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Technical note

Ocean wave forecasting using recurrent neural networks

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Abstract

The tremendous increase in offshore operational activities demands improved wave forecasting techniques. With the knowledge of accurate wave conditions, it is possible to carry out the marine activities such as offshore drilling, naval operations, merchant vessel routing, nearshore construction, etc. more efficiently and safely. This paper describes an artificial neural network, namely recurrent neural network with rprop update algorithm and is applied for wave forecasting. Measured ocean waves off Marmugao, west coast of India are used for this study. Here, the recurrent neural network of 3, 6 and 12 hourly wave forecasting yields the correlation coefficients of 0.95, 0.90 and 0.87, respectively. This shows that the wave forecasting using recurrent neural network yields better results than the previous neural network application.

Keywords: Wave forecasting; NARX recurrent network; Correlation coefficients

1. Introduction

Ocean waves can be either forecasted using the meteorological conditions or hindcasted from the existing meteorological charts. However, the forecast may not accurately represent the measured values. The parametric or differential equation based on wind wave relationship and a differential equation of wave energy are solved numerically in wave forecasting. This is generally employed to give an estimate over the following 6–72 h or so. The spatial wave information on numerical wave forecasting schemes are

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useful and attractive in many applications, but it needs elaborate meteorological and oceanographic data sets and involves an enormous amount of computational effort. Apart from this translation of data from wind to waves results in an element of uncertainty and approximation of forecasts (Herbich, 1990).

The work carried out by Deo and Naidu (1999) describes the application of neural network analysis in forecasting of waves and is carried out for significant wave height (Hs) with 3-h lead period. They have carried out various combinations of training patterns to obtain the desired output. Also the work of average 12 h and a day wave forecasting are carried out. In their work the backpropagation, cascade correlation and conjugate gradient methods are used with the input layer of one node. The correlation coefficients obtained for the lead of 3 h, half day and a day are 0.81, 0.78 and 0.71, respectively. Using updated algorithms in backpropagation neural network, the wave forecasting yielded better results (Rao et al., 2001). Improved correlation coefficients for the lead of 3 h, half-day and a day are obtained as 0.93, 0.80 and 0.73, respectively. Deo et al. (2001) have demonstrated the use of neural networks for wave forecasting for three different sets of data. It shows that a proper trained network could yield good results in open wider areas, in deep water and when the sampling and prediction interval are large (say, week). More and Deo (2003) have used Elman and Jordan types recurrent neural networks (RNN) for wind forecasting. Ho et al. (2002) have carried out a study on predictive compressor failures by autoregressive integrated moving average (ARIMA) and RNN models. They showed that RNN at the optimal weighting factor gives satisfactory performances compared to the ARIMA model. Kermanshahi (1998) has applied RNNs for forecasting next 10 years loads of nine Japanese utilities. Hindcasting of storm waves using backpropagation neural network was carried out by Rao and Mandal (2005).

This paper deals with the forecasting of wave heights directly from measured waves. Significant wave heights are forecasted using recurrent neural networks. Here, nonlinear autoregressive models with exogenous inputs (NARX) recurrent algorithms are used in backpropagation neural network.

2. Backpropagation neural network

The artificial neural network (ANN) is similar to the biological neurons, works on the input and output passing through a hidden layer. The ANN used here is a data-oriented modeling technique to find relations between input and output patterns by self learning and without any fixed mathematical form assumed beforehand. Here one need not necessarily have the knowledge of the underlying physical process being involved. In this work, inputs are the consecutive points of significant wave heights and the output is a predicted wave height. The ANN is organised in the form of layers. The first one is the input layer consisting of nodes equal to the number of input values. The last one is the output layer and the number of nodes is equal to the number of output values. The layer between the input and the output is called the hidden layer having number of nodes. The output of nodes, $f(x)$