Estimating The Number Of Daily Patient Applications By Using Artificial Neural Networks

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Abstract

This study is aiming at estimating the patient volumes of hospitals by using artificial neural networks. In order to train the artificial neural network models in this study, historical patient applications data from a Turkish hospital were used. All patient applications counted as daily numbers during three years and dependent variable of our study (patient_count) is derived. A different approach used in this study and instead of a single independent variable (which is time), four different time periods were used as input variables of the artificial neural network models. These input variables were day of month, day of week, month, and year. Several artificial neural network models have been generated and compared with each other by their predictive performance measures. The best predictive artificial neural network architecture has an estimation accuracy of 94.22 percent. This artificial neural network model has an input layer with four neurons, an output layer with one neuron, and only one hidden layer with nineteen neurons. The arithmetic mean of patient application in a day is 755.93 (S.d.=486.60). Mean error of the artificial neural network model is -0.047 and mean absolute error is 105.64. The linear correlation between the actual values and the predicted values of the number of patients is 0.918.

Keywords: artificial neural networks, decision support systems, modeling, estimation, hospital management.

1. INTRODUCTION

The study of artificial neural networks was inspired by attempts to simulate biological neural systems. Analogous to human brain structure, an artificial neural network is composed of an interconnected assembly of nodes and directed links (Tan et al., 2006). Artificial neural networks have been used in many types of applications and research studies in different areas. These areas including computer security systems, business management, decision making, finance, tourism, chemistry, transportation, medical applications and so on. Artificial neural networks can do classification, pattern recognition, optimization, estimation, and time series prediction tasks. All these tasks can be used for getting valuable information for business decision making and planning purposes.

Healthcare sector is a critical service sector that is highly people oriented and very intensive. Therefore forecasting is very important to plan next month's, next week's, and next day's personnel or operations. One of the top important variables to forecast is the number of patient applications to the hospitals. In this study artificial neural networks are used for estimating the number of daily patient applications to a hospital. There are three types of neural networks, which are differentiate into input variables, are examined in this study. In the first one, only time index value was used as an input variable. In the other one, day of year, day of week, month, season, and year were used as input variables. Then the results of these two networks were compared.

2. ARTIFICIAL NEURAL NETWORKS

Artificial neural networks are one of the most accurate and widely used forecasting models (Khashei & Bijari 2010) that are used extensively to model complex relationships between input and output data sequences, and to find hidden patterns in data sets. An artificial neural network is a computational model that emulates the essential features and operations of biological neural networks (Pintér 2011). The human brain consists primarily of nerve cells called neurons, linked together with other neurons via strands of fiber called axons. Axons are used to transmit nerve impulses from one neuron to another whenever the neurons are stimulated. A neuron is connected to the axons of other neurons via dendrites, which are extensions from the cell body of the neuron. The contact point between a dendrite and an axon is called synapse. Neurologists have discovered that the human brain learns by changing the strength of the synaptic connection between neurons upon repeated stimulation by the same impulse (Tan et al. 2006).

2.1. The Structure of an Artificial Neuron

Every neuron in an artificial neural network represents an autonomous computational unit and receives inputs a series of signals that dictate its activation. Following activation, every neuron produces an output signal. All the input signals reach the neuron simultaneously, so the neuron receives more than one input signal, but it produces only one output signal. Every input signal is associated with a connection weight. The weight determines the relative importance the input signal can have in producing the final impulse transmitted by the neuron. The weights are adaptive coefficients that, in analogy with the biological model, are modified in response to the various signals that travel on the network according to a suitable learning algorithm. A threshold value, called bias, is usually introduced. Bias is similar to an intercept in a regression model (Giudici 2005). The components of an artificial neural network neuron are shown in Figure 1.

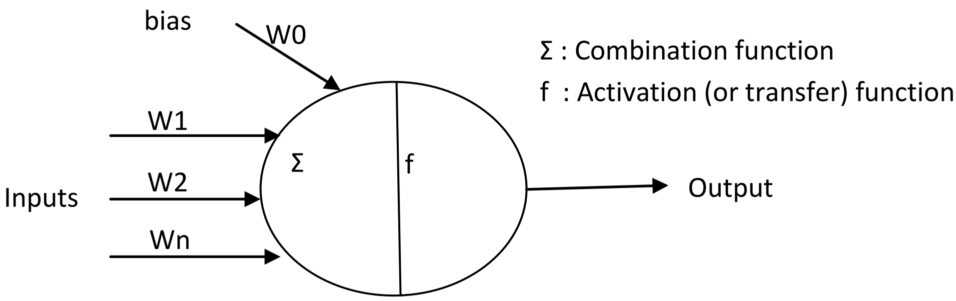

Figure 1. Components of an Artificial Neuron (Irmak 2009)

The combination function commonly uses the standard weighted sum which is the summation of the input attribute values multiplied by the weights that have been assigned to those attributes, to calculate a value to be passed on to the transfer function. The transfer function applies either a linear or non-linear transformation to the value passed to it by the combination function. The hidden layer then employs this transfer function in moving data to the output nodes (Kros et al. 2006). The types of activation functions have very important influences on the learning speeds, classification correct rates and non-linear mapping precisions of artificial neural networks (Daqi & Genxing 2003).

2.2. The Architecture of Artificial Neural Networks

Although researchers have studied numerous different neural network architectures, the most successful applications of neural networks have been multilayer feed-forward networks. These are networks in which there is an input layer consisting of nodes that simply accept the input values, and successive layers of nodes in the next layer. The last layer is called the output layer. Layers between the input and output layers are known as hidden layers. A feed-forward artificial neural network is a fully connected network with a one-way flow and no cycles (Shmueli et al. 2007). Artificial neural networks have been extensively applied in various fields of science and engineering. It is mainly because feed-forward neural networks have universal approximation capability (Wang & Xu 2010). Single hidden layer feed-forward network is the most widely used model form for time series modeling and forecasting (Zhang et al. 1998). Architecture of a feed-forward artificial neural network with a single hidden layer is given in Figure 1.

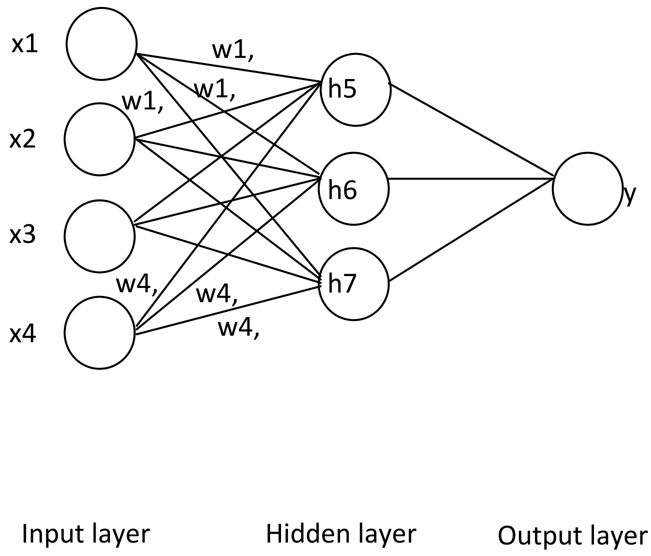

Figure 2. A Feed-Forward Artificial Neural Network (Walczak 2012)

Feed-forward artificial neural networks with one hidden layer are mathematically expressed in a simplified form as

$$N_n(x) = \sum_{j=0}^{n} c_j \sigma\left(\langle w_j\, x\rangle + b_j\right), \quad x \in R^s, s \in N,$$

where for $0 \leq j \leq n$, bj ∈ R are the thresholds, wj ∈ Rs are the connection weights, cj ∈ R are the coefficients, ⟨aj x⟩ is the inner product of wj and x, and σ is the activation function of the network. In many fundamental network models, the activation function is the sigmoidal function of logistic type (Anastassiou 2011).

3. ESTIMATING THE NUMBER OF PATIENTS USING ARTIFICIAL NEURAL NETWORKS

This study is aiming at estimating the patient volumes of hospitals by using artificial neural networks. In order to train the artificial neural network models in this study, historical numbers of patient data from a Turkish hospital were used. Data gathered from main database of the hospital. All patient applications during 3 years counted as daily numbers and dependent variable of our study (patient_count) is derived. This daily time series data set was used along with day, month, year, and day of week variables.

In the first model, only time index value used as an input variable. The best artificial neural network architecture of this model has one neuron in the input layer, three neurons in only one hidden layer, and one neuron in the output layer. The prediction accuracy of this network is 82.94%. The mean absolute error of this network's predictions is 383.76 while the mean number of patient applications to the hospital is 755.93.

Day of week variable was added to the second artificial neural network model in order to represent the changes in the different days of a week, especially the dramatic changes between the weekdays and the weekend. The final topology of this model has eight neurons in the input layer, three neurons in the hidden layer, and one neuron in the output layer. This model has 91.67% prediction accuracy and 139.18 mean absolute error. The error rate is considerably lower than the first model. The reason is that, this model has an ability to represent the fall in the number of patient applications in the weekends.

The third model of this study has four variables that they may represent significant changes in patient numbers in a year. These variables are year, month, day, and day of week. This model has four neurons in the input layer, nineteen neurons in one hidden layer, and one neuron in the output layer. The final network of this model has the highest prediction accuracy that is 94.22 percent, and the lowest error rate. Mean absolute error of this model is 105.64 and the linear correlation between the actual values and the predicted values of the number of patients is 0.918.

The third model of this study is the best predictive artificial neural network model to predict the next days' patient application volumes to the hospital. Table 1 summarizes the results of the artificial neural network models.

Table 1. The Results of Artificial Neural Network Models

Model No	ANN Topology	Input Variables	Prediction Accuracy (%)	Mean Absolute Error (MAE)	Linear Correlation (r)
Model-1	1:3:1	• Time Index	82.943	383.760	0.197
Model-2	8:3:1	• Time Index • Day of Week	91.669	139.186	0.893
Model-3	4:19:1	• Year • Month • Day of Month • Day of Week	94.223	105.643	0.918

A total of 1095 days' data were used for training the neural network models. Generally time series forecasting could be made up to ten percent of the number of data points. In this study 1095 days' data were used for predicting 120 days' number of patient applications. Actual values of patient applications were gathered from hospital database. The actual values and the predicted values of three artificial neural network models are given in Figure 3. As seen from the figure, the predictions of the first model represent the trend but do not reflect daily distinctions. The predictions of the third model best fit to the actual values.

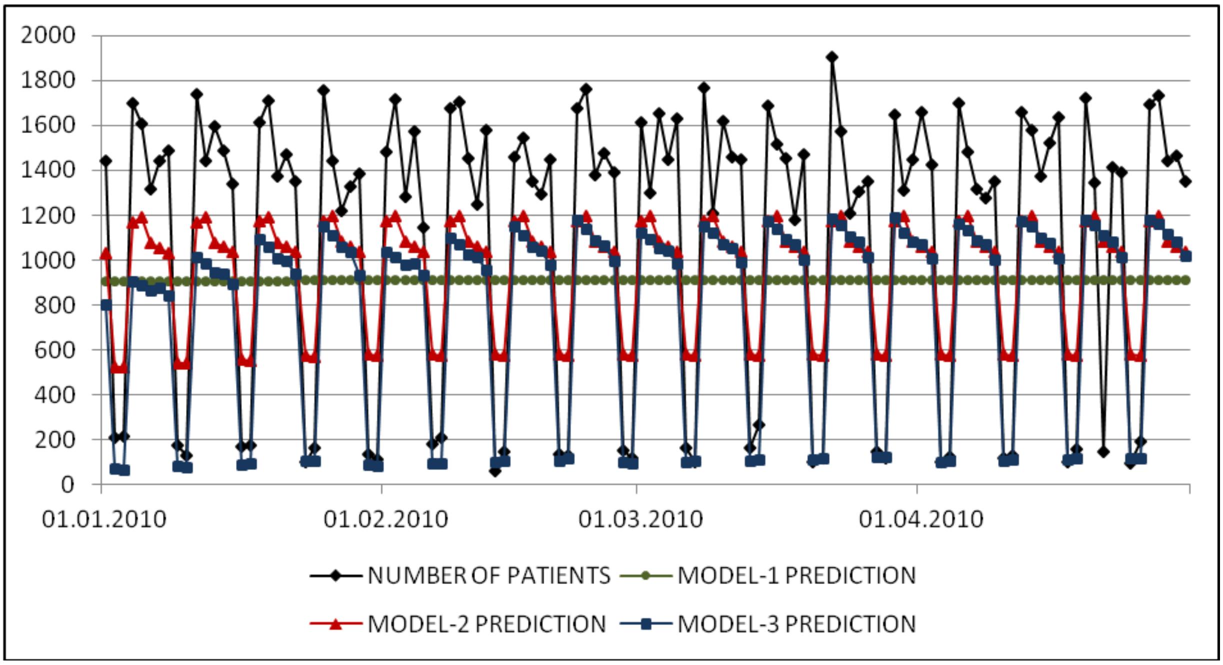

Figure 3. Actual Numbers of Patient Applications and the Predicted Values

4. CONCLUSION

The main strength of artificial neural networks is their high predictive performance. Their structure supports capturing very complex relationships between predictors and a response (Shmueli et al. 2007). In this study time points were used as predictors to estimate patient volume of a hospital. Estimating the future volumes of patients is an important issue for decision making processes of hospital and healthcare sector managers.

Three types of artificial neural network models were generated in this study. The third model which has four input neurons as day of month, day of week, month, and year, showed better predictive results. This result is strongly related to the structure of artificial neural networks. Because artificial neural networks have flexible structures that capture very complex relationships, they can show better results when detailed input information are given to the artificial neural network model. More detailed studies can be implemented to reveal sophisticated information about the predictive performances of artificial neural networks.

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