Signal Processing Issues Related to Deterministic Sea Wave Prediction

Submitted by
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I certify that all the material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University

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Abstract

The bulk of the research work in wave related areas considers sea waves as stochastic objects leading to wave forecasting techniques based on statistical approaches. Due to the complex dynamics of the sea waves’ behaviour, statistical techniques are probably the only viable approach when forecasting over substantial spatial and temporal intervals. However this view changes when limiting the forecasting time to a few seconds or when the goal is to estimate the quiescent periods that occur due to the beating interaction of the wave components, especially in narrow band seas.

This work considers the multi disciplinary research field of deterministic sea wave prediction (DSWP), exploring different aspects of DSWP associated with shallow angle LIDAR systems. The main goal of this project is to study and develop techniques to reduce the prediction error. The first part deals with issues related to shallow angle LIDAR systems data problems, while the remaining part of this work concentrates on the prediction system and propagation models regardless of the source of the data.

The two main LIDAR data problems addressed in this work are the non-uniform distribution and the shadow region problems. An empirical approach is used to identify the characteristics of shadow regions associated with different wave conditions and different laser position. A new reconstruction method is developed to address the non-uniformed sampling problem, it is shown that including more information about the geometry and the dynamics of the problem improves the reconstruction error considerably.

The frequency domain approach to the wave propagation model is examined. The effect of energy leakage on the prediction error is illustrated. Two approaches are explored to reduce this error. First a modification of the simple dispersive phase shifting filter is tested and shown to improve the prediction. The second approach is to reduce the energy leakage with an iterative Window-Expansion method. Significant improvement of the prediction error is achieved using this method in comparison to the End-Matching method typically used in DSWP systems. The final part in examining the frequency domain approach is to define the prediction region boundaries associated with a given prediction accuracy.
The second propagation model approach is the Time/Space domain approach. In this method the convolution of the measured data and the propagation filter impulse response is used in the prediction system. In this part of the research work properties of these impulse responses are identified. These are found to be quite complicated representations. The relation between the impulse response (duration and shift) with prediction time and distance are studied. Quantification of these impulse responses properties are obtained by polynomial approximation and non-symmetric filter analysis. A new method is shown to associate the impulse response properties to the prediction region of both the Fixed Time and Fixed Point mode.
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