WAVE HEIGHT FORECASTING USING ARTIFICIAL NEURAL NETWORK AND FUZZY LOGIC

[1]V. R. KASHIKAR, [2]S. J. MANE

[1]M.E. Student(Env. Engg), [2]Asst. Professor, D.Y. Patil College of Engineering, Akurdi
E-mail: virajkash@yahoo.co.in, msachin77@yahoo.com

Abstract- The present work aims at development of an artificial neural network (ANN) model for forecasting ocean wave height in coastal areas. This study is targeted because these waves are causing a great threat to common man thus disrupting human life. Prediction of significant wave heights (Hs) is of immense importance in ocean and coastal engineering applications. The hourly data set consisting of wave height for 1 year used in the study is collected from National Data Buoy Centre (NDBC) of Station 44013 lying in Boston Area of United States. In order to provide an operational forecasting module for wave height, multilayer perceptron, generalized feed forward and time lag-recurrent network models of artificial neural network and CANFIG Network of Fuzzy Logic are investigated to forecast wave heights. Artificial neural network models based on a three-layered feed forward neural network trained by back-propagation algorithm are investigated and applied. Performance of artificial neural network and Fuzzy Logic for various inputs have been analysed and the results are discussed. The network is trained by different algorithms and it is used to forecast wave height with lead time of 1 hour. The trial and error method is adopted to compare network output with desired output in terms of error statistics viz. R and MSE. The output using generalized feed forward network with conjugate gradient algorithm displayed good results (R=0.98) and (MSE=0.025 m^2) as compared to CANFIG Network of Fuzzy logic giving (R=0.96) and (MSE=0.047 m^2). The results obtained shows that artificial neural network can be efficiently used in the analysis and prediction of wave height as compared to Fuzzy Logic.

Keywords- Artificial Neural Network, Fuzzy Logic, Training, Multilayer Perceptron, Feed Forward Network, Recurrent Network, CANFIG Network, Wave Height.

I. INTRODUCTION

Waves are the forward movement of the ocean's water due to the oscillation of water particles by the frictional drag of wind over the water's surface. Waves have crests (the peak of the wave) and troughs (the lowest point on the wave). The wavelength, or horizontal size of the wave, is determined by the horizontal distance between two crests or two troughs. The vertical size of the wave is determined by the vertical distance between the two. Waves travel in groups called wave trains. Waves can vary in size and strength based on wind speed and friction on the water's surface or outside factors such as boats. The small wave trains created by a boat’s movement on the water are called wake. By contrast, high winds and storms can generate large groups of wave trains with enormous energy. In addition, undersea earthquakes or other sharp motions in the seafloor can sometimes generate waves called tsunamis (inappropriately known as tidal waves) that can devastate entire coastlines.

Lack of efficient wave height prediction has caused various calamities thereby destructing human life. Traditional deterministic methods employed failed to give accurate results. Hence, the trend has been to use statistical methods instead of traditional deterministic methods to forecast ocean waves. ANN models have been used for forecasting of wave height at various time intervals. Many researchers have successfully used ANN models for prediction of ocean waves and found that the ANN model is suitable for predicting ocean waves [1].

The inspiration for neural networks came from examination of central nervous systems. In an artificial neural network, simple artificial nodes, called "neurons" or "processing elements" are connected together to form a network which mimics a biological neural network. There is no single formal definition about artificial neural network. Generally, it involves a network of simple processing elements exhibiting complex global behavior determined by the connections between the processing elements and element parameters. Artificial neural networks are used with algorithms designed to alter the strength of the connections in the network to produce a desired signal flow.

In this study, ANN models with back propagation algorithm are used to forecast ocean waves in Boston Area of the United States.

II. THE NETWORK AND TRAINING ALGORITHMS

2.1 Feed forward network
One of the networks used in the present study is of feed forward type, which has the ability to approximate any continuous function. As shown in Fig.1, the input nodes receive the data values and pass them on to the first hidden layer nodes. Each hidden node collects the input from all input nodes after multiplying each input value by a weight, attaches a

bias to this sum and transforms it through a non-linearity like the sigmoid transfer function. This forms the input to the subsequent hidden layer or to the output layer that operates identically to the first hidden layer. The resulting nonlinearly transformed output from each output node constitutes the network output.

A typical artificial neural network consists of an interconnection of computational elements called neurons. Each neuron basically carries out the task of combining the input, determining its strength by comparing the combination with a bias and firing out the result in proportion to such a strength. Mathematically,

$$O = 1/(1 + e\text{-}S) \quad (1)$$

where, $S = (x1\ w1 + x2\ w2 + x3\ w3 + \ldots\ldots) + \cdot$ (2)
In which,

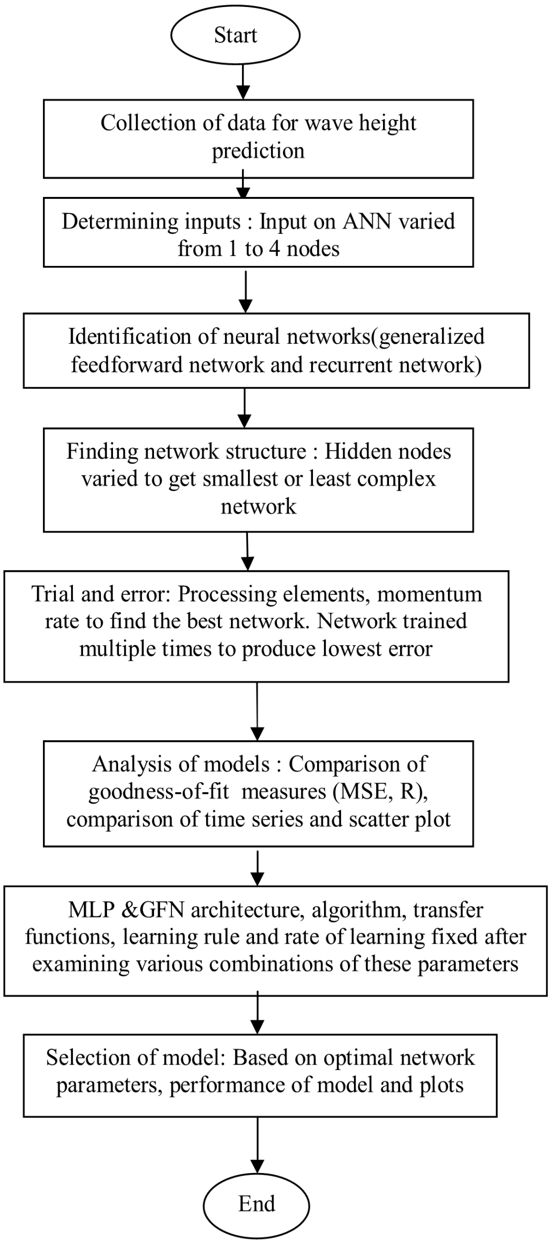

Figure (3). Flow chart of methodology

III. ANN MODEL

Out of large number of ANN models developed for the data sets, best ANN model is investigated in detail. The goodness-of-fit measures considered in the present study to evaluate the developed models are mean square error (MSE) and coefficient of correlation (R) between the forecasted and observed inflows. The R and MSE are good measures for indicating the goodness-of-fit at moderate and high output values, respectively and the values equal to zero indicates perfect fit. The R value quantifies the efficiency of a model in capturing the complex, dynamic and non-linear nature of the physical process being modeled and the value equal to one shows perfect fit [7]. The number of hidden neurons is of the order of 2 to 3 for various networks. The transfer function used is sigmoid for both hidden layer as well as output layer. Various combinations of training and testing are adopted. Out of the various training rules, Conjugate-Gradient rule gives the most satisfactory results. The weight and bias matrices of the trained network are retained for testing the network. The numbers of epochs provided for the network are 1000. The prediction accuracy of the networks is judged by calculating the correlation coefficient, R, between the predicted and observed wave heights at these locations. The corresponding results of (R) and (MSE) for various lead times for station 44013 is shown in Table (1) below:

Network and Pattern	Transfer Function (Hidden Layer)	Learning rule	Epoch	R	MSE (m^2)
CANFIG Network	Sigmoid Axon	Leverberg-Marquarckt	1000	0.93	0.042
	Linear Sigmoid Axon	Conjugate Gradient	1000	0.91	0.036
	Tanh Axon	Leverberg-Marquarckt	2000	0.96	0.047
Generalized Feed Forward Network ANN(4-3-1)	Linear Sigmoid Axon	Leverberg-Marquarckt	1000	0.92	0.052
	Sigmoid Axon	Conjugate Gradient	2000	0.95	0.046
	Sigmoid Axon	Conjugate Gradient	**2000**	**0.98**	**0.025**
Recurrent Network ANN(4-2-1)	Linear Sigmoid Axon	Leverberg-Marquarckt	1000	0.75	0.052
	Tanh Axon	Conjugate Gradient	1000	0.78	0.052
	Sigmoid Axon	Leverberg-Marquarckt	1000	0.79	0.058

Table (1). Testing of ANN in terms of Error Statistics for Station 44013

Out of the results obtained in the above table, generalized feed forward network gives more accurate results as compared to other results. The graphs of Output vs Desired and Predicted Wave Height vs Time for Station 44013 for 1st Hour are being elaborated in Fig (5) and Fig (6) below:

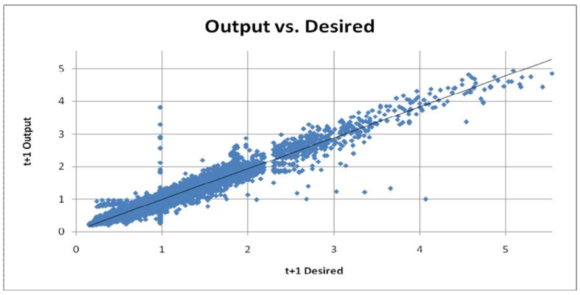

Fig (5). Scatter plot of Output vs Desired Wave height

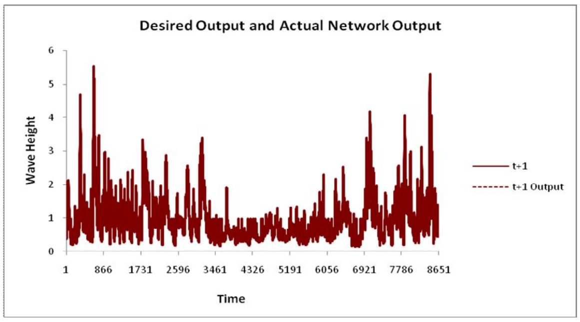

Fig (6). Plot of Wave height vs Time at (t+1) time interval

IV. RESULTS AND DISCUSSIONS

Accurate efficiency is obtained at Station 44013 having value of R to be 0.98 and MSE of 0.025 m^2. The network adopted is Generalized Feed Forward Network and the training rule used is Conjugate Gradient Algorithm. Numbers of epochs provided are 1000 and the network architecture provided is (4-3-1).

V. SOFTWARE USED

The forecasting software used is Neurosolutions 6 by Neurodimensions. It is an efficient software used for forecasting and analyzing. It analyses input data in Excel format and creates various networks. These networks are formed by various training-testing patterns and various learning algorithms. The networks are in turn saved in the form of breadboards. Prediction results are obtained from the software in the form of (R) and (MSE). It has various applications in population forecasting, weather forecasting etc. Hence, it is proven to be an efficient software for analyzing and forecasting.

CONCLUSION

The network adopted is Generalized Feed Forward Network and the training rule used is Conjugate Gradient Algorithm. Numbers of epochs provided are 1000. The best efficiency of 0.98 is obtained at network architecture of (4-3-1) with the above mentioned training rule. Hence, it can be concluded that artificial neural network gives more accurate results as compared to fuzzy logic.

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