APPLICATION OF A NEURAL NETWORK MODEL FOR DISASTER MANAGEMENT IN BANGLADESH

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Summary

Natural disasters, especially cyclones, cause enormous damage to the people and economy of Bangladesh every year. Structural measures to cope with this problem may not be economically feasible. Evasive measures are the most feasible alternative for disaster management in Bangladesh. To take evasive measures, it is essential to forecast damages caused by these disasters beforehand so that commensurate relief and rehabilitation activities can be maintained in and around the cyclone hit areas and mobilized immediately. The forecasts can be made through the use of forecasting models. In this paper a set of models is presented to forecast damages caused by cyclone. These models are developed using neural network (NN) technique. It is observed that the NN technique can be applied successfully to predict the casualties and damages caused by cyclone. The paper also presents the methodology to use these models for the analysis of the effects of cyclone parameters. The models developed in this study may be used to plan relief and rehabilitation works judiciously to alleviate economic losses caused by cyclone.

Introduction

Bangladesh is a disaster prone country. Every year, natural disasters like cyclones cause many casualties and massive loss to the economy of the country. One way of reducing the damages caused by these disasters is to take structural measures through building infrastructures strong enough to withstand disasters of any magnitude. Although this measure is adopted, to some extent, in the developed countries, it is neither economically nor structurally feasible to construct all the structures in such a way. The other alternative is to reduce the damages and people's sufferings through building a few strong structures, like cyclone shelters, and remain prepared with relief and rehabilitation materials in those shelters so that relief activities can be staffed as soon as the cyclone is over. The sooner the relief and rehabilitation activities start, the smaller will be the casualties and economic losses. The major problem with this approach is that all the shelters can not be kept prepared with a large amount of relief and rehabilitation materials all the time. Relief materials must be allocated according to the requirement. Also, these must be sent to the respective areas before the cyclone hits. Otherwise, the cyclone hit areas may become inaccessible by large vehicles required to carry the materials. In this regard, it is required to assess the damages caused by a cyclone before it hits. This can be done by forecasting models. Although, the forecasting models are widely used to predict damages for planning purpose in other countries, it is yet to be used for assessing damages caused by cyclone in Bangladesh. This can be attributed to the complexities of modelling this kind of phenomenon and unavailability of data. In this paper, a set of models is developed to predict damages caused by cyclone and applied to study the effects of different cyclone parameters.

Methodology

For forecasting purpose, several approaches are usually used which include empirical, mathematical, microscopic simulation and neural network models. From preliminary investigation, it is found that the neural network technique is the most appropriate one for prediction of casualties and damages caused by cyclone.

Artificial neural networks (ANN) have received considerable interest during last few years due to their wide range of applications and ability to handle problems involving imprecise and highly complex nonlinear data. Also, it can overcome the problem of specification and variable selection error endogenously. The major advantage of neural network approach over traditional empirical or mathematical modelling approaches is their learning and prediction capabilities which combine with higher accuracy. The concepts of neural networks are initiated by Hebb (1949) and Rosenblatt (1959). Recently it has been extended by Hopfied (1982), Feldman and Dallard (1982), Rumelhart and McClelland (986) and Lippmann (1987) through the development of new topologies and algorithms. The neural network technique is widely used for prediction of damages caused by natural disaster such as earthquake (Song et al., 1996).

Structure of Neural Network and Back Propagation Algorithm

A neural network is composed of a large number of interconnected non linear computing elements or neurons organised in a number of layers. The first and the last layers are known as input and output layer respectively. The layers between these two are known as hidden layer. The flow of information is passed through the network by linear connections and linear or non-linear transformations. A schematic diagram of a neural network is shown in Figure 1.

The weighing factors of the connections between the nodes (neurons) are determined by training the neural network (NN) with observed data. One of the techniques for calibrating the network is to use 'Back Propagation' method. Here the mean square error between the actual output of a multi-layer neural network and the observed output is minimised to obtain the weights of linear connections.

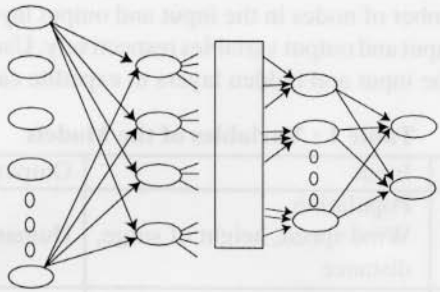

Figure 1 : A multi layer neural network

Design of Neural Network Model

The design of a neural network model requires three steps: selection of the variables, selection of number of layers and nodes, selection of transfer function.

Selection of the Variables

For the construction of a neural network model the selection of the variables primarily depends on the availability of data. Although the importance of the variables to be included in a model is endogenously determined, it is closely related to the number of hidden layers and their nodes (neurons). In the present study, initially it was tried to incorporate all the data in a single model. However, the model could not be calibrated due to too much variability in the data. Had the number of hidden layers and nodes been increased, this could have been successful. Again, the whole process could have become very complex and computational difficulties could have increased greatly. To overcome the problem, the variables are separated into four models so that each model handles one or two outputs only. Input variables are also arranged accordingly. The variables considered in the models are shown in Table 1.

Selection of the Number of Hidden Layers and Nodes

A review of literature suggests that for calculation purposes it is better to minimise the number of hidden layers. One hidden layer, resulting in a three layered NN, is sufficient for most of the applications. Considering this, it is decided that the networks developed in this study will have one hidden layer only. The number of nodes in the hidden layer is determined on the criteria of obtaining minimum total error at optimum with the minimum number of iterations. The number of nodes in the input and output layers are determined by the number of input and output variables respectively. Usually a random bias node is added in the input and hidden layers to expedite calibration process.

Table 1 : Variables of the Models

Models	Input	Output
Human casualties model	Population Wind speed, height of surge, distance	Human casualties
Livestock Casualties model	Livestock Wind speed, height of surge, distance	Livestock casualties
House damage model	Number of houses Wind speed, height of surge, distance	Fully damaged houses Partly damaged houses
Road damage model	Paved roads Unpaved roads Wind speed, height of surge, distance	Paved roads damaged Unpaved roads damaged

Selection of Transfer Function

The output from any node of hidden and output layers is a function of net input (weighted sum) from the earlier layer. Sigmoidal function, shown below, is widely used for this purpose. The salient feature of sigmoidal function is that it reaches the minimum and maximum values asymptotically when its argument approaches negative and positive infinity respectively.

Sigmoidal transfer function for the nodes in j - th layer, $f_j = \frac{1}{1+\exp(\Sigma w x_{j-1})}$ (1)

Where w is the vector of weights and x_{j-1} is the vector of outputs of (j-1)-th layer.

Data Collection and Analysis

Obtaining accurate data on the damages caused by cyclone is extremely difficult especially in the countries like Bangladesh where such records are not collected and maintained properly. For the purpose of training the NN models, data of 1991 cyclone is used. The data has been collected from a couple of sources and verified for accuracy. These sources include Cyclone Preparedness Program (CPP) of Bangladesh, Red Crescent Society (BDRCS), CARE

Bangladesh Ltd., Bangladesh Meteorological Department etc. Reports from various government and non government organisations have also been used for this purpose which include Task Force Report (IEB, 1991) and Report of Operation SEBA (1991).

In the night between 29th and 30th April 1991, a devastating cyclone had hit the coastal areas of Bangladesh, particularly Chittagong area. About 150,000 people died and colossal damage occurred to livestock, agriculture, power and telecommunication systems, housing and other physical infrastructure facilities.

Data has been collected on human casualties, loss of livestock and damages to houses and roads in 89 upazilas. In the models these are related to socio economic variables and cyclone parameters. The socio economic variables include population, amount of livestock, number of houses and length of paved and unpaved roads. The cyclone parameters include wind speed, height of water surge and distance of the area from the path of cyclone.

Using the data described above, four neural network models are developed. The weights of the models are shown in Tables 2-5 where the number of nodes in different layers correspond to the variables described in Table 1. The last rows in each table corresponds to the random bias. The validity of the models is examined through comparing the outputs of the models with observed data for holdout samples. The results of the validation test of Human and Livestock Casualty Model are shown in Figures 2 and 3. It is observed that the model outputs are highly congruent with the observed data.

Application of the Models

The models developed in the study have been applied to predict damages in a couple of hypothetical cyclones to study the effect of various cyclone parameters. The results of the applications of the models to predict human casualties are presented in Figures 4-6. In the applications the variables other than the concerned ones are assumed to be constant. The results converge with expectations and it is observed that the height of water surge has the most detrimental effect on the damages.

Table 2: Weights of human casualties NN model

		Input Layer				
		1	2	3	4	5
Hidden Layer	1	0.19634	-0.87714	1.30158	-0.34459	3.1610
	2	3.33350	-2.45705	-0.73589	2.51458	1.8687
	3	-1.72808	1.36750	1.18827	1.76945	-2.4176
	4	-3.76231	2.22649	-3.61593	6.05176	-3.7473
	5	0.27059	-1.85143	1.37785	2.07715	-2.7734

		Output Layer
Hidden Layer	1	-7.79233
	2	5.33333
	3	1.48255
	4	8.19039
	5	1.62397
	6	1.25171

Note: Target error on the normalized data = 0.07, Nos of Iteration = 2340

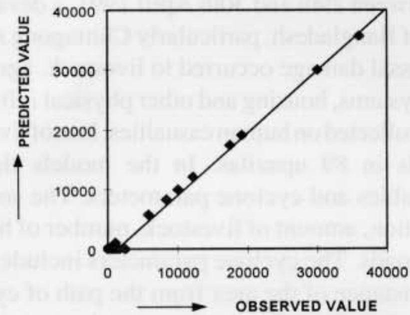

Figure 2 : Validation test for human casualties

Table 3 : Weights of livestock casualties NN model

		Hidden Layer				
		1	2	3	4	5
Input Layer	1	-5.43921	0.97924	-5.51114	-2.28460	-0.90988
	2	-2.20138	-2.24454	-6.86604	2.02925	4.21427
	3	-1.30766	-2.47380	-1.51448	-2.52850	2.95938
	4	4.40256	1.62243	-3.83840	-1.32177	2.19640
	5	2.65970	4.73467	-2.57292	2.83107	-2.33093
	6	1.85437	5.65718	2.71055	-1.68307	-3.34639

		Output Layer
Hidden Layer	1	-6.55137
	2	6.49338
	3	-3.51835
	4	0.83158
	5	-1.36235
	6	4.80872
	7	-2.00542

Note: Target error on the normalized data = 0.07, Nos of Iteration = 20280

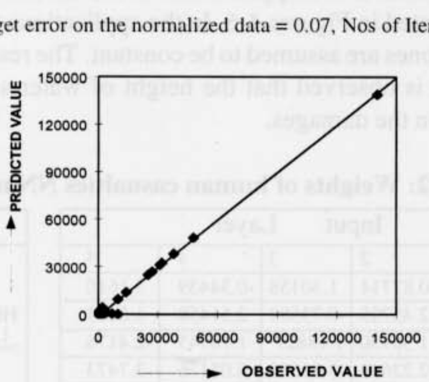

Figure 3 : Validation test for livestock casualties

Table 4 : Weights of house damage NN model

Hidden Layer		1	2	3	4	5
Input Layer	1	-13.00607	3.42196	-5.41748	2.87187	-3.23610
	2	-9.14556	1.23823	-9.83202	3.01175	-8.66759
	3	0.52501	0.89490	-3.90445	0.56169	0.85146
	4	0.22930	-0.78694	8.24885	1.26094	6.55861
	5	0.68223	1.88781	1.36201	-2.01191	4.24527

Output Layer			
Hidden Layer	1	-2.686276	2.43747
	2	0.874634	-1.09848
	3	0.969809	11.18282
	4	-1.621277	8.28026
	5	-8.398708	0.55443
	6	7.221180	-14.83669

Note: Target error on the normalized data = 0.07, Nos of Iteration = 37610

Table 5 : Weights of road damage NN model

Hidden Layer		1	2	3	4	5	6
Input Layer	1	0.63237	-2.04653	-1.29920	0.39568	-4.31960	-12.15550
	2	1.15826	-0.74652	-1.45124	-3.10913	1.17527	2.08696
	3	-6.72298	6.09270	9.74147	11.22022	0.51755	-6.00058
	4	1.02811	-1.76149	-1.18925	-0.71987	2.88101	5.24500
	5	-3.63081	4.99636	1.62363	7.33397	-5.94893	1.34770
	6	2.89923	9.43209	10.69519	-7.39120	3.83784	11.84873

Output Layer			
Hidden Layer	1	2.39117	-4.17047
	2	-5.43411	-1.98627
	3	-3.51430	-2.98663
	4	2.49013	4.63260
	5	2.65300	1.43057
	6	1.65012	-2.37816
	7	-1.78607	0.33740

Note: Target error on the normalized data = 0.07, Nos of Iteration = 43425

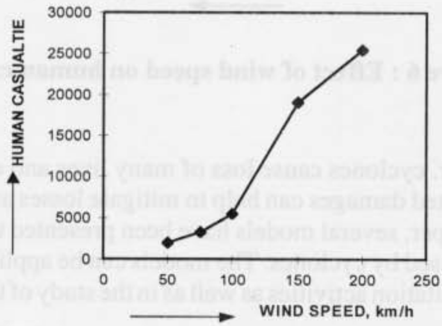

Figure 4 : Effect of wind speed on human casualties

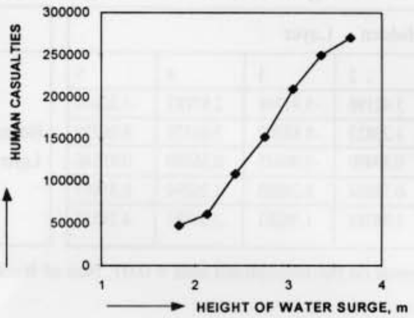

Figure 5 : Effect of water surge on human casualties

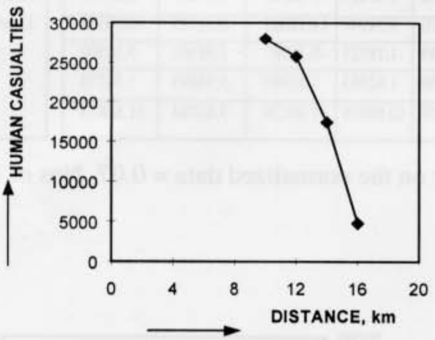

Figure 6 : Effect of wind speed on human casualties

Conclusions

Every year, cyclones cause loss of many lives and economic resources. Properly forecasted damages can help to mitigate losses and suffering Significantly. In this paper, several models have been presented to forecast casualties and damages caused by cyclones. The models can be applied in the planning of relief and rehabilitation activities as well as in the study of the effects of cyclone parameters.

The models presented in this paper have several limitations. The accuracy of the model predictions are dependent on the accuracy of the input data especially cyclone parameters. Also, error (in the form of over and under reporting of data) may result in erroneous calibration, which in turn may cause erroneous predictions (over and under estimation). Another important aspect is the change in people's awareness due to improved warning system and precautionary measures. In this case, the actual casualties and damages may be lower than the same predicted by the models. For this purpose, the models should be updated continuously.

The models presented here can be extended to include other types of casualties and can be integrated into a comprehensive expert system in GIS framework.

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