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Slope Stability Prediction using Artificial Neural Network (ANN)

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Abstract: ***Artificial neural networks (ANN) usually called neural networks are very sophisticated modeling techniques which are capable of modeling extremely complex functions. They are used for predicting the outcome of two or more independent variables. Predicting the stability of slopes is a very challenging task for the geotechnical engineers. They have to pay particular attention to geology, ground water and shear strength of the soils in accessing slope stability. In this paper, a prediction formula has been developed for predicting the factor of safety (FOS) of the slopes using ANN. A total of 110 cases with different geometric and soil conditions were analyzed using Bishop's Simplified Method. Out of these, 100 cases were used to train up the prediction model. The computational method for the training process was a back propagation learning algorithm. The prediction model is validated by comparing the results with the remaining 10 cases.***

Keywords: Artificial Neural Network, Back-propagation, Factor of Safety, Shear Strength, Slope Stability.

1. Introduction

The introduction of artificial neural network (ANN) continues to captivate scientists and engineers from a variety of disciplines. This growing interest among the researchers is stemming from the fact that these learning machines show excellent performance in understanding the patterns and developing the non-linear relationships of multivariate dynamic systems. In this paper, an investigation has done to validate the utilization of ANN in the physical problem of slope stability prediction. The accurate estimation of the stability of rock or soil slope is a very challenging task for the geotechnical engineers. This is mainly due to the complexity of the physical system itself and the difficulty in determining the geotechnical input data parameters. The analysis must be carried out by considering the site subsurface conditions, ground behavior, and applied loads. It is due to its practical importance that slope stability analysis has drawn the attention of many investigators. The judgments regarding the risk factor and the safety factor must be made to evaluate the results of analyses. Therefore, slope investigation and classification are important for the community [1], [2], [3], [4]. Although the slope stability prediction is a very challenging task yet it has developed its existence to a great extent in the last two decades. Many researchers from the geotechnical background are constantly working to find new prediction models for determining the slope stability. Sakellariou and Ferentinou used ANN to predict the stability of slopes for circular failure and wedge failure mechanism and came up with the conclusion that the input parameters are having close relationships with the output parameters [5]. Kayesa predicted the slope failure of Letlhakane mine using Geomos slope monitoring system which contributed a lot in avoiding potentially fatal injury and damage to mining equipments [6]. Davis and Keller studied on uncertainty behaviour of soil and developed a slope stability prediction model based on fuzzy sets and Monte Carlo simulation [7]. The use of evolutionary polynomial regression (EPR) technique for predicting the stability of soil and rock by Ahangar-Asr et al. is found to be very effective and robust in slope behaviour modeling [8]. Mohamed et al. used the concept of fuzzy logic system for prediction and found that the results are having higher degree of accuracy [9]. Erzin and Cetin developed another prediction model uasing ANN and multiple regression (MR) for estimating the FOS of an artificial slope subjected to earthquake forces [10]. The obtained indices make it clear that ANN model has higher prediction performance than the MR model. Sternik made a comparison study of two slope stability prediction models developed by shear strength reduction (SSR) method and gravity increase (GI) method with Bishop's Simplified Method [11]. The comparison results culminated that SSR method gives more close results compared to GI method.

2. Methodology

In this research, 110 slope cases having different geometrical and slope parameters were selected along Guwahati-Shillong Highway (NH-40), India. Soil samples were collected and laboratory tests were performed to find out the various soil parameters. These slope parameters were used to analyze the various slopes using Bishop's Simplified Method to find the FOS. Out of these, 100 cases were used to develop the prediction model using ANN. In the proposed model, several important parameters including, height of the slope (H), cohesion (C), angle of internal friction (φ), angle of the slope (β) and unit weight of soil (γ) were used as input parameters whereas the FOS was used as the target value. The ANN model was prepared in Matlab 2011a (Figure. 1).

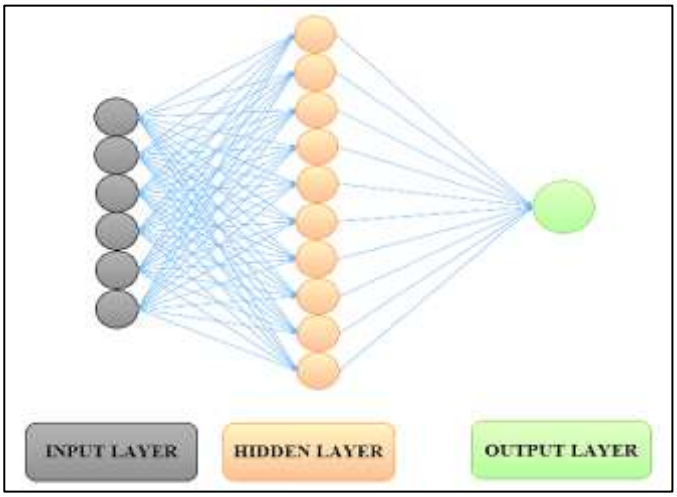

Figure 1: Structure of a three-layer artificial neural network

For understanding the patterns present in the data, the data set needs to be trained. For finding the optimum weight combination, the network was trained up using Levenberg-Marquardt back propagation method. Many approaches can be used to determine when to stop training. Training can be stopped after the presentation of a fixed number of training records, when the training error reaches a sufficiently small value, or when no or slight changes in the training error occur. However, the above techniques of stopping criteria may lead to the model stopping prematurely or over training. Such problems overcome with the use of cross-validation technique, [12] where the data is divided into three distinct sets, viz., training, testing and validation. The objective of training is to find the set of weights between the neurons that determine the global minimum of error function. The main function of the testing set is to evaluate the generalization ability of a trained network and the validation set performs the final check of the trained network. Training is stopped when the error of the testing set starts to increase. Here, out of 100 slope cases, 80 % of the data set was used for training and the remaining were used for testing and validating the model. Once the training process is successfully completed, the performance of the trained model is validated. The coefficient of correlation, R and the root mean squared error, RMSE, are the main criteria that are often used to evaluate the prediction performance of ANN models.

3. Results and Discussions

The regression plot showing the value of R for training, testing and validation is shown in Figure. 2. From the regression plot, it was found that the value of R equals to 0.99 which is very close to unity. Hence, it can be stated that the prediction results should bear a close relationship between the input variables.
The model is validated by comparing the results with the remaining 10 slope cases and found that the predicted results are having a very close relationship with the actual results. The value of correlation coefficient, R is found to be 0.98 and having a very low RMSE value of 0.06. The Simulink model for ANN is shown in Figure. 3 and the comparison of predicted results and actual results of FOS is shown in Figure. 4. Hence, it can be concluded that ANN can be used as a good prediction tool for slope stability analysis.

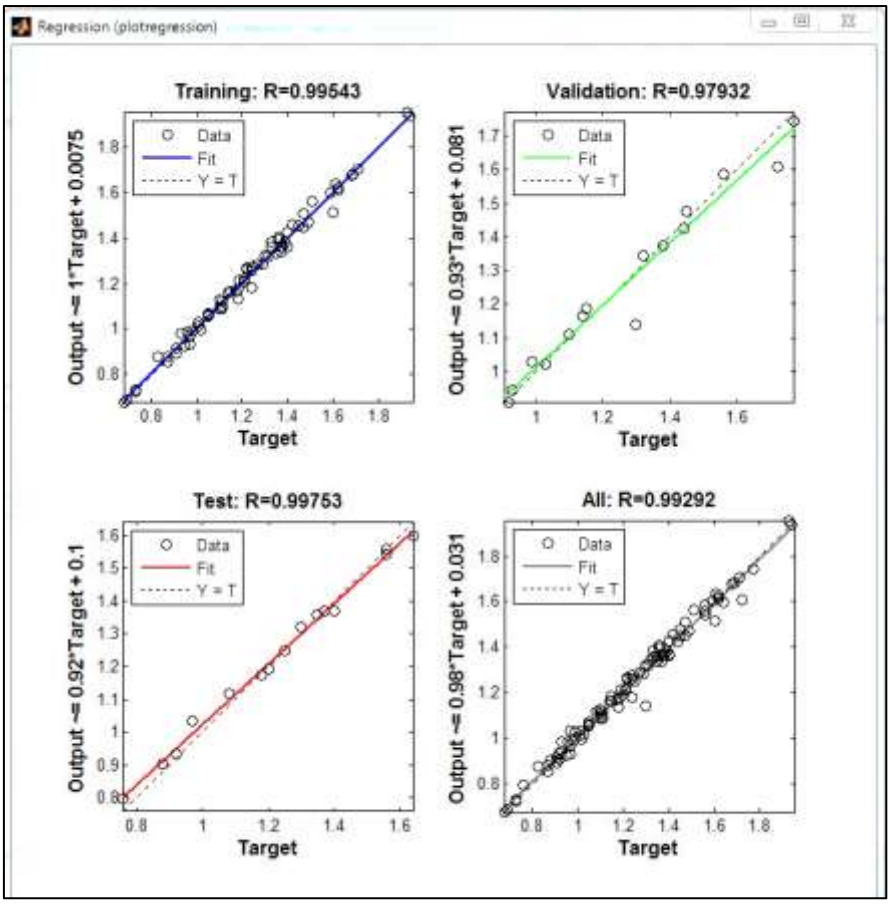

Figure 2: Regression plot of prediction model

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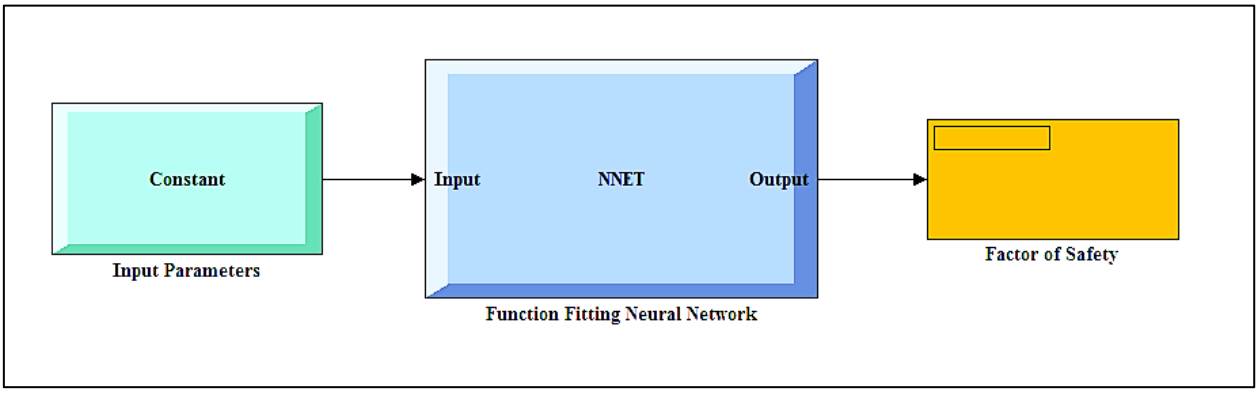

Figure 3: Simulink Model for ANN

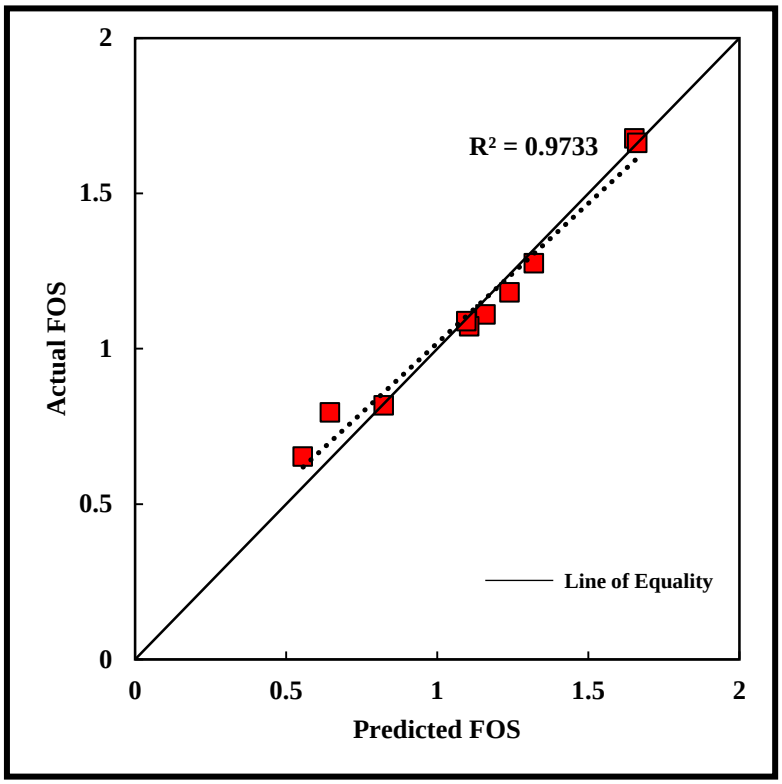

Figure 4: Comparison of predicted results and actual results

4. Summary and Conclusions

The stability of slopes is a major challenge for the Geotechnical Engineers. Prediction of stability of slopes is very difficult because the stability of the slopes generally exists as the combined effects of geology, hydrology and soil parameters. In this paper, 110 slopes were studied along NH-40 and out of that 100 slope cases were used to develop the prediction model using ANN. The validation of the prediction model was done by comparing the predicted results with the actual results of the remaining 10 cases. From the presented results, it has been found that the predicted results bear a very close relationship with the actual results. Hence, it can be finally concluded that ANN can be used as a good prediction tool for slope stability analysis.

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