Time Series Stock Price Prediction using Recurrent Error based Neuro-Fuzzy System with Momentum

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***Abstract*— Stock market analysis is very important not only for making profit or averting big losses, but also to recognize the direction of the market. The direction point of the market has significant effects on capital investment, other business cycle issues and socio-economical level of the country. This study proposes a new approach for stock market price prediction using recurrent error based neuro-fuzzy system with momentum (RENFSM). The experiment found that the proposed model can provide superior performance for stock market price prediction than ANFIS and traditional recurrent type ANFIS networks.**

***Index Terms*— Time series prediction, recurrent ANFIS, stock market price prediction, momentum, RENFSM**

I. Introduction

Prediction is essential to the modern scientific view of life. Time series prediction study is a vital research and application area. The purpose of prediction is to minimize the risk in decision-making. It is a challenging task due to the dimension and volume of data, noise, volatility, and non-linearity issues. For this purpose, the last few decades, artificial intelligence techniques such as artificial neural network, fuzzy system, and adaptive neuro-fuzzy system have been widely used and exploited for time series prediction [1].

Early research of stock market forecasting was based on random walk theory and efficient market hypothesis (EMH) [2, 3]. According to the random walk theory, stock market prices cannot be predicted due to evolution of its random walk fashion. EMH stated that it is possible to predict some degree driven from the current information. It would have been fascinating to prevent major stock market collapse from time series prediction.

The time series prediction technique can be classified into two categories: - statistical approach and technical intelligent approach [1]. Statistical approach includes Autoregressive (AR), Moving Average (MA), and Autoregressive Integrated Moving Average (ARIMA). In the statistical technique, background information is exploited in development, but action is assumed without human intervention. Hence, these techniques show inefficiency for complex and non-linear problems. For this reason in recent years, researchers have been using technical intelligent approach such as Artificial Neural Network (ANN), Fuzzy System, Neuro-Fuzzy System, and Data Mining etc. Such intelligent systems aim to create classification of terminologies that mimic human reasoning sufficiently to provide insight into the decision process.

The existing feed-forward ANFIS model is excessively static and recurrent type ANFIS capable of showing dynamic properties [7], but unable to cope with the stock market's dynamic character. The aim of this study is to find a model that follows a trajectory rather than attain a fixed value. In particular, the main objective is to predict the stock closing price for the next day depending on the time series previous close price accurately. Experimental result found the proposed reliable RENFSM model is able to predict with minimal error and provides higher prediction accuracy rates.

II. Literature Review

ANN was originally inspired by the study of biological nerves systems, and has been applied to solve the problems of time series prediction including stock market price prediction [4-6]. Moreover, a number of prior works have also applied data mining techniques to stock market prediction [3, 9]. Fuzzy logic system is an effective tool to design intelligent systems and successfully applied to control problems, decision-support systems and time series prediction [7, 8]. But the application of existing rule-based fuzzy systems is limited to static problems because of its feed-forward structure. Jang [10] proposed the Adaptive Neuro-Fuzzy Inference System (ANFIS). ANFIS combines the advantage of neural network's learning capabilities and fuzzy system's transparency, which avoids the "black box" feature of common neural network. In recent decades, the neuro-fuzzy system has become a popular research topic and has been successfully applied to research in the time series including stock market price predication [11-13]. However, this feed forward ANFIS structure is capable of static mapping only and cannot effectively cope with dynamic properties as in the case of recurrent network. Recurrent type neuro-fuzzy networks are proposed to build long-range prediction models for nonlinear and dynamic systems [14, 15].

In summary, ANN has limitations, there are no known methods of designing the optimal network and the performance highly depends on the data and application nature. Recurrent Neural Networks (RNN) are computationally more powerful than feed-forward network. However, RNN exhibits some problems in training, such as lack of stability and hard to deal with long-term dependencies in the time series. For more complicated networks the reliability of results can decrease. Furthermore, recently it has been proven that ANFIS works better than ANN or RNN [7].

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III. Proposed RENFSM Model

This research focuses on two features. Firstly, exclusively applying time series momentum for prediction. Secondly, time series error adjustment in ANFIS rather than existing recurrent type ANFIS with only direct output feedback.

A. Time Series Prediction

Time series is a sequence of observations from past to present, denoted by $x(k),\ k = 1, 2, \dots, n.$ Extending backwards from time k has time series $x(k), x(k-1), \dots, x(k-n)$. From this, the prediction x is future time h

$$x(k+h) = f(x(k), x(k-1), \dots, x(k-n)) \tag{1}$$

In the case of $h = 1$, the prediction error $e(k)$ is the difference between actual value $x(x+1)$ and prediction value $y(k)$. For time k error $e(k)$ can be define as

$$e(k) = x(k+1) - y(k) \tag{2}$$

Time is constantly moving forward. It is hard to deal with temporal data. In this study, the experimental model has a unit of prediction error, which can retain successive error value of time series. This can treat each past prediction error as an additional spatial dimension in the input space. Recurrent network are well-suited for time series because the possess components can be adjusted. Usually recurrent networks never reach a fixed point, which presents trajectory rather than attain a fixed point.

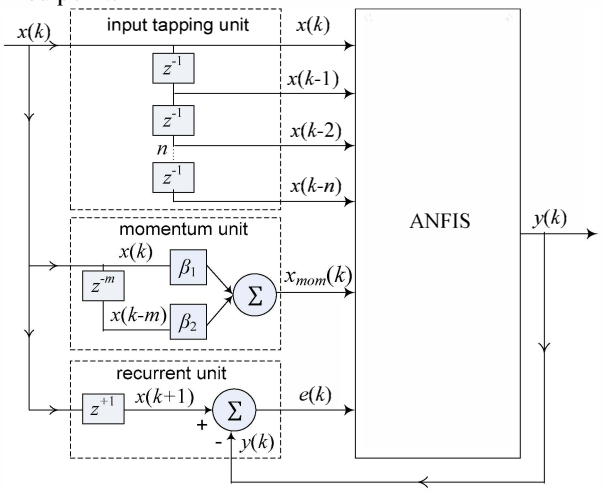


Fig. 1. Proposed model.

B. ANFIS

Jang's [10] ANFIS integrates fuzzy *if-then* rules describe the relationship between input and output of the network. Thus, ANFIS approach learns the rules and membership functions from data. In this study, the use of a recurrent ANFIS network with five layer traditional structure was employed. Two membership functions that are "Bell-shaped" for each four inputs respectively and 16 fuzzy rules generated by *genfis*1 are used to design the network.

C. Momentum

Momentum is a well-known concept in physics. It refers to the quantity of motion that an object has. Price momentum is a useful technical indicator to determine price movement strength. It measures the speed and velocity of price change; and helps to explain the rate of rise or fall. Price momentum is measured from the time series price difference for a certain time interval. The formula for momentum x_{mom} is

$$x_{mom}(k) = x(k) - x(k-m) \tag{3}$$

where $x(k)$ is the present latest price and $x(k-m)$ is the price

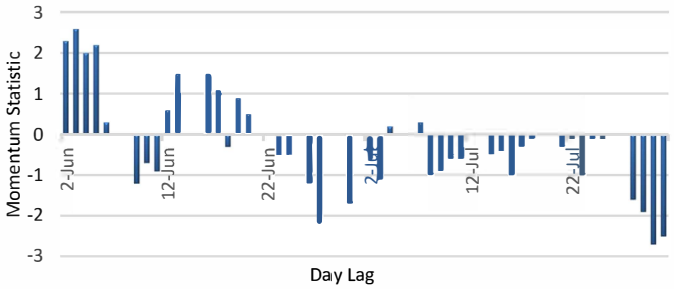


Fig. 2. Five days Close price momentum of AB Bank Ltd. June-July 2013.

IV. Simulation Results and Discussion

The stock price is quite different in value. This price variance may affect the performance of the prediction model. Transforming original price into unit variance mapped within the [0, 1] interval by min-max normalization. For result comparison the output are mapped back into original price.

$$x_{norm} = \frac{x_k - min(x)}{max(x) - min(x)} \tag{4}$$

The experiment emphasizes on predicting stock market close price for two top listed stocks AB Bank Ltd. (ABBANK) and Dutch-Bangla Bank Ltd. (DUTCHBANGL) from Dhaka Stock Exchange (DSE), Bangladesh. And the stocks period carried out five years from January 2009 to August 2013. Among 1078 days close price dataset, 755 (70%) used as the training set and 323 (30%) as the test set. Foregoing consecutive last 3 and 4 days close price with 3 to 20 days closing price momentum are tested to predict next day's close price. It was found that consistent results were achieved for 3 days close price with 6 to 12 days momentum. The experiment carried out on two distinct types of model without momentum and with momentum for ANFIS and RENFSM.

Fig. 3 to 6 shows the actual vs predicted price, and error trend of different models for AB Bank Ltd. To evaluate the comparative performance of the proposed method Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE) statistical metrics are summarized in Table 1 and 2. From Fig. 7 and 8, it is clear to see that the proposed two features price momentum and recurrent system error adjustment has significant effect to improve the prediction accuracy.

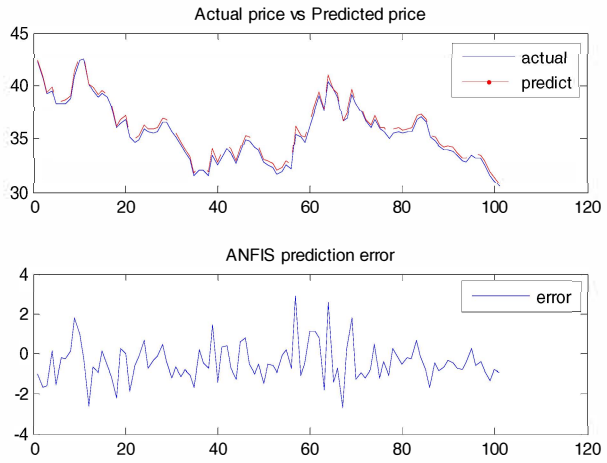


Fig. 3. ANFIS actual vs predicted price of AB Bank Ltd.

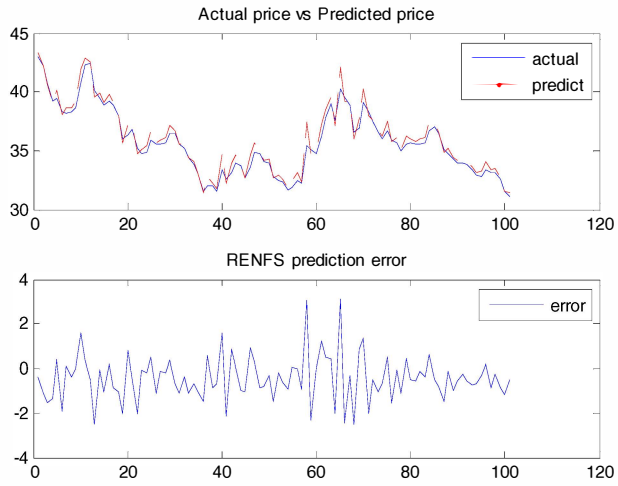


Fig. 4. RENFS actual vs predicted price of AB Bank Ltd.

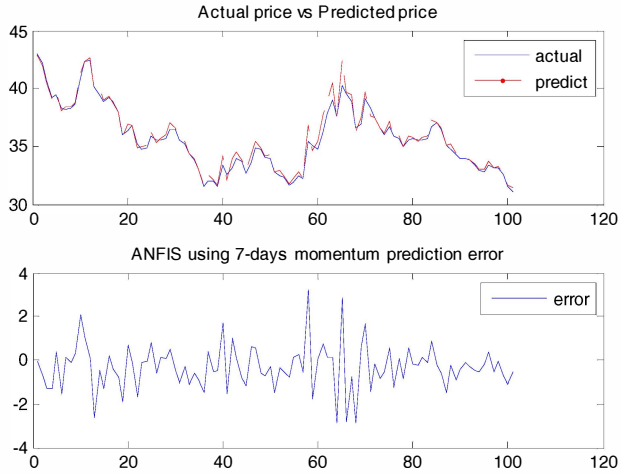


Fig. 5. ANFIS with using seven days momentum actual vs predicted price of AB Bank Ltd.

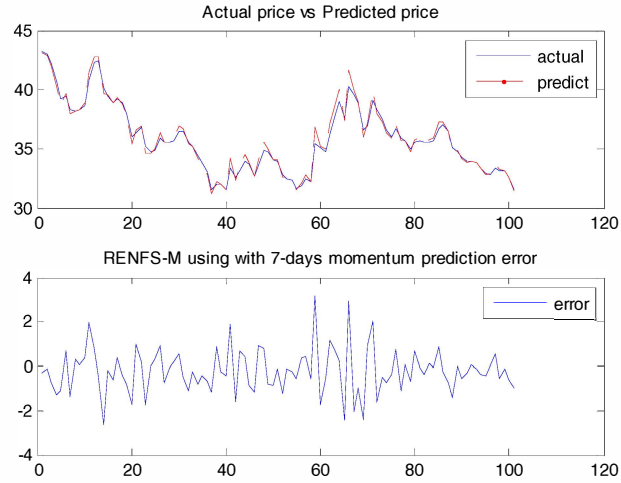


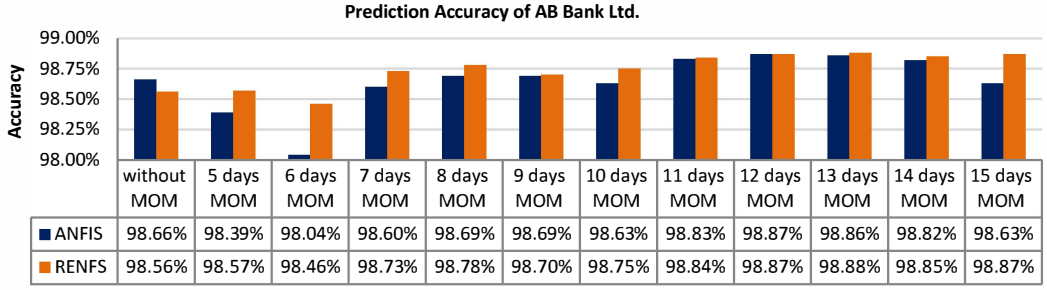
Fig. 6. RENFSM using seven days momentum actual vs predicted price of AB Bank Ltd.

TABLE I. COMPARISON TEST RESULT OF VARIOUS MODEL OF AB BANK LTD.

Model	ANFIS			RENFS		
	Train RMSE	Test RMSE	Test MAPE	Train RMSE	Test RMSE	Test MAPE
without MOM	2.76	0.97	1.34%	2.87	1.05	1.44%
5 days MOM	2.65	1.12	1.61%	2.88	1.05	1.43%
6 days MOM	2.63	1.30	1.96%	2.93	1.09	1.54%
7 days MOM	2.69	1.05	1.40%	2.84	0.98	1.27%
8 days MOM	2.72	1.02	1.31%	2.82	0.96	1.22%
9 days MOM	2.68	1.02	1.31%	2.80	1.00	1.30%
10 days MOM	2.66	1.03	1.37%	2.78	0.96	1.25%
11 days MOM	2.71	0.92	1.17%	2.83	0.92	1.17%
12 days MOM	2.70	0.90	1.13%	2.84	0.91	1.13%
13 days MOM	2.72	0.90	1.14%	2.91	0.92	1.12%
14 days MOM	2.70	0.93	1.18%	2.88	0.92	1.15%
15 days MOM	2.71	1.02	1.37%	2.84	0.91	1.13%

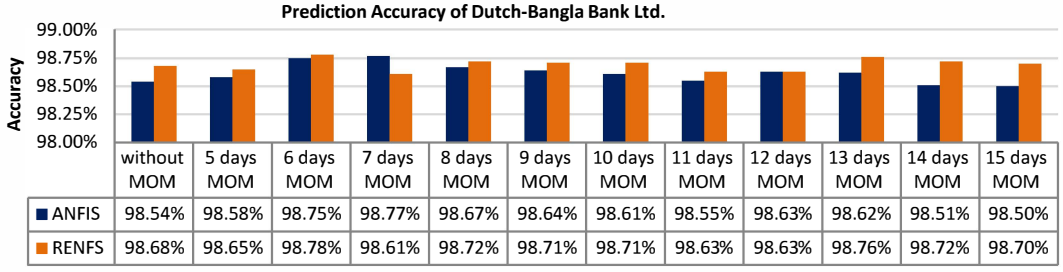
TABLE II. COMPARISON TEST RESULT OF VARIOUS MODEL OF DUTCH-BANGLA BANK LTD.

Model	ANFIS			RENFS		
	Train RMSE	Test RMSE	Test MAPE	Train RMSE	Test RMSE	Test MAPE
without MOM	5.09	2.59	1.46%	5.36	2.44	1.32%
5 days MOM	4.96	2.56	1.42%	5.42	2.49	1.35%
6 days MOM	4.89	2.43	1.25%	5.37	2.38	1.22%
7 days MOM	4.92	2.39	1.23%	5.39	2.52	1.39%
8 days MOM	4.78	2.48	1.33%	5.37	2.40	1.28%
9 days MOM	4.88	2.49	1.36%	5.41	2.42	1.29%
10 days MOM	4.84	2.53	1.39%	5.62	2.45	1.29%
11 days MOM	4.88	2.59	1.45%	5.72	2.52	1.37%
12 days MOM	5.10	2.51	1.37%	5.66	2.51	1.37%
13 days MOM	4.99	2.52	1.38%	5.67	2.40	1.24%
14 days MOM	4.85	2.61	1.49%	5.70	2.43	1.28%
15 days MOM	5.12	2.63	1.50%	5.62	2.44	1.30%



	without MOM	5 days MOM	6 days MOM	7 days MOM	8 days MOM	9 days MOM	10 days MOM	11 days MOM	12 days MOM	13 days MOM	14 days MOM	15 days MOM
ANFIS	98.66%	98.39%	98.04%	98.60%	98.69%	98.69%	98.63%	98.83%	98.87%	98.86%	98.82%	98.63%
RENFS	98.56%	98.57%	98.46%	98.73%	98.78%	98.70%	98.75%	98.84%	98.87%	98.88%	98.85%	98.87%

Fig. 7. Prediction performance of different model with different day's momentum of AB Bank Ltd.



	without MOM	5 days MOM	6 days MOM	7 days MOM	8 days MOM	9 days MOM	10 days MOM	11 days MOM	12 days MOM	13 days MOM	14 days MOM	15 days MOM
ANFIS	98.54%	98.58%	98.75%	98.77%	98.67%	98.64%	98.61%	98.55%	98.63%	98.62%	98.51%	98.50%
RENFS	98.68%	98.65%	98.78%	98.61%	98.72%	98.71%	98.71%	98.63%	98.63%	98.76%	98.72%	98.70%

Fig. 8. Prediction performance of different model with different day's momentum of Dutch-Bangla Bank Ltd.

V. CONCLUSION

In this research, a new approach RENFSM for time series stock market price prediction has been proposed. This approach uses a recurrent error based adaptive neuro-fuzzy system with time series momentum. Realization of the concept "Time is money" the authors have tried to listen to what time momentum is saying. The study found that there are positive relationships between price momentum of certain days and the rate of price change in each day. It is expected if solid momentum continues the growth of accuracy will increase. In addition, the model comparisons showed tested results of different preprocessing methods with different impacts on the performance. The authors have demonstrated the effectiveness of the proposed model by testing it on two companies' stock price prediction, and found that the proposed RENFSM performs superior to the traditional ANFIS and recurrent ANFIS models. The price of stock market is influence by many factors, which are the result of many decisions. This study tries to predict the degree of time series price. In the future, the authors plan to improve the accuracy by incorporating "news" mining.

REFERENCES

[1] D. Michie, D. J. Spiegelhalter, C. C. Taylor, "Machine Learning, Neural and Statistical Classification," Ellis Horwood, 1994.

[2] E. F. Fama, "Efficient Capital Markets: II," The Journal of Finance, vol. 46, pp. 1575-1617, 1991.

[3] G. P. C. Fung, J. X. Yu, W. Lam, "News Sensitive Stock Trend Prediction," Advances in Knowledge Discovery and Data Mining, vol. 2336, pp. 481-493, 2002.

[4] T. Jerome, R. Connor, D. Martin, "Recurrent Neural Networks and Robust Time Series Prediction," IEEE transactions on neural networks, vol. 5, pp. 240 – 254, March 1994.

[5] M. Han, J. Xi, S. Xu, F. L. Yin, "Prediction of Chaotic Time Series Based on the Recurrent Predictor Neural Network," IEEE transactions on signal processing, vol. 52, pp. 3409 – 3416, December 2004.

[6] B. Sun, T. K. Li, "Forecasting and Identification of Stock Market based on Modified RBF Neural Network," IEEE 17th International Conference Industrial Engineering and Engineering Management, pp. 424 – 427, 2010.

[7] Y. R. Huang, Y.Kang, M. H. Chu, S. Y. Chien, T. P. Chang, "Modified recurrent neuro-fuzzy network for modeling ball-screw servomechanism by using Chebyshev polynomial," Expert Systems with Applications, vol. 36, pp. 5317–5326, 2009.

[8] V. Guldal, H. Tongal, "Comparison of Recurrent Neural Network, Adaptive Neuro-Fuzzy Inference System and Stochastic Models in Egirdir Lake Level Forecasting," Water resources management -Springer, vol. 24, pp. 105-128, 2010.

[9] S. A. S. Olaniyi, K. S. Adewole, R. G. Jimoh, "Stock Trend Prediction Using Regression Analysis –A Data Mining Approach," ARPN Journal of Systems and Software, vol. 1, pp. 254-257, 2011.

[10] J. S. R. Jang, "ANFIS: adaptive-network-based fuzzy inference system," IEEE Transactions on Systems, Man and Cybernetics, vol. 23, issue. 3, pp. 665 – 685, 1993.

[11] M. A. Boyacioglu, D. Avci, "An Adaptive Network-Based Fuzzy Inference System (ANFIS) for the prediction of stock market return: The case of the Istanbul Stock Exchange," Expert Systems with Applications, vol. 37, pp. 7908-7912, 2010.

[12] P. C. Chang, C. H. Liu, "A TSK type fuzzy rule based system for stock price prediction," Expert Systems with Applications, vol. 34, pp. 135–144, 2008.

[13] E. Abbasi, A. Abouec, "Stock price forecast by using neuro-fuzzy inference system," Proceedings of World Academy of Science, Engineering and Technology, vol. 36, pp. 320–323, 2008.

[14] J. Zhang, A. J. Morris, "Recurrent neuro-fuzzy networks for nonlinear process modeling," IEEE Transactions on Neural Networks, vol. 10, pp. 313–326, 1999.

[15] P. A. Mastorocostas, J. B. Theocharis, "A recurrent fuzzy-neural model for dynamic system identification," IEEE Transactions on Systems, Man and Cybernetics, vol. 32, pp. 176–190, 2002.