Chapter 1
Introduction

1.1 Prediction in Business Applications

Prediction (Forecasting) is the applicability of earlier historical data for determining the direction of future trends in respect of the commodities considered. Prediction methodologies are used by companies to determine how to allocate their resources for the future, so that the supply and demands possess the balance between each other. This is typically based on demand for the goods and services it offers, compared to the cost of producing them. Investors utilize forecasting to determine if any events affect a company, such as sales expectations, that will result either in increase or decrease in the price of shares in that company. The financial crisis for the past few years has shown the need for new and improved prediction models to be applied for markets in volatile times. Hence proper prediction tools should be employed and validated for forecasting the financial markets of various business applications.

1.2 Prediction tools — An Overview

In the growing scenario of prediction mechanism for various business applications, it is noted that over the past decades numerous prediction tools have been applied [1]. Certain real time financial markets have their datasets varying in a linear manner as well in a non-linear manner. As a result, several linear and non-linear prediction tools are available in order to meet the necessary requisite for forecasting based on the already available data. All the linear programming techniques like Gauss-Seidal approaches, Gaussian elimination method, numerical analysis procedures and so on were employed for performing prediction applications. The problem considered for prediction becomes a class of non-deterministic combinatorial hard problem and henceforth to find solutions and achieve better prediction rate, several other prediction tools employing soft computing techniques, decision trees, association rule mining, evolutionary programming, clustering mechanisms and so on are employed. Amidst the various methods employed for performing prediction applications; soft computing approaches
paved the way in an efficient and effective manner due to its mechanism of adapting to
find solutions based on human brain modeling, human reasoning and human evolution.
Once the human brain is trained with the information of previous years, it possesses the
nature to predict the forthcoming information based on its past experiences. This feature
of human brain is modeled into the machine learning approach and artificial neural
network models are devised to perform numerous prediction applications.

1.3 Soft Computing models

Soft Computing refers to a collection of computational techniques in computer science,
artificial intelligence, machine learning and some engineering disciplines, which attempt
to study, model, and analyze very complex phenomena: those for which more
conventional methods have not yielded low cost, analytic, and complete solutions [2].
Earlier computational approaches could model and precisely analyze only relatively
simple systems. More complex systems arising in biology, medicine, the humanities,
management sciences, and similar fields often remained intractable to conventional
mathematical and analytical methods. Soft computing techniques resemble biological
processes more closely than traditional techniques, which are largely based on formal
logical systems, such as sentential logic and predicate logic, are rely heavily on
computer-aided numerical analysis (as in finite element analysis). Figure 1.1 presents the
key constituents of soft computing techniques.

![Figure 1.1 Block diagram of soft computing models](image-url)
Soft computing differs from conventional (hard) computing in that, unlike hard computing, it is tolerant of imprecision, uncertainty, partial truth, and approximation. In effect, the role model for soft computing is the human mind. The guiding principle of soft computing is: Exploit the tolerance for imprecision, uncertainty, partial truth, and approximation to achieve tractability, robustness and low solution cost. In all the constituents presented in Figure 1.1, neural networks that mimic the working of the biological neuron plays a vital role in prediction applications due to their robustness and versatility and this is justified in the following section.

1.4 Need for ANN Models in Forecasting Applications

Artificial Neural Networks (ANN) is an information processing system that works similar to the Human Nervous system. It is an accurate method for forecasting business applications and it is more helpful for making investment decisions. The ANN can predict the future exchange rates that are more complex for the traditional systems. Even though, neural networks have several advantages, they have some disadvantages too. The advantage of neural networks is that when the network is properly trained, it can be considered as the best network for the particular project. Additionally, the learning ability of neural networks adjusts to vibrant and varying market environment. It is the best forecasting tool than traditional statistical systems. Many business persons and researchers have increased the usage of the neural networks for forecasting various areas in business markets in order to improve their competitiveness. The disadvantage of neural networks is that the entire process is time consuming and the outputs rely on trial and error method. The main problem in neural network is over fitting. During training, the mean square error is small, but when new data is presented to the network, the mean square error will be large. Here the network has learned the training data, but it is not learned to generalize to new situations. Added to this, few other characteristics of artificial neural networks include,

- Massive parallelism,
- Distributed representation and computation,
- Learning ability,
Generalization ability,
Adaptivity,
Inherent contextual information processing
Fault tolerance, and
Low energy consumption.

1.5 Motivation for the Research

This thesis concentrates on forecasting four areas namely foreign exchange rate, stock markets, gold price and crude oil.

1.5.1 Foreign Exchange rate forecasting

For the past few decades, Foreign Exchange markets have reached its height in the financial time series prediction. The Exchange rates are very essential for traders for purchasing the international goods. Since, the currency rates are traded twenty four hours a day all over the world, Traders are very much interested in predicting the exchange rates at which the currencies are exchanged. Understanding the daily movement of Exchange rates becomes a challenging task for most of the researchers. Also, the exchange rate predictions are unpredictable due to noise and high ambiguity. Hence, many researches carried their work in the field of predicting the foreign exchange markets. In this work, novel neural network models are employed to forecast the daily foreign exchange rate of USD in terms of Indian rupees in India during the period 2009-2014.

1.5.2 Stock market forecasting

Accurate stock market prediction is the challenging area for the businessmen to yield profits in the financial markets. The investors need to understand the financial markets which are more volatile and affected by many external factors. Hence, based on literature studies it is inferred that Artificial Neural Network is one of the powerful tools for predicting the stock prices. Hence, this research work proposes novel recurrent neural
networks for predicting the Yahoo stock data and apple stock data during the period of 5 years from 2009 to 2014.

1.5.3 Gold price forecasting

In recent years, the investors pay major attention to invest in gold market because of huge profits in the future. Gold is the only commodity which maintains its value even in the economic and financial crisis. Also, the gold prices are closely related with other commodities. The future gold price prediction becomes the warning system for the investors due to unforeseen risk in the market. Hence, an accurate gold price forecasting is required to foresee the business trends. This work proposes new neural network variants to forecast the future gold prices from four commodities like historical data’s of gold prices, silver prices, Crude oil prices, Standard & Poor’s 500 stock index (S & P 500) index and foreign exchange rate. The period used for the study is for 14 years from 2000 to 2014.

1.5.4 Crude oil price forecasting

Crude oil is one of the most important commodities worldwide. The price fluctuation in crude oil is the major concern which affects our economy. The daily fluctuations in the crude oil prices not only affect our financial market, it also affects each individual in the country. Also, the crude oil prices directly affect the petrol prices. Hence, it is essential to forecast the crude oil prices which are helpful for the investors to make decisions based on the energy markets. A radial basis function and its emotional radial basis function are better than the back propagation network in terms of classification and learning speed. When creating a radial basis functions, the factors like number of radial basis neurons, radial layer’s spread constant are taken into an account. The spread constant and weight values are determined using a bio inspired particle swarm optimization algorithm.

1.6 Neural network models for foreign exchange rate prediction – A literature foundation

Exchange rate forecasting is very tough. Although economic fundamentals are considered to contain information with regard to future exchange rate movements, the forecasting
performance of exchange rate models has turned out to be frequently inferior to a naive random walk benchmark, a finding that dates back to the seminal study by Meese and Rogoff [3].

Kyoung-jae Kim et al [4] used Support Vector Machine (SVM) for financial time series forecasting and compared SVM with Back Propagation Network (BPN) and Case Based Reasoning (CBR). They concluded that the SVM outperforms the other two methods. To model time variation, experiment with two methods in the literature: the time-varying parameter Bayesian vector autoregression with stochastic volatility developed by Cogley and Sargent [5] and Primiceri [6], and its approximation proposed by Koop and Korobilis [7], based on forgetting factors and on an exponentially weighted moving average estimator of the shocks' covariance matrix. The performance of these models is compared to that of two benchmarks, a Bayesian vector auto regression and a random walk (with and without GARCH innovations), by juxtaposing the respective point, interval and density forecasts. The analysis reveals that, though the point forecasts are similar, the time-varying models, and in particular the forgetting-factor one, deliver sharper and more accurately calibrated density forecasts, thus correctly estimating forecast uncertainty.

Rossi in the year 2006 [8] investigates the implications of parameter in-stability for model selection between fundamental-based and no-change models of exchange rate determination: it emerges an unstable relationship between the exchange rate and the fundamentals and accounting for breaks delivers better forecasts than a simple random walk in some cases (Japanese Yen-US Dollar, for example). In 2007, Evans and Lyons [9] formalize the notion that order flow conveys fundamental information about exchange rates in a dynamic general equilibrium model where information is first manifested at the micro (agent) level and is not symmetrically observed among agents. The model essentially combines a number of classical ingredients of the new open-economy macroeconomics literature with the insights of the FX microstructure literature, predicting an exchange rate behavior that matches several empirical facts.
Engel, Mark and West in the year 2007 [10] focus on explaining the fluctuations of exchange rates using selected models, countries and fundamentals, analysis considers a broader set of fundamentals and more recent data. Forecasting the Istanbul Stock Exchange National 100 Index Using an Artificial Neural Network is proposed by Birol Yildiz et al (2008) [11]. This work has an accuracy of 74.51%. A related idea is originally put forward in Sarno and Valente [12] in the year 2008 based on survey data evidence of swings in expectations, they contend that traditional fundamentals do have some predictable content but the market attaches variable weights to them over time. Using ex-post data to select the best model at each time outperforms a random walk model for three out of five exchange rates. The empirical studies on foreign exchange rate prediction employ shrinkage techniques and flexible model averaging or selection criteria: Wright (2008) [13] and Corte et al (2009) [14] use Bayesian Model Averaging and report encouraging results. Andersen et al (2003) [15] show that shocks to fundamentals can affect exchange rate movements at intraday frequencies, whereas Engel, Mark and West (2007) [10] and Molodtsova et al (2008) [16] evidence that fundamentals can outperform a random walk at longer horizons.

Canova (1993) [17] finds that a time-varying coefficient Bayesian model with exchange rates and short-term interest rates has a higher predictive ability than a random walk. More recently, predictive ability of macroeconomic fundamentals in a time-varying setting has been evaluated by Della Corte et al. (2015) [18]. Mehdi Khashei et al (2010) [19] proposed ANN models for time series forecasting for three real time datasets. The empirical results showed that the proposed work was the effective way to improve the forecasting accuracy. Yakup Kara et al (2011) [20] proposed ANN and Support Vector machines for predicting the direction of stock price index movement for the sample of the Istanbul Stock Exchange. Here ten technical indicators are used and the results showed that the performance of ANN model was found significantly better (75.74%) than that SVM model. Hybrid ANN models was proposed to forecast the exchange rates by Mehdi Khashei et al. (2011) [21].

Melvin, Prins and Shand (2011) [22] focus on forecasting exchange rates from an financial investors point of view, e.g. carry trades, need to focus instead on forecasting
exchange rates using economic models and macroeconomic predictors. Time Series Data mining techniques like Multiple Regression in Excel, Multiple Linear Regression of Dedicated Time Series Analysis in Weka, Vector Autoregressive Model and Neural Network Model using Neural Works Predict are analysed by Saigal et al (2012) [23]. The results showed that Multiple Linear Regression of Dedicated Time Series Analysis in Weka outperforms the other three models.

Suresh Kumar Sharma et al. (2012) [24] proposed Artificial Neural network with back propagation network for forecasting the exchange rate of USD in terms of Indian Rupees. Vincenzo Pacelli et al. (2012) [25] presented a comparative analysis between the different mathematical models, such as artificial neural networks (ANN) and ARCH and GARCH models to forecast the daily exchange rates of Euro /USD dollars.

Markiewicz (2012) [26] proposed a learning theory in which forecasts based on the selected macro variable feeds back into the actual exchange rate dynamics. The theoretical argument behind those rational expectation models is that investors focus excessively on a time-varying subset of fundamentals that change over time.

Cross et al (2013) [27] pointed out foreign exchange rates fluctuation forecasting model using new Weka filter based on genetic algorithms and ensemble learning. Compared to other ensemble based learning system the suggested ensemble combination based approach made confidence of 97% accuracy.

Deng et al (2015) [28] performed short-term Foreign Exchange Rates forecasting using hybrid multiple kernel learning-genetic algorithms (MKL-GA), based on the technical indicators change in the exchange rate is predicted by the means of MKR and trading rules are generated using GA. Pointed out approach superior in term of returns and return-risk ratio than that of other baseline methods.

Evans et al (2013) [29] carried out work on an intra-day foreign exchange market prediction using Artificial Neural Networks (ANN) and Genetic Algorithms, 70 weeks of past currency rates of the 3 most traded currency pair datasets are used. Result show that the presented method produces prediction accuracy of 72.5% and get annualized Net Return of 23.3% by means of optimal trading strategy.
Fallahzadeh & Montazeri (2013) [30] carried out work on interval type-2 fuzzy c-means clustering and interval type-2 neuro-fuzzy model for foreign exchange rates forecasting, combination of back-resilient and back propagation is adapted for faster convergence. Result show that the presented model obtains better prediction accuracy with faster convergence than that of fuzzy c-means based type-1 equivalent and a FLANN based neuro-fuzzy system.


Meng & Sun (2013) [33] proposed single hidden layer Back Propagation Neural Network (BPNN) based expert advisor for forex trading, based on separately performed profitability on EUR/USD; GBP/USD currency pair’s parameters are optimized. Nayab et al (2013) [34] performed forecasting model based on Cartesian Genetic Programming Evolved Artificial Neural Network (CGPANN) for foreign currency exchange rates forecasting.

Ouyang & Yin (2014) [35] presented neural gas (NG) and mixture autoregressive based hybrid model for foreign exchange (FX) rates prediction, suggested hybrid model outperform in terms of correct trend prediction percentage and normalized root-mean-squared-error compared to other methods.

Zafeiriou & Kalles (2013) [38] presented ensemble financial technical indicators based neural network model for short-term buy-sell trends in foreign exchange markets forecasting. Compared to the individual technical indicators based neural network the suggested model superior in term of prediction accuracy.


Cai & Zhang (2014) [40] proposed autoregressive conditional multinomial-autoregressive conditional duration (ACM-ACD) model for exchange rate forecasting in high-frequency domain. Forecasting performance is improved by means of the dynamic learning; increasing the threshold of mid-quote price change and filtering the data, result show that the presented approach based prediction achieve 54 to 70% of rate of correct prediction for high frequency domain.


foreign exchange rate prediction using continuous time Bayesian network classifier (CTBNC), compared to dynamic Bayesian networks models the suggested model achieve effective, efficient and high frequency prediction of FX rates.

Zafari et al (2014) [47] performed foreign currency exchange rates forecasting using recurrent Cartesian genetic programming-based artificial neural networks (RCGPANN), the proposed approach based single day ahead prediction with 6 neurons achieve 98.872 % of prediction accuracy and 1000 days ahead prediction obtain 92% of prediction accuracy. Zhang et al (2014) [48] pointed out exchange rate forecasting model by means of Fuzzy Granulation and Deep Belief Networks, profit strategy close to the real foreign exchange trade market is achieved using Stop Loss concept.

Lu et al (2015) [49] investigated application of optimized Nonlinear Grey Bernoulli model (ONGBM) and successfully applied it for foreign exchange rates and traffic flow forecasting, the results prove better adaptability and prediction accuracy. Li et al (2015) [50] pointed out foreign exchange prediction and portfolio multi-objective optimization based on improved artificial fish swarm algorithm, artificial fish swarm algorithm based support vector regression machine is used for improved short-term exchange rate prediction and non-dominated sorting artificial fish swarm algorithm (NSAFSA) with twice pruning strategy improved quality of solution for optimal portfolio selections.

Nootyaskool & Choengtong (2015) [51] performed foreign exchange rate prediction using Hidden Markov Models (HMM), which is trained by means of encoding four factors into one observation sequence. Suggested approach predicts Thai currency exchange with 0.167 % of mean percentage error.

Sahu et al (2015) [52] suggested foreign exchange rate forecasting model by means of adaptive CRO based FLANN (Fuzzy Logic Artificial neural Network). Result confirms that the presented model which is trained using LMS obtain improved performance and efficiency compared to FLANN model. Torregoza & Dadios (2015) [53] proposed exchange rate forecasting of Philippine Peso to US Dollar model based on new method, conventional artificial neural network with limited training data accuracy is improved by
means of the alternative algorithm and analyzed the performance of neural network and hybrid genetic algorithm-neural network for exchange rate forecasting.

Wang (2015) [54] presented theoretical framework for convertibility restriction in China's foreign exchange market and analyzed the effect of forward pricing. Level of conversion restriction determine the weighting, weighted average of the CIP-implied forward rate and the market's expectation of the future spot rate equal onshore forward rate predicts by model and also offshore non-deliverable forwards reflect the market's expectation of the future spot rate.


1.7 Literature review on applicability of neural network models for stock rate forecasting in business applications

Over the past decade several computational intelligent techniques were noted to be applied for stock rate forecasting applications and the review on various models applied for the this applications are as detailed below:

Qiu et al (2016) [57] investigated the use of Artificial Neural Networks (ANNs) to combine time series forecasts of stock market volatility. Ramon Lawrence (1997) [58] surveyed the application of neural network to financial systems. It demonstrated how neural networks have been used to test the Efficient market Hypothesis and how they outperform statistical and regression techniques in forecasting share prices. Lijuan Cao et al. (2001) [59] used SVM model for the prediction of S&P 500 daily price index. They proved that SVM model is better in terms of Normalized mean square error and mean absolute error.
Erdine Altay et al. (2005) [60] studied the Istanbul Stock exchange can be forecasted through the learning procedure of Artificial Neural Network and compared the forecasting performance of artificial neural network with linear regression and buy and hold strategies.

Armano et al. (2005) [61] studied a novel approach to perform stock market prediction using a hybrid genetic neural architecture. Heping pan et al. (2005) [62] investigated several aspects of input feature selection and number of hidden neurons for a practical neural network for predicting Australian stock market index AORD. A basic neural network with limited optimality on these has developed and achieved correctness in directional prediction of 80%.

Hyun-Jung Kim et al. (2005) [63] investigate the effectiveness of a hybrid approach with the time delay neural network (TDNNs) and genetic Algorithm (GAs) in detecting temporal patterns for stock market prediction task and showed that the integrated GA-TDNNs approach proposed for this study performs better than the standard TDNNs and Recurrent Neural Network to reflect temporal pattern.

Quig Cao et al. (2005) [64] used Artificial Neural Networks to predict stock price movement (i.e. price return) for firms traded on the Shanghai Stock Exchange and compared the predictive power of uni-variate and multivariate neural network models and results shows that Neural Network outperform the linear models compared and these results are statistically significant across our sample firms and indicated neural networks are useful tool for stock price Prediction in emerging markets like china.

Rafiul Hassan (2005) [65] used Hidden Markov Models (HMM) approach to forecasting stock price for interrelated markets. HMM was used for pattern recognition and classification problems because of its proven suitability for modeling dynamic system. The author summarized the advantage of the HMM was strong statistical foundation. It’s able to handle new data robustly and computationally efficient to develop and evaluate similar patterns. The author decides to develop hybrid system using AI paradigms with HMM improve the accuracy and efficiency of forecast the stock market.
Takashi Yamashita et al. (2005) [66] utilized Multi-branch neural networks (MBNNs) for prediction of stock prices and simulation were carried out in order to investigate the accuracy of prediction. The results found that MBNNs with fewer parameters could have better accuracy than conventional NNs when predicting Nikkei-225 at time (t + 1).

Niall O’Connor et al. (2006) [67] evaluates the effectiveness of using external indicators such as commodity prices and currency exchange rate in predicting movements in the Dow Jones Industrial Average index and also the performance of each technique is evaluated using different domain specific matrices. Eleni Constantinou et al. (2006) [68] analyses regime witching and Artificial Neural Network in volatility and out of- sample forecasting of the Cyprus Stock Exchange by using daily data.

Rafiul Hassan et al. (2007) [69] used a fusion model of HMM, ANN and GA to forecast financial market behavior. This tool was used for in depth analysis of the stock market. The daily stock price was transformed to independent sets of values that become input to HMM and GA to optimize the initial parameters of HMM. Then HMM is used to identify and locate similar patterns. A weighted average of the price differences of similar patterns are obtained to prepare a forecast for the required next day.

Choudhry et al. (2008) [70] proposed a hybrid machine learning system based on Genetic Algorithm (GA) and Support Vector Machines (SVM) for stock market prediction. Tilakaratne et al. (2009) [71] studied modified neural network algorithms to predict whether it is best to buy, hold or sell shares of stock market indices.

Akinwale et al. (2009) [72] examined the use of error back propagation and regression analysis to predict the untranslated and translated Nigeria Stock Market Price (NSMP). The author used 5-j-1 network topology to adopt the five input variables. The number of hidden neurons determined the j variables during the network selection. Both the untranslated and translated statements were analyzed and compared. The Performance of translated NSMP using regression analysis or error propagation was more superior to untranslated NSMP.

George (2009) [73] used Adaptive Neuro Fuzzy system controller to control the stock market process model and also evaluate a variety of stocks. The Efficient Market
Hypothesis was used to improve the prediction in short-term stock market trends. The result demonstrates clearly to use the proposed Rate of Return (ROR). The better returns was obtained the investor allocated assets to the risk-free government bonds once the predicted stock return turned negative. This is known as asymmetric outcomes of the stock markets. The second time the investor allocated assets to risk-free government bonds have some positive returns. This means gains from correct prediction and losses from incorrect prediction. The neuro-fuzzy system clearly demonstrates the potential for financial market prediction.

Kuang Yu Huang (2009) [74] used the moving average autoregressive exogenous (ARX) prediction model is combined with grey system theory and rough set theory to create an automatic stock market forecasting and portfolio selection mechanism. Financial data were collected automatically every quarter and are input to an ARX prediction model for forecast the future trends. Clustered using a K means clustering algorithm and then supplied to a RS classification module which selects appropriate investment stocks by a decision-making rules.

Fazel Zarandi et al. (2009) [75] used a type-2 fuzzy rule based expert system is developed for stock price analysis. The purposed type-2 fuzzy model applies the technical and fundamental indexes as the input variables. The model used for stock price prediction of an automotive manufactory in Asia. The output membership values were projected onto the input spaces to generate the next membership values of input variables and tuned by genetic algorithm.

In Abdulsalam et al. (2010) [76] the moving average [MA] method is used to uncover the patterns, relationship and to extract values of variables from the database to predict the future values of other variables through the use of time series data. The advantage of the MA method is a device for reducing fluctuations and obtaining trends with a fair degree of accuracy. These techniques are proven numeric forecasting method using regression analysis with the input of financial information obtained from the daily activity equities published by Nigerian stock exchange.
Hsien-Lun et al. (2010) [77] used ARIMA model and vector ARMA model with fuzzy time series method for forecasting applications. Fuzzy time series method especially heuristic model performs better forecasting ability in short-term period prediction. The ARIMA model creates small forecasting errors in longer experiment time period. In this work, the author investigates whether the length of the interval will influence the forecasting ability of the models or not.

Agrawal et al. (2010) [78] presented an innovative approach for indicating stock market decisions by minimizing the risk involved in making investments. The system used Adaptive Neuro-Fuzzy Inference System (ANFIS) for taking decisions based on technical indicators. Among the various technical indicators available, the system used weighted moving averages, divergence and RSI (Relative Strength Index).

George et al. (2011) [79] suggest Wave Analysis Stock prediction based on the neuro-fuzzy. The techniques were used to forecast the trend of the stock prices and results derived. The Elliott wave principle is connected with the Fibonacci sequence, the Fibonacci sequence of numbers derived from the addition of the previous two numbers. Elliott’s wave theory cannot constantly explain the market perfectly but the fuzzy estimates of the market behavior accurately to improve the stock market forecasting.

Suresh Babu et al. (2011) [80] used the data mining techniques are able to uncover the hidden pattern, predict future trends and behaviors in financial market. Pattern matching techniques is found to be descriptive in time series analysis. Sureshkumar et. al. (2011) [81] used prediction algorithms and functions to predict future share prices and compares their performance. The results from analysis showed that used isotonic regression function offers the ability to predict the stock prices more accurately than the other existing techniques. Adebiyi Ayodele et al. (2012) [82] used hybridized approach for predicting the stock prices. They proved that the hybridized approach was considerably better than the other techniques. Neelima Budhani et al. (2012) [83] used Feed forward back propagation network for the prediction of stock market. Their training procedure makes the better improvement in the prediction of stock markets.
Victor Devadoss et al. (2013) [84] suggested ANN models for prediction of closing values of Bombay stock exchange. The inputs to the networks are high, low, opening price, closing price, and volume. Root mean square error, Mean Absolute Deviation and Mean Absolute Percentage Error are used as performance indicators for the network. Yanshan Wang et al. (2013) [85] proposed machine learning techniques like Principal Component Analysis (PCA) for identifying the principal components and Support Vector Machines used for classifier for future stock market movement. They considered Korean composite stock price index (KOSPI) and Hang seng Index (HSI) as stock data for their study. Najeb Masoud et al. (2014) [86] used ANN model for predicting the direction of Libyan Financial market. Mean square error and Root mean square errors are used as performance indicators.


Roy et al (2015) [89] proposed a Least Absolute Shrinkage and Selection Operator (LASSO) method based on a linear regression model as a novel method to predict financial market behavior. LASSO method is able to produce sparse solutions and performs very well when the numbers of features are less as compared to the number of observations. Experiments were performed with Goldman Sachs Group Inc. stock to determine the efficiency of the model. The results indicate that the proposed model outperforms the ridge linear regression model.

Bebarta et al (2015) [90] proposed a low complexity Polynomial Functional link Artificial Recurrent Neural Network (PFLARNN) for the prediction of financial time series data. A comparison with other well-known neural architectures shows that the proposed low complexity neural model can provide significant prediction accuracy for one day advance and speed of convergence using the International Business Machines Corp. (IBM) stock market indices.
Giacomel et al. (2015) [91] proposed a neural network ensemble that receives as input the last values from a time series and returns not its future values, but a prediction that indicates whether the next value will raise or fall down.

Dash et al. (2015) [92] proposed a new hybrid model integrating an interval type2 fuzzy logic system (IT2FLS) with a computationally efficient functional link artificial neural network (CEFLANN) and an Exponential Generalized Autoregressive Conditional Heteroskedasticity (EGARCH) model for accurate forecasting and modeling of financial data with changing variance over time.

Hafezi et al. (2015) [93] proposed a new intelligent model in a multi-agent framework called bat-neural network multi-agent system (BNNMAS) to predict stock price. The numerical results show that BNNMAS significantly performs accurate and reliable, so it can be considered as a suitable tool for predicting stock price specially in a long term periods.

Bebarta et al. (2015) [94] presented an improved Dynamic Recurrent FLANN (DRFLANN) based adaptive model for forecasting the stock Indices of Indian stockmarket. Also introduced three technical indicators named Relative Strength Indicator (RSI), Price Volume Change Indicator (PVCI), and Moving Average Volume Indicator (MAVI) as they are focused on important attributes of price, volume, and combination of both price and volume of stock data. The results show the potential of the model as a tool for making stock price prediction.

Wu et al. (2015) [95] proposed a new hybrid forecasting model utilizing the combined prediction’s principle as well as the artificial intelligence’s technique. This newly presented model functions similarly to the prediction system, which not only exhibits a high accuracy rate but also has an effect on guiding operations in the stock market due to the introduction of intelligent agents.

Wang et al. (2015) [96] presented a stochastic time effective function neural network (STNN) with principal component analysis (PCA) developed for financial time series prediction. The empirical analysis shows that the forecasting results of the proposed neural network display a better performance in financial time series forecasting.
Zhang and Liao (2015) [97] proposed the expression and some feathers of multi-input Hamacher T-norm and constructed the multi-input Hamacher T-norm based ANFIS, and finally forecasted the stock price of Pingan Bank (000001) by constructing a model based on Multi-input Hamacher T-norm and ANFIS (Adaptive Neuro-Fuzzy Inference System).

Kaur et al (2016) [98] proposed a new time series algorithm which employs a minimal variation order weighted average (OWA) operator to aggregate values of high dimensional data into a single attribute. A hybrid network based fuzzy inference system combined with fuzzy c-means clustering is used to forecast Bombay Stock Exchange Index (BSE).

Göçken et al (2016) [99] proposed hybrid Artificial Neural Network (ANN) models, which consist in exploiting capabilities of Harmony Search (HS) and Genetic Algorithm (GA) to capture the relationship between the technical indicators and the stock market for the period under investigation. According to the statistical and financial performance of these models, HS based ANN model is found as a dominant model for stock market forecasting. The proposed method is used in Turkish stock market.

1.8 Prediction of Gold Price using computational neural network models – A review

This section presents the earlier literature foundations carried out on the prediction of gold price employing computational machine intelligent techniques.

The theoretical analysis in Diba and Grossman (1988) [100] considers the market for refined gold separately and explicitly allows for the effect of the expected relative price of gold on the rate of extraction and refining of ore. These complications however, do not change the qualitative implications of the existence of rational bubbles on which the present analysis focuses. Gary et al. (1993) [101] used neural networks for forecasting Standard & Poor’s 500 stock index and gold futures prices. This forecast was based on the historical prices of the stock index and gold prices.

Ongsritrakul and Soonthornphisaj (2003) [102] proposed Support Vector Regression (SVR) to resolve the time series prediction and regression problems. Also demonstrated the use of SVR techniques for prediction the cost of gold price by using factors that have
effect on gold to estimate its price. Mirmirani and Li (2004) [103] suggested neural networks equipped with genetic algorithm have the advantage of simulating the non-linear models when little a priori knowledge of the structure of problem domains exist. Among different methods, back-propagation neural networks with genetic algorithms is used to predict gold price movement.

Khaemasunun (2006) [104] forecasted Thai gold price, using Multiple Regression and Auto-Regressive Integrated Moving Average (ARIMA) model. While fitting the model the author considered the effect of nine currencies (United States, Australia, Canada, Peru, Hong Kong, Japan, German and Italy, Singapore and Colombia), Oil Prices, Set Index, Interest Rate, Gold Derivation on Thai gold price. Parisi et al (2008) [105] analyzed recursive and rolling neural network models to forecast one-step-ahead sign variations in gold price. The results shows the rolling ward networks exceed the recursive ward networks and feed forward networks in forecasting gold price sign variation.

Malliaris et al. (2009) [106] used times series techniques and Artificial Neural Networks for forecasting the prices of gold, oil and Euro. They gave an interrelationship among the three and proposed ANN technique to forecast the individual variables. And they concluded that both short term and long term relationship exist between the three variables.

Mehdi Bijari et al. (2009) [107] proposed a hybrid ARIMA model using Fuzzy logic and Artificial Neural network for forecasting exchange rates and gold prices. Fuzzy logic and ANN was hybridized with the ARIMA model in order to get accurate results. The results explained that the proposed technique predicts the future prices accurately than the other methods. Ismail Yahya and Shabri (2009) [108] developed a forecasting model for predicting gold price using Multiple Linear Regression (MLR) and obtained four different models based on several economic factors.

Hadavandi et al (2010) [109] proposed a PSO-based time series model for the gold price forecasting that uses PSO algorithm for parameter estimation. The results show that the proposed approach is able to cope with the fluctuations of gold price time
series and it also yields good prediction accuracy, so it can be considered as a suitable tool for financial forecasting problems.

Zhang et al (2011) [110] selected U.S. dollar index, oil prices, silver prices, DOW index, OECD leading index and the CRB index and applied varying-coefficient regression model which has dynamic response to the various variables influence to predict the gold price and improve the prediction accuracy. Hussein et al (2011) [111] developed a system based on existing gold data time series and algorithms based on Artificial Neural Networks.

Ali (2012) [112] uses multilayer perceptron neural network model for predicting the changes in stock prices and gold prices. The data employed in this study was Tehran’s Stock Exchange (T.S.E). The results showed that the ANN models perform better than the traditional statistical techniques. Deepika et al. (2012) [113] proposed Autoregressive Integrated Moving Average (ARIMA) models for forecasting the monthly gold price from period 1980 to 2012. This paper also finds the factors influencing the gold price using multiple regression analysis.


Lazim Abdullah (2012) [116] used Auto–Regressive Integrated Moving Average (ARIMA) model for forecasting the selling prices of gold bullion coins and forecasted that the selling prices are in the upward direction and the investors can invest money in the gold bullion coins. Trian et al. (2013) [117] explored gold equivalent for forecasting steel prices in pipeline projects. Massarrat Ali Khan et al. (2013) [118] used Box-Jenkins, ARIMA model for forecasting the gold prices. The period used for the study was from January 2003 to March 2012. Farahani et al (2013) [119] presented a comparison of Artificial Neural Network (ANN) and Adaptive Neural Fuzzy Inference System (ANFIS)
for predicting a real system, gold price. The proposed method is used to predict the gold price in the Forex market.

Bai Li (2014) [120] proposed Improved Artificial Bee Colony algorithm (ABC) for forecasting the gold price modelling using Wavelet Neural Networks. The experimental results showed that the Improved ABC algorithm works more effective than the conventional ABC algorithm. Fengyi Zhang et al. (2014) [121] proposed the methods for forecasting gold price using Radial Basis Function (RBF) neural networks and hybrid fuzzy clustering algorithm. Principal Component Analysis was used to unite technical indicators namely Moving Average, Receive Operator Characteristics and P-Accuracy rate.

Chen (2014) [122] proposed attempts to enhance the learning performance of radial basis function neural network (RBFN) through swarm intelligence methods and self-organizing map (SOM) neural network (SOMnet). The evaluation results for two benchmark problems and a gold price prediction case showed that the proposed SPG algorithm outperforms other algorithms and the auto-regressive integrated moving average (ARIMA) models in accuracy.

Mahato, P.K. and Attar, V. (2014) [123] examined different ensemble models for determining the future momentum of the gold and silver stock price, whether it will increase or decrease for the following relative to current days stock price.

Yang, J.-H. and Dou, W. (2014) [124] introduced Empirical Mode Decomposition (EMD) into Support vector machine (SVM). In order to validate the accuracy of the proposed combination model, the London spot gold price and the Shanghai Futures gold price series were employed. Empirical studies indicated that the EMD-PSO-SVM model outperformed the WT-PSO-SVM model, and was feasible and effective in gold price prediction. The proposed method can be promoted to other related financial areas.

Hossein Mombeini et al. (2015) [125] developed a defined model for forecasting gold prices. The performance measures are used to access the accuracy of the model and presented gold price forecasting using two models namely artificial neural networks and
ARIMA models and showed that the ANN model works better than the ARIMA model in terms of performance metrics.

Kristjanpoller, W. and Minutolo, M.C. (2015) [126] extend the field of expert systems, forecasting, and model by applying an Artificial Neural Network (ANN) to the GARCH method generating an ANN-GARCH. The hybrid ANN-GARCH model is applied to forecast the gold price volatility (spot and future).

Hua, Q. and Jiang, T. (2015) [127] investigated and predicted the price of London gold by using the improved empirical mode decomposition (EMD) method. The forecasting methods and techniques provide inspiring new thoughts for high-frequency data analysis in theory.

Aydin and Caliskan Cavdar (2015) [128] proposed a ENCOG machine learning framework along with Java programming language in order to constitute the ANN. The training of network has been done by resilient propagation method. The empirical results indicate that the ANN approach has more superior prediction performance than the VAR method for different macroeconomic variables such as the exchange rate of USD/TRY, gold prices, and the Borsa Istanbul (BIST).

1.9 Review of neural network architectures for crude oil price prediction

In the current situation, crude oil has also become one of the most important commodities whose variation in price is to be forecasted at an early stage. This section presents the literature review on various machine learning neural models employed for carrying out crude oil prediction.

Wang et al (2005) [129] carried out work on a crude oil price forecasting using novel hybrid AI system framework based on artificial neural networks (ANN) and rule-based expert system (RES) with web-based text mining (WTM) approach, prediction performance improved by means of conditional judgment and correction.

prices using support vector machine. The results are compared with ARIMA models and back propagation neural networks and proved that the proposed method outperforms the other two methods.


Haidar et al. (2008) [134] presented a three layer feed forward networks for forecasting future prices of crude oil prices up to three days ahead. The inputs considered are crude oil future prices, dollar index, gold price, oil spot price and S&P 500 index. Yu et al (2008) [135] pointed out neural network ensemble learning paradigm adapting empirical mode decomposition (EMD) for crude oil spot price forecasting.

Yu et al (2008) [136] performed world crude oil spot price modeling and forecasting using empirical mode decomposition (EMD) based neural network ensemble learning model; original price series decomposed into intrinsic mode functions (IMFs), extracted each IMFs are modeled by means of three-layer feed-forward neural network (FNN) and ensemble output formulated by means of the adaptive linear neural network combination with each IMFs prediction results. Effectiveness of the proposed model is confirmed based on the WTI and Brent crude oil spot price series.


Emad A El-Sebakhy et al. (2009) [139] proposed a new model based on Support Vector Machine for forecasting the PVT properties of crude oil systems. The proposed method is
accurate and reliable and it outperforms other methods. Ibrahim Sami Nashawi et al. (2010) [140] proposed multi-cyclic Hubbert model for forecasting World Crude Oil Production. The model was very simple and accurate than the other methods.

Khashman & Nwulu (2011) [141] analyzed oil price prediction based on support vector machine and back propagation neural network, oil price data with input economic and seasonal indicators define the neural network input data. Efficient future oil price prediction with reduced computational cost achieved by means of the neural networks inferred from results.


Jammazi & Aloui (2012) [143] performed hybrid (HTW-MBPNN) model for crude oil price prediction, model flexibility verified based on three variants of activation function and several level of input – hidden nodes are used to test robustness. Results show that the Harr A trous wavelet decomposition-Multilayer back propagation neural network (HTW-MBPNN) superior than that of conventional BPNN.

Wang & Wu 2012 [144] suggested autoregressive integrated moving average (ARIMA) and Back propagation neural network based combinatorial algorithm for crude oil price prediction, linear information obtained from ARIMA model and nonlinear information obtained from BPNN. Compared with ARIMA and BPNN model precision forecasting achieved by means of the combinatorial algorithm.

Chiroma et al 2013 [145], pointed out crude oil price prediction using novel co-active neuro-fuzzy inference system (CANFIS). The result proves that the proposed approach achieve minimal error, higher correlation and generalization capability than that of other fuzzy neural network and ANFIS. Hence, effectively make strategic planning for both government and private business in order to enhance the economic activities. Panella et al 2013 [146] presented ANFIS network based neuro fuzzy model for crude oil price prediction. Results show that the pointed out model made accurate price prediction and probability distribution than that of other standard and neural models.
Bashiri Behmiri et al. (2013) [147] presented a wide literature study on crude oil price forecasting. The forecasting methods are grouped into two categories namely quantitative and qualitative. Quantitative methods are divided into time series models, structural models, financial models, computational approach. These models are used to find the numeral future values of oil prices. The qualitative methods are divided into Delphi methods, fuzzy logic in which these methods analyzed the irregular patterns on oil prices.

Lubna A Gabralla et al. (2013) [148] proposed a wide literature on two decades of research on crude oil price forecasting. Chiroma et al 2014 [149] performed international crude oil price prediction by means of energy product prices based on genetically optimized Neural Network (GANN). The pointed out GANN achieve improved prediction accuracy with reduced time computational complexity than that of other methods such as SVM, VAR and FFNN.

Chiroma et al (2014) [150] suggested crude oil price prediction model based on orthogonal wavelet support vector machine (OSVM) in order to minimize the number of iteration to converge. Presented OSVM outperform than that of CSVM and MLPNN in terms of robust, accurate crude oil price prediction with reduced computational time complexity and iterations.

Li et al (2013) [151] proposed crude oil forecasting model based on novel (FA-LSSVR) firefly algorithm (FA) with least squares support vector regression (LSSVR), in order to obtain accurate and speed up prediction optimal values of LSSVR parameters are searched by means of FA. Compared to other benchmarks the presented approach robustness, faster and achieve better prediction accuracy. Shao et al (2014) [152] carried out work on different single stage and two stage hybrid prediction models for imported crude oil (ICO) demand forecasting in Taiwan, integration of various modeling components are associated with two stage hybrid prediction model. MLR, SVR, ANN and ELM are considered as single stage modeling and two stage modeling consist of two steps 1) choose lesser but more significant explanatory variables 2) based on significant explanatory variables produce predictions. Twenty three associated explanatory variables are analyzed; result demonstrated that two stage hybrid model superior and predicts the demand of imported crude oil accurately.
Sompui & Wongsinlatam (2014) [153] proposed artificial neural network based short-term crude oil price prediction model. Result revealed that compared to least square method (LSM) ANN of one-four hidden layer achieve better prediction.

Yu et al (2014) [154] carried out work on crude oil price forecasting using novel compressed sensing based artificial intelligence (AI) learning pattern, Noise in the original oil price data are eliminated using compressed sensing based denoising (CSD) and prediction done by the means of AI tool. Compared to other benchmark models the presented CSD-AI learning paradigm outperform in terms of robust, effective prediction.

Zheng et al (2014) [155] presented hybrid forecasting model for crude oil price prediction, crude oil prices are decomposed by means of the Ensemble Empirical Mode Decomposition (EEMD) and Empirical Mode Decomposition (EMD) separately, decomposed time series are predicted using Dynamic Artificial Neural Network (DANN) and Back Propagation (BP) Neural Network separately and Adaptive Linear Neural Network (ALNN) is adapted to integrate DANN and BP produced prediction.

Mayuree Sompui et al. (2014) [156] proposed an artificial neural network of one, two, three and four hidden layers to forecast the crude oil price direction in short term. Data was collected from Energy Information Administration from the period 2002 to 2013. This proposed method outperforms the least square methods.

Chiroma et al. (2015) [157] suggested West Texas Intermediate (WTI) crude oil price prediction model using genetic algorithm and neural network (GA-NN). The pointed out approach obtain higher computational efficiency and prediction accuracy compared to other baseline algorithms and Mann-Whitney test results are statistically equal to the predicted price.

Zhao et al (2015) [158] proposed crude oil price forecasting by means of Vector Auto regression- Support Vector Machine (VAR-SVM), relationship between oil price and influencing factor measured using VAR and Model parameter are select by means of Genetic algorithm (GA). Result proves that the suggested model achieve improved prediction accuracy than that of other forecasting models.
Dai et al. (2016) [159] performed principal component analysis and correlation structure of the global crude oil market. Based on the analysis observed that inter-cluster pairs are low correlated and intra-cluster pairs are high correlated, based on the Eigen portfolio of the largest eigen value index of the global oil market constructed under buy-and-hold strategy obtain better performance than that of benchmark 1/N portfolio.

Yu et al (2016) [160] pointed out crude oil price forecasting based on novel ensemble empirical mode decomposition (EEMD) and extended extreme learning machine (EELM), original time series data are decomposed into regular components using EEMD, prediction employed based on EELM and aggregated by means of simple addition.

1.10 Artificial Neural Network – An Overview

An Artificial Neural Network (ANN) is an information-processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in union to solve specific problems. ANNs, like people, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. This is the same as the case of ANNs also.

ANN’s are a type of artificial intelligence that attempts to imitate the way a human brain works. Rather than using a digital model, in which all computations manipulate zeros and ones, a neural network works by creating connections between processing elements, the computer equivalent of neurons. The organization and weights of the connections determine the output. Artificial neural networks are nonlinear information (signal) processing devices, which are built from interconnected elementary processing devices called neurons. A neural network is a massively parallel-distributed processor that has a natural propensity for storing experimental knowledge and making it available for use [161]. It resembles the brain in two respects:
Knowledge is acquired by the network through a learning process.

Inter neuron connection strengths known as synaptic weights are used to store the knowledge.

Neural networks can also be defined as parameterized computational nonlinear algorithms for (numerical) data/signal/image processing. These algorithms are either implemented on a general-purpose computer or are built into a dedicated hardware. Artificial Neural Networks thus is an information-processing system. In this information-processing system, the elements called as neurons, process the information. The signals are transmitted by means of connection links. The links possess an associated weight, which is multiplied along with the incoming signal (net input) for any typical neural net. The output signal is obtained by applying activations to the net input.

An artificial neuron is characterized basically by:

- Architecture (connection between neurons)
- Training or learning (determining weights on the connections)
- Activation function

The structure of the simple artificial neural net is as shown in Figure 1.2.

![Figure 1.2 A simple artificial neural network](image)

Figure 1.2 shows a simple artificial neural net with two input neurons \((x_1, x_2)\) and one output neuron \((y)\). Their interconnected weights are given by \(w_1\) and \(w_2\). An artificial
neuron is a p-input single-output signal-processing element, which can be thought of as a simple model of a non-branching biological neuron. In Figure 1.2, various inputs to the network are represented by the mathematical symbol, $x_1$ and $x_2$. Each of these inputs is multiplied by a connection weight. These weights are represented by $w_1$ and $w_2$. In the simplest case, these products are simply summed, fed through a transfer function to generate a result, and then output. This process lends itself to physical implementation on a large scale in a small package.

1.11 Need for the research study

From the above extensive literature study on various prediction approaches in business applications employing computational intelligent techniques over the past decades, it has been noted that the following problems are observed when performing prediction process for the considered business applications – foreign exchange rate prediction, stock market price prediction, gold price prediction and crude oil prediction.

- Scalability not attained
- Premature convergence of the network model
- Getting trapped in local and global optima
- Stagnation
- High prediction error
- Elapsing more computational time
- Increased computational burden of the algorithms
- No guarantee on interpretability of the system
- Stability not ascertained

This research work proposed predictive models which are adaptive, flexible and scalable that utilizes the advantages of proposed computationally intelligent neural network models for improving the training learning process and to enhance faster convergence. The proposed work gives highest probability for obtaining high training rate prediction accuracy with minimal mean square error for the considered business applications in the
growing market scenario than the methodologies available in the existing literatures due to the following:

- Faster convergence of the algorithms developed
- Feasible location of better solution
- Set goals are being met
- Avoiding premature convergence and local and global minima
- Improvement in prediction accuracy
- Improving the learning and convergent capabilities of the neural network process.
- Reducing the number of iterations of the network model and the mean square error of the predictor model.
- Reduction of time complexity and computational complexity of the predictor model
- Improving the generalization ability

In general, this research is carried out to propose appropriate predictor models to perform effective prediction of the considered business applications in the growing market scenario with the datasets on previous years considered from their respective repositories. This research contribution leads to the development of novel neural network based predictor models and new stochastic based evolutionary algorithms to tune developed neural network models to offer better quality solutions. In precise, this research work contributes to prediction application by developing effective and scalable proposed approaches that are based on population based stochastic evolutionary algorithms and biological modeling of the human brain. The proposed predictor models are used to facilitate the prediction process based on the knowledge and experience of previous years with a complete guarantee on predictive solutions in a responsive and efficient way. Besides the contribution to business application and forecasting research, this thesis also contributes to the neural network modeling and evolutionary optimization algorithm research. The effectiveness based on the developed predictor model is compared with few
of the other existing and proposed algorithms based on the simulation results computed for its proper validation.

1.12 Objectives of the research work

It has been well noted that performing forecasting via effective predictor models is of prime concern in the growth of business sector. In this scenario, it is required to analyze and develop predictor models to carry out effective prediction of the considered application based on their data pertaining to the previous years. Thus, in this research certain neural network architectures hybridized with stochastic population based evolutionary algorithms are proposed to produce effective forecasting with a guarantee on training and prediction accuracy. This research is based on the applicability of the proposed neural network architectures and evolutionary optimization algorithms which had proven its efficiency to perform prediction with better prediction rate. The following algorithms are proposed for forecasting the models of the considered four benchmark business applications in the growing market scenario.

- Proposed four models namely Pattern Recognition Network model, Feed Forward Back Propagation Networks, Feed Forward Network model with no feedback, and modeled Radial Basis Function Network to forecast the daily foreign exchange rate of United States Dollars (USD) in terms of Indian rupees in India during the period 2009-2014.

- Developed three novel artificial neural network models which includes feed forward back propagation neural network model, feed forward network without feedback and recurrent ELMAN neural model for predicting the stock price index prediction of Yahoo sample data for a period of five years between the duration 2009-2014.

- Modeled subtractive clustering based adaptive Neuro Fuzzy approach for predicting next day’s opening price of apple stock data for a duration of 10 years from 2005 to 2015.
Developed two variants of a fast Extreme Learning Machine (ELM) neural network model; hybrid Particle Swarm Optimization (PSO) – Group Search Optimizer (GSO) based ELM neural network model and Imperialist Competitive Algorithm (ICA) based ELM neural model to predict the next day’s gold price based on the past data of gold price considered for 14 years from 2000 to 2014.

To predict the crude oil pricing employing the proposed two variants of radial basis function neural network; particle swarm optimization based radial basis function neural network and particle swarm optimization based emotional radial basis function neural network with respect to the pricing of other commodities for duration of 14 years from 2000 to 2014.

Each one of the proposed approach contributes a distinct methodology for performing effective and efficient prediction in a cooperative manner rather than a competitive manner. The result of the prediction rate and their learning and generalization performance employing these proposed approaches are more intelligent providing an accurate and human-interpretable result as compared to other predictor models available. Matrix Laboratory (MATLAB) mathematical based simulation software is employed for simulation of the proposed neural network architectures along with population – based stochastic evolutionary optimization algorithms. Detailed numerical simulations are carried out to analyze the performance and validity of all the proposed approaches. The results computed employing the proposed predictor models are compared with some of the existing methods to prove their level of accuracy and validity.

1.13 Organization of the Thesis

The thesis is organized into seven chapters including this discussed chapter 1. An outline of the forthcoming chapters is given below:

Chapter 2 discusses the developed four neural network models pattern recognition model, feed forward back propagation model, feed forward network with no feedback and finally the radial basis function neural network model for predicting the foreign exchange rate equivalent to Indian rupees for the real time datasets. Samples of the datasets along with the technical indicators employed are presented in this chapter. The
computed results are checked for its validity with the solutions available in the existing literature.

**Chapter 3** summarizes the proposed methodology employing developed feed forward back propagation model, feed forward network with no feedback and recurrent ELMAN neural network model to predict the price of Yahoo stock data for the next day. This chapter discusses the various technical indicators employed as input to the developed neural models and presents the architecture models developed for carrying out the prediction application. The proposed algorithm is presented to depict their training and learning capabilities. The results of the proposed study for the considered data samples are explained in detail.

**Chapter 4** details a hybrid subtractive clustering based adaptive Neuro-Fuzzy approach for predicting apple stock data prices. The performance of all the proposed models is analyzed with the other existing studies from the literature. This chapter presents the comparison of proposed neural models with the existing methods and it is found that the proposed work is better in terms of the various parameters considered for validation.

**Chapter 5** presents novel variants of Extreme Learning Machine (ELM) neural networks to perform gold price prediction based on the variations in other commodities. The modeled hybrid Particle Swarm Optimization (PSO) – Group Search Optimizer (GSO) based Extreme Learning Machine (ELM) neural network and proposed Imperialist Competitive Algorithm (ICA) based ELM are presented in detail to forecast the future gold prices based on four commodities. The computed results are checked for its validity with the solutions available in the existing literature.

**Chapter 6** presents two variants of Radial Basis Function (RBF) neural networks which includes Particle Swarm Optimization (PSO) based RBF neural network and PSO based Emotional RBF neural network to predict the crude oil pricing. This chapter computes accuracy measures like Mean Square Error, Mean Absolute Error, Sum Square Error and Root Mean Square Error to validate the performance of the developed neural network models.
Conclusion of the contributions made in the thesis work and suggestions for future scope are presented in the Chapter 7.

Appendix with MATLAB source codes for the business applications considered, list of references and a list of papers published based on this research work are given at the end of this research thesis report.

1.14 Summary

This chapter presented an introduction to the need of prediction in business applications along with a fundamental idea to soft computing techniques. It provides an in-depth justification about the motivation towards this research work and for the need of prediction models based on computational intelligence algorithms. It also discussed the need for the research work and an extensive literature review on business application predictions carried out employing early neural network models and other related hybrid evolutionary optimization techniques. This chapter also presented the major contributions towards the research problem undertaken in the area of market share prediction and sketches the details on the outline of this thesis.