Successive Inverse Estimation of Directional Wave Spectra by Using Ship Motions Based on State-space Modeling Procedure

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ABSTRACT

In this study, a new technique to estimate directional wave spectra with respect to encounter waves of ships based on ship motions data is introduced. Firstly, the ship motion is analyzed by a Time Varying AutoRegressive (TVVAR) modeling procedure, and cross spectra of the ship motion data is obtained. And then, based on the estimated instantaneous cross spectra, directional wave spectra with respect to the encounter wave are estimated by a state-space modeling procedure every time step. The proposed method is verified by numerical experiments.

KEY WORDS: State-space method; Time Varying Vector AutoRegressive (TVVAR) modeling procedure; Akaike Information Criterion (AIC); Monte Carlo Filter; Directional wave spectra; Ship motions data; Inverse problem.

INTRODUCTION

If it is possible to understand a directional-frequency characteristic of ocean waves which is called directional wave spectra onboard every time step, it is very useful for ship operators to remain a ship safety. However, in general a mechanical measurement of ocean waves onboard is not carried out from the view point of benefits by costs. Thus, regarding with a wave height and a wave period as characteristics of ocean waves, the measurement onboard has been visually observed by ship operators, although instrumentation technologies of ocean waves onboard like Wave Monitoring Radar System are advanced in recent year.

On the other hands, as a method to understand directional wave spectra, an inverse estimation procedure from spectra of ship motions is introduced for efficient calculation and is directly modeled as a state-space modeling procedure. In this procedure, there are three kinds of features. First, in order to solve these problems in estimation of directional wave spectra, a new methodology based on a state-space modeling procedure is introduced. In this procedure, there are three kinds of features. First, in order to solve these problems in estimation of directional wave spectra, a new methodology based on a state-space modeling procedure is introduced. In this procedure, there are three kinds of features. First, in order to analyze a time series of an observed ship motions, a time-frequency analysis based on a Time Varying Vector AutoRegressive (TVVAR) modeling procedure is applied as well as Time Varying Bayesian method. Next, the nonlinear equation for estimation of directional wave spectra is directly modeled as a nonlinear equation for estimation of directional wave spectra and a particle filter is applied. The verification of the proposed procedure is carried out based on a simple numerical experiment. In this paper, we report on the obtained finding.

ESTIMATION OF INSTANTANEOUS CROSS SPECTRA OF A SHIP MOTIONS DATA

Time varying vector autoregressive model

According to Kitagawa and Gersh (1996), in general, a TVVAR model for the analysis of a nonstationary k-dimensional time series sampled every Δt second is defined by

\[ y(n) = \sum_{i=1}^{P} A_i y(n-i) - u(n) \]  

(1)

where \( p \) is the autoregressive order, \( A_i(n) \) is the \( k \times k \) autoregressive coefficient matrix for the \( l \)-lag component, and \( u(n) \) is the \( k \)-dimensional Gaussian white-noise sequence with mean zero and covariance matrix \( \Sigma_u \). We also assume that \( u(n) \) is independent of \( y(m) \) for \( n > m \). In this equation, the size of \( u(n) \) is \( k \times k \times p \). This means that the estimation requires a large amount of calculation and computer memory capacity at every step. Therefore, the TVVAR model with an instantaneous response is introduced for efficient calculation and is shown as follows:

\[ y(n) = D y(n) + \sum_{i=1}^{P} B_i y(n-i) + \varepsilon(n) \]  

(2)