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Applications of Neural Networks in Stock Market Prediction

-An Approach Based Analysis

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Abstract—This paper is a survey on the survey on the various applications of neural networks aimed at the complexity of interior and variety of exterior composition of stock pricing system for solving business problems like stock market predictions. Artificial intelligence (AI) methods too have been used for this purpose. Much research on the applications of NNs have proven their advantages over statistical and other methods that do not include AI, although there is no optimal methodology for a particular problem. A comparative analysis of selected applications is performed to identify the major benefits and limitations of previous methods in neural network applications and to find connections between the methodologies, problem domains and data models. It can be concluded from analysis that ANNs are most implemented with Back propagation algorithm as the methodology in forecasting of stock prices, returns and stock modeling. However, the importance of ANN integration with other artificial intelligence methods has been emphasized by numerous authors.

Keywords—Artificial neural network; stock market prediction; stock market.

Introduction

The stock market is a public market where a company can get itself listed for their stock and can also gather financial resources on an agrees prices for their company stock. The stock holder will get yearly dividend/bonus from the profit of the company. Along with this, the stock holder can sell the same stock on an agreed price in the stock market to get the profits from price difference while selling. The price of a company's stock depends on a number of financial factors. It keeps on fluctuating and is unpredictable. Because of their ability to deal with uncertain, fuzzy, or insufficient data which fluctuate in very short periods of time, neural networks (NN) have become very important method for stock market predictions [1]. The nature of stock market is volatile and non-linear and is also able to adapt to data pattern in relationship between input and output and hence provides better prediction accuracy than the traditional methods.

The remainder of this paper will be as follows. Section II provides information on working of ANN. Section III describes the general implementation of ANN for stock prices prediction along with advantages and disadvantages. Section IV is all about the different methodologies used for stock market prediction. Section V lists the benefits and shortcomings of the various methodologies of neural networks.

Working of Ann

An Artificial Neural Network is an information processing model that rose from the desire to artificially stimulate as per the structure and functioning of biological nervous system, the brain [2]. It is made up of a larger number of highly interconnected processing elements working together to give problem specific solutions. These elements are called as neurons. The network displays adaptive learning and is linear in nature. ANN is used for applications specific to the needs like pattern recognition or data classification through a process called as Learning. The field of ANN was discovered in the 1940s by Warren McCulloch and Walter Pitts who showed that with such networks we could compute any arithmetic or logic function. The first practical application of ANN was done in the late 1950s by Frank Rosenblatt (1958) on the perceptron.

The neurons are the basic information processing unit of any neural network. It is made up of

1. A set of links with weights w1, w2, w3, w4…, wn.
2. A linear combiner adding function for calculating the inputs with weights.

$$u = \sum_{j=1}^{m} v$$

3. An activation function.

$$y = ø\ (u + b)$$

There are 3 types of leaning.

1. Supervised Learning: In this type of learning, the network is provided with input and output pairs to train the network. Once the training is completed, the network would be able to map unseen input appropriately.
2. Unsupervised Learning: In unsupervised earning, the network has to figure out a pattern with inputs provided without any external help.
3. Reinforcement Learning: It is similar to supervised learning. It provides some kind of feedback that helps in error calculation; however it wouldn't provide the exact target but instead would give a value based on system's performance.

Multilayered feed forward network is one of the various types of ANN. It is a network of perceptrons (neurons). Each perceptron computes a single output from multiple inputs and this output goes through a nonlinear activation function to find the final solution. This can be written mathematically as

$$\gamma = \varphi(\sum_{i=1}^{n} w_i x_i + b) = \varphi(w^T x +$$

where b is the bias; w is the weights; x denotes the vector of inputs and is the activation function. An MLP consists of multiple layers of nodes in a directed graph, and each layer is completely connected to the next layer. It is trained using the Back Propagation Algorithm and is an example of supervised learning. BPNN trains the network based on error signal by updating the weights between the connections to improve performance. It has a minimum of three layers i.e. input layer, one or more hidden layer and an output layer. These are connected in a feed forward manner. Back propagation algorithm is a supervised learning algorithm and hence the desired outputs are given as part of the training vector. Theoutput thus generated is subtracted from the desired outputs to get the error value. This error value is then passed backward in the network by computing contribution of each hidden node and thereby making adjustments in the weights to produce the correctoutput. The process is repeated for many cycles called as epoch till the output is repeated to a prescribed tolerance level.

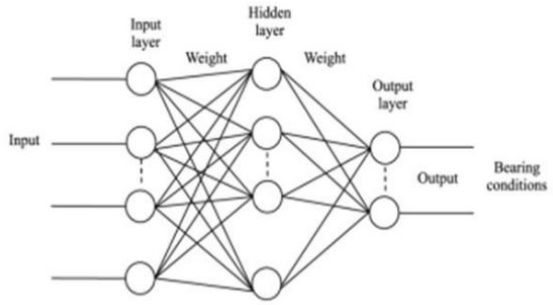

Fig -1 Back Propagation Network

III. General implementation for predicting Stock price using ANN

The architecture consists of three layers which is input, hidden (multiple), and output layer. There is an additional step involved before training the model and that is data processing. This is needed to ensure that correct and complete data is passed to the network as input. The problem arises when there is a partial data or no data, this is usually handles as per Heinkel and Kraus [3] which states that there are three possible ways of dealing with days having no trading viz. ignore the days with no trading and use data for trading days, assign a zero value for the days which have no trading, build a linear model which can be used to estimate the data value for the day with no trading.

The input variables that are usually considered for the last date are:

1. Opening stock price
2. High value of stock price
3. Low value of stock price
4. Stock volume
5. Closing price

Therefore ideally there would be 5 input nodes and one output node of Stock closing price. There is usually single hidden layer with multiple nodes in it.

Activation function can be any of the following however data normalization is needed as per the activation function used:

1. Unipolar sigmoid:

$$f(x) = \frac{}{1+}$$

2. Bipolar sigmoid:

$$f(x) = \frac{2}{1+e^{-\lambda x}}$$

3. Tan hyperbolic

$$f(x) = \frac{e^{\lambda x} - e^{-\lambda x}}{e^{\lambda x} + e^{-\lambda x}}$$

4. Radial basis function

$$f(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{-(x}{2}}$$

Error calculation and weight updation is done as follows:

$$\Delta Wij = (1)Er// \text{ Increment}$$

$$\Delta Wij = Wij + \Delta;// \text{Update}$$

There have been different approaches proposed for weight updation that show significant improvements in relative error rate (%) like Particle Swarm Optimization [4], genetic algorithm [5].

This process is continues till the stopping criteria is met. In BPNN, the convergence rate is controlled by the learning rate . Faster convergence rate is ensured by a larger value of the learning rate; however it may cause the algorithm to oscillate around the minima. A 3 fold stopping criteria ensures that the algorithm doesn't run forever and it stops if any of the condition is met.

1. From on iteration to another, the change in the error falls below a specific threshold.
2. The error value increases. (There is a relaxation for allowing minimal changes)
3. The number of epochs (cycle) goes beyond a specific predefined limit.

Advantages of Artificial Neural Networks:-

Artificial Neural Networks has ability to deal with uncertain, fuzzy or insufficient data, which fluctuate in short period of time, robust that helps to predict stock prices and returns.

1. Accuracy mostly ranges 70 to 80%.
2. Helps to classify the stocks into 3 classes:-
   i. Stocks with either positive or negative returns which gives valuable support in making decisions, but do not specify the amount of expected and expected profit.
   ii. System tries to predict the stock prices for one or more days in advance, based on the previous stock prices and on related financial ratios.
   iii. Concerned with modeling stock performance and forecasting. Predicts future values, but also have significance estimation, sensitivity analysis and other analysis of mutual dependencies.
3. Various data models and expert system combined improves the accuracy. Among all the algorithms the Back propagation have the highest accuracy.
4. Forecasting is done by regression and discriminate analysis of neural networks[6].

5. In Neural Network we provide input variables that are existing training data sets which is obtained by the regression and discriminate analysis and it concentrates on the different characteristics and pattern of data. It also contributes for the calculation of output with the greater accuracy.
6. Neural Network also used in the making decisions and can be effective intelligent support in various problem domain when they are combined with the expert or heuristic system.

Disadvantages of Artificial Neural Networks:-

The "best" algorithm which possibly solves all the problems and can deal with all the 3 classes of data is unknown.

1. Reliability is issue for the complicated networks.
2. Statistical and discriminate analysis is always needed to obtain the training data sets and similarly for the result obtained.
3. Availability for training data sets and historical data is needed.
   For example:- If some new stock emerges in market then it is difficult to have their historical data and it will be impossible to do analysis and prediction of stock prices.
4. Results are dependent of the data models and vary with the data models.

   Since it is subjective where each author suggests different data models and unable to suggest common data model that covers all the aspects and common results.
5. Data Models designs are not systematically analyzed[6].
6. The risk for using Neural Networks is still relatively high.

IV. Comparisons of the various models:-

In the wide variety of different modeling techniques provided so far, each technique has its own set of supporters and detractors and different benefits and shortcomings. The common goal in all the methods is to predict the future market movements from the past information. The assumptions made by each method provides its performance and its application to the markets.

Hidden Markov Models (HMM's) provide a maximum Posteriori approach to deal with predicting stock value for the next day using the historical data[7]. It considers the fractional change in Stock value and the intra-day high and low values of the stock to train the continuous HMM. This maximize the possibility of a sequence of observations over all possible predicted values

$$O_t = \left(\frac{close - open}{open}, \frac{high - open}{open}, \frac{open - low}{open}\right)$$
$$:= (fracChange, fracHigh, fracLow)$$

CHHM(Continuous Hidden Markov Model) is used to model stock value as time series. Mean Absolute Percentage Error is the metric that's been used to evaluate the performance of the model algorithm. A latency of d days is used by the model to predict the stock value for the d + 1 day. A MAP decision is made over all the possible values of the stock using a previously trained continuous-HMM[7]. Fig 1 shows Actual Value v/s Forecasted Value using HMM

Wavelet network is another model that has been known for forecasting of future stock value. It is the extension of feed forward neural network and has quite a lot of advantages over it[8]. Wavelet neural network is proven to be better than back propagation network when it comes to forecasting financial chaotic signals. It inherits all the benefits of wavelet transformation's time-frequency localization, high stability, self-adaptability. It further uses Fourier transformation algorithm or Fourier quasi-transformation algorithm to optimize itself.

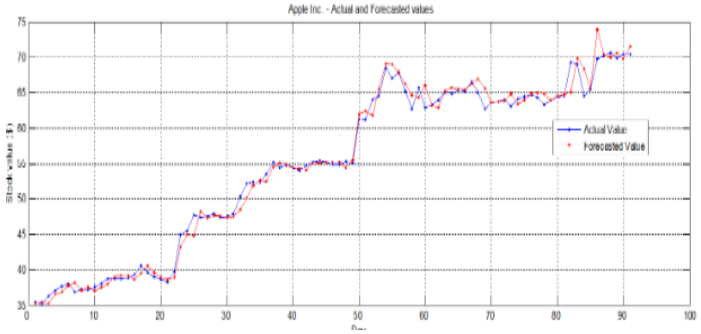

Chart -1 Actual Value v/s Forecasted Value for Apple Inc. from 13 September 2004 to 21 January 2005.(HHM)[7]

Neuro-fuzzy Model can be used with decision tree to develop a stock market prediction system. It is a combination of neural network and fuzzy inference system (FIS) in such a way that the Neural Network learning algorithm is used to find out the parameters of the FIS. It combines human like reasoning style of fuzzy systems through the use of fuzzy sets and a linguistic model consisting of a set of IF-THEN fuzzy rules along with the learning and connectionist structure of neural networks [9]. The main strength of neuro-fuzzy systems is that they are universal approximators with the ability to solicit interpretable IF-THEN rules[9]. A reduced dataset is produced by using dimensionality reduction techniques like Component analysis (PCA), Linear Discriminant Analysis (LDA), Multidimensional scaling (MDS). This reduced dataset is then applied to the adaptive neuro-fuzzy system for the next-day stock market prediction. It is well suited for highly dynamic systems.

NN can also be used with Support Vector Machine (SVM). SVM is developed on the foundation of small samples statistical learning theory that was proposed by Vapnik and its algorithm is based on the structural risk minimization principle [10]. Different linear regression models of SVM can be used to extract linear characteristics of stock market. Next, the non-linear characteristics of stock market can be obtained using different NN algorithms. Finally, the non-linear combination forecasting is done by SVM. The model developed using NN and SVM provide improved predicate ability, prediction accuracy and can also predict the rising and falling of the stock market with a higher prediction accuracy.

In conclusion, the major benefit of using a neural network is to learn how to predict the stock market by using combination of methods effectively. No particular model is correct or sufficient to predict the data. So, integration of the methods or models helps in stock prediction with the highest accuracy. Neural network forms an extraordinary base to predict the stock price. The accuracy rate varies on the type of approach or modification that's been used along with NN. The paper describes and compares most of these approaches. There are various other models that have been implemented apart from NNs like prediction using decision tree, Genetic Algorithm, AIs, however Neural network seems to be the better model as compared to them. There is still more scope for advancement which would aid further accuracy however complete accuracy will be unachievable.

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