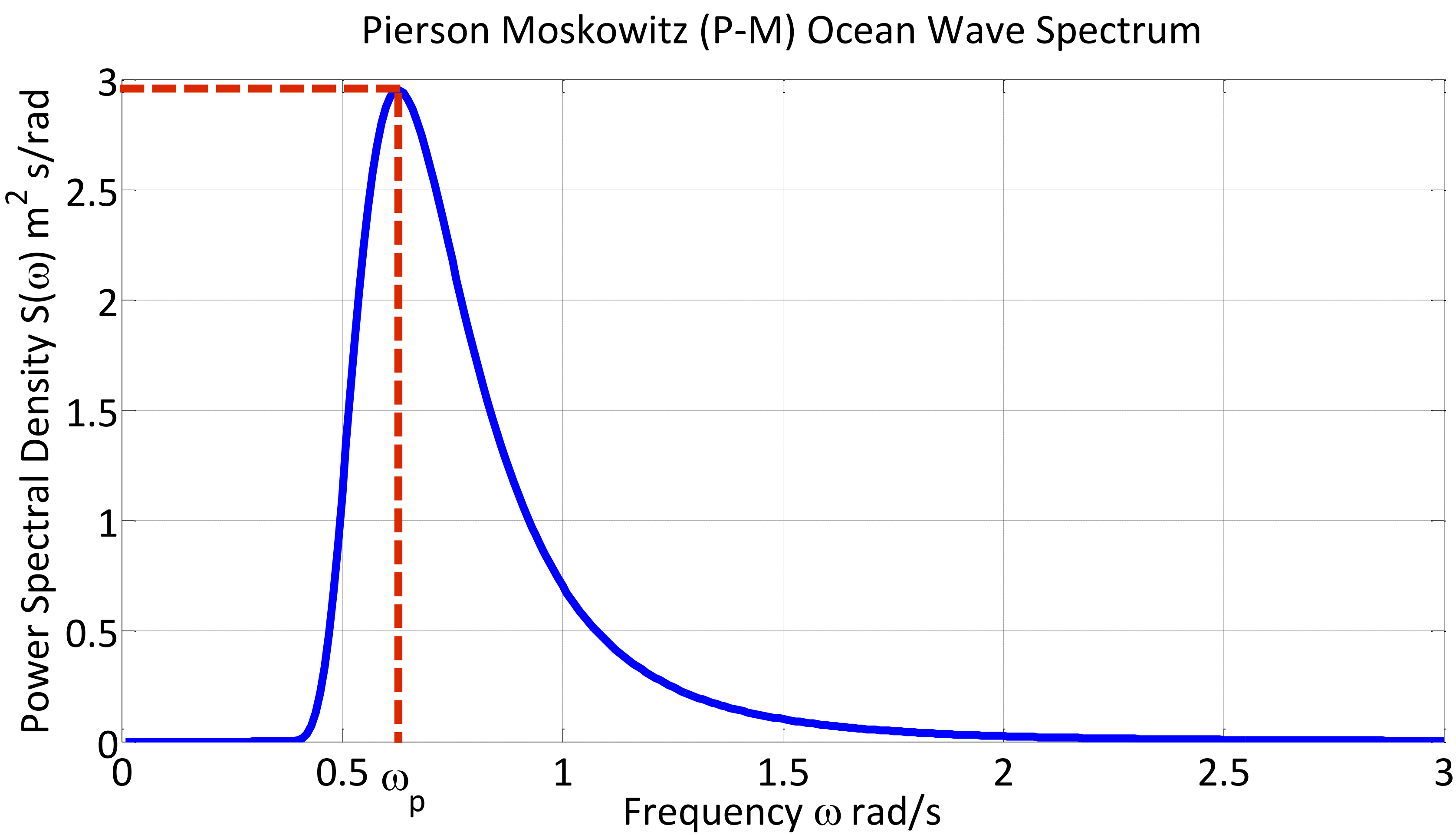
Imperial College London

UKACC PhD Presentation Showcase

Introduction

- Wave Energy Converters (WECs) require knowledge of future incident wave elevation.
- Two types of spectrums : Pierson-Moskowitz (P-M) and Joint North Sea Wave Project (JONSWAP) spectrums.
- Previous works done by other researchers: ocean wave forecasting using auto-regressive and neural network methods.
- My work: ocean wave forecasting using Kalman filter and Kalman Predictor.

Pierson-Moskowitz Wave Spectrum



Linear Prediction Model and Model Reduction

- Assume irregular sea waves made by a superposition of many regular harmonic waves with different frequencies :

$$\begin{bmatrix} a_{i,k+1} \\ b_{i,k+1} \end{bmatrix} := \underbrace{\begin{bmatrix} \cos(\omega_i T_s) & \sin(\omega_i T_s) \\ -\sin(\omega_i T_s) & \cos(\omega_i T_s) \end{bmatrix}}_{F_i} \begin{bmatrix} a_{i,k} \\ b_{i,k} \end{bmatrix}$$

$$\hat{\eta}_{i,k} := \underbrace{\begin{bmatrix} 1 & 0 \end{bmatrix}}_{H_i} \begin{bmatrix} a_{i,k} \\ b_{i,k} \end{bmatrix}$$

- The system model is (ignoring the observation noise):

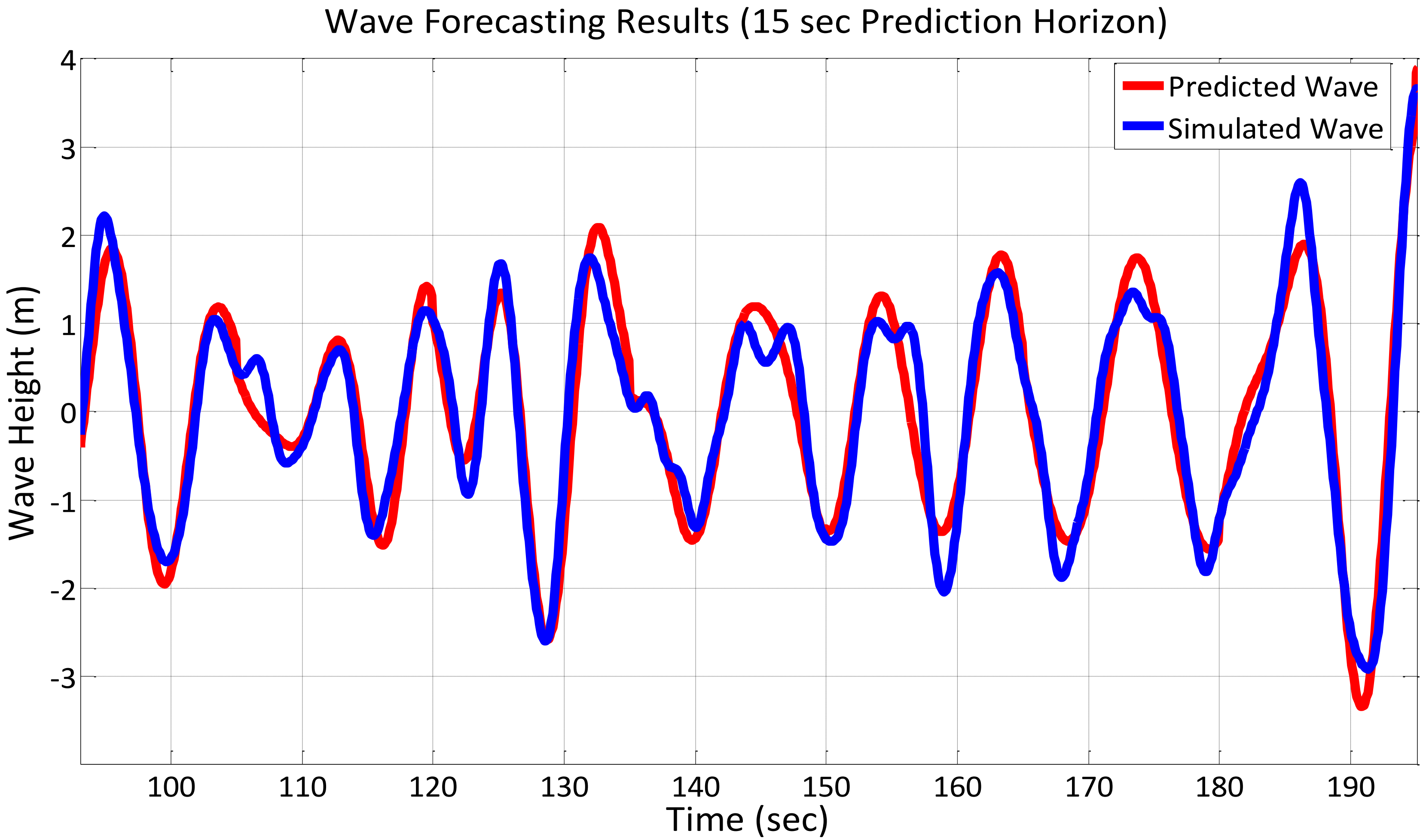
$$x_k := F x_{k-1} + G d_{k-1}$$
$$\eta_k := H x_k$$

$$F := \begin{bmatrix} F_1 & 0 & 0 & 0 \\ 0 & F_2 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & F_n \end{bmatrix}, \qquad H := \begin{bmatrix} H_1 & H_2 & \cdots & H_n \end{bmatrix}.$$

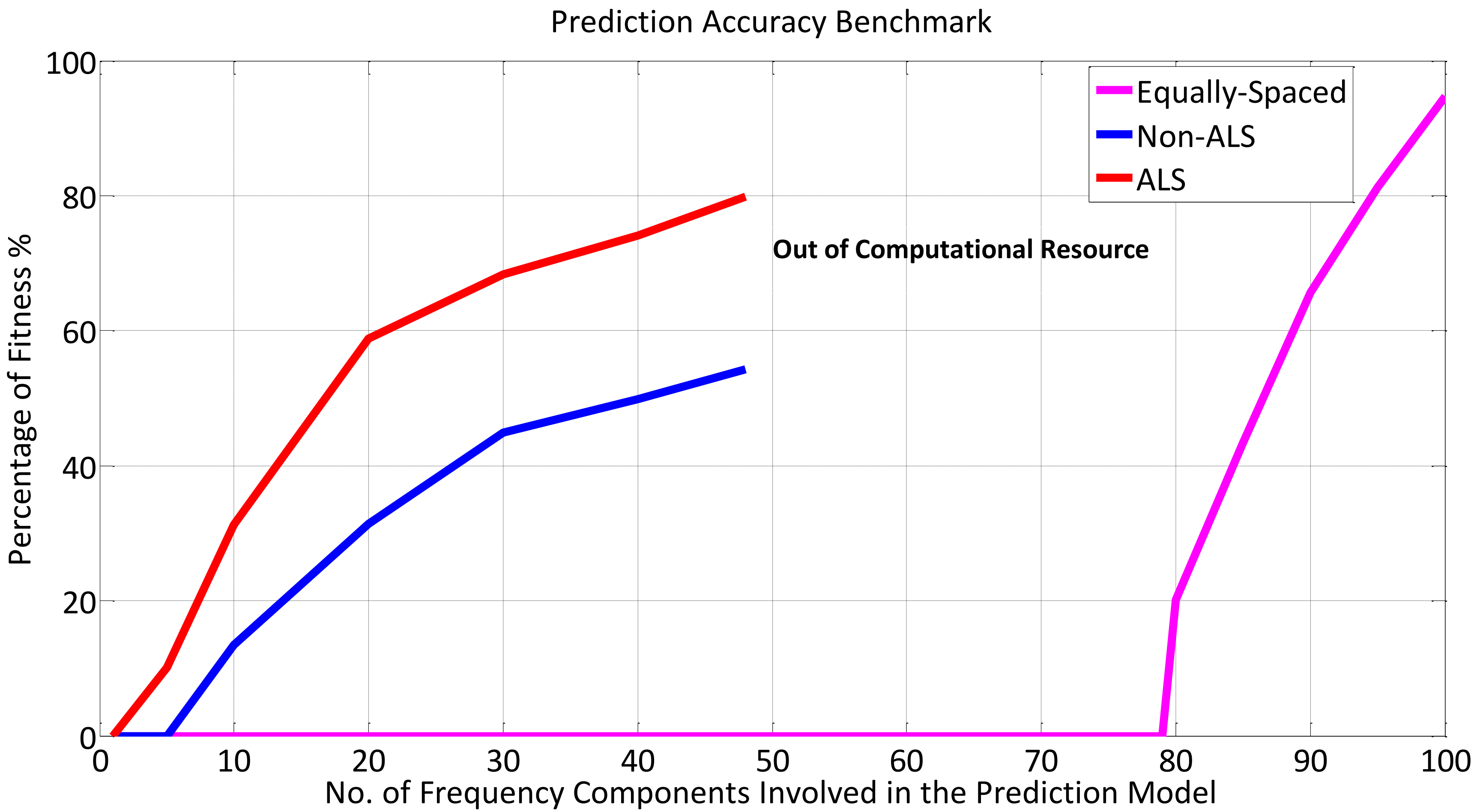
Methodologies

- Stationary ocean status --- Linear Model
- Constant frequency components ω_i are determined by looking at the power spectral density of historical waveforms.
- State noise covariance is determined by the auto-covariance least square method. [*Odelson, Rajamani and Rawlings, 2006*]
- $\mathbf{Fit\%} := \mathbf{100\%} - \frac{\|\eta_{true} - \hat{\eta}\|_{\ell_2}}{\|\eta_{true}\|_{\ell_2}}$

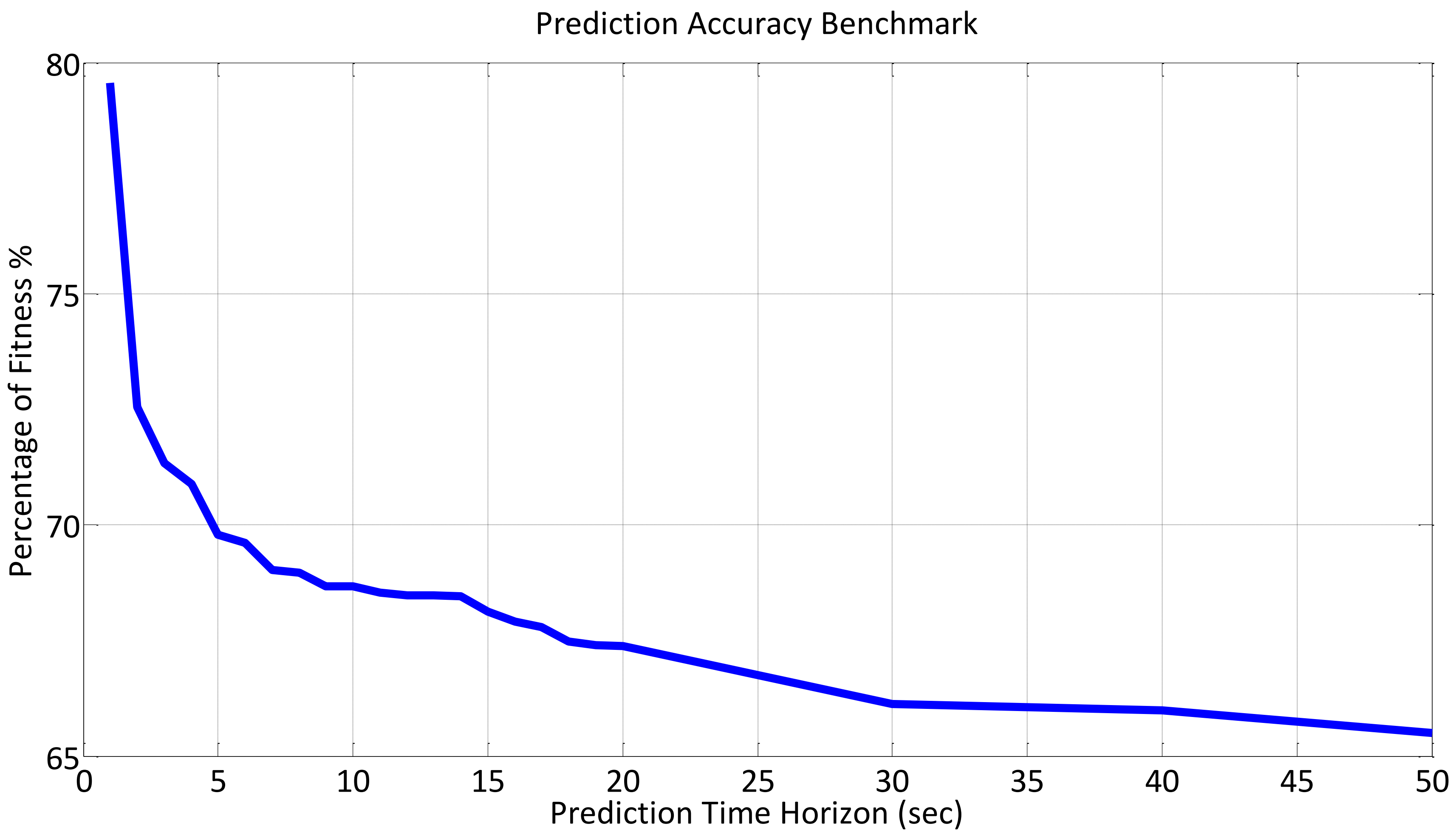
Simulation Results



Simulation Results



Simulation Results



Future Work

- Non-stationary ocean status --- Non-Linear Model
- Nonlinear Covariance Estimation Problems
- Efficient Computing