Forecasting of the Stock Price Index by Using Fuzzy-Neural Network and Genetic Algorithms

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Tabriz Branch, Islamic Azad University, Tabriz, Iran

ABSTRACT

Investment in securities exchange stock is one of the profitable options in capital market. Securities exchange is a center for collection of savings and liquidity of the private sector in order to finance Long - term investment projects in one hand and it is a reliable and official way to use fixed Savings of the investors in other hand. Forecasting of stock price indices is important in spite of complexity of the Stock market. The researches show that stock index does not change randomly and incidentally in Tehran securities exchange, stock market is a nonlinear and revolutionary system affected by political, socio- economical and Psychological factors. Nonlinear intelligent systems like artificial networks, Fuzzy-neural networks and genetic algorithms can be used for prediction of stock price. In this research Fuzzy- neural networks and genetic algorithm are used separately in order to forecast index stock price. The results of Fuzzy- neural and genetic algorithm models are compared by four error measurement criteria after designing and implementation of both models. The results show that Fuzzy- neural and genetic algorithm combinatory model predicts stock price index accurately and rapidly by high approximation capability relative to individual neural network.

INTRODUCTION

Investment in securities exchange stock is one of the Profitable ways in the capital market. There are different viewpoints about evaluation and prediction of exchange in organized markets. In early 20th century, some scholars experienced in evaluation of the securities exchange believed that an image for prediction of future stock price can be offered by analysis of historical trend of stock price changes. Scientific studies by emphasize on exact identification of the behavior of the stock price established tendency towards stock price assessment models. At first, Random Walks theory was considered in determination of the stock price behavior, and then characteristics and structure of the capital market were gained attention by result of capital efficiency market hypothesis. It is believed that in capital efficiency market, stock price reflects share current information and there is no predictable pattern for changes of stock price. Opinions proposed until 1980 determined stock price behavior so that shifting network stock market in 1987 questioned the reliability of the capital efficiency market hypotheses and models like randomness of prices. In 1990 decade and afterward the scholars considered regular chaos behavior and trying to design non linear models for prediction of the stock price gained attention. Techniques like intelligent systems gained attention, since by assumption of linearity of the market structure many models can be designed. The main advantages of the intelligent systems like artificial neural networks and fuzzy-neural networks are capability of modeling and prediction of non linear and chaos sets. Reduction of time for obtaining optimal respond is a characteristic of the genetic algorithm.

Literature Review:

Many studies have been conducted in prediction of stock price. According to methodology of the research the main studies are referred, Refenes, Zapranis Francis (1994) compared performance of neural networks with regression model by modeling stock price behavior. In this research, neural networks are used for prediction of big firms stock as an alternative of classic statistics techniques. The results show neural networks have optimal performance relative to statistical techniques and they offer the better models. Tan, Prokhorov and wunsch (1995) designed system that forecasts short - term considerable changes in stock price. At first the data are preprocessed and then the neural networks are modeled that they predict better profitable situations.

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Moshiri and Cameron (2000) compared performance of artificial neural networks with other economics measuring and time series models for prediction of Canada inflation rate. In this article, neural networks are compared with structural models, VAR, BAVR and ARIMA for different time series (next one, three and twelve months). RMSE and MAE are used as criteria showed that neural networks could predict Canada inflation rate thoroughly and sometimes better than all economic measuring, traditional and time series methods.

Kuo, Chen and Hwang (2001) established consulting system for preservation and selling and buying of stock in securities market in an article as title of “stock decision making support intelligent system by using artificial neural networks and combination of genetic algorithm based on fuzzy neural network”. This system provides possibility of quantifying quality variables in forecasting stock price. Kuo, Chen and Hwang (1998) submitted similar article without considering genetic algorithms. In this article, a questionnaire by Delphi fuzzy method was used in order to obtain experts opinions in forecasting stock price.

Yim (2002) compared neural networks and classic prediction methods (ARMA and GARCH). MSE and R2 are considered evaluation criteria. The results show superiority of neural networks relative to ARMA and GARCH.

Souto-maior (2006) predicted Brazil stock price index trend by fuzzy logic that the results were considered optimal.

Several researches have been conducted on using neural networks in Iran securities exchange and stock market. According to this fact that the methodology of these research is the same as foreign research and this research is different from the research conducted in Iran so only the titles of the researches are mentioned:


Study of Stock Price Forecasting by Using Neural Networks and Combinatory Method:

In these research artificial neural networks, fuzzy neural networks and genetic algorithm were employed in order to forecast stock price and as an example the stock price of ten firms of Tehran securities exchange was selected and predicted by the mentioned methods.

Inputs of three mentioned methods are eleven time series that they were prepared daily in period of 2002-2011 from securities exchange and other organization.

In neural networks methods, two data types were used the first group was used for experiment and the second group was used for test of the model. After investigation for identification of the model variables eleven effective variables were identified in three total groups in order to identification of model variables:

Group one: Technical variables involve stock price, maximum stock price, and minimum stock price, transaction volume, Tehran securities exchange stock price index and price and dividend ratio.

Group two: Psychological investors’ variables involve number of individuals and times.

Group three: economical variables involve foreign currency rate, price of gold ounce in London exchange, oil price in OPEC.

Averagely input data are 1000 data that 65% of them were considered as learning data and the remainder of the data was considered as experimental data.

This research was conducted in period of 2002-2010 and the data were collected from Tehran securities exchange, central bank, OPEC affairs organization, and Iran oil firm and internet sites. After selection of the data, the next step was fuzzy phase and entering to artificial neural network. Then the output of fuzzy neural network was transferred into genetic algorithm finally, the results of both models are compared and the hypotheses are investigated.

Research Methods:
A-Neural networks:

Neural networks are valuable instrument for broad applications in different scopes of the management as an essential element for data measurement systems that change the organization tendency toward the relationship between data and firm strategy (Lisbo 2000).

B-Advantages of neural network:

Although neural networks are not comparable with neural systems, the characteristics that differentiated them from others, these characteristics are as follow:

1- Learning capability
2- Information dispersion (used as participatory or associative memory, memory with capability of addressing and saving)
3- Generalization
4- Parallel processing (rapid processing)
5- Resistance (high resistance, capability of repairment, error tolerance) (Bill, Russel, Teo& Jackson, 2002).

C-Fuzzy Neural Network:
Although artificial neural networks and fuzzy systems have different structures but they are complementary in spite of having strong and weak points. While a common neural network consists of similar and the same neurons, fuzzy neural network neurons are inhomogeneous by different calculation process (like OR and AND) (Fazlollahi and Aliev, 2004). In this article, the possibility of combination of fuzzy systems and artificial neural networks are studied and it is tried to enter neural networks learning capability into fuzzy systems. Genetic algorithm is also a research algorithm that it is based on live organism genetics. This algorithm merges “survival of the fittest of Darwin” with random structure information and provides a research algorithm by natural evolution methods characteristics. In other words, new set of strings is made in each generation by using previous the best elements and new elements are tested based on proportionality. (Shu- Hang, 2002).

Most of the industrial and production systems issues are complex and they are not solved by traditional and common optimization methods. Genetic algorithm tries to solve real world issues by simulation of natural genetic processes. Genetics algorithm is an effective and efficiency method for solving of the complex problems and it is simple but powerful algorithm from calculation viewpoints and limiting hypotheses in search space do not restrict it.

Main Advantages of the Genetic Algorithm:
a) Genetic algorithms work with responses code not with responses (by this capability there is probability to access to complete and accurate responses relative to primary responses).
b) Genetic algorithms search among responses set not in individual response.
c) Genetic algorithms use only required object information not derivation of other auxiliary information.
d) Genetic algorithms use probable rules not certain rules.

Superiority of Genetic in Solving of Complex Problems:
There is no defined limitation for genetic algorithm and it resolves optimization problems without considering internal function. This algorithm can solves any limitations (for example linear and nonlinear problems) defined in continuous and discrete research space or both of them. Genetic algorithm operator's structure aids it in successful finding optimal responses. Genetic algorithm provides high flexibility in combination of innovative techniques and by this way provides effective and efficient problem solving method (Goldberg, 1989).

Designing Neural Network:
Type of Network and Learning Method:
Multi-layer perceptron neural network (MLP) is common neural network and it is used in most of the research (Manhaj, 2001). In this research back propagation neural network with error forward propagation law was used after investigation and comparison of the different neural networks. Artificial neural networks are implemented by software MATLAB by using Netlab toolbox.

Architecture of the Network:
In designing of the neural networks, after determination of type of network and learning method, the number of input nodes, hidden layers, hidden nodes and output nodes should be specified. Three layers (one input layer, one hidden layer and one output layer) with [11 30 1] neurons are optimal layers in this research.

Number of input nodes has been considered eleven nodes exactly equal to network inputs. According to this fact that dependent variable is forecasting stock price in the mentioned period, number of output node is one.

Hidden layers and hidden nodes play an important role in success of neural networks. Hidden nodes in hidden layers allow recognition of data characteristics and provide complex nonlinear mapping between input and output variables. Theoretically, neural networks can obtain desired accuracy in approximation of functions by using sufficient number of hidden node in hidden layer (Lisbo, 2000), 30 nodes in hidden layer are considered in this research.

Following relation was used for preparation of input data base on this fact that the data were normalized in interval of [0, 1]

\[ X_n = \frac{x - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}} \]  

(1)

So, the obtained data and interference points were omitted and then the neural network was designed.
Stimulant Function:
The best function for middle layer is sigmoid function. The criteria for evaluation of prediction performance related to forecasted output error and real optimal output error are as follow:
Mean Square Error (MSE)
Normalized Mean Square Error (NMSE)
Mean Absolute Percentage Error (MAPE)
Coefficient ($R^2$)

Methods and Result of Predictions by Neural Network of MLP:
By applying inputs in the networks, the back propagation is calculated in order to obtain neural network output then output error, optimal amounts are calculated and then they are distributed among current layers according to forward propagation and finally weighting matrices are corrected. Averagely 760 duplications are obtained for each firm.

For example, level of network error improvement for Arak petrochemical firm is shown in figure 1. The level of network error in duplications is shown by MLP in order to aid in changing topology.

Fig. 1: Reduction of error in neural network MLP, Arak petrochemical firm.

As seen, by increase in number of duplications, level of improvement in error is reduced and no improvement is obtained in final duplication. Table 1 shows summarized results of evaluation of different firms by artificial neural forecasting.

Table 1: Summarized results of evaluation of different firms by artificial neural forecasting.

<table>
<thead>
<tr>
<th>method</th>
<th>firm</th>
<th>MSE</th>
<th>NMSE</th>
<th>MAPE</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial neural network</td>
<td>Iran Khodro Diesel</td>
<td>0.00566</td>
<td>0.01487</td>
<td>0.00027</td>
<td>0.91512</td>
</tr>
<tr>
<td></td>
<td>Arak Petrochemistry</td>
<td>0.00108</td>
<td>0.01303</td>
<td>0.00036</td>
<td>0.98697</td>
</tr>
<tr>
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<td>Saipa</td>
<td>0.00186</td>
<td>0.09294</td>
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<td>0.90705</td>
</tr>
<tr>
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</tr>
<tr>
<td></td>
<td>Tehran Cement</td>
<td>0.000975</td>
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<td>0.00012</td>
<td>0.8689</td>
</tr>
<tr>
<td></td>
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<td>0.00211</td>
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<td>0.002871</td>
<td>0.96834</td>
</tr>
<tr>
<td></td>
<td>Kaf</td>
<td>0.0036</td>
<td>0.12964</td>
<td>0.00125</td>
<td>0.87036</td>
</tr>
<tr>
<td></td>
<td>Mines and metals</td>
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<td>0.000252</td>
<td>0.91606</td>
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</tbody>
</table>

Forecasting Stock Price by Using Genetic Algorithm and Fuzzy Neural Network (GFNN):
Artificial neural network and fuzzy logic have advantages and disadvantages that combination of them compensates their shortage (Von Altrock, 1997)
The research shows that genetic algorithm is effective in improvement of artificial neural network performance (Kuo, Chen and Hwang, 2001). So this algorithm reduces neural network learning time by reduction of duplication (Kim, 2006, Han, Kim, 2000)

Network Modeling:
Figure 2 shows proposes combinatorial model for prediction of stock price.
After establishment of fuzzy neural network for each selected variables, the output of networks and the output of pervious stage neural network are considered as input of genetic algorithm based neural network by duty of primary weighting outputs.

**Designing Fuzzy Neural Network:**

According to artificial neural network architecture in previous section, in designing fuzzy neural networks, MLP with error forward propagation learning algorithm was used. In order to optimal designing of fuzzy neural network by continuous change of number of hidden layer and number of neurons, the best topology of the neural network was considered.

Membership function in fuzzy neural networks for input and output data is the difference between fuzzy neural network and neural network. The membership function of fuzzy set used in this research is a mapping of members of A set in interval of \([2, -2]\), thus

\[
A : X \rightarrow [-2, 2] or X \rightarrow [verylow, low, middle, high, very high]
\]  

(2)

Generally, every function with such mapping can be used as fuzzy set membership function.

In fuzzy neural network Linear mapping and histogram mapping are considered for conversion of the data. In linear mapping relation (2) is used for I in [I, H] (Gonzalez and wintz, 1987).

\[
L_i = L + \frac{X[i]}{MAX - MIN}
\]  

(3)

In this research MAX and MIN are maximum and minimum of each time series X involving neural network input data.

In histogram mapping, the abundance of figures of interval is determined and figures by big interval are achieved more abundant, so that the members in each interval are equal approximately (Gonzalez and wintz, 1987). This mapping is more complex than linear mapping and provides the best results.

\[
P_i(r_k) = \frac{n_k}{n} \quad 0 \leq r_k \leq 1 \quad and \quad k = 0,1,... L - 1
\]

(4)

\[
p_i(r) = p_j(r_j) \forall ij
\]

In this relation \(n_k\) is data number in group \(k\), \(n\) is total numbers and \(p_i(r_k)\) indicate probability of data from group \(r_k\). The results of Arak petrochemical company stock prediction are compared by using linear and histogram mapping in table 2.

<table>
<thead>
<tr>
<th>method</th>
<th>mapping</th>
<th>MSE</th>
<th>MAPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuzzy Neural network</td>
<td>linear</td>
<td>2.3323</td>
<td>0.000248</td>
</tr>
<tr>
<td></td>
<td>histogram</td>
<td>0.0878</td>
<td>0.0002857</td>
</tr>
</tbody>
</table>

**Table 2:** The result of prediction by linear and histogram mapping.
Designing genetic algorithm: As before said, genetic algorithm is an optimal method that is used for weighting middle layers in this network. Genetic algorithm was designed by using Genetic Algorithm tool Box and programming in MATLAB.

Chromosome:
In spite of other research methods, genetic algorithm begins with primary set of random respond set initial population despite of other research methods. Each member is called chromosome that indicates present solution.
A chromosome is a strand of signs and it is usually a binary strand, or set of bites that a response (optimal or no optimal) is shown as code.
By using binary coding each bite is zero or one (Goldberg, 1989)
This research chromosome has 400 bites and final neural network has structure of [4 10 1] and so its weight is 50. Since for showing weight, eight bites are sufficient, a chromosome with 400 bites can indicate the best response set for weighting middle layer of the mentioned neural network.

Target Function and Competency:
Target function is used in order to determine the role of individuals in problem solving. Competency function is usually used for conversion of target function into related competency. Thus:
\[ F(n) = g(f(x)) \] \hspace{1cm} (5)
Where \( f \) is target function, function \( g \) converts target function to non zero value. \( F \) is related competency.
Optimality and non optimality of response is measured by competency function value, since it is optimization problem, competency function is the same as target function.
Target function is defined as (5) (Kuo, Chen and Hwang, 2001):
\[ F = \sum_{N=1}^{N} (T - Y)^{c} \] \hspace{1cm} (6)
\( N \) is population size and \( T \) and \( Y \) are real and predicted values of neural network. The program of this function was written in MATLAB and transferred to GA tool box.
In this program, at first optimal weights are selected by using genetics algorithm then they are transferred to fuzzy and artificial neural networking learning base. For doing so, neural network function MLP is recalled and the genetics algorithm based neural networks inputs shown in figure 2 are transferred. After weighting of the chromosomes by established weights of the established networks the optimized weights are calculated by genetic algorithm and they are transferred to the network. The result of genetics algorithm based neural networks (\( Y \)) and output (\( T \)) are used in equation (5).

Size of Population and Number of Production:
Number of chromosomes is called population size. In this research population size in different experiments has been investigated and the population has been improved by reproduction method from one generation to other generation in order to find the best response. The size of this population is 50 chromosomes and the number of generation is 95. Since competency function tends to minimize error, its value is descending during different generations according figure 3.

![Fig. 3: Based on figure the best competency value is 0.0022667.](image-url)
Reproduction Process:
In this process, chromosomes are selected based on their competency function and used for other operators (Chambers, 2003). The method used in this research is uniform and selects parents randomly.

Results of Prediction by Genetic Algorithm and Fuzzy-Neural Network:
At the end of programming and implementation of the combination shown in table (3) the stock price was forecasted by entering data of the studied firms.
Averagely the number of duplication is 450 for each firm. Figure 4 shows level of error reduction in Arak petrochemical firm.

![Figure 4: Level of error reduction in Arak petrochemical firm.](image)

The values of four genetic algorithms and neural network performance methods are shown in table 3 for 10 studied firms.

<table>
<thead>
<tr>
<th>method</th>
<th>firm</th>
<th>MSE</th>
<th>NMSE</th>
<th>MAPE</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic algorithm</td>
<td>Iran Khodro Diesel</td>
<td>0.00286</td>
<td>0.04726</td>
<td>0.000685</td>
<td>0.95274</td>
</tr>
<tr>
<td></td>
<td>Arak Petrochemistry</td>
<td>0.0016</td>
<td>0.0132</td>
<td>0.00121</td>
<td>0.9868</td>
</tr>
<tr>
<td></td>
<td>Sapia</td>
<td>0.003017</td>
<td>0.05538</td>
<td>0.00034</td>
<td>0.94461</td>
</tr>
<tr>
<td></td>
<td>Sarmayeh Gozari Sepah</td>
<td>0.00124</td>
<td>0.0117</td>
<td>0.000237</td>
<td>0.99883</td>
</tr>
<tr>
<td></td>
<td>Tehran Cement</td>
<td>0.0017</td>
<td>0.026</td>
<td>0.00001</td>
<td>0.9739</td>
</tr>
<tr>
<td></td>
<td>Shade-Iran</td>
<td>0.00111</td>
<td>0.01149</td>
<td>0.00001</td>
<td>0.9885</td>
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<tr>
<td></td>
<td>Kaf</td>
<td>0.00344</td>
<td>0.033609</td>
<td>0.000117</td>
<td>0.9663</td>
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<td>Hybrid neural network</td>
<td>Mines and metals</td>
<td>0.0019</td>
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</tr>
<tr>
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<td>Naft Pars</td>
<td>0.00137</td>
<td>0.0214</td>
<td>0.00013</td>
<td>0.9786</td>
</tr>
</tbody>
</table>

After obtain the results of three methods (neural networks-fuzzy- neural networks and genetics algorithm), the results and 2 hypotheses are compared:

Hypotheses:
$H_1 = $ Could genetic algorithm and neural network be used for forecasting of stock price?
$H_2 = $ Could genetic algorithm and fuzzy neural network reduce the error of stock price index prediction relative to artificial neural network technique?

Results:
The first hypothesis is confirmed according to table 3 and completely acceptable results which have been proposed for evaluation of the statistical sample Price forecasting performance by using of fuzzy network and genetic algorithm method.

By comparison of performance evaluation criteria in table 4, it can be concluded that for the second hypothesis, the evaluation error is reduced by combined fuzzy neural network and genetic algorithm method relative to artificial neural network single method. So, the second hypothesis is confirmed. In other words, forecasting of next day stock price is exact by combined fuzzy neural network and genetic algorithm model than neural network and this is confirmed as research second hypothesis.

Conclusion:
Table 4: Comparison of evaluation of both methods performance.

<table>
<thead>
<tr>
<th>Method</th>
<th>Firm</th>
<th>MSE</th>
<th>NMSE</th>
<th>MAPE</th>
<th>R²</th>
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<tr>
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<tr>
<td>Fuzzy neural network and genetic algorithm</td>
<td>Firm</td>
<td>MSE</td>
<td>NMSE</td>
<td>MAPE</td>
<td>R²</td>
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