Modelling of RCC Framed Structure on Sloping Ground using ANN and Random Tree techniques

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Abstract

Framed buildings built on hill slopes exhibit structural behaviour that differs from those built on flat ground. Because these structures are unsymmetrical in nature, they draw a high quantity of shear pressures and torsional moments, and their distribution is uneven owing to different column lengths. Because analysing complex structures takes a significant amount of time and effort. The aim of this paper is to create a model to predict seismic analysis parameters using machine learning methods and evaluate the outcomes of various techniques utilised.

Keywords. Seismic Analysis, Sloping Ground, Machine learning, Artificial Intelligence.

1. INTRODUCTION

Structures are typically built on level land however, due to a paucity of level ground, construction activities have begun on sloping terrain. The mountainous region's economic prosperity and fast urbanisation have hastened real estate development. As a result, population density in the hilly terrain has skyrocketed. As a result, there is a need for multi-story structures on hill slopes in and surrounding cities **[1]**. It is extremely difficult and expensive to dig or level in such conditions. Structural Engineers face the difficulty of achieving the most efficient and inexpensive design with precision in solution while guaranteeing that the final design of a building is serviceable for its intended purpose during its design lifetime. Previous studies attempted to analyse the behaviour of these frames located on sloping ground with various software available and given the value of critical seismic parameters like base shear, storey drift, and fundamental time period **[2-4]**. Also, on hills various configuration of buildings are possible for instance step back and step back-setback so researchers have also tried to predict most suitable configuration **[5- 9]**. But these processes are time-consuming and require a lot of effort. Researchers have used modelling techniques in various processes to make them easy to use **[10-12]**. Therefore, present paper aims at use of machine learning tools and their comparison to predict the seismic behaviour of building, constructed on hilly regions. The model developed using these techniques, will be capable of prediction of base shear in step back configuration. Thereby, resulting in saving of multiple use of various software and manual calculations for the design of these buildings.

2. METHODOLOGY

2.1 Artificial Neural Network

An ANN is a mathematical model that is driven by the organisation and functioning characteristics of biological brain networks in humans. Many applications have been done in this sector from the discovery of ANN in 1943 and till today. The main idea is to use computers to simulate complex problems in order to produce accurate estimates or facts using arithmetic operations, reasoning, and past knowledge, especially when the relationships between variables are not known or non-linear, and to recognise correlations between certain relevant features. ANN may be used to solve a variety of issues, including multivariate regression, categorization, control systems, associative memory, simulation forecasting etc.

Learning in ANN may be done in a variety of methods. For example, supervised learning makes use of a dataset made up of numerous characteristics and their related output values. The neural network learns over numerous iterations, adjusting its weights repeatedly while taking prior deviations into account in order to estimate the outputs. The most popular supervised learning model is the multilayer perceptron (MLP), which is made up of multiple layers of neurons with information moving feed-forward from inputs to outputs through various layers of neurons and a back-propagation (BP) method connecting back to the network.

MLP is made up of three layers, each of which is made up of clusters of neurons that execute similar jobs. The Input Layer, which accepts input from the user application, is the initial layer. The second sort of layer is Hidden Layer(s), in which neurons are only linked to other neurons and never interact directly with the end user. Finally, the neurons in the Output Layer provide data to the user application. Processing may happen at any layer in the neural network (i.e., the input and output layers aren't merely interface points), therefore every neuron in a neural network can do it. Weights play a part in the establishing relation between neurons in determining the relative intensity of the signal; when the weight varies, the network produces varied results. As a result, choosing the right weight values is crucial to constructing a good neural network. This is accomplished through the training phase in the learning process.

Figure 1 shows the artificial neural network model developed in this research. This is the multilayer perceptron of a single-layer feed-forward Neural Network, in which there are twelve main parameters that are mentioned in the previous section. Total 6 neurons were employed for the hidden layer and 1 neuron for the output layer, and the output layer neuron's final value represents the Base Shear value.

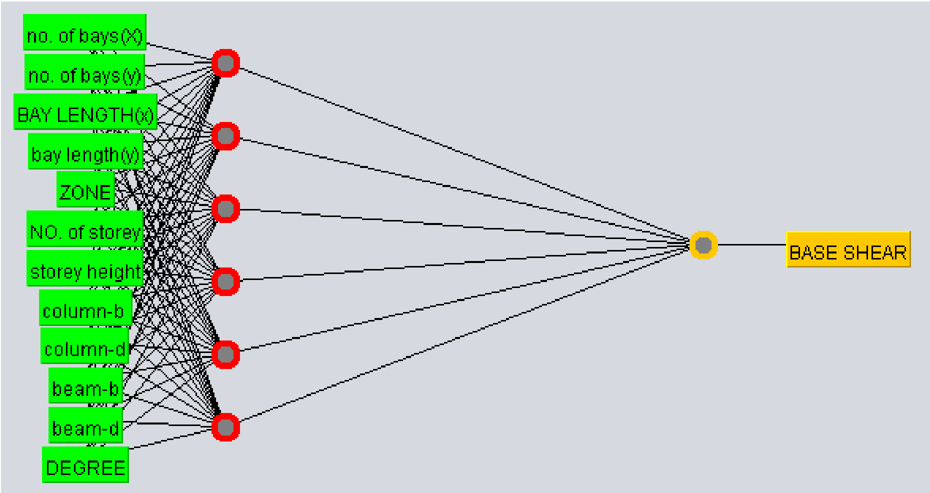

Figure 1. ANN model for base shear evaluation

2.2 Decision Tree

Decision Tree is extremely popular and widely used classification prediction tool. It is a tree structure that look like a flow chart, in which each internal node represents a test on an attribute, each branch represents the test's conclusion and each leaf node (terminal node) holding class label

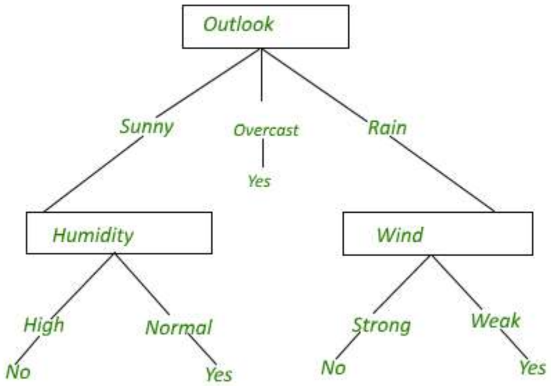

Figure 2. Decision Tree for tennis play

Decision Tree in Figure 2 categorises a particular morning based on whether it is suitable for playing tennis and returned the classification linked with specific leaf

2.3 Data set used

The experimental dataset of 101 sample set has been collected from various literature available, this dataset includes twelve input variables i.e. (no of bay (X), no of bay (Y), bay length (X), bay length (Y), zone, no. of storey, storey height, column depth, column width, beam width, degree beam depth,). Bay length are in meter (m) but cross section dimensions are in millimetre (mm). The minimum, maximum and average value are shown in Table 1

Table 1. Range of various input parameters used.

Name of input	Maximum value	Minimum value	Average value
no of bay (X)	11	3	4.19
no of bay (Y)	7	1	2.71
bay length (X)	7	3	5.39
bay length (Y)	5	3	4.44
zone	5	2	3.92
no. of storey	19	4	7.84
storey height	3.66	3	3.27
column width	600	230	395.54
column depth	1000	300	534.65
beam width	550	230	308.71
beam depth	750	350	516.83
degree	45	0	22.49

To compare the outcomes of the random tree and ANN models, statistical measures such as root relative square error (RRSE), coefficient of correlation (CC), mean absolute error (MAE), relative absolute error and root mean square error were determined. The performance of the models is affected by user-defined parameters in both models. As a result, choosing the best settings for these parameters is critical. The optimised values of user defined parameter in both the modelling approaches are given in Table 2.

Table 2. Statistical parameters used in the predictive models.

Modeling Technique	**Parameters**
Multilayer perceptron (ANN)	L-0.1, M-0.21, N-1000
Random Tree	M-1

3. RESULT AND DISCUSSION

Base shear with varied parameters was predicted and compared to the actual results using MLP and RT models. The fitness level of anticipated Base Shear values was calculated using statistical metrics such as CC, MAE, RMSE, RAE, and RRSE. Figure 3 depicts the statistical characteristics of Base shear predicted by both modelling Techniques.

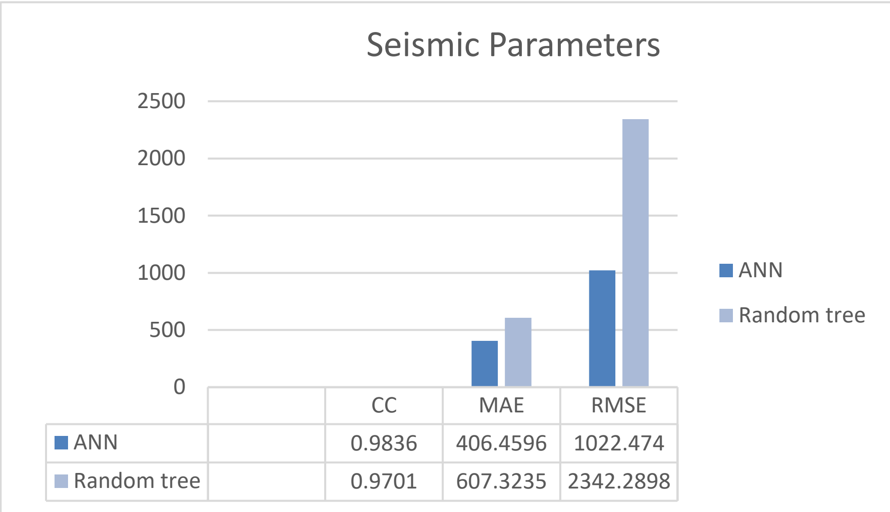

Figure 3. Statistical parameters of MLP and Random Tree

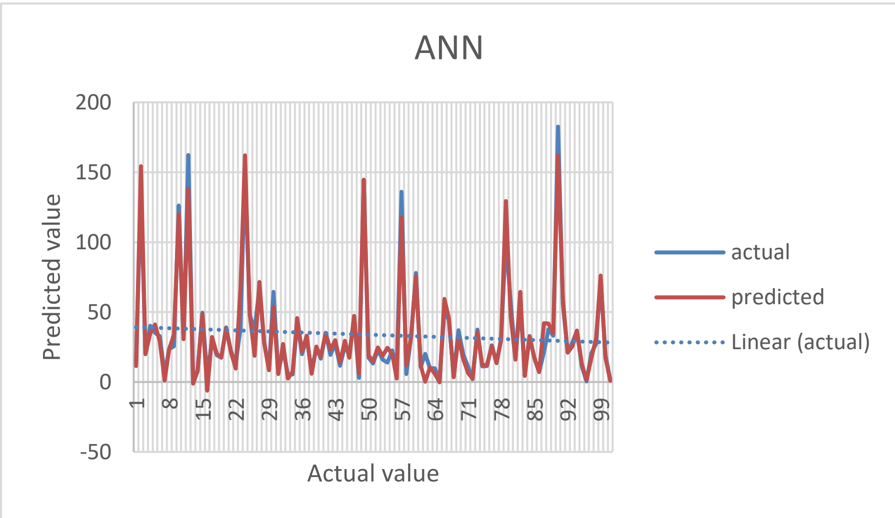

Figure 4. Actual Vs Predicted value from ANN model

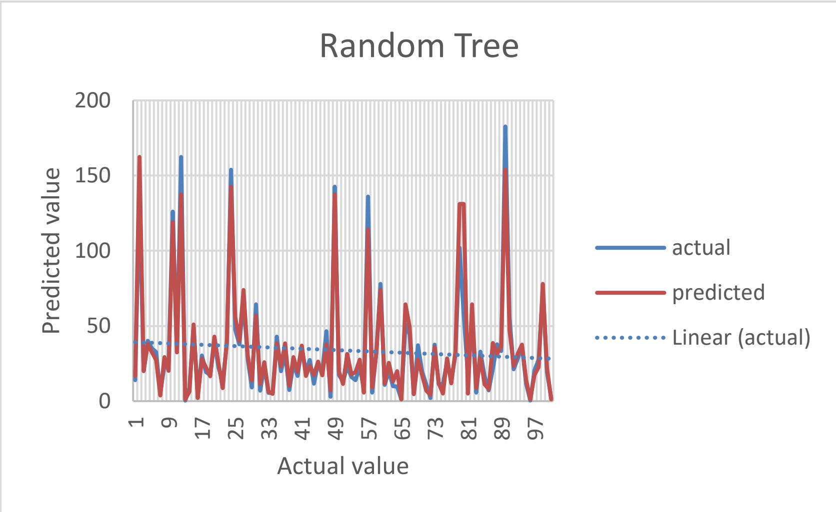

Figure 5. Actual Vs Predicted Value for Random Tree

Scattered graph between the observed and predicted values of Base shear obtained from MLP and RT model with dataset is presented by Figure 4 and Figure 5. According to the graphical results, the projected Base shear values by both models are in excellent agreement with the Base shear values gathered in the data set, while the ANN model predicts negative Base shear values against low Base shear values. Based on statistical metrics (Figure 1), the ANN model performs somewhat better than the Random Tree model in forecasting Base shear values due to higher CC and lower errors (CC- 0.9836, MAE- 405.4596, RMSE-1022.474).

For validation part dataset was randomly divided into 70/30 ratio and 70 percent was used to train the model and remaining 30 percent was used to test it. Statistical parameters thus obtained were recorded but it was observed that these parameters were better in case of cross validation.

4. CONCLUSION

In this paper, ML approaches like ANN and RT is used to predict the model for Base shear value. We can conclude following points from the result

- The ANN model developed in this paper showed its capability to predict the base shear value based on various input parameters mentioned earlier. This will help in predicting the value of base shear in similar type of building hence will save lot of effort and time.
- Among both ANN and RT models ANN performed better on the taken dataset due to higher correlation coefficient and lesser error values obtained.

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