# Bayesian estimation of non-stationary ship response

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## Introduction

Environmental data from reliable sources has been of great importance to ensure safe marine operations at sea. The wave-rider buoy has primarily been the most important source to establish oceanographic statistics. However, recently there has been a development towards using ships as sensors to estimate the wave spectrum, see [1]. This methodology is called the *the wave buoy analogy*, and is shown in **Figure 1**. Most methods today, are assuming that both the short term sea state, and the ship response can be considered as stationary. It is well established in the literature that the short term sea state can be considered as stationary, see [2]. However, the ship response can only be assumed stationary for constant operational conditions, such as constant heading and vessel speed. In this thesis, a method that can recreate a non-stationary ship response is established, making it possible to recreate the wave spectrum when operational conditions vary with time. This is obtained by using a time-varying auto regressive model (TVAR), and Bayesian estimation methods.

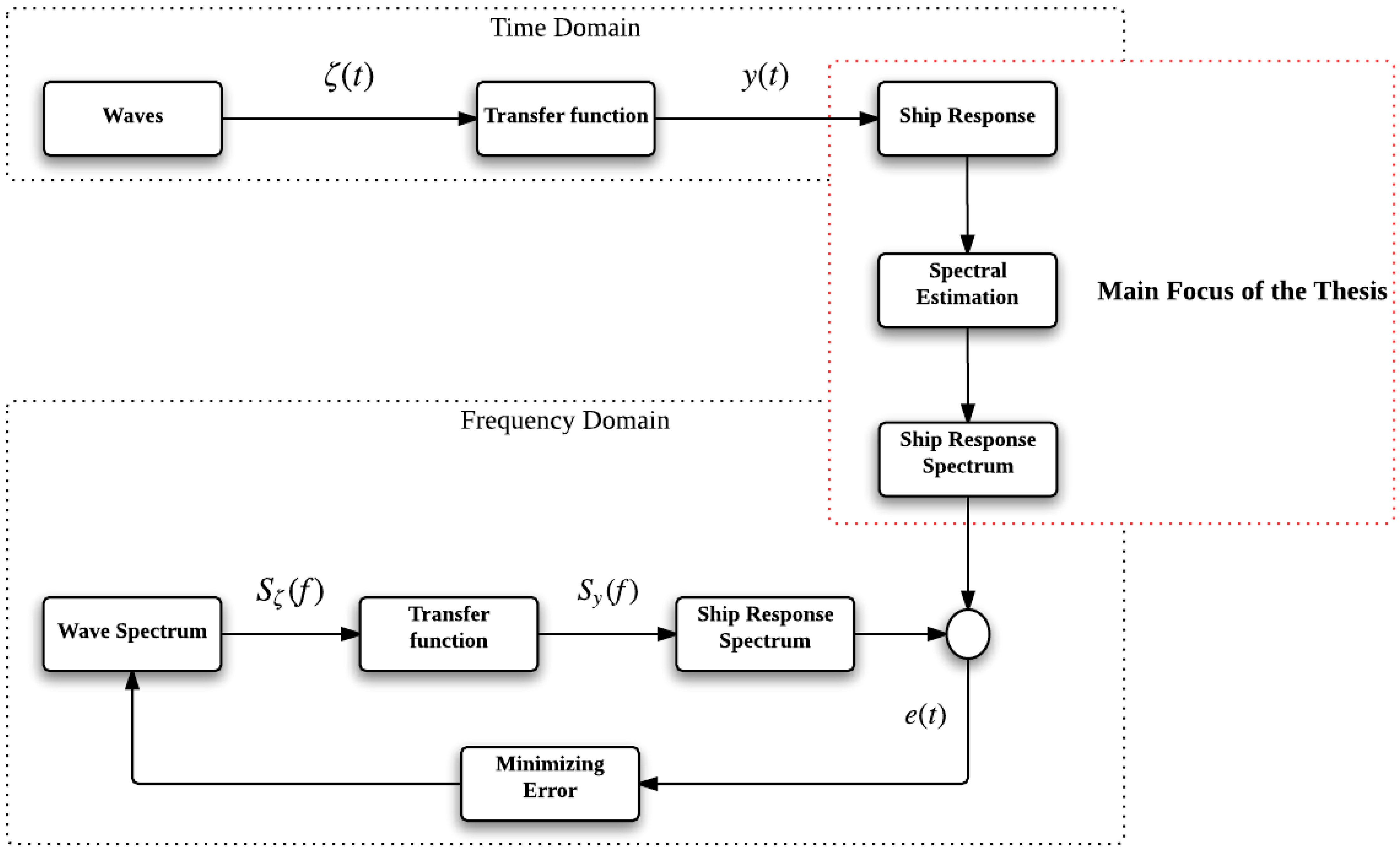


**Figure 1.** Wave bouy analogy.

## Motive

The motive of the thesis is to estimate spectral information of a non-stationary ship response, with the underlying aim of improving sea state estimation.

## Method

Mainly, there exist two methods for spectral estimation of the ship response, which is the parametric and non-parametric method, see [3]. The parametric method assumes that the process follows a predefined parametric model, while in the non-parametric approach there is not any assumption on the structure of the process.

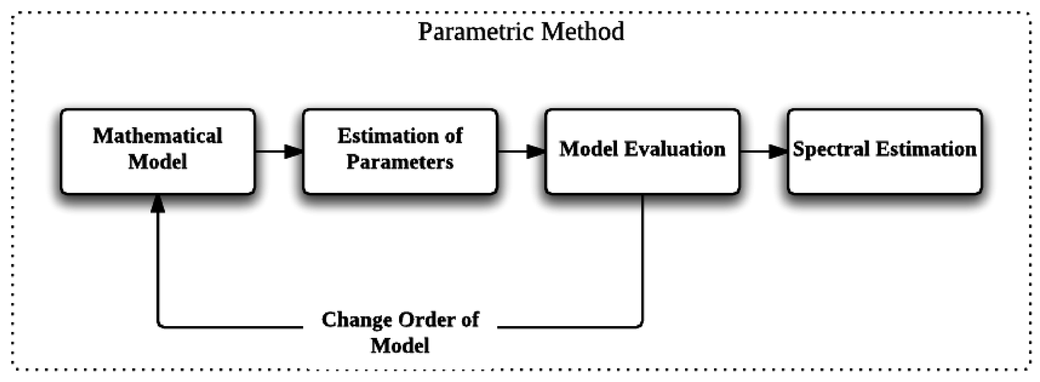


**Figure 2.** Parametric Spectral Estimation.

The main advantage with the parametric approach is that the by letting the parameters vary with time, it is possible to model non-stationary processes.
The mathematical model is set to be a timevarying autoregressive model, given as

$$y_k = \sum_{j=1}^{p} a_{k,j} y_{k-j} + e_k \qquad (1)$$

where $y_k$ is the ship response, $a_{k,j}$ are the time-varying parameter coefficients, $p$ determines the number of parameters, $e_k$ is the model error and $k$ denotes the time instant.
The timevarying parameters are estimated by Bayesian methods, such as the Kalman filter and the Particle filter.

## Results

To easily verify the algorithm's performance, the Response Amplitude Operator (RAO), which is the transfer function between the wave height and the ship response, is set equal to one. Therefore, the objective of the algorithm is to recreate the wave spectrum, and below the JONSWAP spectrum is estimated.

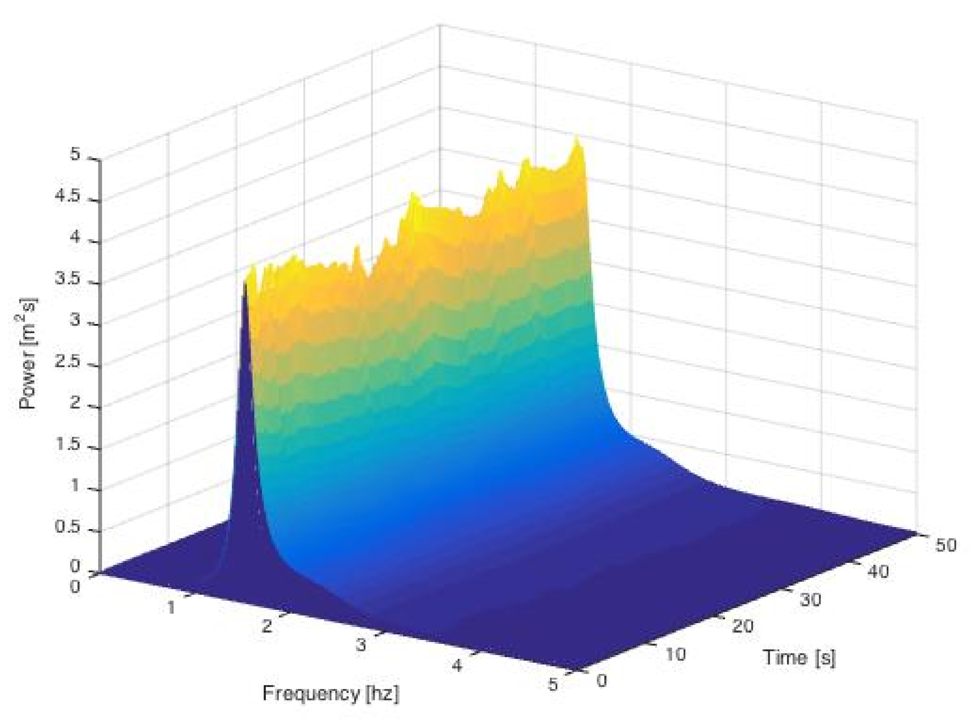


**Figure 3.** Estimated Time Varying Ships Response.

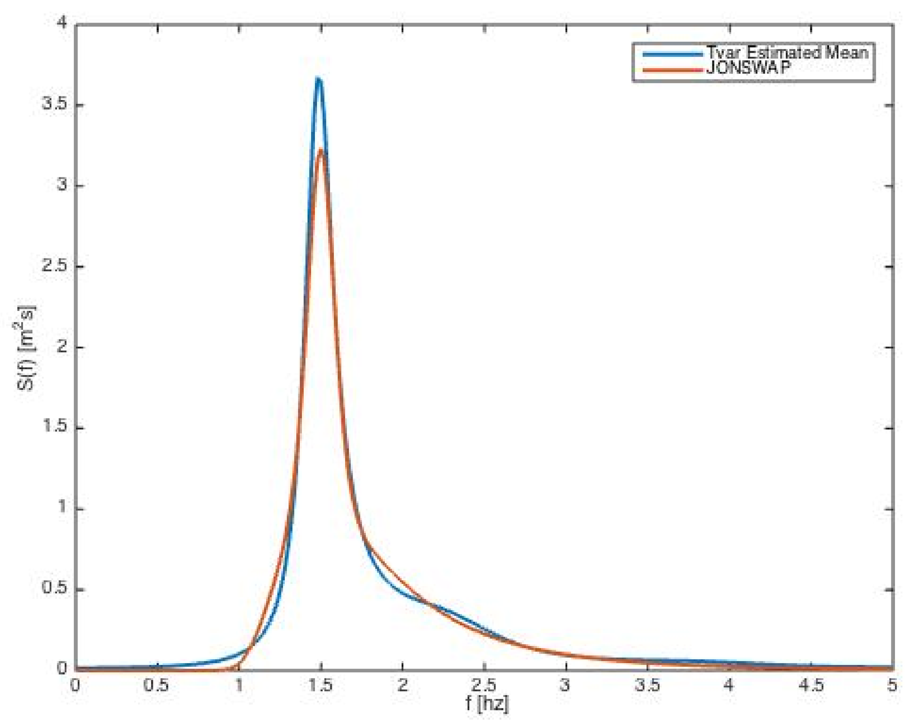


**Figure 4.** Mean of Estimated Ship Response Spectrum vs True Spectrum.

## Contributions

A method to analyse the non-stationary response of vessels is developed, and limitations and key factors of the method is identified.

## Acknowledgement

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## References

[1] U. D. Nielsen *Estimation of Directional Wave Spectra from Measured Ship Responses*, PhD Thesis. Technical University of Denmark 2005.
[2] O.M. Fatlhinsen, *Sealoads on Ships and Offshore Structures*, Campridge 1990.
[3] J.G. Proakis, *Digital Signal Processing: Principles, Algorithms, and applications* , Prentice Hall 1996.