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Stock Prediction using Long Short-Term Memory

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Abstract

The current study deals with the use of advanced machine learning algorithms in prediction of the stock prices, on the Bank Nifty Index. This index is part of Indian stock exchange which is widely known as National Stock Exchange (NSE) of India. In this study researcher used combination of deep learning techniques with interpretability models. To provide accurate stock price predictions, the Long Short-Term Memory (LSTM) network was implemented in the study. With this the well known interpretability methods, for understanding the predictions of model were used in this study that is SHAP (SHapley Additive exPlanations) values and LIME (Local Interpretable Model-agnostic Explanations. These tools facilitated a deeper understanding of the relationships between financial variables and stock prices. The analysis found that, Equity Share Capital (ESC) and Earnings Per Share (EPS) were the two significant variables affecting stock prices. On the other hand, Return on Assets (ROA) was identified as least impacting variable on stock price movements. The results highlight the significance of explainability in financial forecasting by using an LSTM deep learning model with a combination of interpretability methods such as SHAP and LIME. In this perspective, the research will contribute to a confident and more informed decision-making process in investment. Python programming was used for analysis and model implementations, which further shows how advanced programming tools can be used to deal with challenging financial issues.

Keywords: *Stock Prices, Financial Variables, LSTM, SHAP Value, LIME, Bank Nifty.*

Introduction

The stock exchanges are playing vital role for promoting trading in the majority of countries (Achyut Ghosh, 2019). In the market fluctuations, many people make a profit, and that is the main cause that gives huge popularity to the stock market all over the world. However, forecasting the stock price movements remains a challenge due to the volatility in the market. Predicting the movement of stock prices is a challenge due to the complexity of stock market data (Zahra Fathali, 2022). In finance and economics, forecasting by using historical data and providing valuable insights about the future is widespread; similarly, in various fields, it is applied. In this study, the researcher used modelling and prediction of stock prices, using HDFC Bank as a sample from the Bank Nifty Index. The National Stock Exchange (NSE) is famous worldwide for leadership in innovation and technological progress. (National Stock Exchange of India, 1994) Therefore, the present research chosen the NSE for stock market analysis. Banks play vital role in managing financial resources and supporting businesses. The investors, traders and policymakers are monitored the performance of bank nifty index. The financial indicators are the reason for the impact on the index, making it a crucial benchmark for evaluating the health of the banking sector (National Stock Exchange of India). Financial variables play a significant role in predicting the future performance of stock prices. When predicting the future performance of the bank nifty for this study, financial variables are used, such as Equity Share Capital (ESC), Earnings Per Share (EPS), and Return on Assets (ROA).

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For understanding the future trend of bank Nifty or stock prices, it is essential to know about the association between financial variables and stock prices. It will give significant results and valuable insights.

In this study, we utilised the SHAP, known as Shapley Additive exPlanations, a method in machine learning that helps to quantify the contribution of different features in making predictions (Yamaguchi, 2022). According to (Scott M. Lundberg, 2017), the SHAP value technique gives significance to each feature, indicating the extent to which that variable influences the outcome of model. We applied the SHAP technique to focus on the identification of financial variables that are significant in influencing stock price changes. This approach not only enhances the interpretability of model but also provides investors and traders with a more comprehensible understanding of market dynamics. With this, LSTM networks help to give results related to developing a prediction model for forecasting, and the SHAP plot will play a role in support of this objective.

Henceforward, the study also utilises, a type of deep learning algorithm that is Long Short-Term Memory (LSTM) due to its popularity for predicting financial time series data as it has the ability to learn and retain long-term dependencies here, we utilised LSTM. For stock price predictions LSTM network algorithm is well suited as they can capture sequential trends in data, unlike traditional feed-forward neural networks (CHOLLET, 2021). For forecasting financial markets and trends in data; the LSTM is finest model due to its ability of process and predict stock prices based on past data (S. Dinesh, 2022). For successful stock trading and opportunities nowadays, advanced technology like machine learning is useful technique. The paper is prepared in several stages such as review of literature, research methodology, results and discussion based on the LSTM algorithm and interpretability models (SHAP and LIME) and paper is compile with conclusion and future work.

Objectives of Research:

In financial sector many scholars and investors are interested for stock price predictions in order to make informed investment decisions in stock market segment. In modern society and economic structure, it is challenging task to predict accurate stock movements (Wei Bao, 2017). Therefore, this study aims to develop an effective stock prediction by using data from bank nifty index. It has selected the HDFC bank as this bank have high market capitalisation. In this context the main objectives of this research are:

1. To develop Long Short-Term Memory (LSTM) network, a predictive model to forecast stock prices.
2. To analyse the impact of financial variables in influencing predictions of stock price by using SHAP and LIME.
3. To contribute the literature on predictions of stock price and impact of financial variables by using deep learning models

Review of Previous Literature:

Literature of LSTM:

In the field of finance, stock market prediction is one of the important study areas because the stock market is highly fluctuating, constantly changing and unpredictable. Therefore, forecasting share prices is a very challenging task in the financial area. There are various methods for forecasting stock prices, including econometric and statistical models, as well as machine learning techniques. In the same way, methods such as SVM, VAR, VECM, LSTM, and logistic regression are also used for forecasting prices in this study, the researcher used an LSTM model for forecasting because LSTM can recall historical data, which works especially well with time series data. As per the study of (S. Dinesh, 2022) 93 % prediction accuracy is achieved by using LSTM, type of RNN network, to an effective method for predicting trends in the stock market. In addition, to this which uses LSTM for predictions, another researcher has also found relevant results LSTM has higher accuracy in forecasting, as shown by the outcomes of predictive research Results shown that there is positive accurate and profitable outcomes for the returns of the closing price for the next day as compared to other existing methods (Wei Bao, 2017). While Shun Chen (2019) and Achyut Ghosh (2019) share a common focus on LSTM results, they highlight different methodologies, such as predictions and classifications. However, they both employed an attention mechanism in Recurrent Neural Networks (RNNs), and they studied data based on these methods with remarkable success. They examine forecasting changes in stock prices from the Hong Kong market by using LSTM networks to analyse data of historical stock price and improve the accuracy of the results. Other authors have their own findings, the findings of (Zahra Fathali, 2022) and (Thomas Fischer, 2017), have used deep learning model, precisely Recurrent Neural Network, Long Short-Term Memory Networks and Convolutional Neural Networks i.e. RNN, LSTM and CNN, for analyses and predictions of stock prices on the Indian Stock Exchange widely knowing as National Stock Exchange i.e. NSE in that particularly for NIFTY 50 index. The findings of author suggest that the results of LSTM model perform better than other models. It is an advanced machine learning model and is designed for analysing sequences of data, making them compatible for predicting financial trends and patterns. On the other hand, an LSTM

network is used to forecast stock movement in the S&P 500 index from period 1992 to 2015, achieving daily returns of 0.46% and outperforming other methods, such as random forests and logistic regression. Although (Murtaza Roondiwala, 2017) analyses data to predict stock prices, it can be useful to investors in making their decisions reliably. The three machine learning methods, artificial neural networks, support vector machines, and long short-term memory, are specifically examined in his study, and the author discusses the advantages and challenges of predicting stock market trends. RNN and LSTM models to forecast stock market indices were studied by (Schmidhuber) training to improve the accuracy of stock price forecasts by applying the type of deep learning model, the data set choose by author that is Shanghai and Shenzhen markets they took data of period 2019 and 2021, data allowing them to forecast future stock returns effectively and analysed how changes in their parameters of model affect its results. In the field of research, a popular study area is prediction, particularly stock price predictions, which present both exciting opportunities and significant challenges. (Sreelekshmy Selvin, 2017) work, the findings have a significant change in the economy and its significantly effect on the stock market, as changes in share prices directly influence profit of investors. The researchers use linear models like ARIMA and non-linear models such as neural networks for predictions in various fields it's called traditional forecasting methods but now a days advanced methods like sentiment analysis and LSTM networks are widely used in the area of research for achieves more accurate predictions compared to traditional methods, (Shengting Wu, 2021) used advanced technique for representing its effectiveness with real data from five companies.

Literature of Interpretability Models:

(Scott M. Lundberg, 2017) introduces SHAP, a framework that gives important values to different features in a forecasting, making it easier to understand the output of model. SHAP, which known as SHapley Additive exPlanations, is a method used in machine learning to recognize how important different features (or variables) are in making decisions. (Yamaguchi, 2022) analysed data from automakers and electronic companies and found that SHAP value revealed the linear relationship between variables while the raw predictor values didn't show a clear linear relationship with the target values. To further refine the analysis and reduce issues from correlated variables, the author used Principal Component Analysis (PCA), which helped to identify key factors related to profitability and operations management. Similarly, (Xia Xiaomao, 2019) introduces SHAP values, a new method for selecting features, and shows that using SHAP values can lead to better prediction accuracy compared to other common methods when analysing data from polish companies. While SHAP values, which explain the contribution of each feature is used in the study(Huanjing Wang, 2024), which shows that credit card fraud detection to improve the accuracy of their models by identifying the most important data features with feature selection techniques.

Research Gap:

Stock price prediction is a significant area of study in finance. Nowadays, many techniques are utilised; one of them is the LSTM network, which is widely used for predictions. Few studies have combined LSTM with interpretability techniques like SHAP and LIME to make results that are easy to understand. The majority of research merely examines forecast accuracy, ignoring the significance of financial factors. Further, there are no comparisons of interpretability tools, like SHAP and LIME, with respect to predictions based on LSTM. Lastly, the present study offers practical frameworks that combine accurate predictions with interpretability models, making them useful and relevant for investors, market analyst and novices.

Methodology:

Data Collection*:*

In this present research, researcher compiled quarterly data for 10 years, from 2012 to 2023 period. The researcher used SHAP and LIME models. With that, the LSTM network was tested using daily data. The financial dataset was derived using annual reports and historical Stock Prices (SP) of the banks that were part of the Bank Nifty Index from the National Stock Exchange (NSE) of India. The financial dataset includes key financial variables such as Equity Share Capital (ESC), Earnings Per Share (EPS) and Return on Assets (ROA), etc. For the experimental study, researcher selected the HDFC bank as a sample from the bank nifty index due to high market capitalization.

Data Processing:

(Wei Bao, 2017) employ a deep learning framework for financial time series, and for the forecasting of the data researcher used deep learning method. The researcher used LSTM model for the forecasting of stock prices. In this study we used suitable evaluation measures for accuracy in the predictions, such as Mean Squared Error (MSE) and R-squared, we used these measures to train the LSTM networks. Afterward with LSTM model here researcher combine research with interpretability models such as SHAP value and LIME in Python to evaluate the importance of each financial variable in influencing the predictions of model. In the understanding and the decision-making process of model this interpretability

models i.e. SHAP (SHapley Additive exPlanations) and LIME (Local Interpretable Model-agnostic Explanations) are very useful. Hence in this research researcher applied both the models on the data of stock prices for knowing the results related which financial variable is affecting stock price. In this regard (Scott M. Lundberg, 2017) were used both the models in his study for increased efficiency.

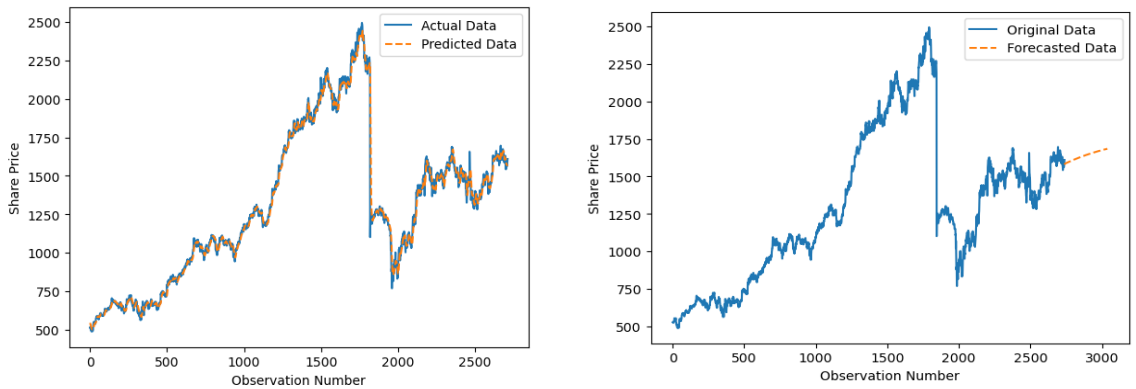
Result and Discussion:

Long Short-Term Memory Model (LSTM):

Long Short Trem Memory network is type of Recurrent Neural Network which is often called LSTM and RNN (Shun Chen, 2019). In various fields LSTM or Long Short-Term Memory algorithm is applied such study areas are weather forecasting, natural language processing (NLP), speech recognition, handwriting recognition, and time-series prediction and stock price prediction. It is designed for effective process and predict sequences of data (S. Dinesh, 2022) In the LSTM algorithm, there are special structure called a gates, that help to achieve the flow of information and allow the network to retain relevant data while removal what is no longer required. LSTM is an advanced type of Recurrent Neural Network and is applied in various areas of research (Zitti, 2023). Correspondingly, to forecast the share price, the present research study utilised LSTM model. By using the historical data of stock price LSTM model help to recognize and understand the patterns and trend of future stock price data.

In the LSTM model we set a batch size of 100 for frequent updates to the model weights it helps improving the learning efficiency and effectiveness of the LSTM model. Sigmoid and Tanh are the activation functions used in the LSTM model by the researcher to handle non-linearity in the dataset. During training of the model, the values between 0 and 1 are used in sigmoid function and, the Tanh function scales values between -1 and +1, it ensures smoother gradients. While(Achyut Ghosh, 2019) used this in their research, as numbers ranging from 0 to 1 that indicate how much of each factor should pass through the output produced by the sigmoid layer when the tanh function values between -1 and +1. For improving performance of model, researchers used the Adam optimiser, which is help to minimise noise in the data. To train the model the researcher set 100 epochs, ensuring that the underlying patterns or trend in the data of stock prices are significantly known. To improve the performance of model the researcher employed hyperparameter tuning which is essential step. By applying techniques like network search, we identify the best combinations of parameter such as Mean Absolute Error (MAE) parameter to minimise the errors. It is the average difference between the true and predicted values (Zahra Fathali, 2022), and make sure that the model provides accurate outcomes. Forecasting the share price trend using the LSTM model provide significant results, as shown by the plots that compare predicted and actual data, which is shown in Figure 1. next 300 observations of daily share prices are forecasted by the researcher.

Figure 1: Actual vs. Predicted Share Prices with Forecasts



For checking the accuracy of model in this research, we calculated Mean Absolute Error known as MAE. Lower value of MAE indicates better model performance or best fit model. Value of MAE for this study is 23.81 which indicates the accuracy of model and shows how well the LSTM model can predict future performance based on data of historical prices. For the growth of company and share price forecasting some researcher used LSTM model which is more suitable (Achyut Ghosh, 2019)

Interpratability Model:

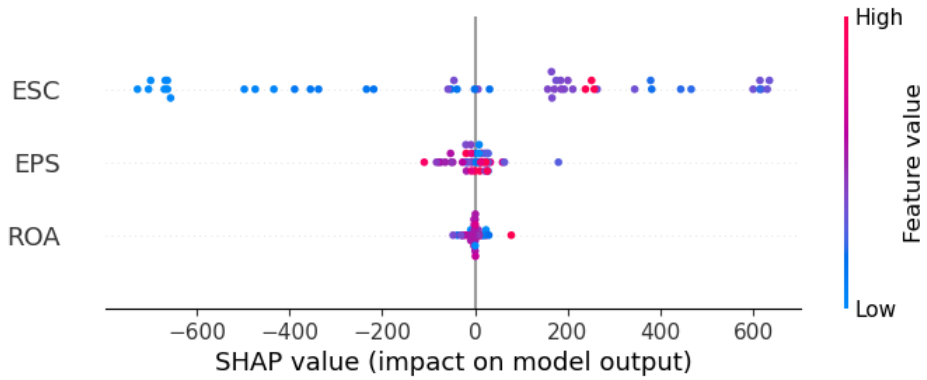
SHAP Value:

A unified measure of feature importance is the SHAP values (Scott M. Lundberg, 2017). In the machine learning model, one of the powerful tools for predictions is the SHAP value. (Xia Xiaomao, 2019) SHAP is used to provide understandings

about the contribution of each feature to specific predictions. The SHAP value method is based on cooperative game theory, which gives an important score to each feature, reflecting its impact on the outcome of model. This approach enhances model transparency by allowing researchers and practitioners to understand which variables most significantly influence on predictions and facilitates better decision-making. As a result, Figure 2 in our study illustrates it. For present study, in the prediction model, the SHAP plot summary helps to know about how each feature impactes on the stock prices of a HDFC bank. By using SHAP, knowing the contribution to each feature for particularly in forecasting (Huanjing Wang, 2024). Likewise, the absolute SHAP value represents the feature's importance, and higher SHAP values are more influential in the model's predictions.

Among the three financial factors, ESC has the most influence on stock price. It can be reflected in the wide range of the SHAP values. Particularly, the most important factor that affects stock price is ESC, namely larger levels, which indicate more red dots on the positive side (right side). However, the variables that had the least influence and significance were those with lower ESC values, which indicate the quantity of blue dots on the negative side (left side). The second most important financial variable i.e. EPS has a less significant and impactful variable on the stock price. This is reflected by the least spread of SHAP values and are ranging around zero only. Therefore, EPS is not the great influence on the stock price of HDFC bank than ESC. It can also be said that, prominent share price changes are due to the ESC than the EPS. Likewise, ROA is the third financial variable have no influence on the stock price. The SHAP values for ROA are somewhat centred around zero, which means this feature has negligible influence on the stock price. Hence, it can be inferred that, EPS and ROA does not play a prominent role in determining the stock price predictions in this model. In nutshell share price predictions are primarily driven by ESC in this model. In this paper SHAP values were utilised to analyse the importance of various financial indicators in predicting the stock prices of the HDFC bank in the Bank Nifty index, which provides the insights to the investors and stakeholders to make more informed choices.

Figure 2: SHAP Value Plot



LIME (Local Interpretable Model-agnostic Explanations):

LIME is an algorithm that accurately predicts any class or regressor by approximating it locally with an interpretable model (Marco Tulio Ribeiro, 2016). Each feature's contribution to the model's predictions is measured by feature significance and higher values signify the greater influence on stock price.

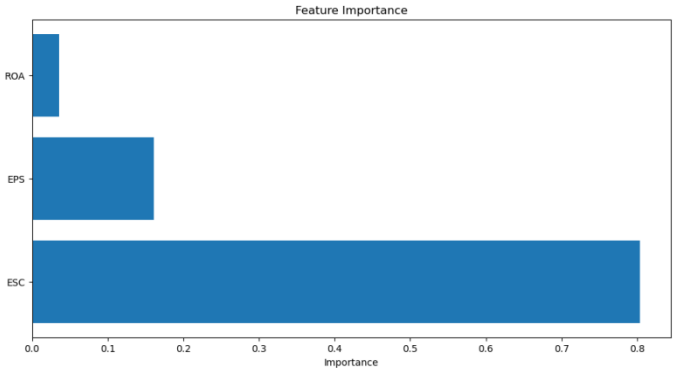
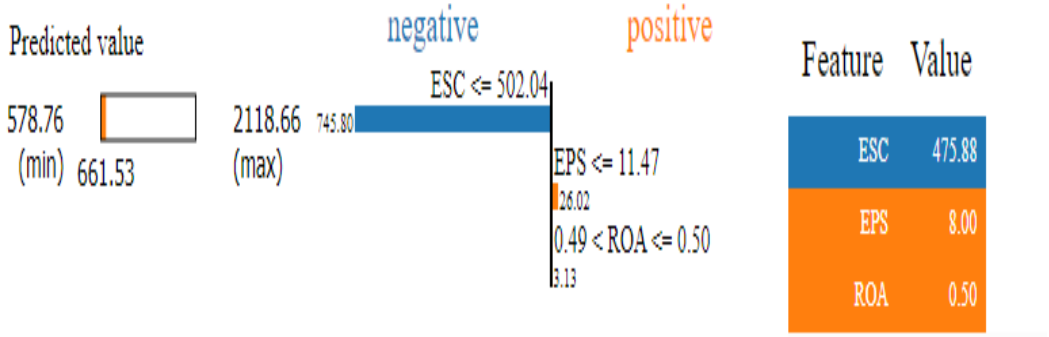


Figure 3: Feature Importance

Figure 3. demonstrates the most significant factor which impacted on the model's output i.e. stock price. It finds that, ESC is the most important financial variable followed by the EPS in this instance. While ROA has the least impact on the forecasts.

Figure 4: LIME Plot



The LIME plot in Figure 4. visualizes how the model arrived at its prediction for a specific instance, with a positive outcome being predicted. LIME is a term used to describe simplified inputs (Scott M. Lundberg, 2017). The present research highlights the most influential features contributing to prediction decisions, based on the ESC, EPS, and ROA. The coloured bars represent each feature's contribution in the prediction of the outcome. In the above figure, the blue coloured bar shows a negative contribution, while the orange-coloured bar indicates a positive contribution. It shows the range of each feature considered during the predictions. The results of ESC show the value below 502.04 are related to a negative prediction. The results showed that when ESC is valued at more than 502.04, it has a significant impact on the model's approximation. However, EPS and ROA have less impact on the stock price. LIME plot gives a brief and interpretable explanation, which highlights the most important variables influencing the decision-making process of model for this particular illustration.

Conclusion:

The researcher used LSTM networks in order to successfully capture the trend in stock price movement, which is a type of financial time series data. Due to the significant accuracy of predictions, this model is used in the current study. The relationship between financial variables and stock prices was understood by using SHAP and LIME. Feature contributions, which are part of the interpretability model, play a crucial role in understanding the results. In this study, researchers have used a combination of interpretability models such as SHAP and LIME, which give a clearer view to investors with huge insights based on the results. The model improve its prediction results with transparency and interpretability by using feature contribution techniques. According to findings from SHAP and LIME, the ESC has the greatest impact on stock prices, followed by EPS, while ROA has the least impact. Overall, the results of the study indicate how an effective combination of interpretability models with a deep learning model can facilitate well-informed decisions. For further research and improvements in the forecasting model of stock prices, this study will be useful.

Future Scope:

For further study, researchers can enlarge the dataset by including a large number of companies on stock market and various variables, such as financial, macroeconomic, and sentiment-driven indicators, including news and social media market sentiment scores. Additionally, various econometric and machine learning models are also useful for future studies. Perhaps in future research, researchers can combine LSTM and interpretability models with other econometric and machine learning models.

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Conflicts of interest:

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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