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Tidal level forecasting using functional and sequential learning neural networks

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Abstract

Prediction of tides is very much essential for human activities and to reduce the construction cost in marine environment. This paper presents two methods (1) an application of the functional networks (FN) and (2) sequential learning neural network (SLNN) procedures for the accurate prediction of tides using very short-term observation. This functional network model predicts the time series data of hourly tides directly while using an efficient learning process by minimizing the error based on the observed data for 30 days. Using the functional network, a very simple equation in the form of finite difference equation using the tidal levels at two previous time steps is arrived at. Sequential learning neural network uses one hidden neuron to predict the current tidal level using the previous four levels quite accurately. Hourly tidal data measured at Taichung harbor and Mirtuor coast along the Taiwan coastal region have been used for testing the functional network and sequential neural network model. Results show that the hourly data on tides for even a month can be predicted efficiently with a very high correlation coefficient.

Keywords: Functional network; SLNN; Error minimization; Correlation coefficient; Euclidean norm; Orthogonalization

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Nomenclature

a	undetermined parameters
C_i^j	weight of synapse connecting jth neuron of input to ith hidden neuron
E	error
F	function
I	input
O	output
u	tidal level
w_i	weight of synapse connecting ith hidden neuron to output neuron
x	variable
η	learning rate
γ	gamma value
λ	sigmoidal gain
ϕ	shape functions
ξ	non-dimensional value

1. Introduction

Accurate tidal prediction is an important problem for construction activities in inlet, coastal and offshore areas. In some coastal areas, the slopes are very gentle and tidal variation makes the waterfront distances in the range from hundred meters to a few km. Similarly tidal data is important for the construction of jetties, harbors and navigation. In offshore areas, accurate tidal data is helpful for successful and safe operations, such as platforms being installed, navigation, loading and unloading in the high tide zonal area. Theoretical expression of tides was first derived by Newton in 1687 and then by Bernoulli in 1741 [1]. The harmonic analysis of tidal prediction made by Thomas was subsequently extended by Darwin [2]. Darwin [3] proposed a classic theory for the equilibrium tide that describes the property of the tidal-level variations for an open sea, but it gives inaccurate results for a region with complicated bottom topography and in the near shore area. Doodson [4,5] employed the method of least squares to ascertain the harmonic parameters of tidal constituents of days or hours. Since then, the harmonic analysis has been adopted conventionally to predict the tidal level. The accuracy of the method depends on accurate data measured over a very long term to determine the parameters of the tidal constituents. Instead of using the least-squares method, Yen et al. [6] utilized the Kalman filtering technique for the short-term prediction of tides at Kaohsiung Harbor, Taiwan. This has helped in overcoming the problem of conventional harmonic analysis, which requires a long period of measured tides. Yen et al. have used harmonic tide prediction model with four main tidal components. However, the accurate prediction of tidal levels has remained a concern for coastal engineers.

The artificial neural network (ANN) has been used for predicting some phenomena in marine environment by Williams [7] and Grubert [8]. Vaziri [9] used ANN and ARIMA models for predicting Caspian Sea mean monthly surface water level. Deo and Chaudhari [10] used ANN