Investor Oriented Stock Market Portfolio Management and Stock Prices Prediction Platform for Colombo Stock Exchange of Sri Lanka

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Abstract — Over the past few years, various studies have been conducted to develop an optimum stock market-related portfolio management platform that will assist investors to actively perform the portfolio management process. Risk and level of investor participation are considered to be challenging aspects identified for optimum portfolio management. Along with portfolio management, stock price prediction is one of the key contributing factors that help an investor to arrive at mid-and long-term strategic investment decisions. Various deep learning concepts are evaluated to determine the most accurate algorithm to implement the stock price-based prediction system. Currently, Colombo Stock Exchange (CSE) has identified a desperate requirement of a portfolio management system with prediction capabilities to support local and foreign investors to actively engage in trading activities among different stock exchanges in different countries. A critical study has been conducted using supportive research papers, similar applications developed and using various requirement elicitation techniques to determine matters such as the functional requirements, non-functional requirements, investor requirements, and UI/UX considerations. The paper further describes various technological mechanisms implemented and system architectures used to develop the portfolio management and stock price prediction system. Accordingly, the implementation of the Brownian Motion algorithm-based model and LSTM (Long Short-Term Memory) model are in detail presented by the author. Finally, evaluation and testing results of the completed system and stock price prediction models are presented to prove the successfulness of the completed application and the accuracy of the models implemented.

Keywords: stock, portfolio, prediction, LSTM, CSE

I. INTRODUCTION

(Hayes, n.d.) Stock market portfolio management is a technique or art of analysing or overseeing, selected number of an interested group of shares in order to achieve long-term financial goals and objectives. The ultimate requirement of portfolio management is to weigh the strength, weaknesses, opportunities, and potential threats over a selected number of stocks. The requirement an investor is intended to be achieved from portfolio management is to increase the investment returns under a deuterated risk level within a specific period. In the non-automated process, an investor requires to re-balance his/her stock portfolio manually according to the trading activities conducted over time. Following are the actions or tasks that needed to be performed by an investor in the manual process to manage the stock market-related investments- Revaluate the financial value of the current stocks if purchased before, Revaluating the investor depending on investment strategy by analysing the stock selection criteria used previously such as stock purchasing sectors e.g.-health care, leisure and entertainment, business, etc. Manually analysing the current market value of stocks preferred to purchase in each public listed company, summing up the total investment and deciding the percentages of possible returns expected, Calculating and evaluating the expected returns with real returns and deciding sectors to add or drop based on returns (Chen, n.d.). Stock prices prediction is an act of forecasting the future stock prices of a particular public listed company. Currently, many countries including NYSE (New York Stock Exchange) provide predictions to the investors to increase the profits or return of investors by investing at present. Although there

are various arguments related to the success of prediction since there could be various macro and microeconomic factors influencing to fluctuate the stock prices. Stock market-related operations are uncertain in nature and most of the investors feel insecure and unconfident when managing their investment portfolio on stock exchanges among different countries. One of the prime concerns of investors, stakeholders, and any other individual in the financial market is to successfully manage the stock market portfolio. On other hand, investors face various difficulties in identifying public listed companies that have a sound growth prospects for investment.

In the current situation, Colombo Stock Exchange would not offer a feasible platform for the investors to manage, view, analyse and forecast the future behaviour of the stocks purchased by an investor. Currently many investors driven stock purchasing platforms are introduced in Srilanka and international where investor could directly engage in buy/sell actions without any assistance from stockbroker or brokerage firm. With the development of said platforms a need of a stock portfolio management and prediction platform is identified. Web and mobile responsive application is developed to facilitate the investors to manage and analyse local and foreign stock portfolio by including stock prices prediction module which support the investors to obtain decisions based on predicted behaviour of a particular stock.

II. PROBLEM DOMAIN

Currently, in Sri Lanka, investors obtain assistance from various stock-brokering firms where stock broking advisors would assist an investor by advising, predicting the market, and managing the portfolio for the best investment return. On each transaction conducted on behalf of the investor, a certain amount of brokerage is charged by the stock- brokering firm. If a local investor is interested to invest in the international stock market either an investor could start purchasing stocks through an online platform using an E-wallet with a dollar account or through a stock-brokering firm that specializes in the international stock market transactions ("Homepage," n.d.). On considering the local/international situations if an investor needs to obtain a quick analysis or update of the current portfolio status, gains, loss, or any other information, he/she needs to request a portfolio summary through the broker or through the portfolio management access granted by the stockbroker firms. ("How stockbrokers misled investors in 2011," n.d.) CSE and Central bank of Sri Lanka have identified various frauds or illegal attempts actioned by stockbrokers due to lack of proper concertation, lack of knowledge on share market activities, or lack of updated portfolio analysis knowledge with the investor. Due to the continuous fraud, malpractices, and untransparent actions conducted by stockbrokers, CSE has identified a reluctance of potential investors to invest in the share market and actively engage in large volumes of shares. One of the most popular incidents is Securities and Exchange Commission (SEC) filing a court case against four well-known stock brokering firms that have been operating over the past few years. According to the SEC, these stock brokering firms had been involved in certain manipulation or creating abnormal/misleading situations regarding a share price named "Radiant Gems International PLC" in 2011 which have interfered with the smooth functioning of the share market and losing the credibility regarding the share among investors who have currently purchased shares or intended to purchase in the future.

At present Colombo Stock Exchange does not facilitate investors with an official Stock market portfolio management platform with prediction capabilities. In order to avoid or minimize the above-mentioned problems, one of the drawbacks CSE has identified is the unavailability of a fully responsive, functional, user-friendly, ubiquitous, and free platform to add and manage the stocks owned by an investor in his/her local or international portfolio. Stock prices prediction system would also assist an investor to obtain the most accurate financial strategic decisions before investing in a particular share according to the predicted data. This development will be the first official Stock market portfolio management and prediction system for CSE in Sri Lanka.

III. LITRETURE REVIEW

A study has been conducted prior to the design and development of the system to obtain in-depth knowledge on related theories, concepts through research papers that are related to the study.

A. Stock Market Portfolio Management:

A Walk-through("(PDF) Stock Market Portfolio Management A Walk-through," n.d.) Stock portfolio refers to purchasing and overseeing several different stocks under various volumes from different or same stock exchanges. When purchasing stocks, the investor may come across two different perspectives such as risk stocks and risk-free stocks according to the investment return factor. Risk stocks are a type of stocks that consist of the uncertainty of investment return with the certainty of today. Risk-free stocks are the shares that have no doubt of the possible return along with the investment. According to the paper some of the advantages of SMPM (stock market portfolio management) are maximizing the investment returns with minimum risk, ensure investor receives profit sufficient for the investment, real-time tracking and notifying profits and losses. The aim/objective of SMPM is to maximize the return along with the minimum possible risk. The relationship between return and risk is contradictory. Certain factors are influencing to affect the performance of stock such as stability of the public listed company, government rules and policies, regulations on business activities, policies implemented on the financial market, current inflation rate, and crude prices. Risk analysis related to portfolio management is one of the main aspects concerned by the author. Accordingly, various factors affect the stock performance and due to the uncertain nature of stocks, the return values could vary, and due to the fluctuating nature of stock prices, the returns vary. Therefore, the paper emphasizes this as a main challenging factor to develop an SMPM. The Paper has further elaborated three categories of portfolio management techniques that an investor would follow when handling the portfolio. Active Management, Passive management, and Hybrid strategy (Combination of active and passive). Active management strategy involves constantly checking, analysing the portfolio for any profit or losses incurred, purchasing stocks when selling prices are low, selling stocks when prices start dropping are few important activities an investor would perform in the active strategy. Market timing is considered a critical activity when following active management. Passive management is followed usually by the investors when the investor believes that the financial market is running at a stable level smoothly. On passive management, investors would not constantly check or analyse the market activities or transactions. The level of returns might drop in the long term since a lack of consideration on individual share sell and buy prices. Hybrid strategy management is considered the modern approach that is developed as a combination of active and passive management strategies.

When considering the paper, the risk and returns/profits consist of opposite relationships. From Srilanka's perspective since there is no feasible, automated way of managing the stock portfolio the proposed system would provide a significant contribution to minimize the risk and maximize the returns on the investments. Either an investor follows an active, passive, or hybrid management process based on the functionalities proposed or delivered by the system (including prediction system) system would try to stick the investor on active management strategy using certain technological implementations such as constant pop-up reminder notifications, detailed summary reports generations, etc.

B. Stock Price Prediction Using LSTM, RNN AND CNN- Sliding Window Model

(Selvin et al., 2017) Forecasting could be defined as predicting future behaviour or trends based on analysing past related historic data. Predictions are used in various systems in the industry such as in the business sector, health care, education, time-related activities, etc. According to the paper, forecasting could be divided into three types- short-term, medium-term, and long-term forecasting. The main difference between forecasting types is the duration predicted in the future. To provide prediction a variable is considered, in the paper "price" is considered as an important variable. Stock price forecasting could be performed using various methods such as technical analysis, fundamental analysis, and Time series-based forecasting. In Fundamental

analysis the investment on a particular stock price decision is based upon the analysis of profits/returns, sales, and other economic (micro and macro) factors. Mainly suited for long-term forecasting. Technical analysis uses the previous data (past stock prices) in order to predict the possible future price. Average/Mean is the main algorithm used to provide the predictions on the said type of analysis. Mainly suited for short-term forecasting. Time series-based forecasting mainly involves two types of algorithms namely, the Linear model and non-linear model. Series of time-related data are analysed and studied along with algorithms to predict the future. Based on the two types of algorithms the paper has stated linear models are not capable to identify a pattern or trend in a set of considered data. The inability to identify the latent dynamics within the data is the main reason for the above-said drawback. The nonlinear model utilizes methods such as deep learning, Neural networks, and various other algorithms in order to provide predictions. The Paper further evaluates concepts such as multi-layer perceptron (MLP), Recursive Neural Networks (RNN), Convolutional Neural Network (CNN), and other types of machine learning techniques such as image processing, natural language processing on testing the suitability to stock price predictions. One of the most feasible and proven methods suggested by the paper is algorithms based on deep learning concepts. After completing several levels of the self-learning process, deep learning has been able to identify a pattern, hidden trend, and dynamics underlying within the data analysed.

Based on the results of an experiment conducted by the author the paper recommends Convolutional Neural Network (CNN) predictions are more accurate when compared with the predictions from Recursive Neural Networks (RNN) and Long Short-Term Memory networks (LSTM). Since CNN does not rely on previous/historic data or information for prediction CNN model has been able to provide proven results. The CNN prediction process understands the patterns/dynamic changes in the current window. This is considered as one of the prime reasons for providing more accurate prediction results. LSTM and RNN depend on historic/past information or data to predict the instances of the future. However, for short-term predictions, RNN and LSTM models were able to provide more accurate predictions according to the results of experiments concluded by the author.

C. MobiMine-Stock market monitoring platform

("[PDF] MobiMine: monitoring the stock market from a PDA | Semantic Scholar," n.d.) MobiMine is an intelligent cross-platform accessible system for monitoring and analysing stock market-related data through a distributed data mining process. Investors could store the current portfolio-related data on the application to manage and monitor the stocks. One of the important factors identified through the research paper is the watchlist feature that allows investors to concentrate on the stocks that are interested to buy soon. The application can construct relationships using the data collected from various finance-related data sources with the ultimate objective of identifying specific focus areas of the investor to provide an enhanced analysis process based on one's interest. Using the data mining process, a customized wish stock list details will be delivered through the application. The existing portfolio management system depends on the manual input of wish stocks (stocks that are expected to purchase in the future). Manual-based construction of watch list features using the predefined focus area of the investor is often cumbersome and unpractical since the investor cannot watch and analyse the market for a longer period when on the move. Investor-based customize focus area development is the main requirement addressed through the application and focused on improving the watch stock list feature. Challenges faced by the author on developing the above process are- Difficulties in handling the continuous flow of data from many incoming data streams, Managing the limited wireless/ GSM network bandwidth when conducting the data mining process, Representation of highly informative data within a limited small screen, Managing the battery consumption when conducting high computational and processing tasks. The application has been developed according to the client-server architecture where investors run the application on any type of handheld device where a Mobile server sources

the financial data streams. To ensure the smooth functioning of the application it is designed to work without any issues on wireless low bandwidth network connections.

The main functional requirements addressed by the MobiMine application are as follow-Portfolio management- Each investor is provided with a dashboard to manage, analyse stocks, and evaluate between different stocks' performance, gains, losses, etc. The investor could edit or delete their stored portfolio-related details from the application.

Area of Focus/Interest- The application delivers a more unique approach to track and monitor changes in the market by dividing the selected events as "interested to investor". The following are delivered through the focus area of the application- Watchlist feature- Each stock added by the investor on this section is assigned with a score. A higher score means more interesting and a lower score means less interesting. The higher score-marked stock is given more priority when delivering related data specific to that stock. Modules such as Stock connection, Stock nuggets, and reporting module are a different collection of services provided by the application to understand the dynamic and volatility nature of the market. MobiMine application employs various data mining techniques to collect and deliver stock market-related data from a variety of sources. One of the main functions performed by the MobiMine server is, it collects related financial data from various related data sources over the internet and stores them in the database in order to be used in the data mining process. The server receives the data feed in XML format. In order to perform the data mining various techniques such as clustering, statistical-based algorithms, decision trees, and Bayesian nets are used.

D. Predicting Stock Prices Using LSTM

("(PDF) Predicting Stock Prices Using LSTM," n.d.) Due to the changing nature of various financial indicators, the prices of stock prices would fluctuate unexpectedly. This has been a difficult and challenging factor for many stock analysts, investors, and researchers who are keen on knowing the future behaviour or situation of the stock prices ("(PDF) Stock Price Prediction Using Machine Learning and Deep Learning Frameworks," n.d.). With the rapid development of technology and correct utilization of important and informative indicators, behavioural predictions could be performed up to certain aspects. According to the author, a significant explanation has been provided on the RNN (Recurrent Neural Networks) which is explained as one of the powerful and well-proved models on processing sequential related data. On the in-depth analysis of RNN, LSTM (Long Short-Term Memory) is identified as the highest successful RNN's architecture. LSTM consist of memory cells which could be explained as a computational unit that replaces hidden layer artificial related neurons among the networks. This structure helps to dynamically identify the data structure and associated patterns to provide more accurate high-capacity predictions. The overall paper is focused on presenting an in-depth idea on developing a prediction system for predicting the returns of NIFTY (50) using an LSTM model. Using a historic dataset that contains 5 years of past stock prices the model training and validation activities are conducted (Ghosh et al., 2019).

The methodology section of the paper is explained using the background research activities conducted on experimenting prediction activities of the NIFTY (50) stock prices. The following series of activities are conducted by the author when developing RNN and LSTM based models. Step 1 -Preparation activities of the historic stock prices data. The window size of the dataset according to the paper is 22 days and stock prices related data ranging between 01/01/2011 and 31/12/2016. Step 2- Pre-processing stage of data- At the pre-processing stage the following activities are conducted as Discretization of data- sorting filtering and determining the important features to be used when developing the prediction model, transformation of data, cleaning, and integration of data. After the pre-processing stage, the dataset is divided into testing data and training data. When selecting data for training most recent data values are used. Step 3- Extraction of features-In feature extraction process more refined and most relevant features are selected in order to be used as input for the neural network.

Step 4- Neural Network Training process- By assigning random weights and biases the neural network is trained in order to conduct the experiments. According to the paper, the author has developed an LSTM model with a sequential input layer. Along with the sequential input layer, two dense layers and LSTM layers are used. Further LSTM model consists of Activation named "ReLU" and linear activation function with output dense layer. Step 5- Prediction of results- In this final step the author evaluates the model by cross comparing the targeted values with the outputted values generated from the RNN output layer. Backpropagation algorithm could be identified as a significant action conducted by the author to reduce the difference between the derived results from the final model and targeted results. Here the initial biases and weights of the network set at earlier steps are readjusted to reduce the difference between the results. The paper signifies analysis phase by which the efficiency of the model is evaluated. In order to test the efficiency of the model a statistical equation namely Root Mean Square Error (RMSE) is used. Using the value of the said equation the difference or error between the derived results and targeted results could be minimized. Accordingly, the table below is extracted directly from the research paper to demonstrate the experimental results of the model outcomes. Various test cases with different parameter numbers and EPOCHS are stimulated by the author. By which the stimulation conducted with selected features such as High, Low, Open, and Close along with 500 EPOCHS has provided the best result of 0.00983 and 0.00859 (testing with RMSE). Results of different parameters and EPOCHs are shown in Table 1.

Table 1: Comparative Results Using Different Parameters and Epochs.

Parameters	No. of Epochs	Training RMSE	Testing RMSE
Open/ Close	250	0.01491	0.01358
Open/ Close	500	0.01027	0.00918
High/Low/Close	250	0.01511	0.014
High/Low/Close	500	0.01133	0.01059
High/Low/Open/ Close	250	0.0133	0.01236
High/Low/Open/ Close	500	0.00983	0.00859

Source: Predicting Stock Prices Using LSTM

In concluding the paper, the author proposes Long Short- Term Memory (LSTM) and Recurrent Neural Network (RNN) as successful approaches to predict more accurate stock prices.

IV. METHODOLOGY

As the primary data source research papers were critically studied, analysed, and evaluated to understand the functionalities, challenges, theories, and concepts to obtain in-depth knowledge on the research area. Along with the critical literature review various requirement elicitation techniques were used as secondary data sources to identify the functional and non-functional requirements from investors/users and officials of the Colombo stock exchange.

Several interviews were conducted to obtain detailed information from the CSE officials since the ultimate development is intended to be developed on behalf of CSE. By conducting an interview informative and detailed information from a broad perspective was collected from different types of stakeholders within the CSE. Several officials of CSE including the head of R&D (research and development), head of Public Relations Department, and Chief Information Officer (CIO) of CSE were interviewed to obtain in-depth information on investor behaviours, legal factors, functional requirements, and non-functional requirements are mainly discussed and focused.

Questionnaires are used as the medium of collecting data from the investors. The questionnaire comprises 17 questions covering a broad context regarding system development including functional requirements, non-functional requirements, visual design aspects, UI/UX (User Interface/User Experience), and content management. The questionnaire was presented to a sample of 23 respondents and obtained their responses. As the sample space investors who are currently engaged in various professions are selected such as doctors, engineers, judges, businessmen, teachers, accountants, architects, etc. Responses from the questionnaire are subjected to a statistical analysis, which helped to determine functional requirements, non-functional requirements, important designing aspects considerations, and

user requirements. The responses from the questionnaire and information gathered from interviews are mainly considered when developing the proposed portfolio management and prediction system. After a comprehensive gap analysis, the following requirements and processes are identified as essential to the proposed system in addressing the important requirements identified.

A. Functional requirements

Initially, an investor could sign up and log in to the system. The first user could add stocks details by entering the stock code name and selecting the Stock Exchange (New York stock exchange, Colombo Stock exchange). Along with the stock code, the user can input the bought price and the volume of the share. Similarly, the user could add the entire portfolio to the system which could be diversified between different shares belonging to various countries. Once the system is updated, each user will be provided an analysis of profit returns/losses, updated stock price details, etc. The portfolio will automatically be updated once the market transaction goes online country-wise/stock marketwise.

- Live and summarized stock market transaction dashboard presented based on user's selection.
- Ability to generate a detailed summary report on the current portfolio in PDF format.
- Delivery of E-mail and SMS-text messages notifications on profits and losses incurred on current portfolio.
- The ability to add and remove stocks of different countries/stock exchanges and portfolio-based customization.
- Informative analysis of a particular share using Candlestick chart filtered according to different time slots such as Monthly, weekly, 30 days, 90 days, 180 days, and 360 days.
- "Wish Stocklist feature" is integrated to analyse the stocks that are intended to invest in soon.
- Future Stock prices prediction using line graph representations provided on each share based on user selection.
- Ability to update and change user/investor account-related details such as personal information and password.

Administrator-

- Ability to obtain detailed analytics on the investors/users who are currently enrolled with the platform.
- Ability to obtain an overview of currently logged and active users.
- Ability to create new users and update the personal information of existing users.

B. Non-Functional requirements

Availability (24x7), User-friendly and highly interactive platform, Privacy/Security, and High performance in large workloads.

C. Design and Development of the Application

The following section of the paper provides a thorough insight into the developed application as a proposed solution to the stated problem. This section deeply justifies various technological mechanisms implemented in order to develop and embed the previously identified requirements into the system.

The web-based platform is developed using HyperText Markup Language (HTML), Materialize CSS, Bootstrap, and React.js as frontend framework and back-ended using PHP with required 3rd party libraries. MySQL relational databases will be used for managing and storing data. The whole application runs on the base of four API endpoints. Two JSON-based APIs will be used to retrieve data on the international stock exchange and another XML-based API is used to retrieve data from Colombo Stock Exchange (Officially provided by CSE to fulfill the current development purposes). The logic behind the portfolio management and stock analyser goes along with the data return in JSON format. Relevant data will be retrieved and passed to data structures where manipulation activities will be carried out and then stored in the database.

Machine learning-based prediction systems will be developed and implemented using API-driven data sets. Two types of models are developed to provide price prediction categories based on short-term (1-7 days) and midterm (15-30 days). For short-term predictions stacked Long Short-Term Memory cell (LSTM) model is used to provide the predictions since LSTM is extremely powerful on sequence-based prediction problems with the analysis of past information. As well as for long-term predictions Brownian Motion algorithm-based model is developed. Both models will be trained and deployed on Azure Machine learning studio to avoid any difficulties or delays in model processing and rendering. Python language along with supportive libraries such as MatPlot libraries, Tensor Flow (Keras), Pandas Data reader will be used to implement the model training and other model-based manipulation tasks. One of the challenges identified when developing the stock price prediction module is the update factor of the dataset used to train the model. For example, if a particular investor uses the stock prices prediction system today, the dataset should contain yesterday stock prices related data when training the model that is used for forecasting the future stock price of a particular stock based on the perspective of today.

(Agustini et al., 2018) In order to perform long-term stock price prediction Brownian motion model is developed using hyperparameters. When conducting the expected formulation of stock prices, a confidence level of 95% is determined. Initially, the dataset is retrieved using the Pandas yahoo finance Data Reader by specifying the Stock symbol of the stock which is required to be predicted. In order to specify the range of the time period the current date is fetched using current=datetime.now () function. Along with the current date and time details, current. year-3 is used to specify the starting year of dataset and current. Month and current. Day is used to specify the latest time period which the particular stock-related dataset needs to contain. As the main parameter from the dataset the "Adjust Close" is mainly used to train the model. After the fetching process, the data normalization is performed using the logarithm function. On completing the normalization process the following calculations are conducted -Mean, Standard deviation, Variance, Volatility, and Drift value are calculated. The Brownian motion algorithm along with hyperparameter is applied in order to forecast the stock price after completing the previous computational step. In order to obtain meaningful representations using the Mat plot library a graph is plotted and saved in .PNG format in order to render and display in the portfolio management system once an investor/user requires prediction results. Final graph generated using Brownian Motion algorithm on APPLE Inc (AAPL) stock original stock price and Predicted Output is represented using the Fig 1.

For short-term stock price prediction Deep Learning Artificial Recurrent Neural Network (RNN) architecture based Long Short-Term Memory (LSTM) model is developed. On elaborating the process of prediction initially using an API driven endpoint data source named Tiingo the relevant stock related dataset is downloaded in .CSV format. Every dataset downloaded from Tiingo consist of stock prices related information ranging from 2016 to the present. Accordingly, the following column attributes are provided from the dataset-symbol, date, close, high, low, open, volume, adjClose, adjHigh, adjLow, adjOpen, adjVolume, divCash, and splitFactor. As the main parameter "close" value of the concerned share is used to train the model. In the next step, the dataset is split as training data and test data in order to avoid overfitting. This will also help to determine the model generalization ability as well. After implementing the splitting process feature scaling process is implemented since the LSTM are sensitive to the scale of data, therefore before model fitting the data are normalized using scikit-learn pre-processing package named Min-Max Scaler and NumPy. One of the advantages of feature scaling could be an increase of performance. Since LSTM expects all the data to be in one specific arrangement using NumPy the data are transformed into 3D dimension array. Once all the above-mentioned steps are fulfilled the LSTM model could be build using the following Keras imports, Sequential-neural network initialization, Dense- to add a densely connected neural network layer, LSTM- to add a Long Short Term Memory layer. After importing the required modules, the model is compiled

using popular optimizer named adam, and the loss is set as mean_squarred_error in order to calculate the squared errors mean. Next, the model is fit to run 100 Epochs with a batch size of 64 and verbose 1. Epoch is specified here to define the number of times the learning algorithms would work on the entire training dataset. After completing the model compiling process, the future stock prices could be predicted using the test data set. Here some of the actions performed earlier are conducted again such as transforming the new dataset using MinMaxScaler and Reshaping the dataset. inverse_transform function is used here to obtain the readable format of the stock prices after completing the predictions. Finally using Matplotlib predicted stock prices are visualized. LSTM model prediction developed for Microsoft Corporation (MSFT) stock is shown using Fig 2.

Figure 1. Apple Stock prediction using Brownian Motion Algorithm
Source: Author

Figure 2. MSFT Stock prediction using LSTM.
Source: Author

After completing the development and testing phases the entire project is hosted on the Microsoft Azure platform (IaaS, PaaS) deployed and implemented on a virtual machine to ensure the platform performances are guaranteed on peak workloads. The finalized system architecture is represented using Fig 3.

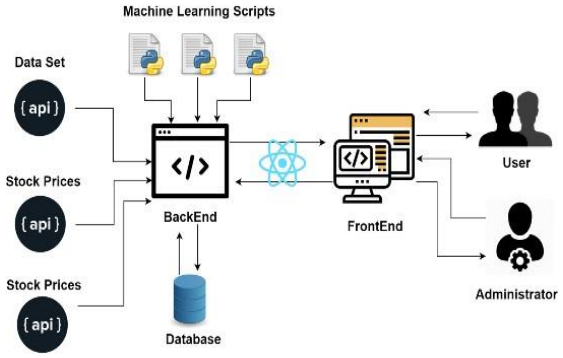

Figure 3. System Architecture
Source: Author

V. RESULTS AND DISCUSSION

A comprehensive system testing and evaluation were conducted to verify the results/output of the finally developed system. System testing and user acceptance testing are conducted on the 95% completed system by the author as well as from the higher officials of CSE. The Fig 4. provides the results of testing conducted on every functional component developed in the system using the manual as well as automation testing mechanisms (e.g.- Selenium and Katalan Studio tools). The sole purpose of system testing and evaluation is to ensure the exactness of the system and the arrangement of functionalities newly developed.

On deeply evaluating the stock price prediction module the Long Short-Term Model (LSTM) and Brownian Motion algorithm-based stock price prediction model have outcome more than 85% of accuracy when forecasting future stock prices. According to the testing conducted on Brownian motion algorithm-based model with different types of Stocks, On Microsoft Corporation (MSFT) stock the difference between the original stock price and predicted stock price was 4.88%. When evaluating the model on Nike Inc (NKE) stock the difference between the original stock price and predicted stock price was 12.1%. On APPLE Inc (AAPL) stock the difference between the original stock price and the predicted stock price was 18.51%. As a conclusion of the testing phase conducted on the Brownian motion algorithm, it clearly justifies that based on

various types of stocks considered the difference between the original stock price and predicted stock price value vary. Finally based on the test cases conducted on the Brownian motion algorithm with different stocks it generally outcomes more than 80% level of accuracy.

Functional Requirements	Pass/Fail	Score
Investor/User		
Login and Sign-up Function	Pass	98%
Live and summarized stock market transaction dashboard	Pass	97%
Summary report generated in PDF format	Pass	95%
Delivery of E-mail and SMS-text notifications on profits and losses incurred	Pass	92%
Ability of adding and removing stocks from portfolio	Pass	100%
Informative analysis of a particular share using Candle stick chart	Pass	100%
Wish Stock list feature	Pass	96%
Future Stock prices prediction using line graph representations, provided on each share based on user selection	Pass	97%
Ability to modify user/investor account related details	Pass	97%
Administrator		
Detailed analytics on the investors/users who are currently enrolled with the platform	Pass	95%
Ability to obtain an overview of currently logged and active users	Pass	95%
Ability to create new users and update personal information of existing users	Pass	98%

Figure 4. Test Case Results

VI. CONCLUSION

In concluding the paper, a highly interactive, more analysis capable, and fully functional portfolio management system with prediction capabilities is developed and implemented along with results of the testing and performance evaluation on independent modules including the stock price prediction. The system would be beneficial for the highly engaged investors to actively participate in the stock market transactions with high volumes of investments at low-risk levels and obtain maximum possible returns from the investments. Higher levels of investor participation in stock market activities would ultimately lead to achieving the goals and objectives of the CSE. Accordingly, this would contribute to boosting the overall volume of market transactions. This will ultimately contribute to improving the country's GDP (Gross Domestic Production) in the mid and long terms.

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