Project Cost and Duration Optimization Using Soft Computing Techniques

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***Abstract*—The Artificial Neural Networks is now used in many fields. They have become well established as viable, multipurpose, robust computational methodologies with solid theoretic support and with strong potential to be effective in any discipline, especially in construction. The input of the Artificial Neural Network (ANN) characterizes the different realizations of resources. The output is capable of characterizing the objectives and constraints of the optimization, such as attainment of regulatory goals, value of cost functions and time. The supervised learning algorithm of back propagation was used to train the network, once trained, the ANN begins a search through various realizations of pumping patterns to determine whether or not they will be successful. The simple genetic algorithm technique has also been used for optimization of project cost and time. A case study of a project under JNNURM program being executed by K P C Projects Ltd. has been presented in this study. Due to the recent severe global recession, company is facing severe problem and all the construction activities slowed down. To increase the productivity of all resources, it is necessary to forecast the costs arriving from resources so that the total cost of project can be reduced. The present case study deals with the construction of 512 Houses in (*G*+3) pattern, in 32 blocks located at Karmanghat, Hyderabad. It is observed from the results that the Neural Networks approach has optimized the total project cost by 3.91%, and the duration of the project has been reduced around 5% of the total duration of the project.**

***Index Terms*—resource optimization, artificial neural network, project cost, project duration**

I. Introduction

The construction industry plays a pivotal role in the socio-economic development of any nation. Construction industry is the second largest occupation in India next to agriculture. The structure of the project depends on how well the construction phases carried out and how well the resources allocated. In management of construction project five important resources such as manpower, materials, money, machinery and time are to be dealt with extreme care to maximize profit. For the successful completion of project under increasing complex situations it is essential that most effective method is used for available tools and techniques. Among the resources labor is the most important resource for effective utilization of human resource in an organization of the structure. The most important resources that project managers have to plan and manage on day-to-day basis are people, machines, materials, and working capital. On the other hand, if these resources are severely limited, then the result more likely will be a delay in the project completion time. Depending on the type of resources, the costs of providing an abundance of such resources to accelerate project completion time can be very high. The various resources involved in the project are labor related costs, material related costs and equipment related cost. As construction laborers belong to unorganized sector whose payment is based on contracts, which are not changed quite frequently. Depending on the complexity of a project, heavy equipment may be required, which is contingent on equipment availability over a given time frame.

An Artificial Neural Network (ANN) is a mathematical model or computational model that is inspired by the structure and functional aspects of biological neural networks. [1] A neural network consists of an interconnected group of artificial neurons, and it processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. [2] used the BP algorithm to estimate the construction resource requirements at the conceptual design stage and apply the model to the construction of concrete silo walls. A mathematical model for resource scheduling considering project scheduling characteristics generally ignored in prior research, including precedence relationships, multiple-crew strategies, and the time-cost tradeoff. Previous resource scheduling formulations traditionally have focused on project-duration minimization. [3] have developed model using ANN for predicting labor cost which has also taken into account the subjective factors. [4] Developed a mathematical method for adapting the weights. Assuming that a desired response existed, a gradient search method was implemented, which was based on minimizing the error squared. [5] developed a technique for enhancing the initial representation of the data to the neural network by replacing the linear inputs with functional links. Functional links are an attempt to find simple mathematical correlations between the input

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and output, such as periodicity or higher-order terms. Functional links are very important in preprocessing the data for the neural network [6].

II. Methodology

Neural networks look for patterns in training sets of data, learn these patterns, and develop the ability to correctly classify new patterns or to make forecasts and predictions. Neural networks excel at problem diagnosis, decision making, prediction, classification, and other problems where pattern recognition is important and precise computational answers are not required. A neural network is a powerful data modeling tool that is able to capture and represent complex input/output relationships [7]. The motivation for the development of neural network technology stemmed from the desire to develop an artificial system that could perform "intelligent" tasks similar to those performed by the human brain. Neural networks resemble the human brain in the following two ways:

- A neural network acquires knowledge through learning.
- A neural network's knowledge is stored within inter-neuron connection strengths known as synaptic weights.

The true power and advantage of neural networks lies in their ability to represent both linear and non-linear relationships and in their ability to learn these relationships directly from the data being modeled. Traditional linear models are simply inadequate when it comes to modeling data that contains non-linear characteristics.

A. Network Development

The first step in developing the network is to define the input factors in the Excel Spreadsheet and then, import them to the Neuroshell software. Since this project deals with obtaining a certain output value, it is necessary to define an actual output column to assist during the supervised learning. The input factors, such as the number of estimates performed, the time during which the estimates had been performed (either before, during, or after work is completed),project completion status, geographical location, labor estimates, equipment estimates, material estimates, and other costs have been listed. The input parameters are subjective and cannot be easily quantified; the best approach is to organize them into a binary format (1, 0) where 1 would accept the value and 0 would not accept the value. Once the input factors are defined, the ANN software computes the maximums and minimums, along with the mean and standard deviation under each parameter. ANN models require variables to be scaled to the range of either [0 to 1] or [-1 to 1]. This assists the network in determining the variable's real value range. The process for development of a neural network model is given in Fig. 1.

A network model of a neuron has three basic parts, input weights, a summer, and an output function. The input weights scale values used as inputs to the neuron, the summer adds all the scaled values together, and the output function produces the final output of the neuron. Often, one additional input, known as the bias is added to the system. If a bias is used, it can be represented by a weight with a constant input of one. Where I_1, I_2 and I_3 are the inputs, W_1, W_2 and W_3 are the weights, B is the bias, x is an intermediate output, and "a" is final output. The equation for "a" is given $a = f(W_1 I_1 + W_2 I_2 + W_3 I_3 + B)$ where *f* could be any function. Most often, *f* is the sign of the argument (i.e. 1 if the argument is positive and -1 if the argument is negative), linear (i.e. the output is simply the input times some constant factor), or some complex curve used in function matching (not needed here). For this model we will use the first case where *f* is the sign of the argument for two reasons: it closely matches the 'all or nothing' property seen in biological neurons and it is fairly easy it implement.

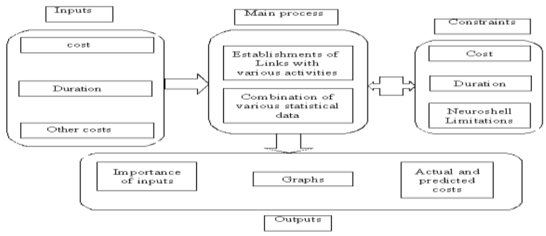


Figure 1. The process for development of a neural network model

When artificial neurons are implemented, vectors are commonly used to represent the inputs and the weights so the first of two brief reviews of linear algebra is appropriate here. The dot product of two vectors $\vec{x} = (x_1, x_2, \cdots, x_n)$ and $\vec{y} = (y_1, y_2, \cdots, y_n)$ is given by two vectors $\vec{x} = (x_1, x_2, \cdots, x_n)$ and $\vec{y} = (y_1, y_2, \cdots, y_n)$ is given by $\vec{x} \cdot \vec{y} = x_1 y_1 + x_2 y_2 + \cdots + x_n y_n$ .Using this notation the output is simplified to $a = f(\vec{W} \cdot \vec{I} + B)$ where all the inputs are contained in $\vec{I}$ and all the weights are contained in $\vec{W}$.

B. Neuron Layer

In a neuron layer each input is tied to every neuron and each neuron produces its own output. This can be represented mathematically by the following series of equations:

$$a_1 = f_1(\vec{W}_1 \,.\, \vec{I} + B_1)$$

$$a_2 = f_2(\vec{W}_2 \,.\, \vec{I} + B_2)$$

$$a_3 = f_3(\vec{W}_3 \,.\, \vec{I} + B_3)$$

$$\vec{a} = f(W \cdot I + B)$$

After simplifying the above notation, the final form of the mathematical representation of one layer of artificial neurons.

III. Model Development

The following are the basic steps which is involved in the development of a model,they are given as follows:

A. Steps 1 and 2 Begin the Program

As we have created a spreadsheet of those figures i.e actual cost and duration. The spreadsheet is called CSV.csv. It is a comma separated text file, since her Windows Control Panel is set to U.S. number formats and list separator. The Instructor begins by prompting her to load a data file.

B. Step 3 - Select a Data File

A dialog box is displayed which allows her to select the spreadsheet she created and saved as a text file, called CSV.csv in the C:\Predictor\Examples subdirectory. (The subdirectory may be different if you chose to install the NeuroShell Predictor in a directory other than the default.) She pushes the next button to view the spreadsheet.

C. Step 4-The Data File

The spreadsheet is displayed in NeuroShel datagrid. The top of the datagrid displays some information that is useful in determining if she is opened the correct file. The path name of file shows the location of the file on the computers hard drive, including the drive letter (C), the directory and subdirectory if there is one, and the name of the file. The screen also shows if the file included column names by placing a yes or no in the initial label row detected box. The number of columbs and rows in the file are also displayed.

D. Step 5-Select Rows for Training the Model

The Instructor allows you to choose some rows from your data file that will be used to train the network. You may use the rows that are not chosen (an out of sample set) to test the network to see how well it is performing after it has been trained.

E. Step 6-Decide How to Train the Model

This step of the instructor begins a series of steps that involve a single screen in the NeuroShell. The purpose of the screen is to:

- Select the input variables and the predicted output.
- Select the training strategy.
- Select the graphic screen that will be displayed while the network is training.
- Select the Input Variables and the Predicted Output
- Select the inputs from the top list box. Click on Estimate/total costs. All of the column names between the two are automatically selected.

The NeuroShell predicts one thing at a time. If a column is selected as an input, it may not be selected as an output. If a column is selected as an output, the program will not allow you to select the same column as an input. If any selections are made, the program assumes that the last column is the output and all other columns are input variables and push the next button to select a network training strategy.

F. Step 7-Select a Training Strategy

In neural Training Strategy, which uses a neural net that dynamically grows hidden neurons to build a model which generalizes well? Choose which graph to be displayed while the network is learning? For the Neural Training Strategy, these options are available. Actual versus Predicted plots the actual answers from the training data against the network's predictions for all of the rows selected for training. The values change as learning progresses so you can observe if the network is improving. This graph slows down the learning, however.

G. Instructor Step 8-Select a Graphic Display

Learning level plots the number of hidden neurons as it increases against the best network performance, which is computed from a formula in statistics books known as R Squared, the coefficient of multiple determinations. It is a statistical indicator usually applied to multiple regression analysis. It compares the accuracy of the model to the accuracy of a trivial benchmark model wherein the prediction is just the mean of all of the samples.

- Importance of Inputs

This option displays a bar graph which indicates the significance of each input in predicting the output value. The measure of importance for each input is relative to the current problem, so values should not be compared for different problems. Refer to Relative Importance of Inputs for details. Select Actual versus Predicted and then push the Next button to begin to train the network.

H. Step 9 - Train the Model

The green light is on while the network is training and the graph she selected is displayed on the screen. When training is finished, click on the Learning level button to display the other screen. Several statistics record the network's progress.

- Best network performance

The value for network performance ranges from 0 to 1. The closer the value is to 1, the better the net is able to make predictions. The net is not able to make good predictions if the value is near 0.

- Number of hidden neurons trained

Training the net involves adding hidden neurons until the net is able to make good predictions. This is the total number of hidden neurons that have been added while the net is learning.

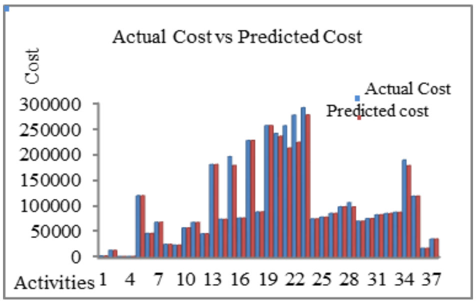
- Optimal number of hidden neurons

This is the number of hidden neurons that best solves the prediction problem, Relative importance of Inputs Displays a list of inputs and a corresponding number which indicates the importance of the variable in predicting the output. The higher the number, the more important that variable is in predicting the output. The relative importance of inputs may also be displayed in a bar chart by selecting Importance of Inputs as one of the Graphic Screen options. The relative importance numbers range from 0 to 1, and they are "normalized" so that for all inputs, they add up to approximately 1. Therefore, it allows us to think of the numbers as a percent contribution to the model of the respective inputs. The Actual versus Predicted graph shows the actual answers from the training data and the network's predictions. scroll the mouse inside the graph and clicks on the left mouse button to display actual and predicted values for different rows. If we hold the left mouse button down and drag the mouse, we can see actual and predicted values for all examples. click the right mouse button to display options to copy the graph to the Windows clipboard for use in another document, to save the graph as a bitmap file, or to print the graph. Push the Next button to apply the network to the training data.

I. Step 10 - Obtain Results

We notice that this new screen adds a scroll box of actual and predicted values for each row in the training file. Statistics are displayed for the number of rows processed and the network performance on this data. For our problem, the number of rows processed is 38 because she previously selected 38 rows for training data..Actual and predicted results are in U.S. number format.

IV. Results Discussions



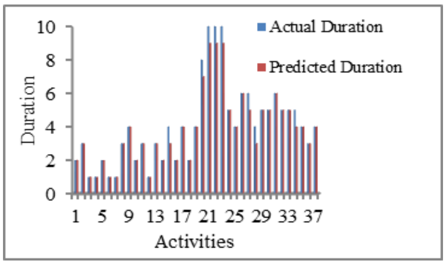


Figure 2. Activity wise comparison of actual versus predicted duration and cost

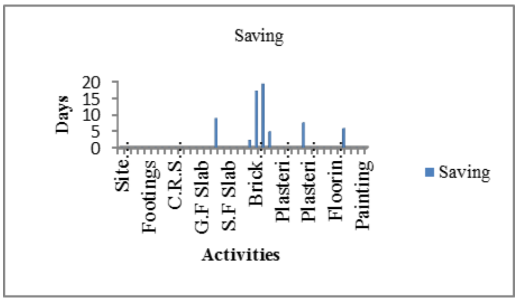


Figure 3. Shows the savings in duration

The present case study deals with the construction of 512 Houses in (*G*+3) pattern, in 32 blocks located at Karmanghat, Hyderabad and the estimated cost of the project is Rs. 14.79 crores. K P C Projects private limited company is under taking construction activity of the project. For each block was divided number of work breakdown structures such as substructures, super structures and finishing structures etc. All the three works are sequenced with the resource requirements, scheduling, tracking and controlling of all these activities were carried out originally by using Primavera software. The total 37 activities are involved in this project and the estimated duration of the project is 150 days. Activity wise comparison of actual versus predicted duration and cost is shown in Fig. 2. From the Fig. 2 it is observed that the variation in duration is because of these activities- F.F Columns and S.C, Brick Work G.F, Brick Work F.F, Brick Work S.F, Brick Work T.F, Plastering S.F and Plastering T.F. The duration of each block is reduced from 150 to 142 days. Similarly, from the Figure 3it is clear that the variation in cost is because of these activities- F.F Columns & S.C, Brick Work G.F, Brick Work F.F, Brick Work S.F, Brick Work T.F, Plastering S.F and Plastering T.F. The cost of each block is optimized by an amount of Rs. 1.5 lakhs approximately. The percentage of savings and differences between actual and predicted costs are shown in Fig. 3. It is observed from the study that, the decrease in total cost of the project is approximately 3.91 percent. Fig. 4 shows the activity wise savings of the project.

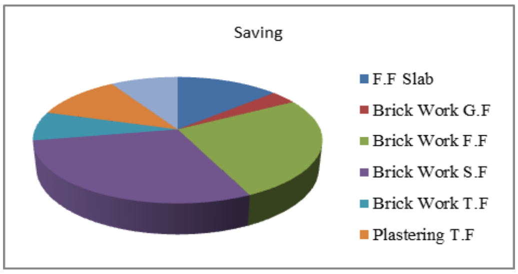


Figure 4. Activity wise savings

From the Fig. 4 maximum savings in cost appears to be firstly from the activity Brick Work of S.F, secondly from Brick Work of F.F and thirdly from F.F Slab. The rest being intermediate, all together it results in saving of Rs. 1, 50,700 for each block. It is clear from the Figure that the maximum variance is found in activity of brick work of the project.

V. Conclusions

The developed model has been used for an improvement in the accuracy compared to that produced by the cost factors. Results are proof that neural networks provide accurate cost and time of the project. It is observed that the results obtained from the model is as good as the quality of the data input which is based formwork packaged. It is believed that the relationship neural network cost provide the basis of the model developed. The results obtained using a neural network model compared well in the mean. This indicates that a neural network offers a viable alternative for optimization model. Similarly in the same manner the resources which carry non numeric elements can be established and variation of each resource can be identified which helps us to prepare the cost estimation and understand the effect of each resource over the other. Thus this model proves to give good results. This generated model also provides the weightages of each resource during the execution of project. In conclusion, the developed network model is more accurate and simple to use most efficient with significant time and cost saving.

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