A Review of Stock Market Prediction with Artificial Neural Network (ANN)

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Abstract—**Stock market is a promising financial investment that can generate great wealth. However, the volatile nature of the stock market makes it a very high risk investment. Thus, a lot of researchers have contributed their efforts to forecast the stock market pricing and average movement. Researchers have used various methods in computer science and economics in their quests to gain a piece of this volatile information and make great fortune out of the stock market investment. This paper investigates various techniques for the stock market prediction using artificial neural network (ANN). The aim of this paper is to provide a review of the applications of ANN in stock market prediction in order to determine what can be done in the future.**

Keywords-Artificial neural network; stock market prediction; stock market; stock index.

I. INTRODUCTION

A stock market is a public market for a company to list their stock and to gather financial resources by trading their company stock with an agreed price. In return, the stock holder will receive a yearly dividend or bonus from the company profit. Besides that, stock holders can also trade the stock in the stock market with an agreed price if they want to earn from the price difference of buy and sell activities. The turnover in the world stock market involves huge financial transaction. For example, in year 2008, the estimated size of the stock market is around $36.6 trillion [1].

Some of the popular stock markets where the investor can trade includes New York Stock Exchange (NYSE), NASDAQ, Toronto Stock Exchange, Amsterdam Stock Exchange, London Stock Exchange, Paris Bourse, Philippine Stock Exchange, the Singapore Exchange, Kuala Lumpur Stock Exchange, the Tokyo Stock Exchange, the Hong Kong Stock Exchange, the Shanghai Stock Exchange, the Bombay Stock Exchange and many others.

There are two kinds of stock that are traded; shares and stocks. Both share and stock are documents issued by a company, which entitles its holder to be one of the owners of the company. Share is directly issued by a company through Initial Public Offering (IPO) or can be purchased from the stock market. By owning a share one can earn a portion of the company's profit called dividend. Also, by buying and selling the shares, investor gets capital gain. Stock exchange (formerly securities exchange) is a corporation or mutual organization which provides "trading" facilities for stock brokers and traders, to trade stocks and other securities, thus providing a marketplace (virtual or real) [2].

An index is a statistical composite measure of the movement in the overall market or industry. Basically, indexes allow measuring the performance of a group of companies over a period of time. Companies are organized in an index according to two main methods or weighting as it is commonly termed. The movements of the prices in a market or section of a market are captured in price indices called stock market indices, e.g., the S&P, the FTSE and the Euro next indices [2].

The nature of the stock market is non-linear and volatile. Many traditional methods and statistical methods have been applied to forecast stock market. The combinations of different learning algorithms with artificial neural network (ANN) are the most commonly used methods. The ability of ANN to learn and generalize from the non-linear data trend is well suited to problem domain such as stock market prediction. Moreover, the ANN is able to adapt to the data pattern and relationship between the input and output, resulting in better prediction accuracy than the traditional method.

The remainder of this paper will be as follow. The traditional stock market prediction is described in Section II. Section III provides detail information of ANN. Section IV is devoted to the application of ANN in the stock market prediction. Finally, Section V concludes.

II. TRADITIONAL STOCK MARKET PREDICTION

Many traditional methods have been applied to predict either stock market moving price or stock market closing price. There are two important theories used in conventional approach for stock market prediction namely efficient market hypothesis (EMH) [3] and the random walk theory [4].

The efficient market hypothesis is introduced by Fama in 1964 [3]. According to EMH hypotheses, the future stock price is unpredictable based on the stock historical data. As new information enters the system the unbalanced stock is immediately discovered and quickly eliminated by the correct change in the price [2]. The EMH exists in three forms namely weak EMH, semi-strong EMH, and strong EMH [3]. In weak EMH, historical data are used to predict the stock price. In semi-strong EMH, besides historical data all the current public

information are used to predict the stock price. In the strong EMH, all the data including historical, public and private information such as insider's information are used to predict the stock price. On the other hand, the random walk hypothesis states that stock prices do not depend on past stocks [5]. Thus, these are not patterns to be exploited since the historical data do not reflect the pattern of the current stock price.

Two conventional approaches used for stock market prediction are technical analysis and fundamental analysis [4]. Technical analysis is a numerical time series approach to predict stock markets based on historical data using charts as the primary tool [6]. This approach tries to mine information from the historical data to recognize the pattern, sometimes referred as mining the time series [2]. Fundamental analysis is the study on the factors that affect supply and demand [7]. The fundamental analysis states that information gathering and interpretation is the main process to predict the stock price. The trading opportunity of this analysis utilizes the gap between the occurrence of an event and the market response to the event. The important data that is used for fundamental analysis are economic data of companies (such as annual and quarterly reports), auditor's reports, balance sheets, and income statements. News also plays a role in fundamental analysis as news also reflects the current supply and demand chain in the market. These conventional approaches are now becoming inferior due to the increase in the computational power where computer can now analyze larger data set more accurately within a shorter time. However, these approaches still act as the base of new artificial intelligence approaches such as machine learning, computational intelligence and others. In this paper we will discuss some of the ANN approaches. In the next section, the concept of ANN is briefly described.

III. ARTIFICIAL NEURAL NETWORK (ANN)

Bio-inspired algorithm has shown tremendous success in the field of AI. Many researchers have shown that applying bio-inspired algorithm has greatly improved the research domain result. These algorithms include ANNs, evolutionary computation, swarm intelligence, artificial immune systems, and fuzzy systems [8]. ANN is a form of bio-inspired algorithm which is modeled based on the central nervous systems of the brain.

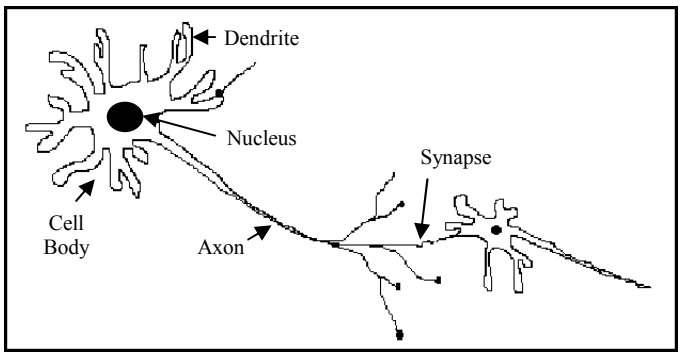

Figure 1. Biological Neurons

An artificial neuron is a model of a biological neuron. Fig. 1 shows a biological neuron [9]. The artificial neuron receives signals/input from other neurons or the environment. This signal will be fired on certain condition, thus, transmitting the signal to all other connected artificial neurons [9]. Fig. 2 is a representation of an artificial neuron. A numerical positive and negative are associated with each neurons to either inhibit or excite the input with each connection to the artificial neuron. An activation function is used to control the firing of an artificial neuron. The artificial neuron collects the incoming signals by computing its net input signal as a function with the associated weights. These net input signals then serves as input to the activation function which calculates the output signal of the artificial neuron(s) [10].

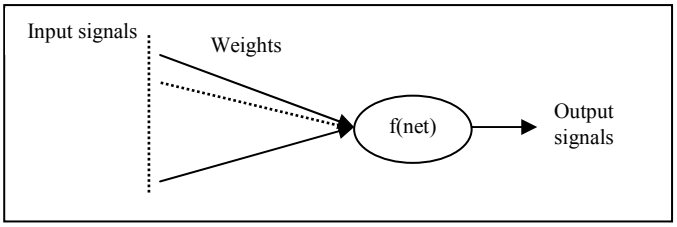

Figure 2. Artificial Neurons

An ANN is a layered network consisting one or more artificial neuron(s). ANN normally consists of input layer, hidden layer(s) and output layer. An example of ANN structure is shown in Fig. 3. Other ANN characteristics include the ability to learn, the ability to generalize, robust, mapping abilities and the ability to process information in parallel.

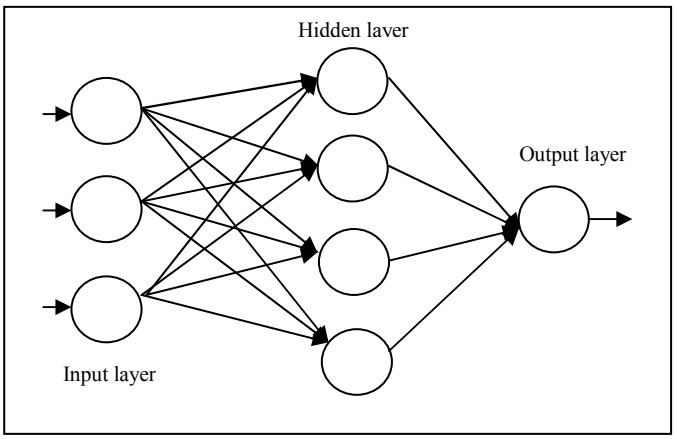

Figure 3. ANN Architecture

Several ANN architectures have been developed such as feedforward NN, recurrent NN, and spiking NN. In addition, there are also different types of NNs such as single-layer NN, Multi-Layer Perceptron (MLP), temporal NNs, radial basis function NN, self-organizing NNs and others [11].

A wide range of applications and researches have been tested and applied with NNs, including diagnosis of diseases [12][13], speech recognition [14][15], data mining [16][17], image processing [18][19], forecasting, robot control [20][21], and many others.

A. History of ANN

W. S. Mcculloch and W. Pitts established mathematical model of NN called multi perceptron model in 1964 [22]. The history of ANN development can be divided into three stages [23] which is the initial stage where MP model was proposed in the 1960s. The main characteristic of this period was to produce the network model and conform to the learning algorithm. However, the hardware limitation discouraged the progress of ANN. The second stage of the development of NN started to show some profound result with the increase of processing capacity in 1980s. Finally, the golden period occurred when NN theory development started to mature and many improvements were made in the existing architecture and theory [24]. At present ANN has several hundreds of network model, as an active, marginal and cross subject. ANN has been widely used in many application fields.

B. Guidelines and Steps for ANN Forecastings

Guidelines are provided by researchers to assist and to guide others to conduct experiment in ANN forecasting. The first step is the data preparation where the output and the results are validated. In this paper, we present two common guidelines that can be used as reference to conduct experiment in ANN forecasting. The first guide was proposed by William Remus and Marcus O'connor in [25]. The steps are as follow:

1. Clean the data prior to estimating the NN model.
2. Scale and de-seasonalize data prior to estimating the model. Scaling is used to normalize the raw data used as input for the ANN. De-seasonalizing data is to remove the seasonal component in the time series for analyzing non-seasonal trends in the data.
3. Use appropriate methods to choose the right starting point.
4. Use specialized methods to avoid local optima.
5. Expand the network until there is no significant improvement in fit.
6. Use pruning techniques when estimating NNs and use holdout samples when evaluating NNs.
7. Take care to obtain software that has in-built features to avoid NN disadvantages.
8. Build plausible NNs to gain model acceptance by reducing their size.
9. Use more approaches to ensure that the NN model is valid.

Then, the second guide is proposed by JingTao Yao and Chew Lim Tan that outlines seven steps approach to conduct ANN forecasting [26]. The steps are as follow:

1. Data pre-processing
2. Selection of input and output variables
3. Sensitivity analysis
4. Data organization
5. Model construction
6. Post analysis
7. Model recommendation

The researchers believed providing these guidelines will help others in building and conducting successful forecasting models and experiments.

IV. Literature Review

NN has been shown to be able to predict the volatility and non-linear stock market prices due to its learning, mapping, generalizing and self-organizing characteristics. This section will present some of the works that have been carried out by researchers in adopting and applying NN in financial stock market prediction.

Feedforward NN is the most common NN architecture used in stock market forecasting. It is the simplest NN, in which the information of feedforward NN only moves in one direction. The information moves from the input layer to the hidden layer(s) and from the hidden layer(s), it moves to the output layer. [27] predicted the IBM daily common stock price using three layers feedforward NN which consisted of one input, one hidden layer and one output layer. In the study, 5000 days dataset were used to conduct their experiment. Out of the 5000 days data, 1000 days were used for training and the rests were used for testing. The performance of the NN is not satisfactory but they provided valuable insight in implementing NN in stock market prediction. In [28] the closing value of the Indian S&P CNX Nifty 50 Index was predicted using a NN model. 10 years data sets from the 1st January 2000 to 31st December 2009 of the S&P CNX Nifty 50 Index closing values were used in the study. Four years out of the ten years data were used for validation. The authors developed an optimal ANN structure which is a hybrid backpropagation three layers feedforward NN with 10 input neurons, a hidden layer with five neurons and one output neuron with tan sigmoid and linear transfer functions in the hidden and output layers. They achieved the best accuracy of 89.65% and an average accuracy of 69.72% in their predictions.

Many researchers have also conducted experiment to compare ANN with linear model in predicting the stock market price. [29] carried out a comparison study on the volatility of the BSE Sensex 30 and NSE Nifty 50 using statistical models such as GARCH, EGARCH, GJR GARCH, IGARCH with MLP models.

Generalized autoregressive conditional heteroskedasticity (GARCH) developed by Bollerslev [30] is an extended version of AutoRegressive Conditional Heteroskedasticity (ARCH) developed by Engle [31]. ARCH is an econometric approach to analyse volatility of time series in financial markets, GARCH is developed to overcome the limitation of ARCH in violation of non-negativity constraints by using specific conditional variances. Exponential GARCH (EGARCH) is another extension of GARCH framework to model volatility under the conditions of asymmetric reaction of the investors / leverage effect proposed by Nelso [32]. Integrated Generalized Autoregressive Conditional Heteroskedasticity (IGARCH) is

another extension of the restricted version of the GARCH model, where the persistent parameters sum up to one, and therefore there is a unit root in the GARCH process. Glosten-Jagannathan-Runkle GARCH (GJR–GARCH) model is another extension of GARCH model which takes additional term added to account for possible asymmetries [33].

The authors used 14 years of data set from January 1995 to December 2008. The result showed that although volatilities obtained MLP model was less than the other models, the ANOVA test revealed that the difference was insignificant. Similar work was done in [34], in which the research was carried out to compare the performance of their proposed ANN-GARCH model against GARCH, EGARCH, and GJR models in forecasting stock return volatility. They used the daily stock returns from four different international markets including London, Tokyo, New York and Toronto between 1970 and 1990 as the data set. The result showed that their proposed ANN with a single hidden layer model performed better than the other two models.

Feedforward NN was also used in both [35] and [36] to forecast the stock market index. [35] forecasted trading signals of the AORD one day ahead based on the current day's close price of the US S&P 500 Index, the UK FTSE 100 Index, French CAC 40 Index, German DAX Index and AORD. Two NNs were examined in the forecasting study which is the feedforward and probabilistic NNs. The evaluation of the performance is based on the classification/misclassification rate and trading simulations. Their result showed that feedforward NN outperformed probabilistic NN both in the classification/misclassification rate and trading simulations. [36] forecasted the S&P 500 index using MLP and probabilistic NN. The data set were composed of daily closing S&P 500 index and also the currency exchange rate of Yen, Pound and Mark from Feb 1994 to Sept 1995. The results obtained showed that probabilistic NN performed slightly better than MLP. Another similar work is in [37], where they predicted both the trend of stock price and value of stock price using feedforward NN and radial basis NN with backpropagation. They used the Bhavcopy (dataset repository for NSE) copied data from the National Stock Exchange (NSE) for November 2005. Their experiment showed that feedforward NN using backpropagation is better for trend prediction where it achieved almost 100% accuracy compared to 80% accuracy attained by the radial basis NN. However, the radial basis NN performed better in stock price prediction by achieving higher percentage of accuracy than the feedforward NN.

Many researchers have also experimented with feedforward NN architecture with different learning algorithms such as backpropagation, genetic algorithm, fuzzy logic and others.

[38] used backpropagation NN to predict the stock exchange of the Thailand index. They used 124 trading data and mean squared error (MSE) and mean absolute percentage error (MAPE) were used to measure the error rate, which is the difference between the forecasted value and actual value. The result showed the error rate of MAPE to be less than 2%. However, when compared to adaptive evolutionary algorithm, the backpropagation NN result is a bit higher than the adaptive evolution strategy. In [39], the Kuala Lumpur Composite Index was predicted using backpropagation NN with technical indicators and levels of the index. The data set was from 86 Malaysian's stock from the 3rd January 1984 to 16th Oct 1991. In the study, they compared backpropagation NN with ARIMA models and proved the backpropagation NN can predict better than the ARIMA model thus, generating more paper profit in predicting the KLCI. [40] forecasted the daily returns of the BSE Sensex using a MLP network with backpropagation as the learning algorithm. The data set used was the daily index values of the BSE Sensex from 16th Jan 1980 to 26th December 1997. They achieved a satisfactory result in predicting the daily returns of BSE Sensex and found that the previous day value heavily influenced the predictive model. [41] applied a multilayer backpropagation NN in financial data mining to forecast the buy and sell signal. The study used a seven years data set from Shanghai Composite index from June 1995 to June 2003. They showed that the predictive model was better than the buy and hold strategy. They achieved an average accuracy of 56.3% over 30 days and 85.71% success rate in selling. [42] used a multilayer feedforward NN with backpropagation to predict the direction of Istanbul stock exchange national 100 indices. 1905 observation data were used in this study. Parameters used for the prediction include highest, lowest, closing price, exchange rate with USD and the response rates. Their results showed an accuracy of 74.51% in predicting the stock market direction.

In order to improve the result further, some researchers used the hybrid backpropagation approaches such as in [43]. They applied Levenberg-Marquardt backpropagation algorithm in a three layered feedforward NN to predict the index of Shanghai stock exchange. The paper showed that the Levenberg-Marquardt backpropagation NN performed better in stock data prediction. Some researchers went on to apply evolutionary computation with backpropagation. [44] compared the backpropagation NN and genetic based backpropagation NN to predict the stock price of the day. Genetic Algorithm based backpropagation NN predicted more accurate price than the backpropagation NN. The data set used in the experiment is the Maruti stock from Jan 2004 to Dec 2006 for training and 2nd Jan 2007 to 30th Mar 2007 for testing. They stated that the accuracy achieved by Genetic Algorithm's based backpropagation NN system was 98.31% while conventional backpropagation NN only achieved an accuracy of 93.22%. Yet, there are also other algorithms that generated interesting result such as in [45]. The authors showed the performance comparison between MLP feedforward with backpropagation and Group Method of Data Handling (GDMH) with Genetic Algorithm in predicting the stock price index in Tehran Stock Exchange (TEPIX) using the moving average crossover. The result showed that GDMH with Genetic Algorithm performed better than MLFF with backpropagation NN.

Neuro fuzzy and neuro evolutionary have also shown promising results in stock market prediction. A comparison study was carried out in [46] on the Dow Jones Industries Average using three methods namely MLP, adaptive neuro-fuzzy inference and general growing and pruning radial basic function NN. In the study, ten years data from 1995 to 2004 of 1630 equities of Dow Jones Industries Average were used.

They compared the computational time, generalize rate, recall rate and confusion matrices, and correlation to appreciation. From the study, it showed that general growing and pruning radial basic function required more computational time and outperformed the other two methods in terms of recall rate. A similar method was used in [47] to predict the indices of Shanghai stock exchange using fuzzy NN. The data set used was from 15th March 2004 to 15th March 2005 with a total of 244 working dates. They showed that fuzzy NN performed better than common NNs. [48] used a neuro-evolutionary method of NN with Genetic Algorithm to predict short-term stock index of German Stock Exchange DAX. The data set used in the research were the index of the German Stock Exchange (DAX), Tokyo Stock Exchange (NIKKEI 225), New York Stock Exchange (DJIA) and the exchange rates of EUR/USD and USD/JPY from 7th April 2004 to 26th August 2004. Their results showed that the neuro-evolutionary approach performed better compared to other testing models.

Besides feedforward NN, other NN architectures have also been adopted in the stock market prediction. Recurrent NN is another class of NN architectures where the network connection of this NN forms a directed cycle. Thus, this allows the recurrent NN to have different internal states which can exhibit dynamic temporal behavior.

[49] predicted the stock market value using MLP feedforward, Elman recurrent NN, and linear regression model. The data set used in the study was obtained from 1094 companies in Tehran stock market from year 2000 to 2004. Their findings showed that MLP NN is better than Elman recurrent NN and linear regression method in predicting stock value changes. However, they also found that the Elman recurrent NN and linear regression can predict the direction of the changes of the stock value better than the MLP. [50] forecasted the stock index using Elman recurrent NN with Genetic Algorithm. This study used opening and closing quotation of Shentiandi's stock on 16-5-2006 from 9.30am to 15.00pm as their dataset. They claimed that Elman recurrent NN is much more feasible in stock market prediction.

The multi-branched NN is another NN architecture variations used in the stock market prediction. [51] proposed a multi-branched NN for predicting the Tokyo Stock Exchange Prices Index (TOPIX). They claimed that multi-branched NN has a higher representation and generalization than the conventional ANN. Their result showed that multi-branched NN was able to generate higher accuracy than the conventional ANN.

V. CONCLUSIONS

This paper provides a review on the application of ANN in stock market prediction. Although NN has shown acceptable results, many researchers are still trying to improve the accuracy of the stock market prediction by using a hybrid method, and by taking into account more external factors in order to generate more accurate prediction. It is a known fact that the dynamic stock market world is non-linear, volatile and subject to influences by so many external factors. This paper can be used as an introductory material to those who are interested to work on stock market prediction using NN.

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