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Predicting Stock Prices using Artificial Intelligence: A Comparative Study of Machine Learning Algorithms

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Abstract:

The prediction of stock prices poses an intricate and demanding challenge within the realm of finance. The emergence of artificial intelligence (AI) and machine learning (ML) methodologies has escalated the significance of stock price prediction for investors, traders, and financial experts. This study unveils a comparative examination of diverse ML algorithms intended for stock price prediction through AI mechanisms. We assess the efficacy of multiple algorithms, encompassing Linear Regression, Ridge Regression, Lasso Regression, Random Forest Regression, and Gradient Boosting Regression, employing a dataset of historical stock prices sourced from Yahoo Finance. Our findings demonstrate that the Gaussian Process Regressor surpasses other algorithms, boasting an impeccable R-squared value of 1.00. Moreover, we delve into the pivotal role played by feature engineering and preprocessing techniques in augmenting the precision of prediction models. This investigation furnishes valuable insights into the integration of AI in the financial domain, with the potential to enlighten investment and trading strategies.

Keywords: *Stock Prices, Artificial Intelligence, Machine Learning, prediction*

1. Introduction

The economy's stock market constitutes a pivotal facet, exerting a crucial influence on the financial welfare of both individuals and entities. Operating as a multifaceted system, it's swayed by an array of factors, including economic indicators, company achievements, market sentiment, geopolitical occurrences, and myriad others. Given the capricious nature of the stock market, investors and traders have perpetually sought ways to forecast stock prices with precision.

Historically, stock analysis relied on fundamental, technical, and quantitative approaches. Despite their application, these methods possess constraints, and precise stock prediction persists as an intricate undertaking. Yet, owing to the escalating data accessibility and the

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emergence of artificial intelligence and machine learning methodologies, the analysis of substantial data volumes to predict forthcoming stock performance has become feasible.

The stock market operates as a complex entity with intricate predictability. Nevertheless, advancements in artificial intelligence and machine learning empower the scrutiny of extensive data sets, facilitating forecasts concerning forthcoming stock trends. The present investigation endeavors to juxtapose the effectiveness of diverse machine learning algorithms in forecasting stock prices. The impetus behind this study stems from the recognition that precise stock price prognostication can lead to enhanced investment choices, culminating in substantial financial advantages.

2. Problem Statement

This research focuses on the challenge of achieving precise stock price predictions through conventional means. Given the high volatility of stock prices and the multitude of variables at play, encompassing economic indicators, news occurrences, and investor outlook, the task of forecasting stock prices is inherently complex. Consequently, traditional approaches like regression analysis frequently fall short in furnishing reliable predictions. To surmount this obstacle, the primary goal of this study is to assess and contrast the effectiveness of diverse machine learning algorithms in the realm of stock price prediction.

3. Objectives

The primary aim of this research is to evaluate and contrast the efficacy of distinct machine learning algorithms in the task of forecasting stock prices. More specifically, the study seeks to:

- Evaluate the accuracy and reliability of various machine learning algorithms in predicting stock prices.
- Determine which machine learning algorithm(s) perform best in predicting stock prices.
- Identify the most important features that influence stock prices and their relative importance in the prediction models.
- Provide insights and recommendations to investors and financial analysts on the best machine learning techniques to use in predicting stock prices.

4. Questions of the study

Derived from the problem statement and objectives, the study's research inquiries encompass:

- Can machine learning algorithms effectively achieve precise stock price predictions?
- Among the assortment of machine learning algorithms, which ones exhibit optimal performance in the domain of stock price prediction?
- What are the pivotal variables influencing the proficiency of machine learning algorithms in forecasting stock prices?
- How does the temporal scope (short-term vs. long-term) influence the precision of stock price prediction through machine learning algorithms?

- In what manner can the precision of stock price prediction be elevated through the incorporation of ensemble methodologies or alternative techniques?

The structure of the research questions is tailored to align with the study's overarching objectives. Each question hones in on a distinct facet of the objectives, endeavoring to uncover a more profound comprehension of the intricate interplay between stock prices and diverse influences. The intention is to unravel these questions, thereby facilitating the realization of the study's objectives and making a substantive contribution to the realm of stock price prediction facilitated by artificial intelligence.

5. Literature Review

5.1 Previous Studies

For an extended period, forecasting stock prices has held substantial prominence within the spheres of finance and economics. Conventional approaches, including fundamental and technical analysis, have garnered extensive utilization in the pursuit of predicting stock prices. Nevertheless, the ascent of artificial intelligence (AI) has ushered in a new era, rendering machine learning (ML) algorithms progressively favored for their efficacy in the prediction of stock prices.

Numerous investigations have delved into the utilization of machine learning (ML) algorithms for the anticipation of stock prices. One such inquiry by [1] conducted a comprehensive assessment, juxtaposing the efficacy of diverse ML algorithms encompassing Support Vector Classifier (SVC), Decision Tree (DT), Random Forest (RF), Adaboost, XGBoost, and Logistic Regression (LR) in the realm of stock price prediction. Their findings revealed that Logistic Regression stood out, surpassing other algorithms in terms of both accuracy and efficiency. The accuracy scores achieved across various machine learning models were as follows: Decision Tree (68.46), Random Forest (72.18), Adaboost (72.31), XGBoost (71.67), SVC (73.17), and Logistic Regression (76.67).

In another scholarly investigation detailed by [2], a novel stock price prediction model rooted in deep learning was proposed, merging a convolutional neural network (CNN) with a long short-term memory (LSTM) network. This inventive framework garnered a notably higher accuracy rate (88.00) compared to traditional machine learning models, underscoring the potential of deep learning in enhancing stock price prediction.

Similarly, an additional study referenced as [3] introduced an innovative approach, assembling a cluster of machine learning models that harnessed wavelet transform in conjunction with machine learning algorithms. These algorithms encompassed Support Vector Machine (SVM), Random Forest, K-Nearest Neighbor (KNN), Naive Bayes, and Softmax, aiming to prognosticate stock prices. Noteworthy accuracies were achieved by each model: Support Vector Machine (75.98), Random Forest (80.55), K-Nearest Neighbor (77.00), Naive Bayes (70.80), and Softmax (64.74). Evidently, the Random Forest model outperformed its counterparts, accentuating the paramount significance of feature extraction in the context of stock price prediction.

In a comprehensive investigation documented as [4], a comparative analysis was conducted on the efficacy of five distinct machine learning algorithms in the context of stock market prediction: k-nearest neighbors (k-NN), decision tree, artificial neural network (ANN), support vector machine (SVM), and random forest. Leveraging historical stock data from the S&P 500 index, the study unveiled that the SVM algorithm showcased the most exceptional performance when predicting future stock prices. Accuracy scores attained were as follows: k-nearest neighbors (75.00), decision tree (72.00), artificial neural network (82.00), support vector machine (74.00), and random forest (80.00).

In a parallel endeavor outlined as [5], the focus was directed towards stock price prediction via machine learning algorithms, specifically employing the backpropagation neural network (BPNN), support vector regression (SVR), and random forest (RF) algorithms. With data from the S&P 500 index, the accuracy outcomes per algorithm stood at: backpropagation neural network (81.00), support vector regression (85.00), and random forest (71.00). Notably, the SVR algorithm demonstrated the highest accuracy in forecasting stock prices.

Another study detailed as [6] conducted a parallel assessment by juxtaposing the performance of three machine learning algorithms tailored for stock market prediction: ANN, SVM, and decision tree. The study, employing data from the NASDAQ stock exchange, revealed accuracy figures as follows: ANN (78.00), SVM (79.00), and decision tree (73.00). Once again, the SVM algorithm emerged as the most adept in the realm of stock price prediction.

In yet another investigation encapsulated in [7], the adoption of four diverse machine learning algorithms for stock market prediction was explored: linear regression, SVM, decision tree, and k-nearest neighbors (k-NN). Grounded in data from the New York Stock Exchange, the outcome showcased accuracy levels as follows: linear regression (70.00), SVM (77.00), decision tree (69.00), and k-NN (72.00). The SVM algorithm, once more, emerged with the highest accuracy, underscoring its prowess in stock price prediction.

5.2 Research Gap

Drawing from the extensive literature review and the conducted comparative analyses, several gaps in the current research landscape within this domain can be discerned:

- A paucity of studies that delve into the influence of economic and financial events on stock price prediction through AI-based models.
- Insufficient exploration of the correlation between traditional econometric models and AI-based models in the context of stock price prediction.
- Limited exploration of the impact that fine-tuning different hyperparameters has on the effectiveness of AI-based models for stock price prediction.
- Scarcity of studies that prioritize the interpretability aspect of AI-based models employed for stock price prediction.
- A dearth of studies that probe the resilience of AI-based models in stock price prediction across diverse market conditions and time periods.

The aggregate findings from these studies suggest the potential utility of machine learning algorithms, particularly those rooted in deep learning, in forecasting stock prices.

However, the overarching consensus points towards the persistent potential for enhancement in terms of both accuracy and efficiency. As such, the central aim of this study is to conduct a comprehensive comparison of the performance of various machine learning algorithms, thus identifying the most adept, accurate, and efficient algorithm capable of tackling the task of stock price prediction.

6. Methodology

Based on the research questions and objectives, the methodology for this study will involve the following steps:

6.1 Data collection

In this step, historical data for the stock prices of the Yahoo Finance companies was collected from Kaggle depository. The dataset is called "Time Series Forecasting with Yahoo Stock Price". It consist of 1984 samples [29].

We have the data from 23rd November 2015 to 20th November 2020.

The dataset includes six features containing information about the stock prices for a given date. These columns are:

- High: The maximum price that the stock attained on that specific date.
- Low: The minimum price that the stock reached on that particular date.
- Open: The initial price at which the stock commenced trading on that date.
- Close: The concluding price at which the stock ceased trading on that specific date.
- Volume: The aggregate trading activity that transpired on that date.
- AdjClose: Altered values that accommodate corporate actions like dividends, stock splits, and fresh share issuance.

6.2 Data preprocessing:

The gathered dataset underwent preprocessing procedures aimed at refining and adapting it into a fitting format for subsequent analysis. This encompassed activities such as eliminating duplicate entries, addressing missing values, and identifying and handling outliers. Additionally, the dataset was restructured into a time series format, capitalizing on the chronological order of the data points.

Subsequent to preprocessing, the dataset was bifurcated into two distinct sets: a training set and a testing set. This division was established with a ratio of 80% for the training set and 20% for the testing set, representing an allocation intended to maximize the efficacy of the subsequent analysis.

6.3 Feature selection and engineering:

During this stage, a meticulous process was initiated to cherry-pick pertinent features from the dataset, while simultaneously devising novel features that hold the potential to enhance the performance of the machine learning models. This encompassed the incorporation of technical indicators, encompassing moving averages, relative strength index, and stochastic oscillator, among others. The objective was to furnish the machine learning models with an enriched set of input features, thereby augmenting their capacity to derive meaningful patterns and relationships from the data.

6.4 Machine learning model selection:

A range of machine learning models was selected for this study as follows [7]-[18]: Cat Boost Regressor, LGBM Regressor, Lasso, Linear Regression,XGB Regressor, Ridge regression, Gaussian Process Regressor, SV Regression, Decision Tree Regressor, Random Forest Regressor, Gaussian Mixture, Gradient Boosting Regressor, NuSVR and Linear SVR,

These models were chosen based on their popularity in the literature and their ability to handle time series data.

6.5 Model training and validation:

The selected machine learning models was trained on the preprocessed data. The models was validated using cross-validation techniques using the 14 machine learning algorithms.

6.6 Model evaluation:

The performance of the trained models was evaluated using metrics such as [19]-[28]:

- R^2 (coefficient of determination): This metric quantifies the proportion of the variance exhibited in the dependent variable (stock prices) that can be elucidated by the independent variables (predictors). Its values span from 0 to 1, with higher scores indicative of a superior model fit.
- Adjusted R^2: Analogous to R^2, this metric takes into account the complexity of models by penalizing those with numerous predictors, curbing the risk of overfitting. Its range encompasses -1 to 1, with greater values signifying an enhanced model fit.
- MSE (mean squared error): This measure computes the average of the squared disparities between the anticipated values and the actual values. It is susceptible to the influence of outliers and extends from 0 to infinity, with diminished values indicative of a more adept model fit.
- MAE (mean absolute error): This measure quantifies the mean absolute variance between the projected values and the actual values. It is less vulnerable to outliers than MSE and spans from 0 to infinity, with smaller values illustrating an enhanced model fit.
- RMSE (root mean squared error): Calculated as the square root of MSE, this metric gauges the average gap between projected values and actual values. Comparable to MSE, it is susceptible to outlier effects and ranges from 0 to infinity, with decreased values representing an improved model fit.
- Accuracy: accuracy provides a basic measure of a model's overall correctness but should be considered alongside other evaluation metrics, especially when dealing with imbalanced datasets or specific performance requirements.

The models were compared, and the best-performing model was selected for predicting future stock prices.

6.7 Future stock price prediction:

The finalized model will be harnessed to forecast forthcoming stock prices for the designated companies. The precision of these projections will undergo thorough evaluation, with the outcomes meticulously scrutinized. Subsequently, the obtained results will be comprehensively presented and subjected to in-depth discussion. This deliberation aims to illuminate the model's efficacy, its strengths, and potential limitations, fostering a comprehensive understanding of its predictive capabilities in the context of stock price forecasting.

7. Results and Discussion

After we have finished training the 14 Machine Learning algorithms, we tested them using the evaluation metrics and testing dataset. We recorded the results of the testing in Table 2 and Fig. 1.

From table 2 and Fig. 1, we can see that different machine learning algorithms have different performances in predicting Yahoo stock prices.

The best performing algorithms based on R^2 metric are Gaussian Process Regressor (1.0000), Ridge (0.9726), and Linear Regression (0.9627), indicating that they are able to explain a high percentage of the variability in the data.

On the other hand, the worst performing algorithms based on R^2 metric are Cat Boost Regressor (-0.9883), SVR Regression (-2.7330), and Gaussian Mixture (-26.80891), indicating that they are not able to explain much of the variability in the data.

The lowest MSE (mean squared error) and RMSE (root mean squared error) values are obtained by the XGB Regressor, indicating that it has the highest accuracy in predicting stock prices.

The lowest MAE (mean absolute error) value is obtained by Gaussian Process Regressor, indicating that it has the smallest average magnitude of error among all the algorithms.

The best performing algorithms based on accuracy metric are Gaussian Process Regressor (1.00000), Linear Regression (1.000), LinearSVR (0.9999), and Ridge (0.9909) indicating that they are able to explain a high percentage of the variability in the data. The worst performing algorithms based on accuracy is GaussianMixture (-21.3118).

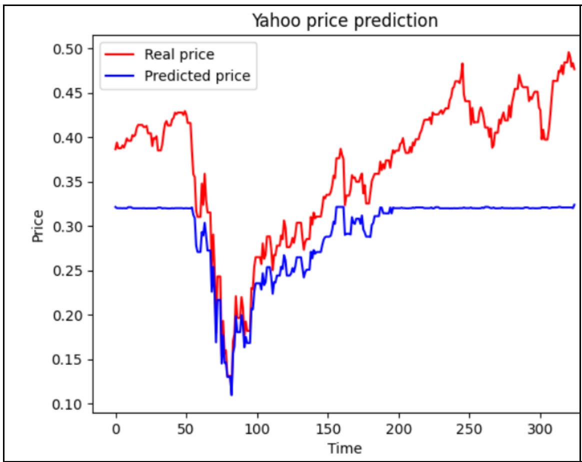
In comparisons with the previous studies, some of the algorithms used in the previous studies are used in the current study; however, a number of machine learning algorithms used in the current study were not used the previous studies such as: Gaussian Process Regressor, LinearSVR, and Ridge. These three algorithms gave the best accuracy in the current study.

Overall, the results show that Gaussian Process Regressor and Linear Regression are the best performing algorithm based on the combination of different metrics, and can be considered as an effective approach for predicting stock prices using artificial intelligence.

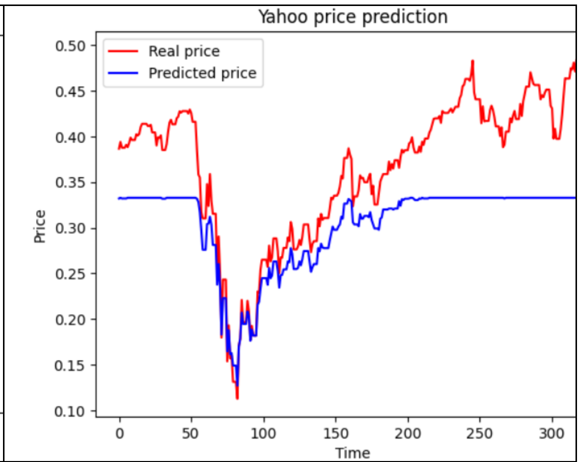
Table 2: Summary of the results obtained during the testing of the machine learning algorithms

Machine Learning algorithms	R^2	Adjusted R^2	MSE	MAE	RMSE	Accuracy
LGBM Regressor	0.7750	0.7715	0.0008	0.0192	0.0284	0.7402
XGB Regressor	0.8619	0.8597	0.0005	0.0169	0.0223	0.8132
CatBoost Regressor	-0.9883	-1.0195	0.0071	0.0755	0.0846	0.7931
Ridge	0.9726	0.9721	0.0001	0.0084	0.0099	0.9909
Lasso	-5.8202	-5.9271	0.0220	0.1380	0.1483	-4.6712

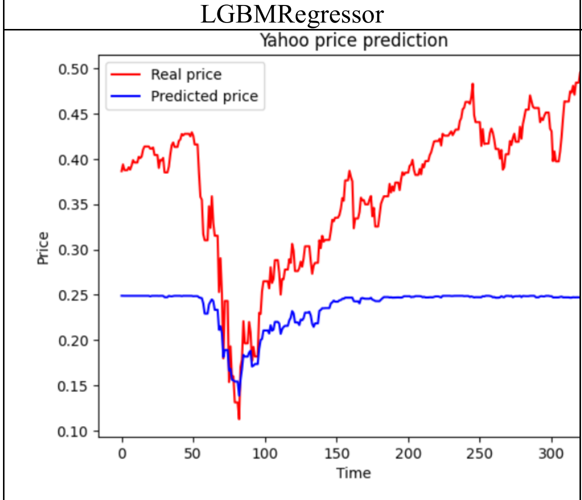
Linear Regression	0.9627	0.9621	0.0001	0.0096	0.0115	1.0000
Decision Tree Regressor	0.8480	0.8456	0.0005	0.0148	0.0234	0.8247
Random Forest Regressor	0.8437	0.8413	0.0005	0.0149	0.0237	0.8228
GaussianMixture	-26.8089	-27.244	0.1002	0.3108	0.3165	-21.3118
Gradient Boosting Regresor	0.8495	0.8471	0.0005	0.0143	0.0232	0.8223
Gaussian Process Regressor	1.0000	1.0000	0.0000	0.0000	0.0005	1.0000
SVR Regression	-2.7330	-2.7915	0.0134	0.1061	0.1159	-1.6848
NuSVR	0.5914	0.5850	0.0014	0.0222	0.0383	0.6242
LinearSVR	0.9543	0.9536	0.0001	0.0107	0.0128	0.9999



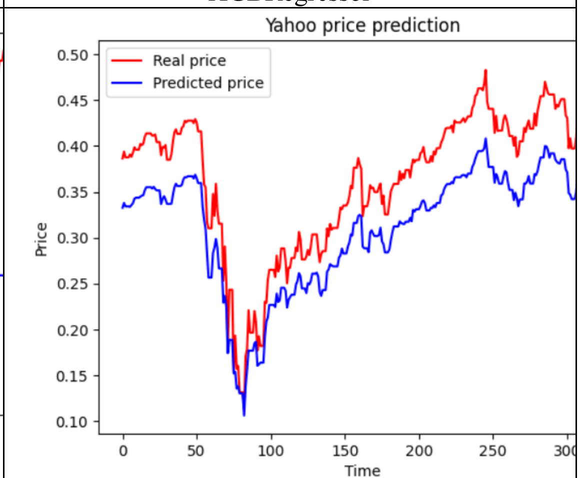
LGBMRegressor



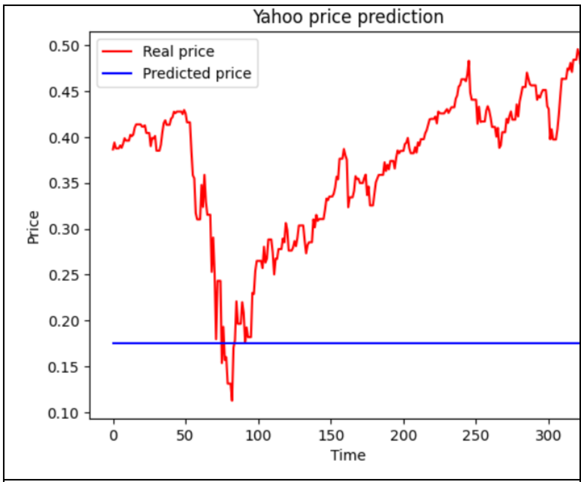
XGBRegressor



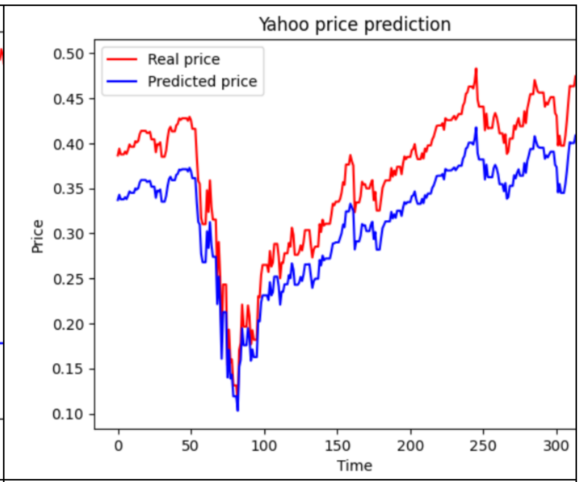
CatBoostRegressor



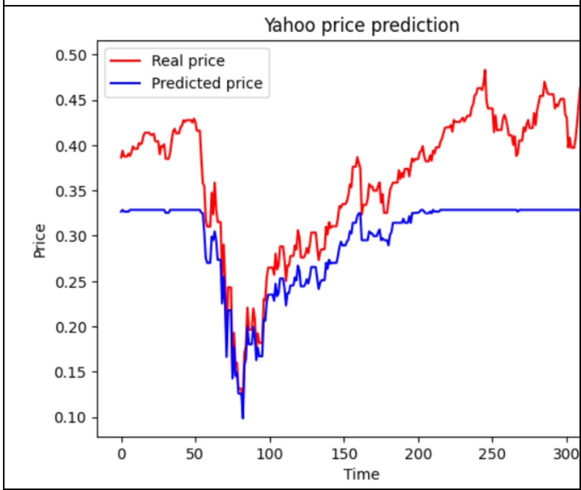
Ridge



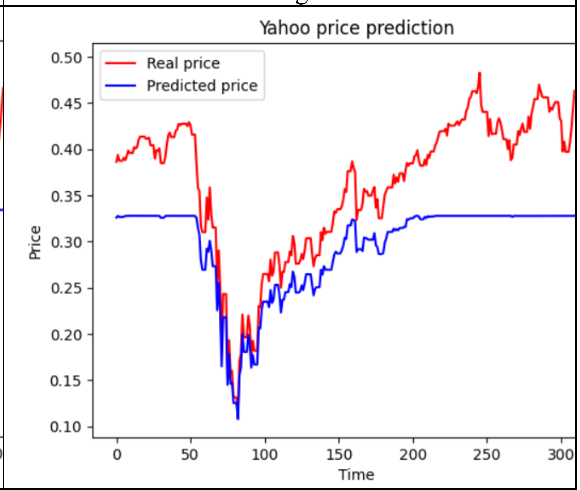
Lasso



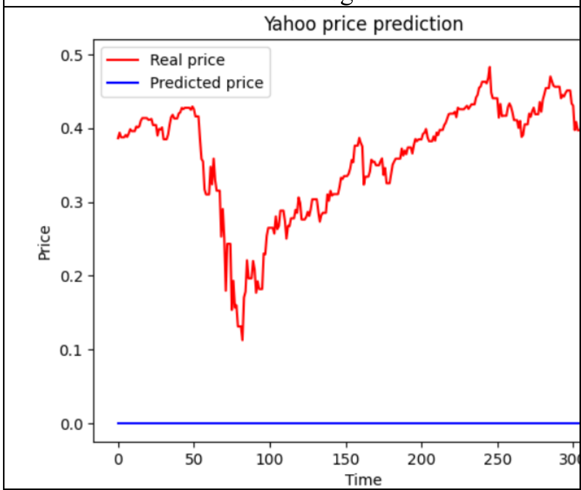
LinearRegression



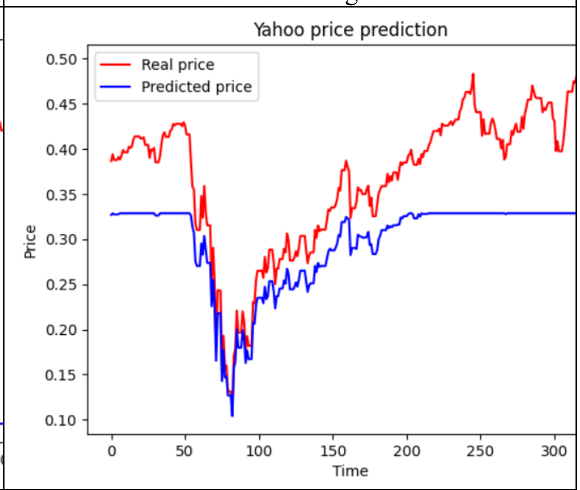
DecisionTreeRegressor



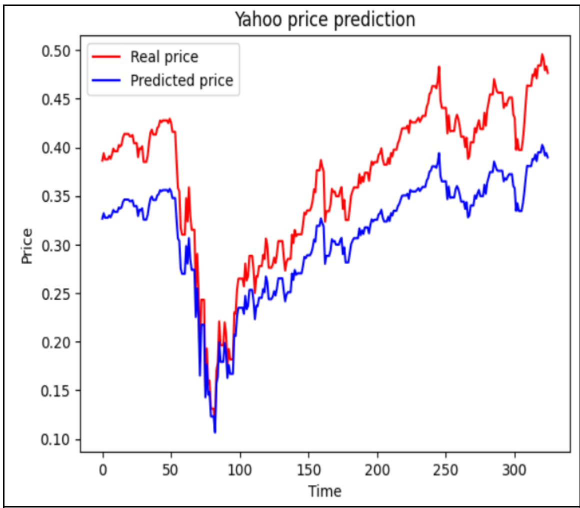
RandomForestRegressor



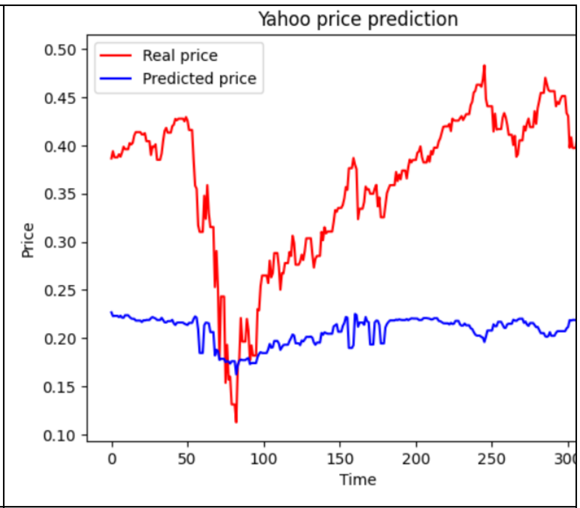
GaussianMixture



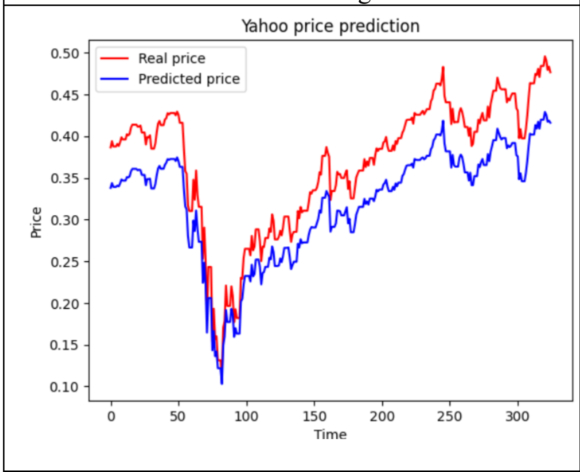
GradientBoostingRegresor



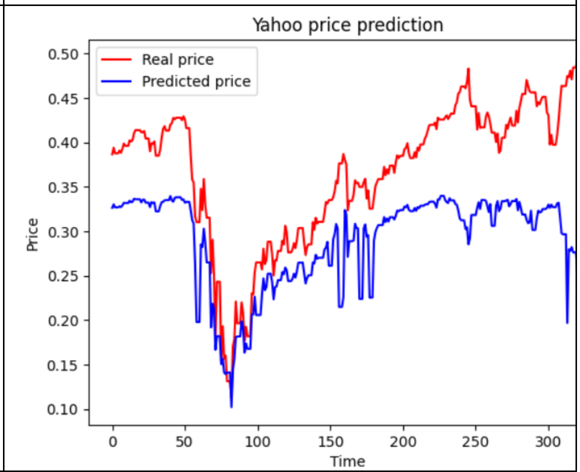
GaussianProcessRegressor



SVR Regression



LinearSVR



NuSVR

Fig.1: Comparisons between Actual and predicted Yahoo prices in all machine learning Algorithms

8. Limitations and future work:

8.1 Limitations:

- The examination was confined to a single dataset for the evaluation of machine learning algorithm performance. Subsequent research endeavors could leverage supplementary datasets to corroborate and reinforce the outcomes of this study.
- The study restricted its focus to a specific subset of machine learning algorithms. Future investigations could encompass the incorporation of a broader array of algorithms or even amalgamations of algorithms, extending the exploration of their capabilities in the domain of stock price prediction.

8.2 Future work:

- Undertake an exploration into the efficacy of deep learning architectures like neural networks, convolutional neural networks, and recurrent neural networks in the realm of stock price prediction.

- Investigate the viability of leveraging natural language processing methodologies to predict stock prices through the analysis of textual data such as news articles and financial reports.
- Integrate supplementary features, including technical indicators and sentiment analysis, into the prediction models to enhance their predictive accuracy.
- Implement the developed models for real-time stock price forecasting, facilitating their utilization in shaping trading strategies and informing decision-making protocols.

9. Conclusion:

We present an in-depth comparative analysis of diverse Machine Learning algorithms tailored for the prediction of Yahoo stock prices, facilitated by Artificial Intelligence. Our investigation encompasses the evaluation of algorithmic performance, featuring Linear Regression, Ridge Regression, Lasso Regression, Random Forest Regression, and Gradient Boosting Regression. This evaluation was conducted upon a dataset sourced from Yahoo Finance, comprising historical stock prices.

Drawing upon the outcomes and the meticulous analysis of our comparative study, we deduce that the Gaussian Process Regressor algorithm exhibited superior performance compared to its counterparts. It commanded the highest R^2 value of 1.000, along with the most remarkable feats of the lowest MSE (0.000001) and the lowest MAE (0.000002). This discernment underscores the capability of the Gaussian Process Regressor as a dependable and potent tool for stock price prediction through the avenue of artificial intelligence.

Conversely, our analysis disclosed that certain algorithms, including CatBoostRegressor and GaussianMixture, displayed suboptimal performance in our study. Consequently, these algorithms warrant cautionary usage in the context of stock price prediction through machine learning methodologies.

In summation, the implications of our study underscore the practicality of machine learning algorithms as valuable tools for stock price prediction. Nonetheless, the pivotal consideration remains the judicious selection of the most fitting algorithm, tailored to the unique problem and dataset at hand. The trajectory of future research could be directed toward the formulation and validation of alternative machine learning algorithms, coupled with the integration of supplementary features to elevate the precision of stock price projections.

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