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Prediction of Concrete Compressive Strength Using Artificial Neural Network

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Abstract

Concrete is the most widely used material by humans after water. Rapid growth in the construction industry, concrete will continue to be the dominant material in the future. Concrete is a composite material like aggregates, water, and admixtures. Destructive testing of concrete to know its strength achieved after the mix design will be an expensive and time-consuming process. With recent advances in soft computing techniques like artificial intelligence, these results can be predicted by feeding the algorithm with a large number of data available to obtain the desired results. In the present research work, it is proposed to use artificial neural networks to predict the strength of different types of concrete. A Multilayer Perceptron has input and output layers, and one or more hidden layers with many neurons stacked together. Data capturing will be done regarding different types of concrete and artificial neural networks are preliminarily trained with various inputs to solve problems with data applica- ble to obtain the desired results. This ANN with captured data helps in minimizing repetitive process and tests involved to obtain the results through experimental procedures which is time, material, and money- consuming with practical difficulties. The advantage of python is that designer can create a customized program for interactive design, Python determination also improve the analytical skill of the student and programs can be converted into executable software. Concrete Cubes are cast to validate the predicted Result of the Software.

1. Introduction

An artificial neural network is an informational system simulating a biological neural network capability by interlocking several simple neurons. Artificial NN is an example of a modern interdisciplinary focus that helps solve various engineering which could not be solved by statistical methods. Neural networks are skilled of collection, remembering, studying, and processing many numbers of data gained from some experimentations /mathematical analysis. An artificial neural network is an informational system (**Kabir and Hasan**)simulating a biological NN's capability by interlocking several simple neurons. Artificial NN is an example of a modern interdisciplinary focus that helps solve various engineering which could not be solved by statisti-

cal methods. Neural networks are skilled of collection, remembering, studying, and processing many numbers of data gained from some experimentations /mathematical analysis.

In the present research work, it is proposed to use artificial neural networks to predict the strength of different Grades and types of concrete. A Multilayer Perceptron has input and output layers, and one or more hidden layers with several neurons loaded together. And keeping in mind that in the Perceptron the neuron should have an enactment capability that forces an edge, as sigmoid, neurons in a Multilayer Perceptron can utilize any erratic enactment capability. Data capturing will be done regarding different Grades and types of concrete and ANN are preliminarily trained with various inputs to solve problems with data applicable to obtain the desired results.

An ANN can generalize and thereby recognizes similarities among different inputs provided. This ANN with captured data helps in minimizing repetitive process and tests involved to obtain the results through experimental procedures which is time, material, and money-consuming with practical difficulties. Python software is used to write the program for the Artificial Neural Network model. The advantage of python is that planner can make a create program for intelligent plan, Python will likewise work on the scientific expertise of the understudy and projects can be changed over into executable programming.

An artificial Neural Network is introduced as an improved on numerical model, a model which is comparable and almost equivalent to the natural brain organization. They can without much of a stretch reenact the essential qualities of the natural sensory system. The organization is equipped for social affair, retaining, and handling various exploratory information. Some of their basic characteristics are:

- They can analyse a large amount of data.
- They can study from the earlier data
- They can solve problems that are complex, not clear, and problems that don't have any one solution.

Because of this characteristic, ANN is often better that can be used to solve problems with large inputs and prediction methods. The definition of an Artificial Neural Network is precisely like that of the organic neuron in people. The main components of the biological neuron are soma or cell body (where the cell nucleus is present), dendrites (where the nerve is connected to the cell body), Axon (which carries the impulses of the neuron).

2. RESEARCH METHODOLOGY

The following steps are followed:

In order to compare the predicted result with the actual result, the Concrete Compressive test will be carried out.

2.1. Procedure of the existing method

Target strength determination, Selecting the water-cement ratio, Selecting the water content, (Baykasoğlu, Dereli, and Tanış) , (Ni and Z Wang) Cement content calculation, Sand and Coarse aggregate calculation, Estimation of mixed ingredients, Correction due to absorbing /moist aggregate, Concrete trail mixes.

With corrected proportion determined from the above steps, 3 concrete cubes are cast and tested for 28 days of compressive strength. If desired strength is not achieved with the ingredients calculated, then all the steps are repeated losing precious time and adding to costs.

In this M40 grade concrete is used with partially replaced by GGBS in place of cement with varying percentages with the varying percentage to analyzed for 28 days. Concrete Cubes are tested using CTM. Test results are recorded. (Muliauwan et al.) , (Bu, Du, and Hou Mohamed et al.)

2.2. Procedure using Artificial Intelligence method

2.2.1. Programming Flow Chart

Collecting of data from various sources like experimental data, Journal Papers are shown below

Coding:

```
print(r2_score(y_test,y_pred))
```

```
0.8722004162827205
```

```
y_pred=NN_model.predict([[245,105,0,140,7,1137,894,28]])
print(y_pred)
```

```
[[49.947105]]
```

- Dividing the collected data into two sets of data like training subset and testing subset in which 80% to 90% can be saved in the training subset and the

Casting of cubes Concrete

Concrete Compression Machine

Compressing of Cube

FIGURE 1. (a) Casting of Concrete Cubes (b) Concrete Compressive Machine (c) Compressing of Cubes

TABLE 1. Sample of Excel Data

SL No	Cement (kg in a mˆ3 mixture)	Blast Furnace Slag (kg in a mˆ3 mixture)	Fly Ash (kg in a mˆ3 mixture)	Water (kg in a mˆ3 mixture)	Superpla (kg in a mˆ3 mixture)	Coarse Aggregate (kg in a mˆ3 mixture)	Fine Aggregate (kg in a mˆ3 mixture)	Age (day)	Concrete compressive strength (MPa)
1	198.6	132.4	0.0	192.0	0.0	978.4	825.5	28	28.02
2	427.5	47.5	0.0	228.0	0.0	932.0	594.0	270	43.01
3	190.0	190.0	0.0	228.0	0.0	932.0	670.0	90	42.33
4	304.0	76.0	0.0	228.0	0.0	932.0	670.0	28	47.81
5	380.0	0.0	0.0	228.0	0.0	932.0	670.0	90	52.91
6	139.6	209.4	0.0	192.0	0.0	1047.0	806.9	90	39.36
7	342.0	38.0	0.0	228.0	0.0	932.0	670.0	365	56.14
8	380.0	95.0	0.0	228.0	0.0	932.0	594.0	90	40.56
9	475.0	0.0	0.0	228.0	0.0	932.0	594.0	180	42.62
10	427.5	47.5	0.0	228.0	0.0	932.0	594.0	180	41.84

remaining 10% to 20% can be saved in the testing subset.

- Above set of data will be trained using Artificial Neural Network.
- Using trained data predation can be done.
- Frontend can be prepared using a Graphical user interface using programmed data.

It is the checking of data quality concerning prediction. It will represent by the percentage of 100%.If the R2 Square value is High it is good for the prediction of the result.

The above code represents a prediction of concrete compressive strength, where input value ordered in Cement, Blast furnace slag, Fly ash, Water, Superplasticizer, Coarse aggregate, Fine aggregate, Age, and predicted value concrete compressive strength will be displayed after running the code. (Ziolkowski and Niedostatkiewicz Chopra, Sharma, and Kumar Shanker and Sachan)

3. The frontend is created by using a written backend program

To get the frontend, the below program is to be executed

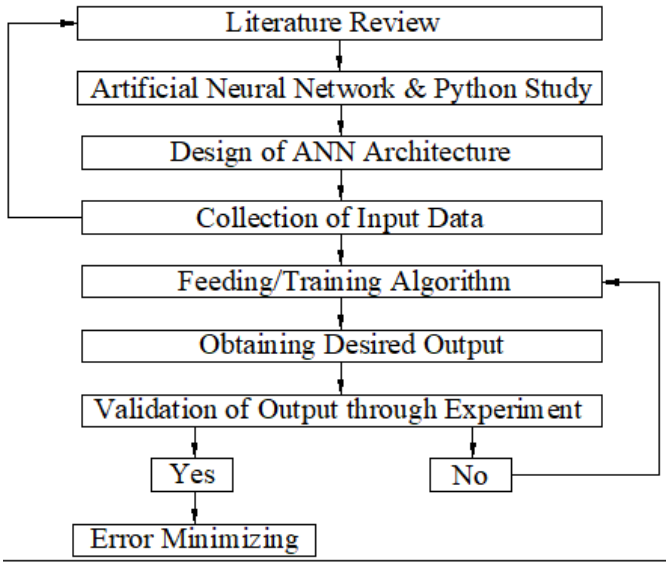

FIGURE 2. Methodology Flow Chart

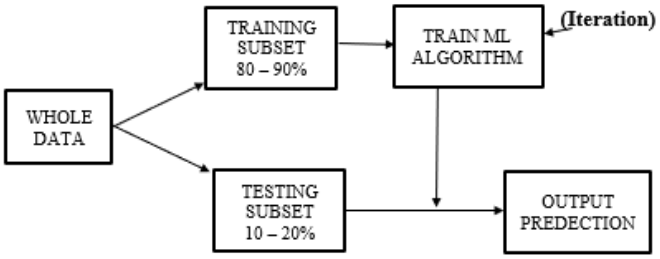

FIGURE 3. Flow Chart of Training Data

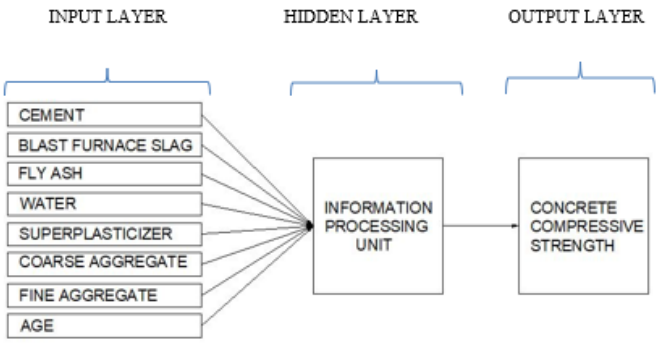

FIGURE 4. Layers of Neural Network

After running the code, a server link will be generated that must be copied and pasted in the Browser tab then the below Screen will be displayed for the users to give the inputs.

As the number of data increases the accuracy of the output will be more accurate. In programming, if hidden layer iteration increased the output accuracy will be more accurate, as iteration increases it will require more time to train data. If high configuration hardware property of computer will increase the speed of iterations.

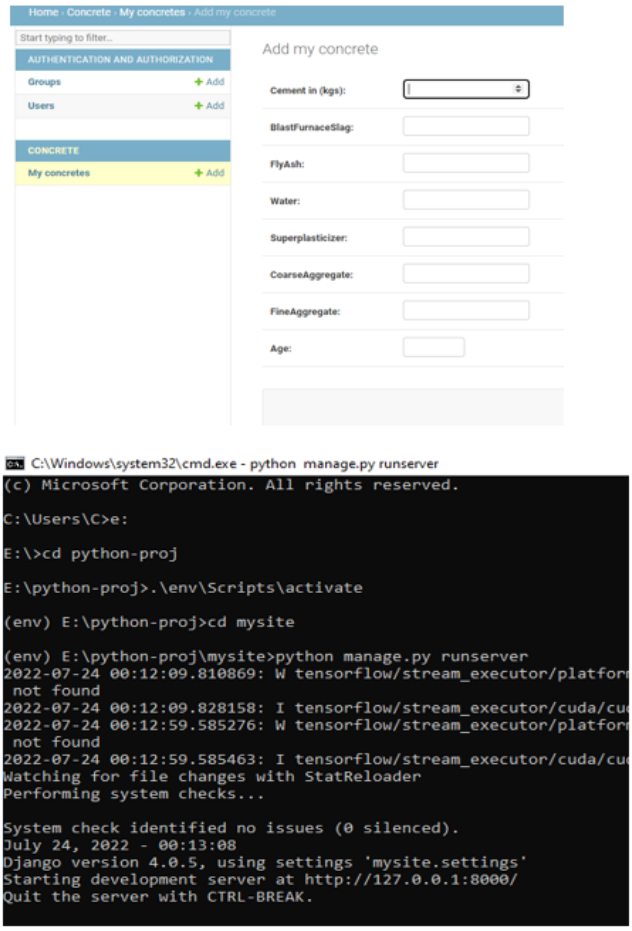

FIGURE 5. (a) Code to Open Frontend (b) Frontend of the Project

It can be seen that Artificial Neural networks can help to achieve accurate prediction of concrete compressive strength, and also can be applied in other various civil engineering predictions, to increase the prediction accuracy, and more data collected during the experimental stage, thereby increasing the sample amount of the training set.

Epochs can be varied from the trial-and-error method, as epochs increased the time required for training, and it will depend on the Hardware property of the computer's high configuration computer it will train very fast. ANN gets an R^2 value of 0.85, higher than the other methods and close to 1. Therefore, the data used are of good quality. As Python is open source it can be used for free without purchasing a license.

4. RESULTS AND DISCUSSION

4.1. Results of concrete compressive strength

The laboratory compressive strength for 28 days concrete of M40 grade was 56.4MPa, 53.2MPa,

TABLE 2. Experimental and Prediction Results of Concrete compressive strength

Sl No	1	2	3	4
Cement (kg/m^3)	350	315	280	245
Water (kg/m^3)	140	140	140	140
Fine Aggregate (kg/m^3)	896	895	895	894
Coarse Aggregate (kg/m^3)	1140	1139	1139	1137
Chemical Admixture (kg/m^3)	7	7	7	7
Water Cement Ratio	0.4	0.4	0.4	0.4
GGBS (kg/m^3)	0	35	70	105
Compressive Strength of Experimental Result (MPa)	**56.40**	**53.20**	**52.10**	**50.60**
Compressive Strength of Prediction Result (MPa)	**51.10**	**52.87**	**51.59**	**45.40**

52.1MPa, and 50.6MPa respectively for 4 cubes,

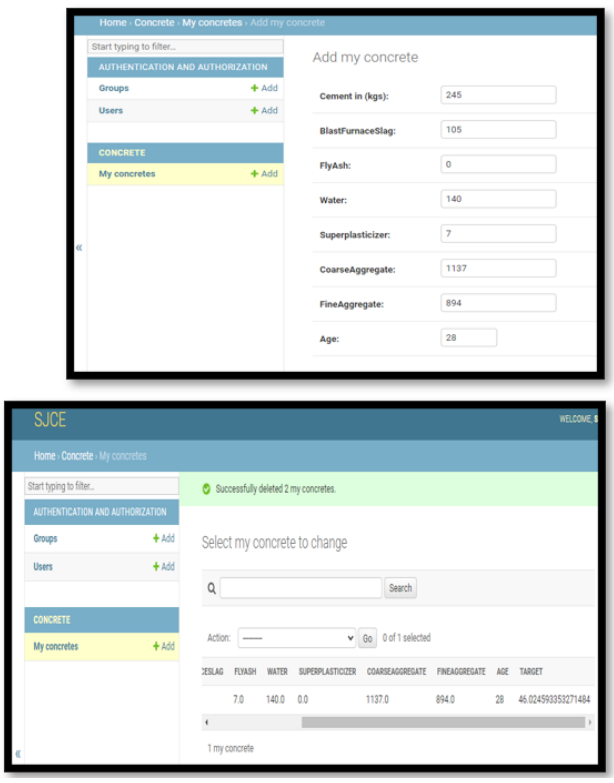

FIGURE 6. (c) Input of Frontend (d) Prediction ofthe Project

whereas the predicted results for the same mix design quantity for 28 days, the predicted strength form the neural network was 51.1MPa, 52.87MPa, 51.59MPa and 45.4MPa, the difference in values between laboratory test results and ANN predicted values are within the acceptable limits, i.e., the average Percentage of error is 2.8%. In linear regression, the R2 value was found to be 85% which implies that the data which is used to train the neural networks are of good quality.

5. CONCLUSIONS

As the number of data increases the accuracy of the output will be more accurate. In programming, if hidden layer iteration increased the output accuracy will be more accurate, as iteration increases it will require more time to train data. If high configuration hardware property of computer will increase the speed of iterations.

It can be seen that Artificial Neural networks can help to achieve accurate prediction of concrete compressive strength, and also can be applied in other various civil engineering predictions, to increase the prediction accuracy, and more data collected during the experimental stage, thereby increasing the sample amount of the training set.

Epochs can be varied from the trial-and-error method, as epochs increased the time required for training, and it will depend on the Hardware property of the computer's high configuration computer it will train very fast. ANN gets an R^2 value of 0.85, higher than the other methods and close to 1. Therefore, the data used are of good quality. As Python is open source it can be used for free without purchasing a license.

From the numerous works conducted by many researchers, it is evident that Artificial Neural Network is an effective tool for solving Civil Engineering problems. There are many types of Artificial Neural Network which has huge applications in the field of Civil Engineering which can predict the accurate outputs for particular problems and reduces the error that arises during manual calculations. ANN by analyzing a large number of data can learn from the past data and solve complex problems.

The results obtained from ANN and manually calculated results have the least variations in a sense. ANN can process non-linear, random, and time-consuming problems with greater accuracy.

In this study, we used the application of machine learning in concrete mix design to the determination of concrete compressive strength and build a practical tool that can be used in engineering practice.

Concrete mix ingredients have a corresponding laboratory destructive test, in this study while building a neural network, the main goal is to predict the compressive strength of the concrete resulting from the specific composition of concrete mix ingredients. ANN Prediction depends on the number of training data and its variations. More reliable predictions can be made with more data with wide variations. Concrete is an exceptional material and expectation of the precise compressive strength of cement is a seriously troublesome run to demonstrate. The proposed Artificial intelligence models will save time, and reduce the waste of material and the design cost.

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