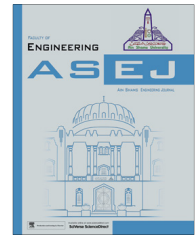




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Artificial chemical reaction optimization of neural networks for efficient prediction of stock market indices

S.C. Nayak ^{a,*}, B.B. Misra ^b, H.S. Behera ^a

^a Department of Computer Science Engineering & Information Technology, Veer Surendra Sai University of Technology, Burla 768018, India

^b Department of Information Technology, Silicon Institute of Technology, Bhubaneswar 751024, India

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Abstract The underlying system models of time series prediction are complex and not known a priori, hence, accurate and unbiased estimation cannot be always achieved using well known linear techniques. The estimation process requires more advanced prediction algorithms, such as multi-layer perceptrons (MLPs). This paper presents an artificial chemical reaction neural network (ACRNN), which uses artificial chemical reaction optimization (ACRO) to train the MLP models for forecasting the stock market indices. The underlying motivation for using ACRO is the ability to overcome the issues of convergence, parameter setting and overfitting and to accurately forecast financial time series data even when the underlying system processes are typically nonlinear. Historical data of seven different stock indices have been collected for 15 years to test the performance of the ACRNN approach. After extensive experimentation, it is observed that the ACRNN technique demonstrates significant improvements in prediction accuracy over the MLP approach.

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1. Introduction

Forecasting the stock market remains a challenging task for researchers. The influence of uncertainty in the stock market increases the degree of difficulties to a great extent in proper prediction of the index prices. Such difficulties in prediction of stock market prices arise due to its nonlinearities, highly volatile nature, discontinuities, movement of other stock markets, political influences and other macro-economical factors and even individual psychology [1–3]. Further various economic factors such as oil prices, exchange rates, interest rates, stock price indices in other countries, and domestic/global

* Corresponding author. Tel.: +91 9438420234.

E-mail addresses: sarat_silicon@yahoo.co.in, saratnayak234@gmail.com (S.C. Nayak), misrabijan@gmail.com (B.B. Misra), hsbehera_india@yahoo.com (H.S. Behera).

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economic situations, affect the movement of a stock market. These factors have been employed on the study of stock price prediction and found to be important elements for influencing the market [4,5].

A stock market behaves very much like a random walk process and their serial correlation is economically and statistically significant. Nonlinear dynamics proposes that in financial time series past prices help to determine future prices, but not in a straightforward way. The relationship between past prices and future prices is nonlinear, and this non-linearity implies that past price change can have wide ranging effects on future prices.

As more and more money is being invested in the stock market by common investors, brokers and speculators, investors get anxious about the future trend of the stock market. If the direction of the market is successfully predicted, the investors may be better guided and also monetary rewards will be substantial. Hence an effective and accurate forecasting model is necessary in order to predict the stock market behavior. In recent years, many new methods for modeling and forecasting the stock market have been developed.

Mainly there are two broad categories of forecasting models used, i.e. linear and nonlinear models. For many decades linear models have been the basis of traditional statistical forecasting models in financial engineering. Several statistical techniques have been used extensively for stock market prediction [6]. Among those statistical techniques employed in this regard, moving averages (MAs), auto-regressive integrated moving average (ARIMA), auto-regressive heteroscedastic (ARCH), and generalized ARCH (GARCH) have received wide acceptance. MA is a type of finite impulse response filter used to analyze a set of data points by creating a series of averages of different subsets of the whole data set in the stock market. This is used to smooth out the short-term fluctuations with the help of time series analysis and highlight long term trends. These models may not capture the non-linearity of other types of time series, being developed for specific types of problems.

The Box–Jenkins method using autoregressive moving average (ARMA); linear models have extensively been used in many areas of time series forecasting [7]. These linear models have been successfully applied to different engineering, economic and social applications. These models do not possess the capacity to capture the high degree of non-linearity associated with financial time series. The presence of noise and non-linearity in the financial time series makes these traditional methods ineffective to adapt toward nonlinear models. The popular nonlinear models used for financial forecasting include artificial neural networks, support vector machine, Bayesian Networks, and fuzzy system models. Among these frequently adopted methods, artificial neural networks have drawn significant attention from several researchers in the field of stock market behavior forecasting.

During the last two decades there has been tremendous development in the field of soft computing methodology which includes artificial neural network (ANN), evolutionary algorithms, and fuzzy systems. This improvement in computational intelligence capabilities has enhanced the modeling of complex, dynamic and multivariate nonlinear systems. These soft computing methodologies have been applied successfully to the areas of data classification, financial forecasting, credit scoring, portfolio management, risk level evaluation, etc. and found to produce significant results. ANNs are software

constructs designed to mimic the way the human brain learns. The neural network can imitate the process of human behavior and solve nonlinear problems, which have made it popular and are widely used in calculating and predicting complicated systems. The quality of non-linear mapping achieved in ANN is difficult with the conventional approaches. It has the capability of dealing with complex problems of structural instability. They are analogous to nonparametric, non-linear regression models. Their novelty lies in their ability to model non-linear processes with few a priori assumptions about the nature of the generating process. The neural networks have the ability to discover non-linear relationships in the input data set without a priori assumption of the knowledge of relation between the input and the output. ANNs are found to be good universal approximator which can approximate any continuous function to desired accuracy. ANNs are considered to be an effective modeling procedure when the mapping from the input to the output contains both regularities and exceptions which is the way stock market behaves. It also allows the adaptive adjustment to the model and nonlinear description of the problems. These advantages of ANN attract researchers to develop ANN based forecasting models to the area of stock market prediction. These forecasting models incorporate prior knowledge in ANN to improve the prediction accuracy. Neural networks are also extensively used in medical applications such as image/signal processing [8], pattern and statistical classifiers [9] and for modeling the dynamic nature of biological systems. This is particularly useful in financial engineering applications where much is assumed and little is known about the nature of the processes determining asset prices. ANN is relatively a recent method for business forecasting and has been successfully applied to wide range of forecasting problems such as exchange rate, credit scoring, business failure, bankruptcy, interest rate, stock return, stock market index, portfolio management and option & future prices. ANNs have been successfully applied in financial engineering and gained wide acceptance due to their better learning abilities and approximation capabilities. Gradient based methods are one of the most widely used error minimization methods used to train back propagation based ANN models. Back propagation algorithm is a classical domain dependent technique for supervised training. It works by measuring the output error calculating the gradient of this error, and then adjusting the ANN weights and biases in the descending gradient direction. Back propagation based ANNs are very popular methods to predict stock market with better calculation, spreading abilities and stronger nonlinear mapping ability. But the stock market deals not only with nonlinearity but also with chaos, and it is a dynamic system related to time. Therefore the network for prediction is a dynamic system. Back propagation neural networks, particularly the multilayer perceptron (MLP) have many shortcomings such as the slow learning rate, larger memory size, easy to get into local minimum, bigger randomness and so on, which affects the prediction accuracy of the stock price. These shortcomings force researchers toward developing hybrid models by combining linear and nonlinear models. These hybrid models that have been developed by many researchers combining nonlinear models such as ANN and evolutionary soft computing techniques such as swarm optimization, genetic algorithm and other nature and bio-inspired search techniques, have come up with better performance.

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