Modelling direction detection in selected stocks in

Indian BFSI sector

Anand Mohan  
*REVA Academy for Corporate Excellence(RACE)*  
*REVA University*Bangalore, India  
anandmohan.embedded@gmail.com

J.B Simha  
*REVA Academy for Corporate Excellence (RACE)*  
*REVA University*Bangalore, India  
jbsimha@gmail.com

ShinuAbhi  
*REVA Academy for Corporate Excellence (RACE)*  
*REVA University*Bangalore, India  
shinuabhi@reva.edu.in

*Abstract*— several research initiatives have been taken to predict stock market returns using historical data. During this capstone project, twenty-two years' price of the stock's daily close price is being utilized for direction detection. The objective of the project is to get the right stock and understand the data pattern using Exploratory Data Analysis and perform data preparation and then build the right models by using multiple Modelling techniques to predict whether the price will move up or move down. Closing prices are being utilized as 6 different feature variables for building the classification Model. The difference between the 7th and 8th-day Closing price is determined. The 0.7% difference, 1% difference, and 1.5% difference are different classes of direction for which the rule is being set to determine either positive change, negative change, or no change. A similar process is again repeated for a range of consecutive days to be utilized as the feature variable increased to 10 days and 14 days. Then momentum, trend, volatility, and volume indicators are utilized as feature variables and different classification models are built to determine upward direction detection. Random forest modelling has given the highest efficiency in direction detection. Logistic regression modelling done for percentage change in close price as 0.5% has given the highest efficiency for volume and momentum indicators whereas XG Boost Classifier provided the best prediction performance for trend and volatility indicators. The invaluable take away from the capstone is that various classification modelling techniques had been remarkably useful in direction detection for the stock under consideration.

Keywords— Direction detection, Stock Market, Technical Indicators, Classification Models, HDFC, KOTAK, SBI

# Introduction

Live validations are still becoming a grim prospect, because of several things like value variations, quiet news, and existing noise [14].

Several Machine-Learning associated techniques are developed which have created the potential to predict the market to an extent [15].

For the transaction of shares via a broker, there is mostly a fee paid to the broker for each buy and sale which will almost eat up the gains [7].

The requirement is to overcome the ambiguities of Fundamental and technical evaluation, and advanced development in the modelling strategies has pushed several researchers to check new strategies for stock value forecasting [12].

In the next section, some of the available literature will be scanned which would throw light on various related aspects of Machine-Learning methods and other methodologies, and also study and research other related issues which would help assist better in direction detection in Stock Market.

# LITERATURE REVIEW

## Algorithmic trading

Ultrafast algorithms improve traders’ ability to seize opportunities long before any human would be able to do the same [6].

Regulators have restrained algorithmic commerce, following accusations of market manipulation [11].

## Fundamental analysis of the stock market

Fundamental analysis helps to identify and implement short positions by selling the shares of companies showing downtrends and then covering these positions by buying back the shares of these companies when they start showing upward trends [5].

## Technical indicators for the stock market

The expectation of various crypto currencies like Bitcoin, Ethereal, Litecoin, and Ripple digital currency value in examination with the anticipated price by the volatility regression model and trend indicators gave pretty higher returns for the entire month [3].

Momentum-based Trading commerce is amongst proved investment strategies across major stock markets [10].

## Supervised and Unsupervised learnings

Some literature has used both supervised and unsupervised machine learning techniques for securities market predictive modelling [2].

## Principal Component analysis

The central plan of Principal Component Analysis is to spot correlations and patterns in a dataset with high dimensionality and scale back it to a considerably lower dimension without losing any important info [4].

## Logistic Regression

Logistic Regression is used instead of linear regression in situations where the target variable is not numeric, but a nominal or an ordinal variable [1].

## Decision Tree

In Decision Tree, the model becomes more complex as the size of the datasets increases. This is being handled using more advanced algorithms in Decision Tree for classification and regression problems [8].

## Random Forest

RF is quite flexible to non-linearity in the dataset and is the most appropriate ensemble learning algorithm for medium-sized to very large-sized datasets [13].

## K-Nearest Neighbours

K-Nearest Neighbors is the most popular statistical technique utilized in pattern identification over the last four decades [16].

## Extreme Gradient Boosting

XGBoost is extensively recognized as an extremely useful ensemble learning algorithm. However, its performance needs more improvements ideally in scenarios where the dataset is imbalanced [17].

## confusion matrix for Classification Models

The confusion matrix evaluates numerous performance metrics which include accuracy, precision, and recall [9].

# METHODOLOGY

Initially Fundamental and Technical analysis of HDFC, KOTAK, and SBI stock is performed to demonstrate why the HDFC, KOTAK, and SBI stock dataset has been used for this project. Data understanding explains the different columns used in the HDFC, KOTAK, and SBI dataset and performs their Univariate analysis. Data preparation explains Handling Missing values, Features Addition, and Data Scaling using MinMax Scaler. Logistic Regression Classifier, Decision Tree Classifier, Random Forest Classifier, K Nearest Neighbour Classifier, and XG Boost Classifier were used in the Data Modelling phase. The data evaluation phase examines the results of different Modelling techniques which were used in the Data Modelling phase. Deployment speaks about developing a front-end API for the deployment Dashboard.

## Data Collection

Daily Trading Data of HDFC, KOTAK, and SBI Bank from the year 2000 to 2022 are being used for this study. This study uses NSE Data.

The symbol column tells us the corporate symbol mentioned for the stock. The opening price is the first trade worth that was recorded throughout the day’s trading. The high and low is the highest and lowest value respectively at that a stock is listed during a period. The previous closing is going to be a consecutive session's opening price. The last price is the one at which the foremost recent transaction happens. The close is the last value recorded once the market is closed on the day. The volume-weighted average worth (VWAP) is a trading benchmark based on both volume and worth. Trading Volume shows the number of shares listed for the day, listed in lots of 100 quantities of shares.

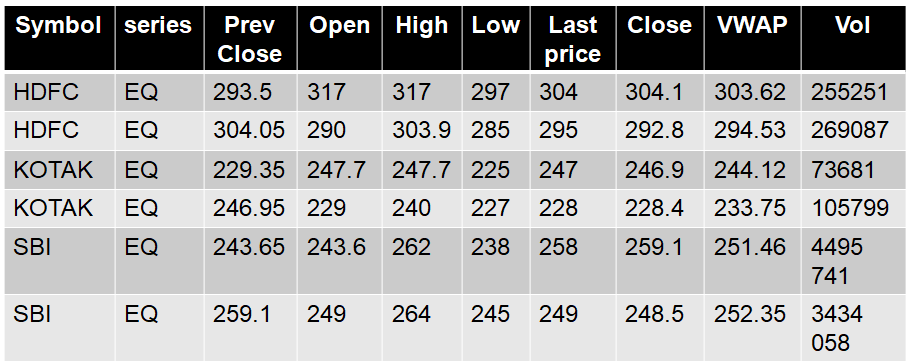
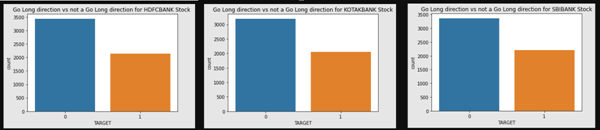


Table1. Top rows of HDFC, KOTAK, and SBI stock dataset

## Data Exploration

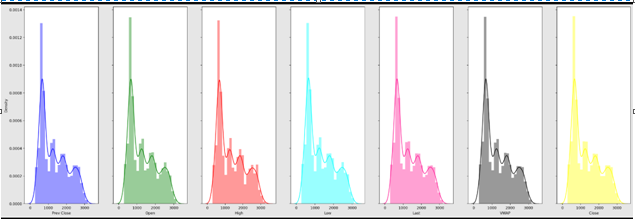


1. Class distribution For HDFC, KOTAK, and SBI stock

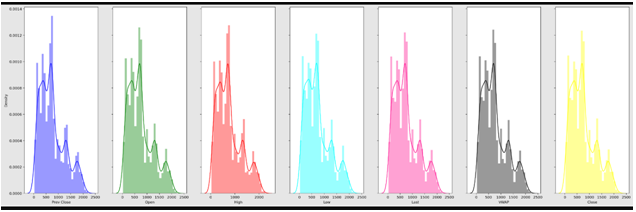
HDFC STOCK is moving 2140 times in an upward direction and is suitable for long trading whereas 3435 times, it is not moving in an upward direction. KOTAK STOCK is 2055 times suitable for long trading whereas 3199 times, it is not moving in an upward direction. SBI STOCK is 2211 times suitable for long trading whereas 3364 times, it is not moving in an upward direction.



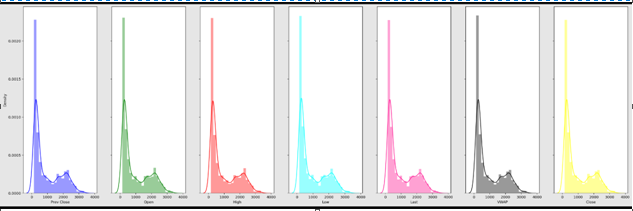
1. Close values of HDFC, KOTAK, and SBI stock from 2000 to 2022



1. Distribution Plot for the HDFC Stock

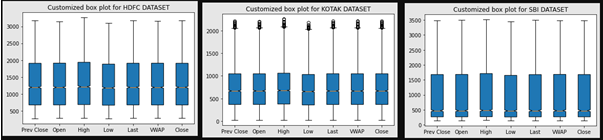


1. Distribution Plot for the KOTAK Stock



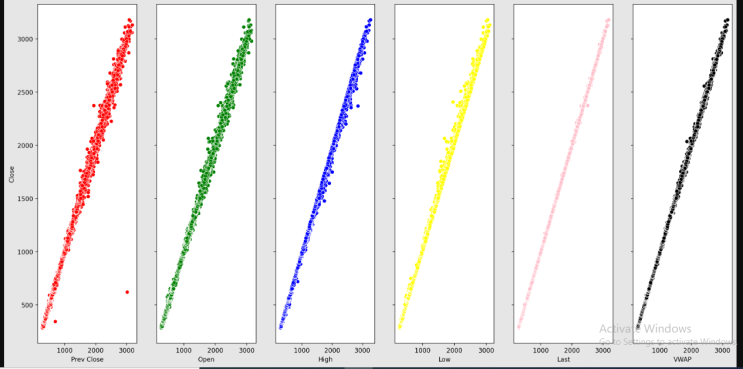
1. Distribution Plot for the SBI Stock

The Data has a positively skewed distribution which is observed in all 3 stocks namely HDFC, KOTAK, and SBI bank stock. SBIBANK stock is looking as the least volatile stock followed by HDFC and then KOTAK.

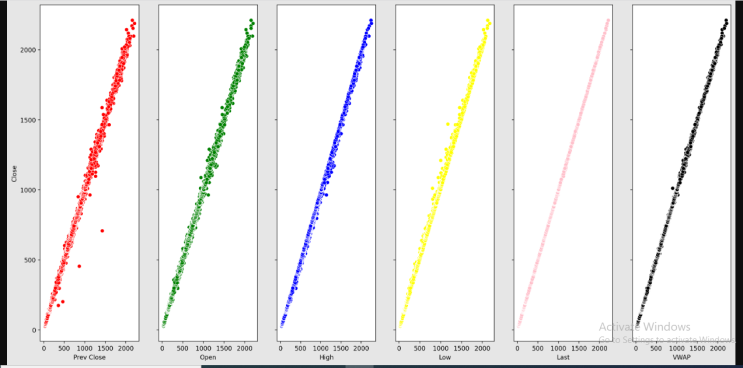


1. Box plot-HDFC, KOTAK, and SBI stock from 2000 to 2022

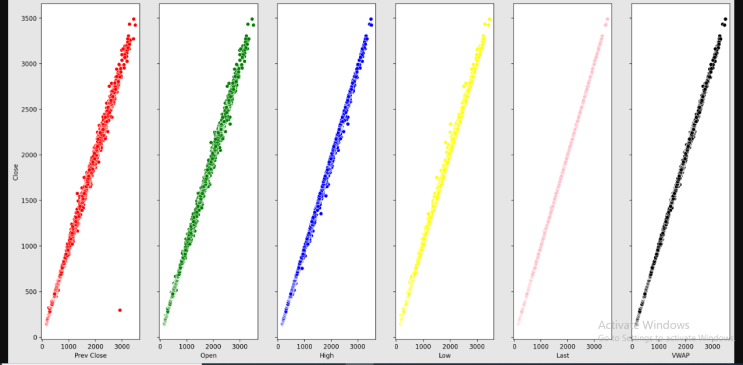
There is a large difference between the 75th %tile and max values of most of the feature variables for all 3 stocks. Therefore, it suggests that there are extreme values-Outliers in our data set.



1. Customized Scatter Plot against close price for the HDFC Stock from 2000 to 2022



1. Customized Scatter Plot against close price for the KOTAK Stock from 2000 to 2022



1. Customized Scatter Plot against close price for the SBI Stock from 2000 to 2022

A customized Scatter Plot is drawn for all feature variables against the close price of the HDFC, KOTAK, and SBI stock. It is observed that a linear relationship exists between Independent variables and the Target variable except for fewer outliers which is quite negligible.

## Data Pre-processing

The HDFC, KOTAK, and SBI data which are taken from NSE come with a lot of limitations that have to be processed.

Handling Missing values: Three of the features’ trades, ‘Deliverable Volume’, and’% Deliverable were dropped as they are having several missing values.

Features Addition: Computed variables added to the dataset are simple and exponential moving averages for rolling periods of 7, 13, 20,100, and 200 days. 1 day's previous lag values of volume are also added as features.6, 10, 14, and 30 days consecutive closing prices are tabulated week on week for the entire dataset and utilized as different feature variables. Momentum, trend, volatility, and volume indicators are also used as feature variables.

Data Scaling: Minmax Scaler is the data scaling approach that is being used. MinMax Scaler shrinks the data inside the given range, from zero to one.

## Data Modeling

Various Classification models namely Logistic Regression, Decision Tree, Random Forest, K Nearest Neighbour, and XG Boost Classifier are deployed and their prediction accuracy is compared.

When the majority of the 20 various models or all of them move in the same direction, a choice on whether to invest or not to invest in the stock under consideration must be made.

Daily Trading Data of SBI and Kotak Bank from the year 2000 to 2022 are being used to repeat the entire process which had been implemented for the HDFC Bank dataset.

|  |  |
| --- | --- |
| **Modelling Strategies** | **Model Evaluation Rule** |
| Direction Detection by 6, 10, and 14 days consecutive closing prices split week on the week. | percentage change on closing price>0.7% =>Positive Trend  percentage change on closing price<-0.7% =>Negative Trend  percentage change on closing price between 0.7 and 0.7% =>Neutral |
| Go Long Direction Prediction performed separately using Momentum, Trend, Volatility, and Volume Indicators | percentage change on closing price>0.5% =>Positive Trend  percentage change on closing price<=0.5% =>Not Positive Trend |

Table 2– Modelling strategies and Model Evaluation Rule

# FINDINGS/DISCUSSION

The Data Evaluation phase is the result of the Data Modelling phase and discusses the Metrics utilized to determine the extent of the success achieved from the different Modelling Algorithms employed on the Target Variable.

## Model Evaluation using LR Classifier for Go Long Direction Prediction

Various Classification Models are utilized to predict the direction of the close value of HDFC, KOTAK, and SBI stock and estimate using different error metrics. All the results derived from the various models are examined and the best model is figured out which has been most successful in minimizing the prediction errors.

|  |  |  |  |
| --- | --- | --- | --- |
| **Modelling Strategies** | **HDFC** | **KOTAK** | **SBI** |
| Direction Detection by 6,10,14 days consecutive closing prices split week on the week | precision-0.35  recall-0.60  accuracy-0.35 | Precision-0.37  recall-0.74  accuracy-0.36 | Precision-0.36  recall-1.00  accuracy-0.36 |
| Go Long Direction Prediction using Volume Indicators | **precision-0.98**  **recall-0.83**  **accuracy-0.92** | **precision-0.99**  **recall-0.93**  **accuracy-0.97** | **precision-0.92**  **recall-0.80**  **accuracy-0.90** |
| Go Long Direction Prediction using Momentum Indicators | precision-0.71  recall-0.63  Accuracy-0.76 | precision-0.73  recall-0.61  accuracy-0.75 | precision-0.69  recall-0.62  accuracy-0.74 |
| Go Long Direction Prediction using Trend Indicators | precision-0.83  recall-0.59  Accuracy-0.80 | precision-0.76  recall-0.48  accuracy-0.72 | precision-0.78  recall-0.49  accuracy-0.74 |
| Go Long Direction Prediction using Volatility Indicators | precision-0.93  recall-0.47  Accuracy-0.77 | precision-0.90  recall-0.40  accuracy-0.74 | precision-0.81  recall-0.30  accuracy-0.70 |

Table 3– Model Evaluation using LR Classifier for Go Long Direction Prediction

From Table3, it can be observed that Go Long Direction Prediction using Volume Indicators has given considerable precision, recall, and accuracy in direction prediction.

## Model Evaluation using RF Classifier for Go Long Direction Prediction:

|  |  |  |  |
| --- | --- | --- | --- |
| **Modelling Strategies** | **HDFC** | **KOTAK** | **SBI** |
| Direction Detection by 6,10,14 days consecutive closing prices split week on the week | **precision-0.85**  **recall-0.89**  **accuracy-0.87** | **Precision-0.71**  **recall-0.79**  **accuracy-0.74** | **Precision-0.83**  **recall-0.88**  **accuracy-0.85** |
| Go Long Direction Prediction using Volume Indicators | **precision-0.93**  **recall-0.69**  **accuracy-0.85** | **precision-0.92**  **recall-0.79**  **accuracy-0.89** | **precision-0.90**  **recall-0.73**  **accuracy-0.86** |
| Go Long Direction Prediction using Momentum Indicators | precision-0.76  recall-0.51  Accuracy-0.75 | precision-0.78  recall-0.50  accuracy-0.75 | precision-0.72  recall-0.55  accuracy-0.74 |
| Go Long Direction Prediction using Trend Indicators | precision-0.87  recall-0.56  Accuracy-0.80 | precision-0.85  recall-0.44  accuracy-0.74 | precision-0.83  recall-0.57  accuracy-0.78 |
| Go Long Direction Prediction using Volatility Indicators | precision-0.92  recall-0.53  Accuracy-0.79 | precision-0.89  recall-0.50  accuracy-0.78 | precision-0.83  recall-0.61  accuracy-0.80 |

Table4.Model Evaluation using RF Classifier for

Go Long Direction Prediction

From Table 4, it can be observed that Direction Detection has given the highest precision, accuracy, and recall in prediction. Also, Go Long Direction Prediction using Volume Indicators has given considerable precision and accuracy in direction prediction but recall can still be improved.

## Model Evaluation using XG Boost Classifier for Go Long Direction Prediction

|  |  |  |  |
| --- | --- | --- | --- |
| **Modelling Strategies** | **HDFC** | **KOTAK** | **SBI** |
| Direction Detection by 6,10,14 days consecutive closing prices split week on the week | precision-0.35  recall-0.42  accuracy-0.40 | Precision-0.38  recall-0.41  accuracy-0.40 | Precision-0.38  recall-0.47  accuracy-0.37 |
| Go Long Direction Prediction using Volume Indicators | **precision-0.90**  **recall-0.73**  **accuracy-0.86** | **precision-0.92**  **recall-0.87**  **accuracy-0.92** | **precision-0.88**  **recall-0.82**  **accuracy-0.89** |
| Go Long Direction Prediction using Momentum Indicators | precision-0.70  recall-0.61  Accuracy-0.75 | precision-0.74  recall-0.59  accuracy-0.75 | precision-0.70  recall-0.59  accuracy-0.74 |
| Go Long Direction Prediction using Trend Indicators | precision-0.85  recall-0.65  Accuracy-0.82 | precision-0.82  recall-0.61  accuracy-0.79 | precision-0.83  recall-0.67  accuracy-0.81 |
| Go Long Direction Prediction using Volatility Indicators | precision-0.84  recall-0.69  Accuracy-0.82 | precision-0.81  recall-0.63  accuracy-0.79 | precision-0.80  recall-0.67  accuracy-0.81 |

Table 5– Model Evaluation using XG Boost Classifier for

Go Long Direction Prediction

From Table 5, it can be observed that Go Long Direction Prediction using Volume Indicators has given considerable precision, recall, and accuracy in direction prediction.

All the models are now combined and below is the description of the final results.

## Direction Detection and Go Long Direction Prediction using the best classifier model

|  |  |  |  |
| --- | --- | --- | --- |
| **Modelling Strategies** | **HDFC** | **KOTAK** | **SBI** |
| Direction Detection by 6,10,14 days consecutive closing prices split week on the week  (RF Classifier) | **precision-0.85**  **recall-0.89**  **accuracy-0.87** | **Precision-0.71**  **recall-0.79**  **accuracy-0.74** | **Precision-0.83**  **recall-0.88**  **accuracy-0.85** |
| Go Long Direction Prediction using  Volume Indicators  (LR Classifier) | **precision-0.98**  **recall-0.83**  **accuracy-0.92** | **precision-0.99**  **recall-0.93**  **accuracy-0.97** | **precision-0.92**  **recall-0.80**  **accuracy-0.90** |
| Go Long Direction Prediction using  Momentum Indicators  (LR Classifier) | precision-0.71  recall-0.63  Accuracy-0.76 | precision-0.73  recall-0.61  accuracy-0.75 | precision-0.69  recall-0.62  accuracy-0.74 |
| Go Long Direction Prediction using  Trend Indicators  (XG Boost Classifier) | precision-0.85  recall-0.65  Accuracy-0.82 | precision-0.82  recall-0.61  accuracy-0.79 | precision-0.83  recall-0.67  accuracy-0.81 |
| Go Long Direction Prediction using  Volatility Indicators  (XG Boost Classifier) | precision-0.84  recall-0.69  Accuracy-0.82 | precision-0.81  recall-0.63  accuracy-0.79 | precision-0.80  recall-0.67  accuracy-0.81 |

Table6. Leader Board-comparison of Metrics for Direction Detection and Go Long Direction Prediction using the best classifier model

From Table 6, it can be observed that RFclassifier modelling has given the highest efficiency in Direction Detection among all Modelling techniques namely LR, DT, RF, KNN, and XG Boost Modelling. This has been tested and proven with 6, 10, and 14-day consecutive closing prices split week on week as 6, 10, and 14 feature variables. Also, LR classifier modelling has provided the best precision, recall, and accuracy for Go Long Direction prediction using Volume Indicators.

## Utility from the Business perspectives

For a stop loss of 2.0 reward-risk ratio for approximately 0.8 Precision would be 2\*.8/2\*.2=4:1 if a 0.5% difference in consecutive day close price for any stock is only 2.0.for higher percentage difference reward to risk ratio would be higher.

Here, Modelling Algorithms were provided for the close price of HDFCBANK, KOTAK BANK, and SBIBANK Stock over 20 years with the train test split of 70%:30%. If we invest Rs.10000 for 6 years and roughly calculate profit with 0.5% change on close price with the highest precision in detecting true positives then the following results are possible as per the formulae given below:



Using Trend Indicators with the highest precision of 0.85 for HDFCBANK stock, the confusion matrix provides information as below:



Figure 10. confusion matrix For HDFCBANK Stock using

Trend Indicators as Feature variables

Therefore, Net Returns will be:

0.5\*10000\*282\*0.85/100-0.5\*10000\*51\*0.85/100=Rs. 9817.5 profit which would be

9817.5 / (10000\*6)\*100=16.36% returns.

## Risk-Adjusted Returns

The real Data dump is imported for HDFC, KOTAK, and SBI stock between 2000 till 2022. Then the Return, Variance, and Volatility of these stocks are calculated following which the Annualized return to Risk ratio and finally, the Sharpe ratios are calculated. The Sharpe ratio for HDFC, KOTAK, and SBI Stock is calculated as 0.173818, 0.149589 and 0.005306 respectively.

Therefore, from the results obtained it becomes evident that HFDC shows a better Return vs. Risk performance over the specified period compared to KOTAK stock followed by the SBI stock which shows the least Return vs. Risk performance.

# CONCLUSION/IMPLICATIONS

The 6-day consecutive closing price for the stock under consideration is being taken. These 6 days' consecutive closing prices will be tabulated week on week for the entire dataset and will be utilized as 6 different feature variables for building the classification Model. The difference between the 7th and 8th-day Closing price is determined. The 0.7% difference,1% difference, and 1.5% difference are different classes of direction for which the rule is being set which is to be followed for computing the direction change as either positive change, negative change, or no change. Once it is determined say for example 0.7% difference has the best prediction accuracy among all different classes of direction then the similar process is again repeated for a range of consecutive days to be utilized as the feature variable increased to 10 days and 14 days using the Classifier Modelling algorithm which provided the best directional prediction.Similarly, All different types of technical indicators namely momentum indicators, trend indicators, volatility indicators, and volume indicators are utilized as feature variables based on the input dataset and Various Classification models namely LR Classifier, DT Classifier, RF Classifier, KNN Classifier, and XG Boost Classifier are deployed and their prediction accuracy is compared using Metrics namely precision, recall, f1-score, accuracy score, and ROC AUC Score. The construction of all 20 models was used to predict the direction of the close price for the stock under consideration. When the majority of the various models or all of them move in the same direction, a choice on whether to purchase or sell the stock must be made.

This paper then solely focuses on predicting the direction of the close price of the HDFC stock using classification algorithms Techniques. A later similar process is applied for predicting the direction of the close price of other stocks in the banking sector namely SBI and KOTAK stocks. In the Future, there is a deployment Dashboard proposed. As per the proposal for future assignments, the dashboard takes API as an input Derived from the machine learning algorithms and can be utilized in predicting the direction of the close price for any stock in the Banking sector. Any stock on the stock market can utilize the same procedure to forecast buy or sell choices, which is helpful.

# RECOMMENDATIONS

This paper has not discussed how to address one major drawback of stock prediction, namely that over different periods the stock returns can change drastically.

In future projects, it can be shown how to define Bullish and Bearish regimes using modern machine learning techniques. The Sentiment Analysis Approach may also need to be explored using Text Analytics for predicting stock market returns. In the Future, there is a deployment Dashboard proposed. An intelligent automated system for Options Trading would be also the next step forward.

##### References

[1] Al-Bairmani, Z. A. A., & Ismael, A. A. (2021). Using Logistic Regression Model to Study the Most Important Factors Which Affects Diabetes for the Elderly in the City of Hilla / 2019. *Journal of Physics: Conference Series*, *1818*(1). https://doi.org/10.1088/1742-6596/1818/1/012016

[2] Alhomadi, A. (2021). Forecasting stock market prices : A machine learning approach. *Digital Commons*, *11*(2), 16–36.

[3] Dahham, A. Z. D., & Ibrahim, A. A. (2020). Effects of Volatility and Trend Indicator for Improving Price Prediction of Cryptocurrency. *IOP Conference Series: Materials Science and Engineering*, *928*(3). https://doi.org/10.1088/1757-899X/928/3/032043

[4] Dar, A. N. (2021). PRINCIPAL COMPONENT ANALYSIS (PCA) (Using Eigen Decomposition). *Gsj*, *9*(7), 240–252. www.globalscientificjournal.com

[5] Elbialy, B. A. (2019). The Effect of Using Technical and Fundamental Analysis on the Effectiveness of Investment Decisions of Traders on the Egyptian Stock Exchange. *International Journal of Applied Engineering Research*, *14*(24), 4492–4501. http://www.ripublication.com

[6] Hansen, K. B. (2020). The virtue of simplicity: On machine learning models in algorithmic trading. *Big Data and Society*, *7*(1). https://doi.org/10.1177/2053951720926558

[7] Huang, Y., Capretz, L. F., & Ho, D. (2021). Machine Learning for Stock Prediction Based on Fundamental Analysis. *2021 IEEE Symposium Series on Computational Intelligence, SSCI 2021 - Proceedings*. https://doi.org/10.1109/SSCI50451.2021.9660134

[8] Jena, M., & Dehuri, S. (2020). Decision tree for classification and regression: A state-of-the art review. *Informatica (Slovenia)*, *44*(4), 405–420. https://doi.org/10.31449/INF.V44I4.3023

[9] Markoulidakis, I., Kopsiaftis, G., Rallis, I., & Georgoulas, I. (2021). Multi-Class Confusion Matrix Reduction method and its application on Net Promoter Score classification problem. *ACM International Conference Proceeding Series*, 412–419. https://doi.org/10.1145/3453892.3461323

[10] Mohapatra, S., & Misra, A. K. (2020). Momentum returns: A portfolio-based empirical study to establish evidence, factors and profitability in Indian stock market. *IIMB Management Review*, *32*(1), 75–84. https://doi.org/10.1016/j.iimb.2019.07.007

[11] Mukerji, P., Chung, C., Walsh, T., & Xiong, B. (2019). The Impact of Algorithmic Trading in a Simulated Asset Market. *Journal of Risk and Financial Management*, *12*(2), 68. https://doi.org/10.3390/jrfm12020068

[12] Rouf, N., Malik, M. B., Arif, T., Sharma, S., Singh, S., Aich, S., & Kim, H. C. (2021). Stock market prediction using machine learning techniques: A decade survey on methodologies, recent developments, and future directions. *Electronics (Switzerland)*, *10*(21). https://doi.org/10.3390/electronics10212717

[13] Schonlau, M., & Zou, R. Y. (2020). The random forest algorithm for statistical learning. *Stata Journal*, *20*(1), 3–29. https://doi.org/10.1177/1536867X20909688

[14] Shah, D., Isah, H., & Zulkernine, F. (2019). Stock market analysis: A review and taxonomy of prediction techniques. *International Journal of Financial Studies*, *7*(2). https://doi.org/10.3390/ijfs7020026

[15] Sonkiya, P., Bajpai, V., & Bansal, A. (2021). *Stock price prediction using BERT and GAN*. http://arxiv.org/abs/2107.09055

[16] Wang, L. (2019). Research and Implementation of Machine Learning Classifier Based on KNN. *IOP Conference Series: Materials Science and Engineering*, *677*(5), 0–5. https://doi.org/10.1088/1757-899X/677/5/052038

[17] Zhang, P., Jia, Y., & Shang, Y. (2022). Research and application of XGBoost in imbalanced data. *International Journal of Distributed Sensor Networks*, *18*(6). https://doi.org/10.1177/15501329221106935