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Artificial Neural Network Based Assistance System for Estimating Productivity of Construction Activities

Ms. G.P.Gavane[1], Prof.D.B.Desai[2] & Prof.V.P.Paramane[3]
PG Student, Civil Engineering Department, TKIET, Warananagar, Maharashtra, India.
Associate Professor, Dr.JJMCOE, Jaysingpur, Maharashtra, India
Assistant Professor, Dr.JJMCOE, Jaysingpur, Maharashtra, India

Abstract- **Construction can be considered as a dynamic industry which is constantly facing uncertainties. Factors affecting on productivity become an integral part of construction projects worldwide. A construction project is usually considered successful if it achieves good productivity. There are several factors due to which productivity varies. Therefore to achieve good productivity there is need to study on this various factors affecting on productivity and overcomes against the problem. The aim of this paper is to study of various Factors affecting on productivity and the root causes of productivity quality variation on construction site in various cities & analyze them on the basis of discussion carried out with experts in locality. The expand-focus principles & techniques will be applied for gathering the various causes from professional literature & also from local experts. The analysis helps to trace responsibility & improve the work process. After analyzing causes of construction cost overrun it will be easy to manage the project effectively so as to improve the quality of productivity. This study will provide a solution based on ANN for management of construction project to achieve optimum or good production quality for various construction projects in cities.**

Index Terms**—Productivity, Construction Activity, Artificial Neural Network (ANN), Back Propagation Network (BPN).**

I. INTRODUCTION

Construction industry is considered as one of the most complicated and uncertain industry. The Construction industry plays an important role in the development of a country through the delivery of projects and other related activities that generate income for individuals and firms [1]. This contribution is deemed to be greatly enhanced when project delivery is on target in terms of stated performance parameters. However, this is generally considered not to be the case, either nationally or internationally. Globally, the construction performance is lagging behind the performance of other industries such as manufacturing and services [1]. Historically, construction performance is measured by the percentage of achieving client's satisfaction in terms of cost, time and quality, cost & time overrun. A construction project is usually considered successful if it is completed within its time, budget & quality targets [2]. However, poor quality productivity occurs in the construction projects due to many factors. Therefore there is required to take factors affecting on productivity taken into consideration and by analyzing it achieve the optimum solution. In the construction activity, different factors play the important role to improve productivity [3]. To overcome the variability and the impact of subjective factors on the cost of construction-related activities, neural networks can offer a guiding tool [4]. The outcome of construction activities depends on a large number of factors. To predict the outcome of such activities is difficult because of the complex interrelationships between different factors such as framework fixing, steel fixing, concrete pouring, curing period, etc [5]. Productivity is constantly declining over a decade due to the lack of standard productivity measurement system. The impact of the some factors influencing construction productivity is neglected due to which various construction productivity models developed have not been implemented successfully. The purpose of this project is to provide assistance for estimating productivity of construction activities [6]. Experienced estimators rely on their personal expertise to incorporate the effect of qualitative factors in their estimate. Less experienced estimators could benefit from tools that would incorporate such effects [7]. The usage of neural networks to develop such tools has been gaining a widespread attention in the construction industry to aid in many applications. This analysis helps to predict productivity to improve the work process. With the categorized reasons, the Developer, Engineer & Labour can have common understanding of productivity so the changes can be issued & settled with fewer disputes. After analyzing factors affecting on productivity it will be easy to manage the project effectively so as improve the production quality [8]. This study will provide a solution for management of construction project improving production quality. Identification & solution for root causes of productivity factors is the tool for quality production all over the world [9].

II. PROPOSED METHOD

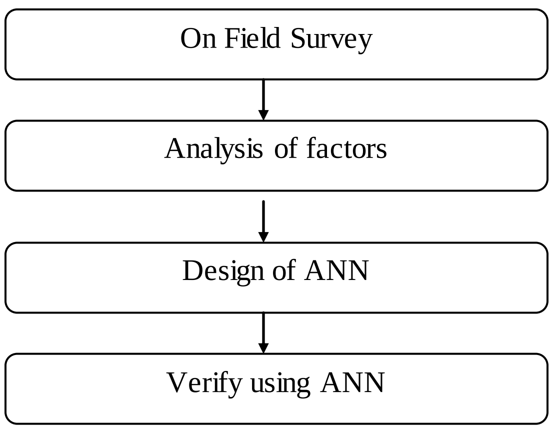

Fig 1: *Flow of the Work*

The projects considered for this study are the residential, construction projects that are located in Sangli, Miraj & Jaysingpur cities. The focus of the study is largely on private sector than public sector. The scope of the project basically consists of achieving the objectives which are mentioned in the previous section. However, this dissertation is one, which is done for academic reasons and hence its scope is limited in a sense to roughly understand the various causes of cost overrun occurring in the construction projects of Sangli, Miraj & Jaysingpur cities in general. The data will be collected through a questionnaire study in which respondents have expressed their own views and hence these may not be totally accurate. But the survey would help us in deciding the quality of production in future. Less experienced estimators could benefit from tools that would incorporate such effects. Neural networks are tools that attempt to mimic the human brain functions. Like the brain, neural networks learn from past trials; they attempt to generalize on the data provided.

The neural Network has a specific workflow. Productivity estimation using neural network follows some steps:

1) Collection of Data.
2) Structure of Network.
3) Training of Neural Network.
4) Testing and Validation of Neural Network.

1. *Collection of Data*

Database affiliation for ANN Training will be done using two options. First option is to use standard database available on private or public sources & second option is to develop own database with the help of survey for productivity analysis. Here we have design the classifier with specified assumption. One may change the classifier according to need of improvement. The database of 10 sites is assumed for development of classifier.

2. *Structure of Network*

Feed forward networks often have one or more hidden layers of sigmoid neurons followed by an output layer of linear neurons. Multiple layers of neurons with nonlinear transfer functions allow the network to learn nonlinear relationships between input and output vectors. The linear output layer is most often used for function fitting (or nonlinear regression) problems. Figure 2 shows the structure of neural network to detect productivity. The network consists of 43 input and three outputs.

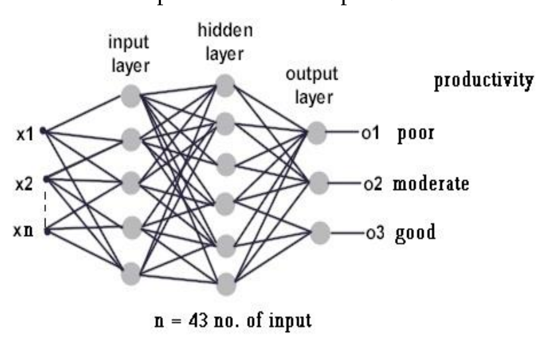

Fig 2: *Structure of ANN*

After a neural network has been created, it must be configured. The configuration step consists of examining input and target data, setting the network's input and output sizes to match the data. Choosing settings for processing inputs and outputs enables best network performance. The configuration step is normally done automatically, when the training function is called. However, it can be done manually, by using the configuration function.

3. *Training of Neural Network*

The nature of neural network is to learn by examples. Learning is a very important feature of ANN, as it creates the base of ANN. Learning defines the training process as an algorithm that replaces the absence of a pre-defined set of instructions to follow. The multilayer Feed forward network can be trained for function approximation (nonlinear regression) or pattern recognition. The training process requires a set of examples of proper network behavior. It is referenced as network inputs p and target outputs t. The training process modifies the weights of the ANN, in order to improve a pre-defined performance criterion that corresponds to an objective function, over time. This process is also called learning rule.

In Supervised learning, a net is defined with a dataset of input/output pairs, namely the training set. The learning process consists in updating the weights at each training step so that, for a given input, an error measure between the network's output and the desired known target value is reduced.

The process of training a neural network involves tuning the values of the weights and biases of the network to optimize network performance. Performance is represented as network performance function. The default performance function for feed forward networks is mean square error—the average squared error between the networks outputs and the target outputs t. It is defined as follows:

$$F = mse = \frac{1}{N}\sum_{i=1}^{N}(e_i)^2 = \frac{1}{N}\sum_{i=1}^{N}(t_i - a_i)^2 \qquad (1)$$

There are two different ways in which training can be implemented: incremental mode and batch mode. In incremental mode, the gradient is computed and the weights are updated after each input is applied to the network. In batch mode, all the inputs in the training set are applied to the network before the weights are updated.

For training multilayer feed forward networks, any standard numerical optimization algorithm can be used to optimize the performance function, but there are a few key ones that have shown excellent performance for neural network training. These optimization methods use either the gradient of the network performance with respect to the network weights, or the Jacobian of the network errors with respect to the weights.

The gradient and the Jacobian are calculated using a technique called the back propagation algorithm, which involves performing computations backward through the network. The back propagation computation is derived using the chain rule of calculus.

Network learns on the training sample, the weights are being adjusted in order to minimize the objective function. The network is trained to minimize the mean square error between output and input values.

4. *Testing and Validation of Neural Network*

When the training is complete, we want to check the network performance and determine if any changes need to be made to the training process, then network architecture or the data sets. The first thing to do is to check the training record, which was the second argument returned from the training function.

The validation gives information concerning the training of the network. The structure also keeps track of several variables during the course of training, such as the value of the performance function, the magnitude of the gradient, etc. we can use the training record to plot the performance progress by using some commands in MATLAB.

Various training algorithms such as gradient descent, gradient descent with moments is available to train neural network. But Levenberg Marquardt algorithm shows best performance with respect to minimization error. The Levenberg Marquardt (LM) algorithm is used as a training algorithm in this dissertation.

A. *Levenberg Marquardt Algorithm*

The Levenberg Marquardt (LM) algorithm is a variation of Newton's method that was designed for minimizing functions that are sums of squares of other nonlinear functions. This is very well suited to neural network training where the performance index is the mean squared error. For LM algorithm the performance index to be optimized is defined as

$$F(W) = \sum_{p=1}^{P}\sum_{k=1}^{K}(d_{kp} - o_{kp})^2 \qquad (2)$$

Where $W = [W_1 W_2 \ldots\ldots\ldots W_N]^T$ consists of all weights of the network, d_{kp} is the desired value of the k^{th} output and the p^{th} pattern, o_{kp} is the actual value of k^{th} output and the p^{th} pattern N is the number of the weights, P is the number of patterns, and K is the number of network outputs. Equation (6.4) can be written as,

$$F(W) = E^T E \qquad (3)$$

In above equation E is the Cumulative Error Vector (for all patterns)

$E= [e_{11}\ldots e_{k1;}\, e_{12}\ldots e_{k}\ldots.e_{1p}\ldots e_{kp}]^{T}$ (4)

Where, $e_{kp}= d_{kp}- o_{kp}$, for k=1. .. ..K and p=1…P

When training with the LM method the increment of weights ΔW can be obtained as follows,

$\Delta W_k = - [J^T (W_k)\, J\,(Xk) + \mu_k I]^{-1} J^T (W_k)\, E\,(W_k)$ (5)

Where J is the Jacobin matrix

$$J(W)=\begin{bmatrix} \frac{\partial e_{11}}{\partial w_1} & \frac{\partial e_{11}}{\partial w_2} & \cdots\cdots & \frac{\partial e_{11}}{\partial w_N} \\ \frac{\partial e_{21}}{\partial w_1} & \cdots\cdots\cdots & & \\ \vdots & & & \\ \frac{\partial e_{kp}}{\partial w_1} & \cdots\cdots\cdots & & \frac{\partial e_{kp}}{\partial w_N} \end{bmatrix}$$

'I' is identity matrix, μ is the learning rate which is to be updated using the β(decay rate) depending on the outcome. In particular, μ is multiplied by decay rate 'β' , whenever F (W)decreases, where -as is μ divided by β whenever F(W) increases in a new step. Levenberg –Marquardt algorithm is fast method for training .The weights are calculated as,

$W_{k+1} = W_k – [J^T (W_k)\, J\,(Wk) +\mu_k I]^{-1} J^T (W_k)\, E\,(W_k)$ (6)

III. RESULT ANALYSIS

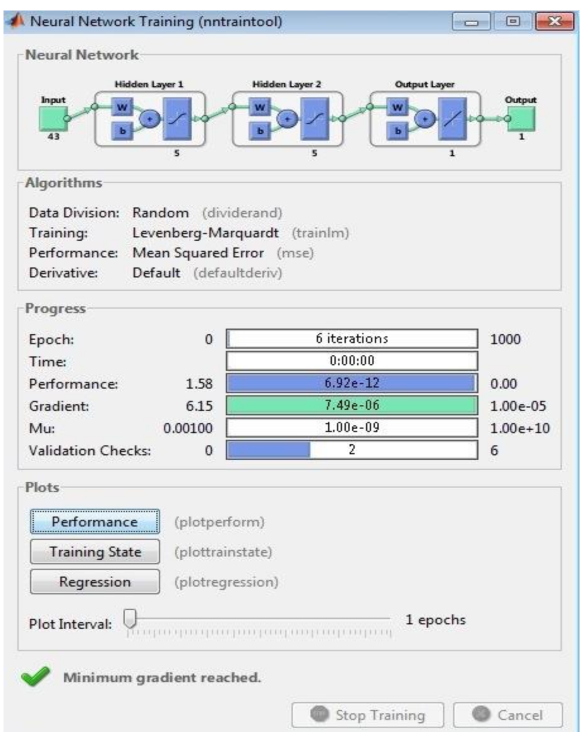

Fig 3: *Designed Neural Network*

Fig 3 shows the developed neural network which showing 43 inputs, two hidden layers having 5 nodes in each layer & one output node. The algorithm used for neural network is Levenberg Marquardt. Performance analysis is done based on MSE (Mean Square Error).The Progress is shown in terms of Epoch, Time, Performance, Gradient, Mutual Information and Validation Checks.

Fig 4, 5& 6 shows training analysis of neural network Fig 4 neural network training performance for training, testing & validation. X-axis shows no.of Epoch while Y-axis shows mean square error. Fig 5 shows training state of neural network while Fig 6 shows regression of neural network

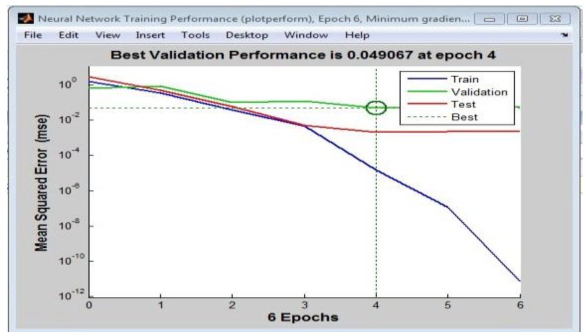

Fig 4: *Neural Network training Performance*

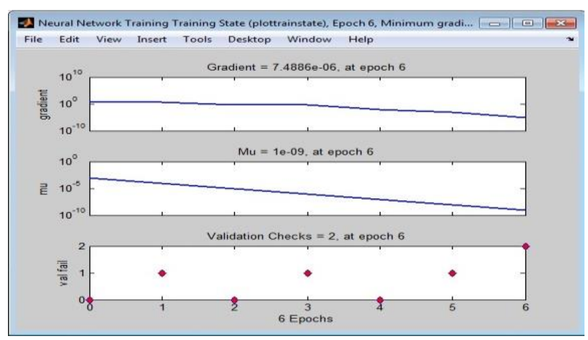

Fig 5: *Neural Network training states*

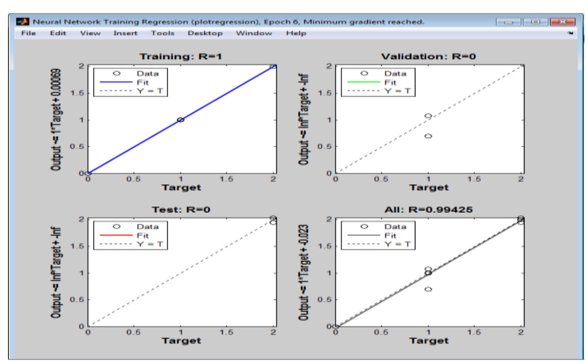

Fig 6: *Neural Network training Regression*

Sr.No.	Site No.	Results from survey	Results from developed system
1	1	Moderate	Moderate
2	2	Poor	Poor
3	3	Good	Good
4	4	Good	Good
5	5	Good	Good
6	6	Poor	Poor
7	7	Moderate	Moderate
8	8	Moderate	Moderate
9	9	Good	Good
10	10	Good	Good

Table 1: Results comparison

Table 1 shows the results comparison where the actual survey results are compared with results obtained from developed ANN system. For training data the system is giving 100% correct results for unknown testing data the system is showing 94% accuracy.

IV. CONCLUSION

For the local market of a developing country, a framework to predict the productivity of construction activities using neural networks was designed, developed, trained, and tested. The results show that the networks adequately converged and have reasonable generalizing capabilities.

The developed framework was also used to perform a sensitivity analysis on the input factors influencing the productivity of construction activities. The framework has demonstrated a good potential in identifying trends of such factors.

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