Design of a Financial Decision Support System based on Artificial Neural Networks for Stock Price Prediction

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Abstract
Stock markets are highly volatile by nature and difficult to predict due to the non-linear and complex nature of the market. A system that can forecast and predict the stock prices is of great value to individual investors who do not have sufficient knowledge to understand the complex dynamics involved in evaluating and predicting stock prices. Machine learning focuses on the development of computer programs that can access data and use it to learn for themselves. Machine learning is widely being used in the financial domain including prediction of stock prices. Based on the extensive literature review in this domain, traditional methods of using Machine Learning techniques including Artificial Neural Networks (ANN) for stock price prediction have taken in to account only the Technical Features. The current machine learning models do not take in to account the Intrinsic or fundamental features of the stock; the results of such prediction models are not accurate and at best could predict an intraday price of stocks with high levels of Variance. Literature review in the domain of stock predictions has shown that future stock prices are seldom dependent on the past performance and technical indicators and they invariably depend on the fundamental value and macro-economic factors. In this paper, we propose development of an Artificial Intelligence based decision support system (DSS) for guiding individual investors to buy and sell stocks. The Financial decision support shall be based on mathematical modeling of the various financial parameters to predict stock prices on a long term basis with a reasonable degree of accuracy and eliminate the behavioral biases of human decisions. The ANNs in this study were trained using open source financial data of select stocks listed on the BSE/NSE. The results of this study are quite encouraging as the stock prices can be predicted at least one month in advance and are closer to the real-time market prices. This DSS has the potential to help millions of Individual Investors who can make their financial decisions on stocks using this system for a fraction of cost paid to corporate financial consultants and value eventually may contribute to a more efficient financial system.

Keywords : Decision Support Systems (DSS), Stock Markets, Artificial Intelligence (AI), Machine Learning (ML), Mathematical Modeling (MM)
I. Introduction

Financial decision making is the most critical area in domain of financial economics which has wide ramifications. Stock markets returns are highly unpredictable and complex to understand. Ordinary and Naïve investors do not have sufficient knowledge to understand the complex dynamics involved in evaluating and predicting stock prices. Even with advances in data mining, Machine learning and business intelligence, there are no well-developed financial decision support systems that can replicate human intelligence, intuition and go through wide range of past historical data.

The current state of financial decision is still dependent on the behavior aspects of human decision making, while the decision making is supported by IT technology such as Business Intelligence (BI) and MIS based systems to assist the decision makers for risk assessment and reward estimation, but the final decision of “GO-NO GO” is still dependent on human intelligence and intuition which come under the purview of Behavioral Finance. Even with advances in data mining and business intelligence, the decision making has a lot of errors which leads to bad financial decisions incurring huge losses to the stake holders. The problem with BI/MIS related systems are they are developed using complex set of preprogrammed rules and do not have any situational awareness nor they are pro-active in nature to change the rules when ground realities change which leads to improper decision making particularly in the financial domain where the ground realities change without any intimation.

There is no automated financial decision making system that can replicate human intelligence, intuition and go through wide range of past historical data and take in to account the changing ground realities and take autonomous decisions which are based on proper risk-reward assessment.

In this paper, we propose development of an Artificial Intelligence based decision support system (DSS) for guiding individual investors to buy and sell stocks. The Financial decision support shall be based on mathematical modeling of the various financial parameters to predict stock prices on a long term basis with a reasonable degree of accuracy and eliminate the behavioral biases of human decisions. We propose to develop such a novel system based on Artificial Intelligence/Machine learning and mathematical models which take in to account the fundamental value of the stock and the external factors affecting the stock price. We provide details about the financial decision support model and machine learning algorithms suitable for such a system. The later part of the paper discusses the various parameters that are suitable to be used in the model for predicting the intrinsic value of the stock and also the external macro-economic parameters which affect the stock price. Finally we discuss the advantages of having a financial decision support system for individual investors and provide details of the future scope and work involved in making the Financial DSS.
II. Literature Review

A detailed survey of literature was done on current stock prediction computational methods and usage of Decision Support systems in financial domain. Following are some of the widely cited papers in this domain.

In the recent times, with the proliferation of Machine learning algorithms in the financial domain, many studies both in the corporate and academia have focused on the usage of various machine learning algorithms including ANNs for stock price prediction, however there are many limitations in the current application of ANNs which have mostly focused on the technical parameters which result in inaccurate and unusable prediction by investors. Many studies in this field have suggested the use of various computational models for stock price prediction such as ANNs, SVMs and Genetic algorithms which have mostly used technical indicators (Ican & Çelik, 2017). Recent studies on the comparison of various computational and machine learning models used for prediction of stock market indices have indicated that ANN’s performance is better than other computational models (Banik, Khodadad Khan, & Anwer, 2014).

There are many limitations in the current machine learning computational models including ANNs used for stock price prediction (I. E. Diakoulakis , D. E. Kououriotis, 2018), the inaccuracies are mainly because most of these models do not take in to account the fundamental parameters affecting the stock price as they are mostly rely on daily technical indicators which are very volatile. Anbalagan&Maheswari show that the Simple Moving Average (SMA), Exponential Moving Average (EMA), Moving Average Convergence Divergence (MACD) and Relative Strength Index (RSI) are some of the Technical Indicators which are used as input to train the ANN system which is integrated with Fuzzy Metagraph(Anbalagan & Maheswari, 2014).

An empirical study conducted show that the selection of input variables can generate higher forecast accuracy and it is possible to enhance the performance of the optimized ANN model by selecting input variables appropriately (Qiu & Song, 2016). Many studies have analyzed existing and new methods of stock market prediction and have identified a common flaw in Technical Analysis methodology (Dunne, 2017). It is very important to select the input parameters for ANNs which have a direct effect on the stock price which depend on the intrinsic financial ratios of the stock.

There has been a recent effort to explore stock price and trend prediction from finance perspective as well as from the combination of two major IT areas which are AI and Data Mining (Yong & Taib, 2009). Many ANN models have used technical indicators as the input feature set and have presented detailed limitations with the models (Dase & Pawar, 2010).The studies which have used ANNs for stock price prediction with fundamental parameters have limited themselves to small subset of features such as EPS (Earnings per Share) (Rudin, 2012).
III. Research Methodology

We provide a novel approach to build a Financial Decision Support System that can be used for predicting the stock prices and can aid an individual investor with decision support. The approach is novel because, instead of using pre-determined methods like mathematical equations, time-series models and other valuation methods which re-determine the weightage given to financial data, this model uses a machine learning approach using neural networks which adjusts the appropriate weights given to financial data that determine the actual stock price, in other words the model is based on the market reality and collective experience of investors participating in the stock markets. The design of the Financial DSS involves design of System Architecture, Mathematical Modeling of the system and the Machine learning modeling involving various supervised learning algorithms.

The system architecture of Financial DSS consists of:
- Stock Information Data
- ANN Model
- DSS Computational System
- User Interface

III.i. Stock Information Data

The historic data consists of past financial information about stocks over an extended period of time. Such data is primarily sourced from public sources on the internet. Sites such as Yahoo Finance and Money Control provide historical data on stocks up to 10 years. The data is sourced from these sites and stored in a database to be used.
by the Financial DSS. Historical data forms an input the machine learning model as a training set. The current data about a particular stock of interest is sourced from the internet on real-time basis by the database based on the query from investor on any particular stock using user interface and forms an input to the “Trained” Machine learning model for real-time stock price prediction.

III.ii ANN Model
The block consists of financial attribute inputs to the ANN model where the model is trained on the past data; once the model is trained it can now predict the future stock prices. The model is based on Mathematical algorithms to train and predict and consists of layers of processing elements.

III.iii DSS Computational System
The Computational system consists of the model used for DSS and the machine learning models. The computational system is a general purpose PC which is capable of running mathematical computational software such as Octave / Matlab and Weka, the machine learning algorithms receive inputs in the form of financial data files about stocks from public domain

III.iv User Interface
The user interface of the DSS provides access to users to provide inputs and analyze the outputs from the DSS. The user interface is a standard desktop based application with easy to use features to select stocks for price prediction

III.v Mathematical Model of Stock Price
The mathematical Model of Financial DSS used for Stock price prediction is based on Fundamental Value / Intrinsic Value of a Stock. Fundamental analysis is a method of evaluating a security in an attempt to measure its intrinsic value, by examining related economic, financial and other qualitative and quantitative factors. Fundamental analysts study anything that can affect the security's value, including macroeconomic factors such as the overall economy and industry conditions, and microeconomic factors such as financial conditions and company management. The end goal of fundamental analysis is to produce a quantitative value that an investor can compare with a security's current price, thus indicating whether the security is undervalued or overvalued. The financial parameters groups considered for intrinsic value are listed below:

- Investment Valuation Ratios ($R_v$)
- Cash Flow Indicator Ratios ($R_{cf}$)
- Liquidity Measurement Ratios ($R_l$)
- Profitability Indicator Ratios ($R_{pf}$)
- Debt Ratios ($R_{db}$)
The mathematical function that represents the Intrinsic Value of a Share \( I_v \) is given below:

\[
I_v = \phi (R_v, R_{cf}, R_l, R_{pf}, R_{db})
\]

III.vi. Artificial Neural Networks Model for Stock Price Prediction

Artificial neural networks (ANNs) or connectionist systems are computing systems vaguely inspired by the biological neural networks that constitute animal brains. Such systems "learn" tasks by considering historical data, generally without task-specific programming.

An artificial neural network is an interconnected group of nodes, akin to the vast network of neurons in a brain. Here, each circular node represents an artificial neuron and an arrow represents a connection from the output of one artificial neuron to the input of another. Each connection between artificial neurons can transmit a signal from one to another. The artificial neuron that receives the signal can process it and then signal artificial neurons connected to it.

The ANN model used for this study is the three layered Multilayer Perceptron consisting of one input layer, one hidden layer and one output layer. The Multilayer perceptron model is used to benefit from the non-linear features of the hidden layer. The output layer consists of a transfer function and predicts the stock price based on the weights assigned to the hidden layer neurons.

Fig.3 shows a network with three layers, the first layer of the network represents the attributes in the data. The input layer has an additional constant input called the bias. The 2nd layer is called “hidden” because the units have no direct connection to the environment. This layer is what enables the system to represent share prediction model.

![Diagram of ANN Model for Share Price Prediction](image)

**Fig.2.** ANN Model for Share Price Prediction
\[
\begin{align*}
    a_1^{(2)} &= \theta_{10}^{(1)} x_0 + \theta_{11}^{(1)} x_1 + \theta_{12}^{(1)} x_2 + \ldots + \theta_{1n}^{(1)} x_n \\
    a_2^{(2)} &= \theta_{20}^{(1)} x_0 + \theta_{21}^{(1)} x_1 + \theta_{22}^{(1)} x_2 + \ldots + \theta_{2n}^{(1)} x_n \\
    a_n^{(2)} &= \theta_{n0}^{(1)} x_0 + \theta_{n1}^{(1)} x_1 + \theta_{n2}^{(1)} x_2 + \ldots + \theta_{nn}^{(1)} x_n \\
    h_\theta(x) &= \theta_{10}^{(2)} a_0^{(2)} + \theta_{11}^{(2)} a_1^{(2)} + \theta_{12}^{(2)} a_2^{(2)} + \ldots + \theta_{1n}^{(2)} a_n^{(2)}
\end{align*}
\]

Where,

- \(a_i^{(j)}\) Represents the activation unit “i” in jth layer and
- \(\theta_j^{(i)}\) Represents the weights between interconnecting nodes
- \(h_\theta(x)\) Represents the output function that represents the share price

The ANN is trained using by adjusting the weights of the connections between each neuron nodes by using the backpropagation algorithm, the solution is to modify the weights of the connections leading to the hidden units based on the strength of each unit’s contribution to the final prediction. The hidden layer uses the “Sigmoid” transfer function which gives the nonlinear learning advantage.

### III. Data Analysis

The ANN for was trained with the data from 20 companies with financial information from years between 2004 and 2018. The ANN training results are listed below:

--- Classifier model (full training set) ---

| Linear Node 0 | Inputs | Weights |
|---------------|--------|---------|
| Inputs        |        | Threshold | 0.2835420555713012 |
| Node 1        |        | -1.47731523310047729 |
| Node 2        |        | 1.502706057958565 |

| Sigmoid Node 1 | Inputs | Weights |
|----------------|--------|---------|
| Inputs         |        | Threshold | -0.747771633325329 |
| Attrib Basic EPS (Rs.) | -2.00499972622249045 |
| Attrib Dividend / Share (Rs.) | -0.20816306778554786 |
| Attrib PBITT Margin (%) | -6.7062511626498373 |
| Attrib Price/BV (X) | -1.1938380619070765 |

| Sigmoid Node 2 | Inputs | Weights |
|----------------|--------|---------|
| Inputs         |        | Threshold | -1.268109455233129 |
| Attrib Basic EPS (Rs.) | 0.035554932229770415 |
| Attrib Dividend / Share (Rs.) | 1.4108750645711787 |
| Attrib PBITT Margin (%) | -1.1956675614925935 |
| Attrib Price/BV (X) | -0.026417355732059233 |

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**Fig.3.** ANN Training Results

The validation of ANN was performed using multiple rounds of data inputs given by re-sampling the master data, the master data is put through a random selector using WekaTool and a set of 10 training sets is prepared, in each round the data is given to
the ANN model and then check for the accuracy levels, the ANN is validated and the weights are adjusted finally after the 10 rounds, the advantage of this method is that is less prone to over fitting, the results are listed below:

Time taken to build model: 0.06 seconds

--- Cross-validation ---
--- Summary ---

Correlation coefficient 0.9262
Mean absolute error 255.5844
Root mean squared error 362.1668
Relative absolute error 33.6342 %
Root relative squared error 37.6521 %
Total Number of Instances 71

Fig.4. ANN Validation Results

The results of the validation show that the ANN has a very high level of correlation with the input attributes and predicts the share price with high level of accuracy. The below fig.8 shows “Actual” vs “Predicted” stock prices for one of the sample test runs to validate the accuracy of the ANN, which shows high level of correlation between the “Actual” and Predicted” stock prices.

Figure 5: Sample run of “Actual” and Predicted” stock prices

IV. Findings of the Study and Implications

The machine learning model chosen for further development is the Artificial Neural networks over the Linear Regression models as the stock markets seldom behave in a linear way. Also the curve fitting using linear regression is complex and not very accurate for higher order polynomials.The advantage of using artificial neural networks is that it automatically adjusts for the complex curves using the “Hidden” Layer.

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The major findings of this study which consisted of select stocks listed on the BSE/NSE are as follows:

- It is possible to train the ANN models with past financial data and predict future prices with a hybrid model of intrinsic and exogenous feature set.
- Choosing the intrinsic feature set for ANN increases the prediction accuracy.
- It is possible to generate a portfolio of top performing stocks based on machine learning un-supervised Classification algorithms.
- The classification algorithms are very effective in performing the risk analysis and selecting stocks with lowest risk and highest returns.
- The financial decision support systems are a valuable source of tools for individual investors as they enable them to cut losses and reduce risk in their trading operations.

The implications of the Financial DSS for predicting the Stock Prices and assisting individual investors with decision support are multi-fold:

- The Intrinsic features ensure that predicted stock prices are more closer to the real-time market value eventually may contribute to a more efficient financial system.
- Automatic Generation of stock portfolios will become efficient as the selection will be based on machine learning risk analysis and reduces the human error.
- Financial Decision Support Systems can revolutionize virtually every aspect of financial and investment decision making. Financial firms worldwide can employ neural networks to tackle difficult tasks involving intuitive judgement or requiring the detection of data patterns which elude conventional analytic techniques.
- The Financial Decision Support Systems benefits individual investors with little knowledge of the dynamics involved in stock markets, any reasonable prediction can enable common investors to invest in stock markets and enable the growth of the economy.

V. Conclusions

The stock market is an unforgiving place for many individual investors due to the highly volatile and unpredictable nature of the stock prices. The aim of the proposed Financial DSS is to assist the individual investors with analysis and prediction of stock prices with reasonable accuracy. Using Machine learning and Artificial Neural networks the financial data is subjected to deep analysis and valuable insights are generated. The Novel approach of using artificial neural networks to determine the weightage given to each financial parameter and thus predict the stock prices is path breaking methodology in financial decision support research area. The Proposed DSS has considered both Intrinsic and macro-economic
parameters which will enable the system to comprehensively predict stock prices. The authors are working on enhancing the machine learning models and fine tuning the financial parameters to more accurately predict the stock prices.

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