Autonomic Learning Algorithm to Predict Stock Price via Metaheuristics-Based Optimization

Sahar Khaleghi
Master of IT Engineering Group, Electronic Educations Department
Shiraz University
Shiraz, Iran
SaharKhaleghi1368@gmail.com

Javad Soroor
Industrial Engineering Department
Shiraz University of Technology
Shiraz, Iran
Soroor@sutech.ac.ir

***Abstract*—**Investment in the stocks exchange is one of the most common attitudes in the capital market. If one has the knowledge and the experience, he has the chance to make a lot of profits from this risky market. On the other hand, since stock market has a nonlinear and chaotic behavior, one mistake is enough to lose. This dynamic market is greatly affected by psychological, economic, and political conditions. Scientific methods and practical techniques may be used to carefully investigate the issue. To mention, nonlinear intelligent methods such as metaheuristics, learning automata, and artificial neural network are some of well-known methods which can be used to predict share price before the actual investment. In order to realize that, a model for predicting the share price has been developed and presented by combining the aforementioned methods. Firefly Algorithm has been taken into account as the metaheuristic solution to the stock prediction problem. Such a hybrid method has been proposed and implemented; in order to evaluate the proposed solution, a dataset gathered from 20 companies listed on Tehran Stock Exchange has been considered as a case study. It has been shown that the proposed algorithm can approximately predict 30 to 50% of the future behavior of shares in the market. The outcomes have shown great potential for the hybrid algorithm to be applied in other fields of business administration and investment problems.

Keywords—Metaheuristics, Learning Automata, Firefly Algorithm, Artificial Neural Network, Optimization, Stock Exchange

I. INTRODUCTION

Different theories have been raised on evaluating and predicting exchange in organized markets. In the early 20th century, a group of specialists with experience in the evaluation of securities strongly believed that an image could be presented for predicting future price of shares by studying and analyzing the historical trend of price changes. With an emphasis on the precise behavior identification of share price, more scientific studies tended more toward stock price valuation models. At first, random walks theories were proposed as a starting point for determining the behavior of share price. Then, features and structure of capital market were considered. Consequently, these studies resulted in efficient capital market hypothesis. Owing to its special structure, this hypothesis drew the attention of scientific circles.

It is believed in efficient capital market that share price is a reflection of the current information relating to that share and changes of share price do not have a specific predictable model. The theories which were posed up to 1980s had been good determiners of the behavior of share price in the market until evolutions of the New York Stock Exchange in 1987 extremely questioned the validity of the hypotheses of efficient capital market and other models such as random prices [1]. In 1990s and later, most specialists concentrated on the chaotic and regular behavior and more efforts were increasingly made to develop nonlinear models for predicting share price [2].

According to these theories, intelligent systems are among the techniques which have gained high importance, because, by assuming the linearity of the market structure, many models can be easily designed. Nevertheless, it is very difficult to completely demonstrate the behavior of complex sets such as capital in a modern economic model as a set of simple and linear equations. Modeling and predicting irregular and nonlinear sets are the major advantage of intelligent systems such as neural networks. Most researchers believe that other tools such as firefly algorithm and learning automata can be helpful in terms of reducing response time and even optimizing predictions in artificial neural networks [3].

II. Background

By modeling the behavior of share price by neural networks, Refenes, Zapranis, and Frandis (1994) compared its performance with that of regression models. In this research, neural networks were employed as an alternative for classic statistical techniques in terms of predicting the share of large companies. The results revealed that neural networks had better performance than statistical techniques and presented better models [4]. Tan, Prokhorov, and Wunsch (1995) designed a system which could predict considerable short-term changes in share price. In this system, first, pre-processing was conducted on data and then the neural network was modeled to estimate very good profitability situations [5].

In an article entitled "An intelligent support system for decision-making on share transactions by employing and aggregating genetic algorithms based on fuzzy neural network and artificial neural network", Kuo, Chen, and Hwang (2001) developed a counseling system for preserving, selling, or buying shares in stock market. The proposed system was characterized by providing quantification possibility for the qualitative variables involved in predicting share price. They also presented another paper with a similar title in 1998 without considering genetic algorithms. In this paper, a questionnaire was developed using fuzzy Delphi method to take advantage of expert opinions in terms of predicting share prices [6].

Yim (2002) conducted a research to compare neural network method and classic prediction methods (ARMA, GARCH). Evaluation criteria included MSE and R^2. The results indicated the superiority of neural networks to ARMA and GARCH samples [7]. Comparison of error back-propagation artificial neural network with Logit model and ordinary least squares (OLS) method was performed by Olson and Mossman (2003); results demonstrated that artificial neural network could better identify nonlinear relations between dependent and independent variables and provide more precise predictions [8]. Souto-Maior (2006) predicted the direction of Brazil's stock price index using fuzzy logic. The results were evaluated to be appropriate [9].

III. Implementation Issues

The proposed model consisted of three algorithms: firefly [10], learning automata [11], and artificial neural network [12]. First, stock information of a company was given to the firefly algorithm. This algorithm divided the information into equal subintervals. Then, an automaton was drawn for each subinterval and the equations were approximated. The approximation was then evaluated; if it was not approved, the algorithm will be performed again. At this stage, the number of divisions may need to be edited or the primary parameters may be required to be altered. Below, this process will be explained. After extracting the optimal equation by the proposed automata, the equations are given to a neural network, which approximates the equation. Structure of the proposed algorithm can be observed in Figure 1.

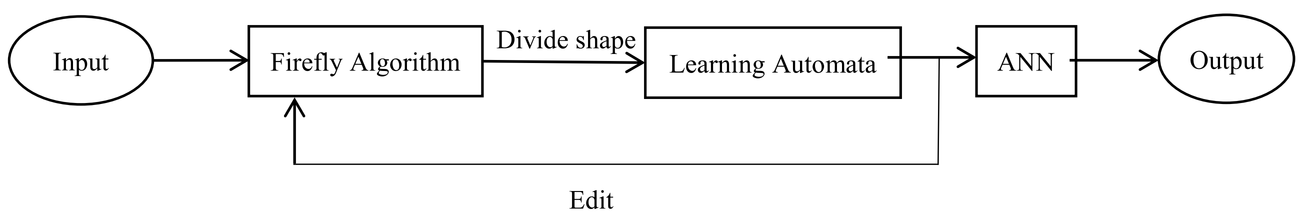

Fig. 1. Structure of the proposed algorithm

A. Problem-solving by Firefly Algorithm

To solve the problem, artificial fireflies should be first defined. In this problem, the number of days in a year is considered artificial firefly, which is in an array of 1 to 365. Each element of the array shows the number of the day in a year; i.e. if the number of a firefly is 8, it is the eighth day in the year. The initial number of fireflies is 9 by trial and error. During the process, it is altered by the algorithm. Figure 2 shows the structure of the artificial firefly.

Structure of firefly is valued as follows in Figure 3. Then, it is divided into 10 sections based on the information. The phonotype structure is observed in Figure 4.

First Section	Second Section	Third Section	....	Section IX	Fitness
x_1	x_2	x_3	....	x_9	

Figure 2: Structure of artificial firefly

1	2	3	4	5	6	7	8	9	Fitness
8	20	75	81	127	136	162	181	186	

Figure 3: An example of the structure of artificial firefly

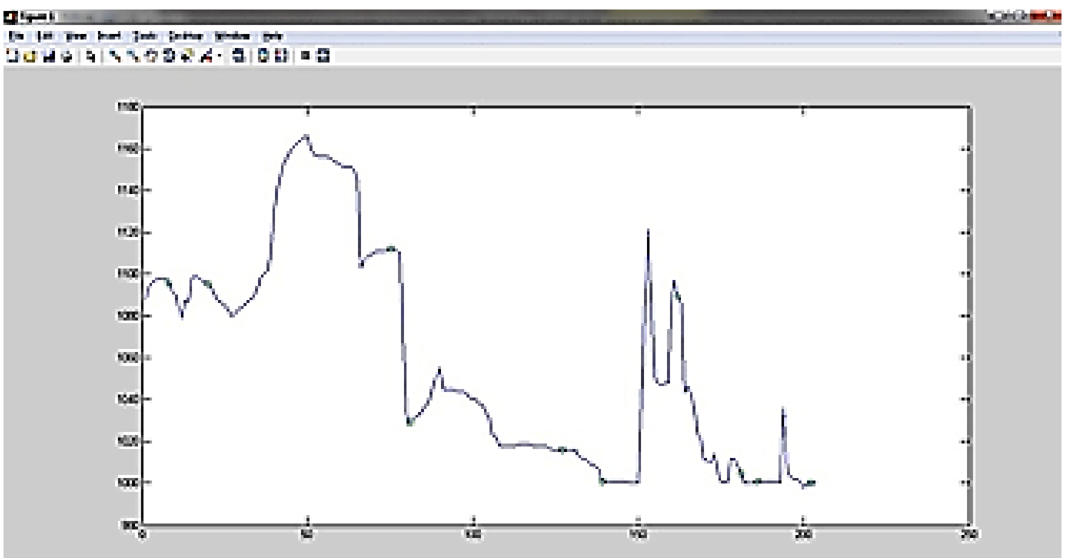

Figure 4: Phonotype structure of artificial firefly

B. Primary Population and the Fitness Function

First, 10 artificial fireflies are generated and randomly valued. Number 10 is selected by trial and error. Changes are calculated for each subinterval. To estimate maximum changes, the score will be +1 if there is one maximum and minimum point; if both maximum and minimum points exist relative to start and end points, the score will be -1. If there is no maximum or minimum point, no score will be allocated. Each score is then divided by the length of subsection while size of the subsection is effective. Then, sum of the scores is considered as fitness function. The more the number of fitness function, the better the place of firefly would be.

C. Law of Attraction

All artificial fireflies are compared with each other. The flies with brighter light attract those with less light. More light indicates better fitness function. Less bright flies then are attracted to brighter fliers. Relation (1) is used for attraction.

$$x_i' = x_i + \beta(x_j - x_i) \ , \beta = \beta_0 e^{-\gamma r^m} \quad (1)$$

In this paper, y = 1, m = 0.2, and $\beta_0 = 2$. Then, while implementing the algorithm, m is increased after each generation. Finally, m = 2. Afterward, all the obtained xi values are placed in a new array.

D. Mutation for Artificial Fireflies

Mutation algorithm is applied to the population obtained from attraction and is calculated by Relation (2).

$$x_i'' = x_i' + \alpha\varepsilon_i \qquad (2)$$

εi is a random vector with uniform distribution which uses numbers between 0 and 1, α is calculated by Relation (3), and K shows direction reduction in firefly algorithm which equals 0.5.

$$\alpha(t) = \alpha_0 (e^{-k})^t \qquad (3)$$

If the values obtained from mutation operator are out of the legitimate interval, they will be eliminated from the dataset.

E. Replacement

Generational replacement is used. At the beginning of the algorithm, 50% of parents, 25% of the offspring generated by attraction method, and 25% of the offspring generated by mutation methods are transferred to the next generation. This process leads to scanning in the problem. After each generation, percentages of the offspring and parents are decreased and increased to end the problem in convergence. Increasing percentage of parents is calculated by trial and error.

F. Terminating Condition

Termination condition of the algorithm is 50 generations, which is calculated by trial and error.

IV. Problem-solving by learning automata

The output of firefly algorithm is the input of learning automata. The number of learning automata is the same as the number of subintervals and structure of each automaton is the number of variables. Each variable is a state for automata. Table 1 shows the structure of automata.

Table 1: Structure of automata for approximating Spline equation

State	A	B	C	D	E	F	G	H
A	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
B	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*
C	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*
D	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*
E	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*
F	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*
G	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*
H	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*

Probability of all points equals 0.125 and values of *a* to *h* are randomly defined. Each state has three states of increase, decrease, and non-change with the probability of 0.33. States of automata and probabilities are then altered to reach a normal level.

A. Fitness Function

Spline diagram is depicted by means of a, b… h values. The difference between input points and obtained equation is calculated by Relation (4):

$$MSE^1 = \sum_i (y_i - \acute{y}_i)^2 \qquad (4)$$

[1] *Mean Squared Error*

y_i is the input value on day i and $\acute{y}_i$ is Spline value.

B. Changes in the Probability of Each State

Changes in each probability equal 0.01 at the beginning of algorithm implementation which creates scanning in the problem. After each generation, the probability of each state is decreased to 0.0001% to result the problem in convergence. Primary percentage and reduction rate of each generation are calculated by trial and error.

C. Termination Condition of Automata

Termination condition is one of the following states:

- Reaching MSE of less than 10 units (generation is calculated by trial and error),
- Generating 100 generation without any change in fitness function,

If the second state is the reason of automata termination, the program will carry out the following three actions in parallel:

- Re-implementation of automata,
- Re-implementation of firefly algorithm using more fireflies (10% increase of fireflies),
- Re-implementation of firefly algorithm with a new parameter in producing generation and mutation percent.

This process continues until reaching the desired MSE. It should be noted that, if some automata reach the desired MSE and others do not reach the considered response, the algorithm will be implemented on the automata which have not achieved the response.

D. Neural Network

Outputs of all the automata are given to feed forward neural network. The three-layer neural network with 10 neurons in the middle layer and 1 neuron in the outside layer approximates the equation of stock exchange (the number of neurons is calculated according to the input which can be 100 units in maximum).

V. Evaluating the Proposed Algorithm

Information related to one year of 20 companies listed on the stock exchange was used for comparison. To perform the experiments, Linuxredhat 9 operating system on a 5 core computer with 2.5 GHz processors and RAM 6G was used.

Figure 5 presents the structure of the neural network. In Figure 6, the output of the algorithm precision is shown for the information of Saderat Bank in 2012. Precision of the algorithm was then calculated for 20 companies, the results of which are given below.

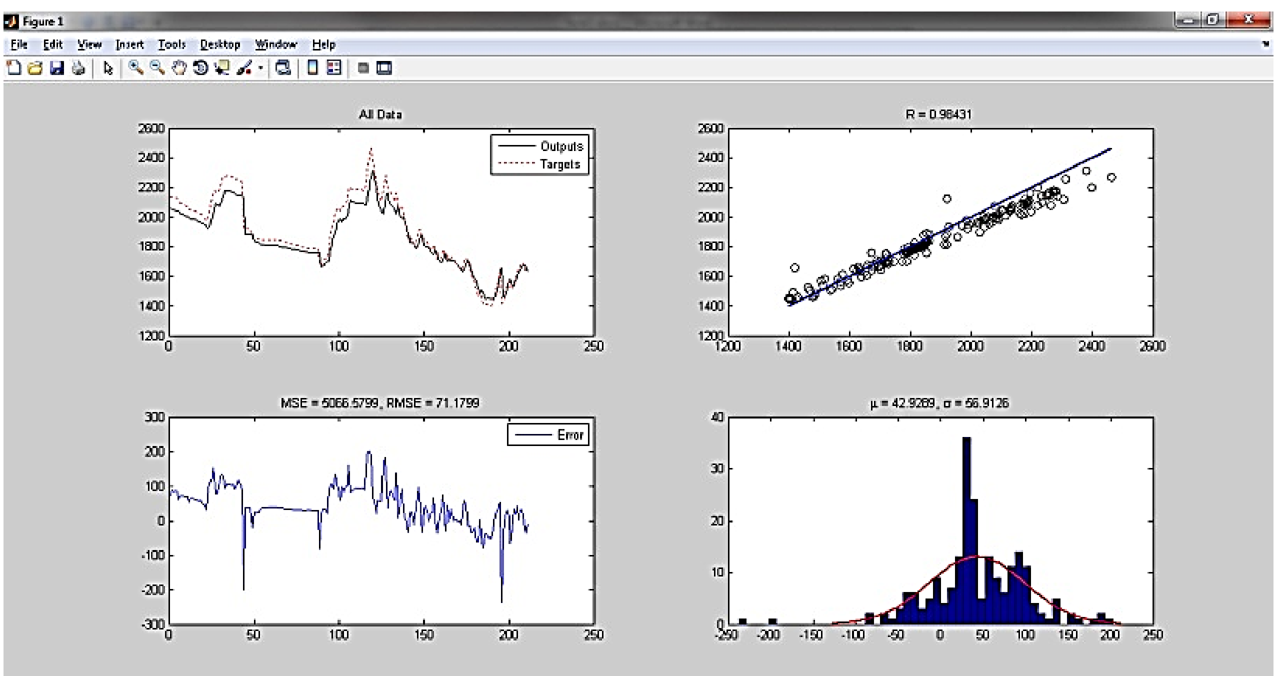

Figure 5: Output of the neural network for rate of prediction error

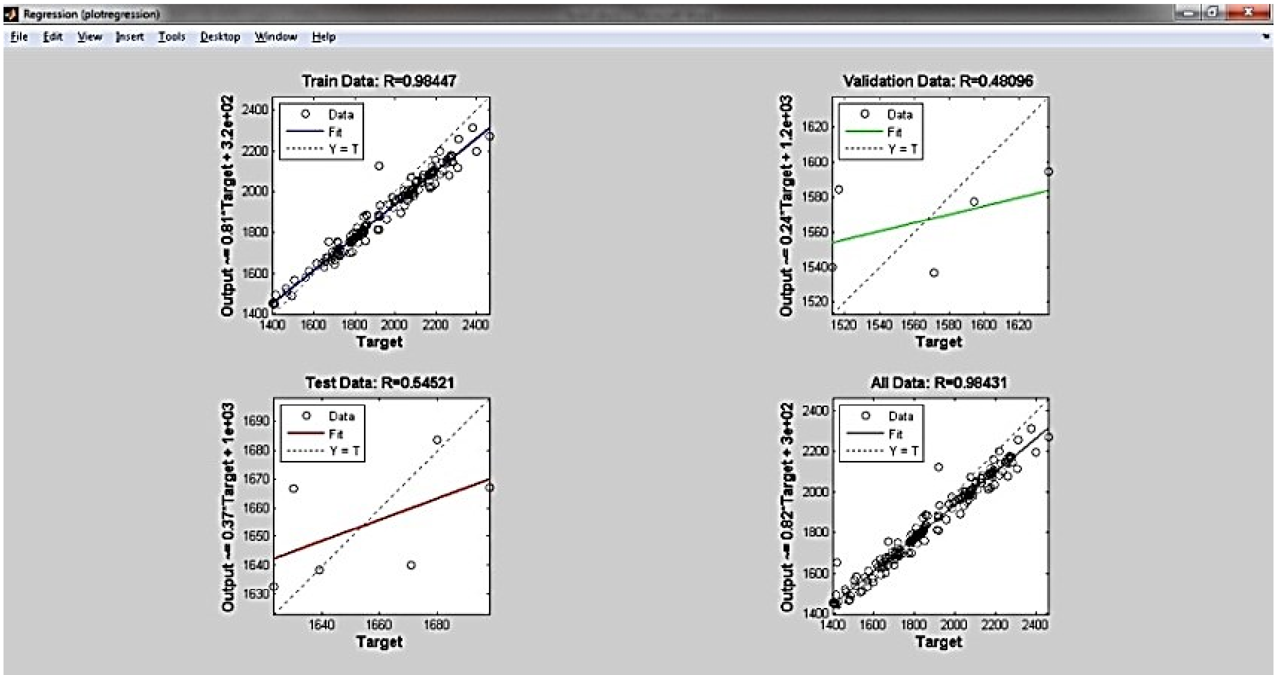

Figure 6: Precision output of the neural network

Table 2: Prediction precision of the algorithm for 20 companies listed on the stock exchange

Row	Company	Precision of algorithm
1	Zamyad	38.342
2	Pars Khodro	40.652
3	Iran Khodro	42.944
4	SAIPA	43.010
5	Farabi Petrochemical Company	34.134
6	Paksan	43.345
7	Fanavaran Petrochemical Company	45.345
8	Iran Lent Tormoz	38.541
9	Pars Khazar	47.401
10	Sahand Rubber Industries	38.424
11	Iran Tire	36.126
12	Alvand Tile	49.123
13	Isfahan Tile	43.521
14	Iran Porcelain	40.105
15	Sina Bank	41.456
16	Parsian Bank	50.423
17	Saderat Band	48.096
18	Eghtesad Novin Bank	43.345
19	Behshahr Industrial Group	45.561
20	Sahand Rubber Industries	46.673

The proposed algorithm was then compared with the neural network, the results of which can be found in Table 3.

Table 3: Comparing the proposed algorithm and the neural network

Row	Company	Precision of proposed algorithm	Precision of neural network
1	Zamyad	38.342	30.203
2	Pars Khodro	40.652	29.201
3	Iran Khodro	42.944	20.9713
4	SAIPA	43.010	28.246
5	Farabi Petrochemical Company	34.134	26.943
6	Paksan	43.345	23.171
7	Fanavaran Petrochemical Company	45.345	29.502
8	Iran Lent Tormoz	38.541	20.345
9	Pars Khazar	47.401	24.384
10	Sahand Rubber Industries	38.424	23.815
11	Iran Tire	36.126	27.652
12	Alvand Tile	49.123	27.952
13	Isfahan Tile	43.521	21.867
14	Iran Porcelain	40.105	24.896
15	Sina Bank	41.456	24.459
16	Parsian Bank	50.423	26.463
17	Saderat Band	48.096	27.096
18	Eghtesad Novin Bank	43.345	27.549
19	Behshahr Industrial Group	45.561	22.763
20	Sahand Rubber Industries	46.673	26.790

VI. Conclusion and Future Work

In this paper, three algorithms of learning automata, firefly algorithm, and artificial neural network were used to predict the stock index in Iran Stock Exchange. Since time series does the task of predicting economic variables in the time series approach, the researcher will not be allowed to determine the share of other effective factors for the changes in the related variable and the proposed model will only deal with learning and studying previous data of the variable. Therefore, if an error occurs in the previous data, the model will predict future values based on its input and errors of the previous values will be transferred to the future values.

If the network inputs (the effective variables for the variable whose behavior should be predicted) are selected based on an economic theory, better and more reliable results will be obtained. Thus, it is recommended to design an artificial neural network, which includes the variables affecting inflation norm such as liquidity, production, price index of imported commodities, and currency rate besides price index stop (inflation rate). Furthermore, an intelligent system can be designed for predicting and decision-making by the models of artificial neural network, in which effective variables could be intelligently identified and prediction can be performed by them.

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BIOGRAPHY

Sahar Khaleghi is a junior researcher in Soft Computing and Data Mining. She holds a Master of Science in Information Technology Engineering from the Department of Electronic Educations at Shiraz University, Fars, Iran. She earned B.S. in IT Engineering from PNU, Iran. She has published several rich journal and conference papers. She has done research projects with high-quality international organizations. His research interests include soft computing methods, simulation, data mining, and intelligent systems. She is a member of ASEE, IEEE, IEOM, IIE, INFORMS, and SME.

Javad Soroor is currently a senior researcher and fulltime faculty member in School of Computer Engineering and Information Technology at Shiraz University of Technology. Dr. Soroor holds a Bachelor of Science degree in Computer Science from Amirkabir University of Technology, a Master of Science degree in Information Technology from KN Toosi University of Technolgy and a PhD in Industrial Engineering form the same university. He is an Assistant Professor of Industrial Engineering and a Certified IT Consultant with over 10 years of experience in working with closely-held businesses. He has taught courses and performed researches in big data analysis, fuzzy theory and practice, operations management, and computing methods for optimization problems in management and engineering. Javad has served as editor, reviewer, scientific committee member of several international journals and conferences. He is a permanent member of IEEE, ACM, IIE, etc. More information may be acquired from his official website at http://itc.sutech.ac.ir/en/DrSoroor and his personal homepage at http://jsoroor.ir.