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Weekly Prediction of tides using Neural networks

Akhil Muhammad Salim[a]*, Dr. G.S. Dwarakish[a], Liju K.V. [a], Justin Thomas[a],Gayathri Devi [a], Rajeesh R [a].

[a]*Department of Applied Mechanics and Hydraulics, National Institute of Technology Karnataka, Surathkal, Srinivasnagar P.O, Mangalore, Karnataka, India - 575025*

Abstract

Knowledge of tide level is essential for explorations, safe navigation of ships in harbour, disposal of sediments and its movements, environmental observations and in many more coastal engineering applications. Artificial Neural Network (ANN) is being widely applied in coastal engineering field for solving various problems. Its ability to learn highly complex interrelationships based on the provided data sets, along with less amount of data requirement, makes it a powerful modelling tool. The present work is related to predicting the hourly tide levels at Mangalore, Karnataka, using a week's hourly tidal levels as input. The data has been obtained from NMPT, Mangalore and is made use of in predicting tide level using Feed Forward Back Propagation (FFBP) and Non-linear Auto Regressive with eXogenous input (NARX) network. FFBP network yielded correlation coefficient value of 0.564 and NARX network yielded very high correlation coefficient of the order 0.915 for predictions of yearlong hourly tide levels. The study proves that ANN technique can be successfully utilized for the prediction of tides at Mangalore.

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Keywords : *ANN; Forecasting; Tides; Feed Forward Back Propagation; Nonlinear Auto Regression.*

1. Introduction

Oceans have always intrigued humans from time immemorial. They were believed to be the end the world, the edge, for a long time. With the advent of ships, humans slowly mastered travelling over the huge water masses. Later,

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: author@institute.xxx

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with the help of water travel, we understood the shape of the earth was more or less spherical. But even after centuries of contact with oceans, man knows very little about them. The oceans involve physical, chemical and biological processes going on all the time. One of the major physical processes going on in the ocean is that of sea level variation. Tides are the alternating rise and fall of the surface of the seas and oceans. They are mainly due to the gravitational attraction (pull) of the moon and sun on the rotating earth. In recent years, accurate information of tidal level has become very important for the disposal and movement of sediments, tracers and pollutants, offshore constructions in engineering, environmental observations, exploration and oceanography.

The most commonly used technique to predict sea level variation is harmonic analysis, which permits forecast of tidal variations due to a locally modified response to astronomical forcing. Harmonic analysis is a powerful prediction tool but, in fact, sea level variations often differ significantly from predictions. Harmonic analysis also suffers from the fact that the parameters used are numerous and some of which have a very long return period, thus necessitating the collection of a large number of parameters, some of which have a returning period of over a decade. Artificial Neural Network is a relatively new system idealized to mimic the working of human brain. It is helpful in learning the complex relationships of parameters involved in an interaction without having to understand the underlying physics behind. Since it works with the help of units corresponding to neurons in a human brain, it obtained its present nomenclature. It has been extensively used in the field of coastal engineering.

Traditional method of prediction of tides is done by Harmonic method, which accounts for the parameters or constituents of astronomical tide. It is given by the eqn.

$H = H0 + A\cos(at+\alpha) + B\cos(bt+\beta) + C\cos(ct+\gamma) + \ldots$

where, H is the height of the tide at location, H0 is the MSL, A, B, C are the amplitudes of the constituents and $(at+\alpha)$ are the phases of the constituents.

A new model based on the working of human brain has been idealized to meet the objective of learning relationship between complex parameters involved in the interaction without having to know the underlying physics behind it. As it is an attempt to mimic the capabilities of human neural system it is called Artificial Neural Network (ANN). It imbibes the qualities of exploiting non-linearity, adaptability to adjust free parameters (in this case the connection weights, comparable to synaptic connections in human nervous system) by mapping input output data sets using various learning algorithms and fault tolerance. Also it gives accurate results when compared to the available techniques in majority of the cases.

Nomenclature

ANN	Artificial Neural Network
FFBP	Feed Forward Back-propagation
NARX	Nonlinear Auto Regressive Network with exogenous Inputs

2. Methods

2.1. FFBP Network

Development of ANN can be attributed to the attempt carried out to mimic the working pattern of human brain. Its success lies in its ability to exploit the non-linear relationship between input and output data by continuously adapting itself to the information provided to it by means of some learning process. ANN can be classified based on network type in to feed forward and feedback or recurrent networks. The basic difference between the two is that, in feed forward networks the information is passed from one layer to the other in a forward manner till the output is obtained in the output layer. Whereas in, feedback network the output obtained in the output layer is fed back in to the network through input layer thus this type of network will have a minimum of single loop in its structure. Further, ANN can also be classified based on learning type i.e. supervised and unsupervised learning. In supervised learning a set of data input and corresponding output is fed in to the network and the calculated output is compared with target output (given output values to the network) the difference between the two is the error and through various error correction measures available, the network adapts itself till the error reaches a minimum value or fixed number of iterations are complete. In unsupervised learning the networks are tuned to statistical regularities of the input data by learning rules like radial basis function and others, here no input-output data set is presented to the network.

2.2. NARX Network

In the present study along with FFBP, a recurrent type of network namely Non-linear Auto Regressive network with eXogenous inputs (NARX) has also been used. In recurrent networks, the output depends not only on the current input to the network but also on the previous input and output of the network. The response of the static network at any point of time depends only on the value of the input sequence at that same point whereas, the response of the recurrent networks lasts longer than the input pulse. Its response at any given time depends not only on the current input, but on the history of input sequence. This is done by introducing a tapped delay line in the network which makes the input pulse last longer than its duration by an amount which is equal to the delay given in the tapped delay. This makes network to have a memory of the input that is fed. If the network has feedback connections then the effect of the first input sequence will be passed on for all the upcoming outputs.

NARX is a recurrent network, with feedback connections enclosing several layers of the network. It is based on the linear ARX model, which is commonly used in time series modelling. The defining equation for the NARX model is:

$$y(t) = f(y(t-1), y(t-2),...,y(t-ny), u(t-1), u(t-2),\dots, u(t-nu))$$

where, the next value of the dependent output signal y(t) is regressed on previous values of an independent (exogenous) input signal. The output of NARX network can be considered to be an estimate of the output of some non-linear dynamic system that is being modeled. The output is fed back to the input of the feed forward network as part of standard NARX architecture.

3. Results and Discussion

3.1. Prediction using FFBP Network

Three month's hourly data from 1/1/2014 to 30/3/2014 was used to train FFBP networks to predict 1 week, 2 weeks' and 4 weeks' hourly tide level. One week's hourly data from 1/1/2014 to 7/1/2014 was taken as input for prediction of 1 week hourly tide level. The data division for training and simulation are done. The results obtained are not encouraging for 4 weeks prediction with pretty high 'mse' value and low 'r' value in both training and simulation of the network as seen in Table 3.1. The training performance showed considerable increase in 'r' values but simulation 'r' values drastically reduced hinting at the overfitting behaviour of the network when the number of neurons is increased beyond nine during 4 weeks tide level prediction. Overfitting phenomenon refers to a state where there is large number of neurons in hidden layer increasing the complexity of the network, but there is no significant amount of patterns to be learnt by the network based on given input-target datasets. Also the prediction duration is large (4 weeks) compared to input data of one week. Naturally the range of targets will be greater than those of input provided, weakening the prediction capability of the network when new data set is fed to the network.

Table 4.1. Mean square error ('mse') and coefficient of correlation ('r') values for tide level predictions

Network architecture	mse		r	
	Training	Simulation	Training	Simulation

1-1-1	0.0445	0.0785	0.887	0.769
1-3-2	0.0670	0.0816	0.761	0.662
1-9-4	**0.0555**	**0.0885**	**0.789**	**0.564**

3.2. Prediction using NARX Network

Data is divided in to weekly and monthly sets in a similar fashion as done for the purpose of prediction of tides using FFBP network. Weekly predictions are carried out using one week's input data to predict 1, 2, and 4 weeks' tide level predictions respectively. The results obtained in terms of 'mse' and 'r' is very good from 0.98 for one weeks' prediction to 0.92 for 4 weeks prediction. The best performance for prediction of 4 weeks' is obtained for five numbers of neuron in the hidden layer. The variation of 'r' values for the case is shown in table 4.2. The 'r' value will be one when the plot of observed versus predicted values follow a perfect straight line pattern passing through the origin.

Table 4.2. Mean square error ('mse') and coefficient of correlation ('r') values for tide level predictions

Network architecture	mse		r	
	Training	Simulation	Training	Simulation
1-1-1	0.0027	0.0067	0.98956	0.97989
1-3-2	0.0080	0.0084	0.97348	0.97062
1-5-4	**0.0050**	**0.0186**	**0.98317**	**0.91547**

4. Conclusions

The present study makes use of relatively new technique of ANN which has been tried and tested in various coastal engineering applications. In the present study FFBP and NARX network were used to predict tides at New Mangalore Port station on the west coast of India. Predictions for 4 week long tide levels using weekly sets gave unsatisfactory results in FFBP network with co-efficient of correlation values greater than 0.56. Whereas, using the NARX network, one week's data was successfully utilized to predict tides at the same location for four weeks duration with 'r' value greater than 0.91. The NARX network outperformed FFBP network in terms of data requirement and accuracy achieved, also it took less computational time as well. It can be concluded that NARX network with three layered architecture and 5 neurons in the hidden layer can be successfully used to predict month long tide levels at Mangalore station using one week's tide level as input.

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