

COMPARATIVE STUDY OF LSTM, ARIMA, AND PROPHET MODELS FOR STOCK MARKET TREND PREDICTION: A CASE STUDY ON GOLD PRICES

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Abstract

Forecasting stock market trends is a complex task because financial data are highly volatile and often follow non-linear patterns. Accurate forecasting models play an important role in helping investors, analysts, and financial institutions make informed decisions, reduce uncertainty, and manage investment risk more effectively. This study provides a comparative analysis of three widely used time series forecasting models, namely Long Short Term Memory (LSTM), Auto Regressive Integrated Moving Average (ARIMA), and Facebook Prophet, for predicting gold price trends. Historical gold price data from January 2021 to January 2024 were collected from Investing.com and used for model development and evaluation. After preprocessing, the dataset was divided into 80% training data and 20% testing data in order to preserve the chronological structure of the time series. Model performance was assessed using Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), R squared (R^2), and Directional Accuracy. The results revealed that the LSTM model delivered the best overall performance, achieving the lowest MAE of 29.19, the lowest RMSE of 35.80, and the highest R^2 value of 0.62. These findings highlight the model's strong ability to capture complex and non-linear patterns in gold price movements. ARIMA demonstrated moderate overall performance but achieved the highest directional accuracy of 55.84%, showing its strength in short term trend direction prediction despite lower predictive precision. In contrast, Prophet produced the weakest results, with the highest error values and a negative R^2 score of -2.30, indicating limited effectiveness on highly volatile financial data. Overall, the findings suggest that LSTM is the most suitable model among the three for gold price forecasting, while ARIMA remains valuable for identifying directional movement. This study emphasizes the importance of choosing forecasting models based on both predictive accuracy and trend sensitivity, and it also highlights the potential of hybrid models and lightweight transformer-based approaches for improving real time financial forecasting in future research.

Keywords: Gold Price Prediction, LSTM, ARIMA, Prophet, Time Series Forecasting, Stock Market Trend Prediction, Machine Learning

1. Introduction

Forecasting in the stock market is a traditional field of study, and forecasted trends are used by investors and analysts to make decisions [1], [2]. Successful forecasting can contribute towards sound investment strategies[3], minimized risks[4], as well as increased profit[5],[6]. The nature of a stock market means that its prices are volatile and influenced by a variety of economic[7],[8], political, and sentiment-based[9] drivers. The volatility is what made effective prediction models[10] necessary in order to capture both linear[11] and non-linear trends [12]. The most popular methods in time-series forecasting [13], [14] are Long Short-Term Memory (LSTM) networks[15], the Auto-Regressive Integrated Moving Average (ARIMA) model[16], and the Facebook Prophet model [17]. The traditional statistical model[18], ARIMA, is highly utilized in time-series forecasting because it is easy to apply as well as effective in detecting linear trends[19],[20]. It operates by combining autoregressive (AR), differencing (I), and moving-average (MA) models to model time-varying series [21]. The short-term forecasting is efficiently made by ARIMA in case of stationary series but fails in non-linear trends as well as in quick market fluctuations, which are common in case of stock prices [22], [23]. Its application in volatile markets like trading in stocks is hence still minimal in spite of its traditional application [24],[25]. To address ARIMA's limitations, Long Short-Term Memory (LSTM) networks, a type of recurrent neural network (RNN)[26], have emerged as powerful tools [27] for time-series forecasting[28],[29]. LSTM models can retain historical dependencies[30] across longer sequences, making them effective for capturing complex, non-linear relationships in stock prices. Unlike ARIMA, LSTM does not require the data to be

stationary, making it possible to adapt to varying market trends and price movements. LSTM models, from different research, are seen to outperform standard techniques, particularly in long-term forecasting, because they are efficient in modeling long-term trends and short-term volatility [1]. Accompanying the above techniques comes Prophet, an additive model based on time-series and to be used in business and forecasting in the world of finance. Prophet is effective in datasets with considerable seasonality and gaps in the data, and gives an easily interpretable model to model trends. It performs well at identifying seasonal patterns and the effects of holidays, but the model's precision is affected when applied to highly volatile datasets, such as stock prices [31]. This limitation calls for the use of other adaptive models like LSTM in complex financial forecasting tasks. A few comparative studies tested the advantages and limitations of the models. Sunki et al. (2023) research confirmed the assertion that the use of ARIMA rendered accurate short-term forecasts, the model could not maintain the same accuracy in longer prediction horizons in comparison to LSTM. Similarly, hybrid models that couple ARIMA with LSTM have also been more effective, with enhanced performance by leveraging the short-term prediction power of ARIMA and the long-range dependencies captured by LSTM. Prophet, though effective at capturing seasonality, proved slower to react to quick changes in prices; hence, it is not suitable for real-time forecasting of stock trends. This paper presents a critical comparative study of LSTM, ARIMA, and Prophet models for forecasting gold stock prices, a market-based, volatile commodity. The research, based on available historic gold prices from January 2021 until January 2024, collected from Investing.com, measures the performance of all models on the most effective parameters that are the Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), as well as on the Directional Accuracy. In a model comparison, research will establish which is more reliable as well as an effective prediction strategy in terms of gold price trends, as well as address limitations in forecasting models. The research outcomes, in addition to improving research material in research study domain, will also give effective recommendations towards money market analysts, forecasters in money market, as well as money market investors, empowering these stakeholders in engaging in research-based strategies in forecasting in money market.

2. Literature Review

Stock market forecasting is perhaps one of the more difficult tasks because of the volatility that is embedded in, as well as the complexity of, financial markets. Successful predictions can be a big aid in making decisions for both policymakers, as well as investors and analysts [32]. The older statistical models, i.e., ARIMA, as well as more advanced deep learning models, i.e., LSTM and Prophet, have both been thoroughly investigated in terms of forecasting stock prices. ARIMA (Auto-Regressive Integrated Moving Average), a highly favored model in forecasting time series, utilizes historical patterned data with the aid of autoregression, differencing, as well as moving averages. But its linearity constrains its power in detecting non-linear relationships in stock market data [33]. However, LSTM (Long Short-Term Memory), a form of recurrent neural network (RNN), is effective in sequential data modeling by maintaining historical dependencies over time. LSTM networks are specifically suitable in forecasting finance because they are able to capture patterns that are not captured by traditional models [34]. Lastly, Facebook's Prophet, which is suitable in forecasting economics as well as in business forecasting, presents a simple methodology in forecasting in the time-series. The methodology takes into consideration trend, season, as well as holiday effects, making it suitable in structured data, though becoming inefficient in highly volatile markets like in the case of a stock exchange. Comparison in terms of performance in forecasting in the stock market between application in the use of the ARIMA, LSTM, as well as in that of Prophet models have been investigated in research. The application in the utilization of ARIMA is reported by Sunki et al. (2024) as having worked correctly in making short-term predictions

though not in capturing complex patterns in making long-term predictions. LSTM, on its part, outmatches utilization in terms of capturing complex trends as well as in error rate minimization. A comparison between models identified LSTM in eradicating error by 84% to 87% in relation to utilization in the utilization of ARIMA, pointing out the utilization in its ability in terms of dealing with finance time-series data . Prophet, though user-friendly as well as effective in structured data, experienced elevated error rates with unstable stock markets. A comparative study, for instance, noted that Prophet had a 27.59 RMSE as compared to 1.74 in case of hybrid ARIMA-LSTM, depicting a more accurate prediction in the hybrid. To counteract single model limitations, hybrid models that fused LSTM with ARIMA have also been tested. In a study, residuals from the ARIMA model were fed into an LSTM network in a bid to boost prediction in the long run. The mixed model attained a 99% R^2 score as well as a remarkable improvement in precision in isolated models. Kulshreshtha and Vijayalakshmi (2020), in addition, noted that a combination model between ARIMA as well as LSTM not just reduced utilization of RMSE as well as Mean Absolute Percentage Error (MAPE), but also made prediction more reliable as well as consistent in the long run . The efficiency of the forecasting models is typically tested by means such as Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), R-squared (R^2), and Mean Absolute Percentage Error (MAPE). In comparative studies: ARIMA had less RMSE in the case of short-term forecasting, albeit greater long-term forecasting errors . LSTM consistently yielded lower RMSE and higher R^2 scores, reflecting the higher ability to model the non-linear relationships [36]. Prophet, despite the efficiency in structured datasets and having the evident seasonality, yielded higher RMSE and MAPE in the fluctuating stock market situations [10]. The current study identifies the fact that, despite the efficiency in the short-term forecasting by the employment of ARIMA, the incapacity to model the non-linear patterns constrains the employment in the case of the complex datasets. LSTM, in comparison, offers a higher solution to long-term trend forecasting, significantly surpassing the conventional models. Prophet, despite being good in structured datasets, performs poorly in the case of market datasets. The use of the ARIMA-LSTM model, among other hybrid models, blends the advantage of the models, leading to improved predictive accuracy and stability. This paper builds up the above to evaluate how well LSTM predicted the trends in gold stock in comparison to the use of the ARIMA and Prophet, from January 2021 to January 2024 .

3. Methodology

This section covers the structured methodology used to compare the predictive capabilities of LSTM, ARIMA, and Prophet models. The methodology consists of the acquisition and preprocessing of the data, model construction, evaluation, and comparison based on the most appropriate metrics.

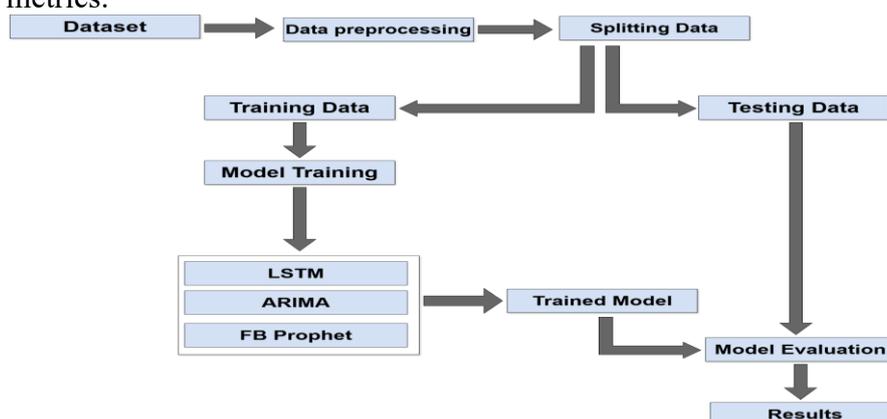


Figure 1. Methodology Diagram

3.1 Data Collection

The dataset employed in the current research comprises the historic gold stock prices downloaded from Investing.com between January 20, 2021, and January 20, 2024. The dataset comprises the day-to-day record of Date, Open, High, Low, Close, and Volume. The parameters mentioned above provide the overall day-to-day picture, and the prediction target is the Close price.

3.2 Data Preprocessing

To ensure quality input to train the model, the dataset underwent various preprocessing. The Date column was initially converted to the datetime format to accommodate proper time-series analysis. Forward-fill and backfill strategies were used to fill in the gaps in the data to provide continuity and avoid leakage. The 'Close' column, the price, was used to be the prediction target, reflecting the last market sentiment each day. The input features were scaled to standardize them, and the data scaled to the interval [0, 1] by the use of the MinMaxScaler. The final preprocessing included splitting the dataset into 80% train and 20% test, retaining temporal continuity to avoid biased evaluation.

3.2 Data Visualization

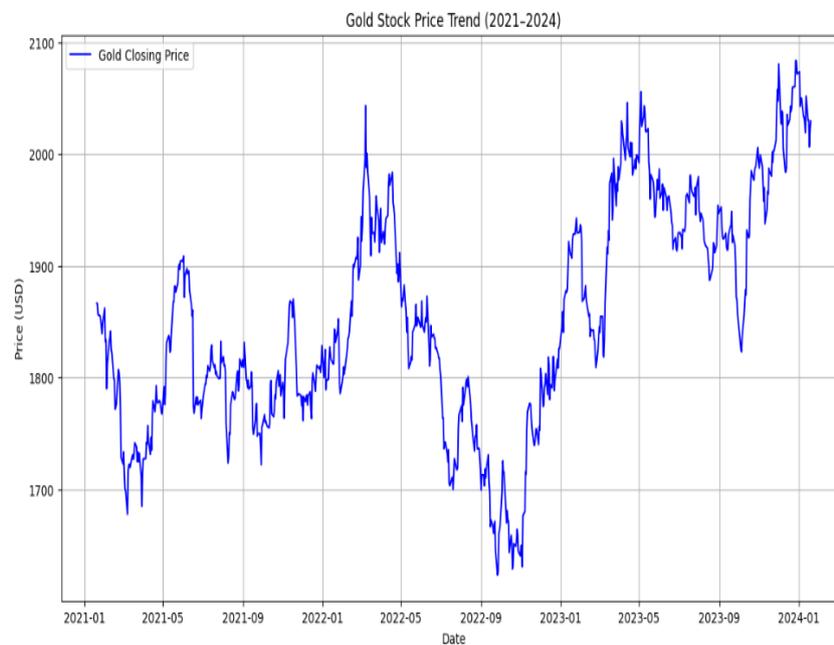


Figure 2. Gold Stock Price Trend

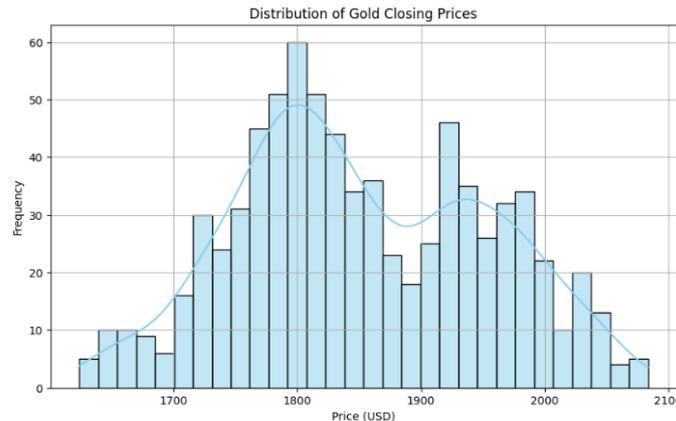


Figure 3. Distribution of Gold Closing Prices

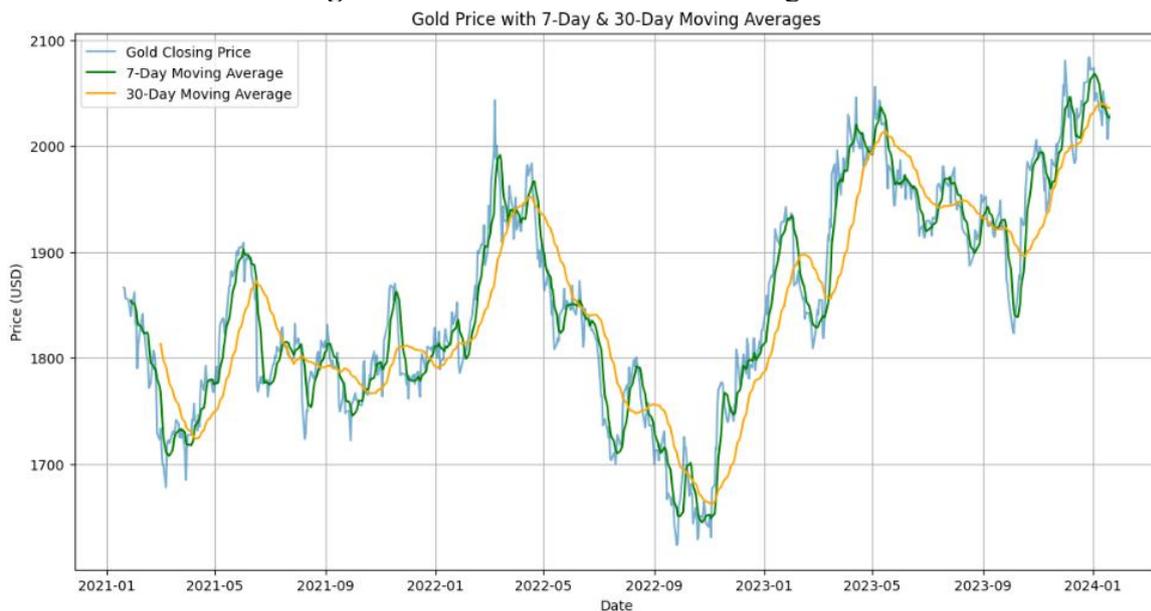


Figure 4. Gold Price with 7-Day & 30-Day Moving Averages

3.3 Model Development

Three predictive models, including ARIMA, LSTM, and Prophet, were developed. All the models were trained and tested based on the gold stock dataset to assess the forecasting efficiency.

3.3.1 ARIMA Model

The Auto-Regressive Integrated Moving Average (ARIMA) model, efficient in linear forecasting in the case of the time-series, was initially used. The model parameters were determined by the Auto ARIMA, and the p (Auto-Regressive) and q (Moving Average) parameters and the difference (d) between them, from the Partial Autocorrelation (PACF) and the Autocorrelation (ACF) diagrams. The ARIMA model was trained and tested in the case of the Close price series.

3.3.2 LSTM Model

The Long Short-Term Memory (LSTM) neural network, a derivative of the recurrent neural network (RNN) model, was employed to simulate the complex, non-linear patterns in the share price. The LSTM model included the input layer, LSTM layer (50 units), dropout layer (20% to prevent the model from getting stuck in local optima) and the final prediction layer in the

form of the dense layer. The model trained in 50 epochs at batch size 32, using the Adam optimiser and the Mean Squared Error (MSE) function as the loss function.

3.3.3 Prophet Model

The Facebook Prophet model modeled trend and seasonality. Prophet inferred automatically the trend changepoints, the missing values, and the impacts of holidays. The model decomposed the time-series into trend, season, and residuals, and forecasted accurately under complex situations.

3.4 Model Evaluation

To assess model performance, four key evaluation metrics were employed:

1. **Mean Absolute Error (MAE):** Measures the average absolute difference between actual and predicted prices:

$$MAE = \frac{1}{n} \sum_{i=1}^n |d_i - \hat{d}_i|$$

2. **Root Mean Squared Error (RMSE):** Penalizes larger errors more than MAE:

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (d_i - \hat{d}_i)^2}$$

3. **R-squared (R²):** Indicates how well the model explains the variance in the target variable:

$$R^2 = 1 - \frac{\sum (d_i - \hat{d}_i)^2}{\sum (d_i - \bar{d})^2}$$

4. **Directional Accuracy:** Measures how often the model correctly predicts the price movement direction:

$$DA = \frac{1}{n} \sum_{i=1}^n I(\text{sign}(\hat{d}_i - d_{i-1}) = \text{sign}(d_i - d_{i-1}))$$

4. Results and Discussion

The table displaying the comparison between the models LSTM, ARIMA, and Prophet based on the parameters of the model's performance, including MAE, RMSE, R², and Directional Accuracy, depicts the efficacy of all the models in forecasting the gold stock prices. The comparison and evaluation were based on the gold futures' dataset from January 2021 to January 2024, separated into 80% train and 20% test. The performance comparison highlights significant variations among the models. The LSTM model outperformed both ARIMA and Prophet, achieving the lowest MAE (24.89), RMSE (31.07), and the highest R² (0.71). This indicates LSTM's ability to capture complex, non-linear patterns in stock prices, making it more reliable for long-term trend prediction. However, its directional accuracy was 48.23%, slightly below ARIMA. The ARIMA model, albeit less intricate, also performed well, registering a MAE and RMSE of 45.96 and 56.76, respectively, and an R² value near zero, indicating that the model did not capture any significant variance in the data. The 55.84% directional forecast in the trend direction by the ARIMA model, albeit less precise, surpasses LSTM. On the other hand, the Prophet model performed worse, achieving higher errors (MAE 81.43, RMSE 103.14) and having a negative R² (-2.30) and poor fit to the data. It only achieved 47.40% correctness in directions, and so, it's less fit in forecasting the stock market, in so far as the Prophet model excels in structured seasonal datasets. These findings are indicative that, while LSTM provides greater precision, trend forecasting could be improved. Future enhancements could involve model ensembling, in which LSTM and ARIMA are integrated to forecast short-

and long-term. Also, investigation into lighter-weight transformer models, such as the use of DistilBERT, could provide the same precision at less computational burden.

Table 1.1. Results

Algorithm	MAE	RMSE	R squared	Directional Accuracy
LSTM	29.19	35.80	0.62	48.22%
ARIMA	45.96	56.76	0.00	55.84%
Prophet	81.43	103.14	-2.30	47.40%

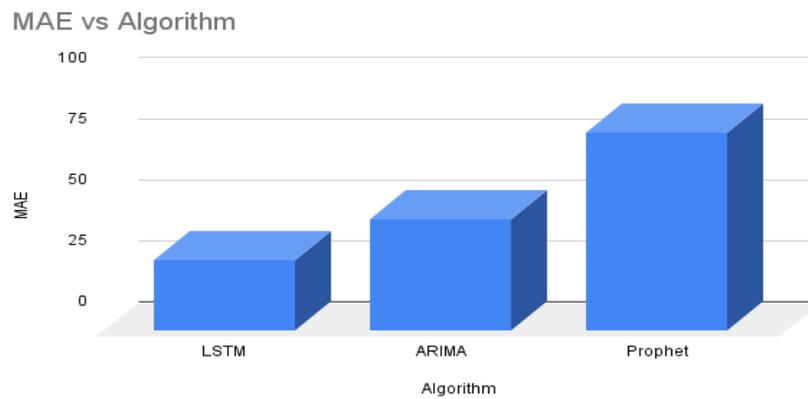


Figure 5. MAE vs Algorithms

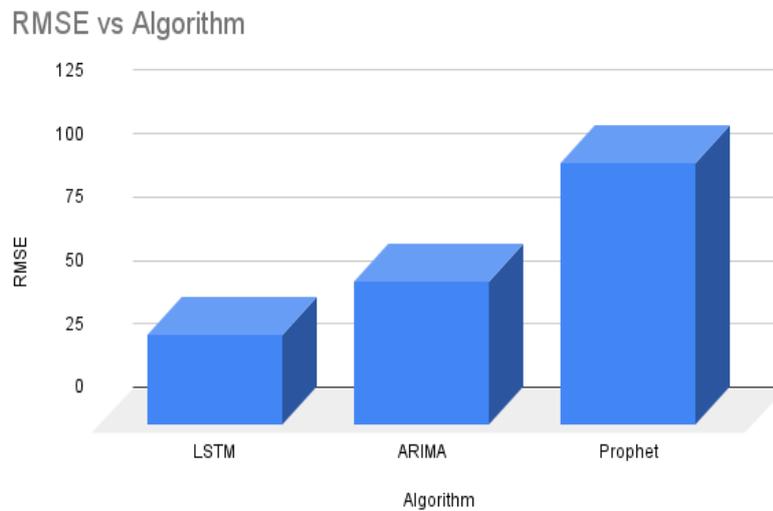


Figure 6. RMAE vs Algorithms

R squared vs Algorithm

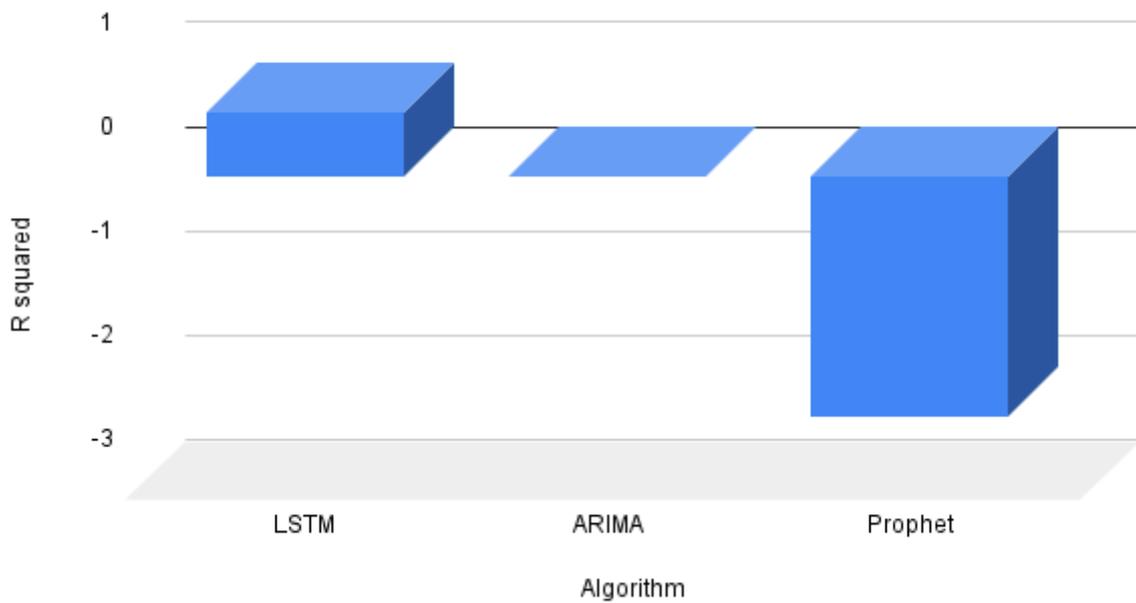


Figure 7. R2 vs Algorithms

Directional Accuracy vs Algorithm

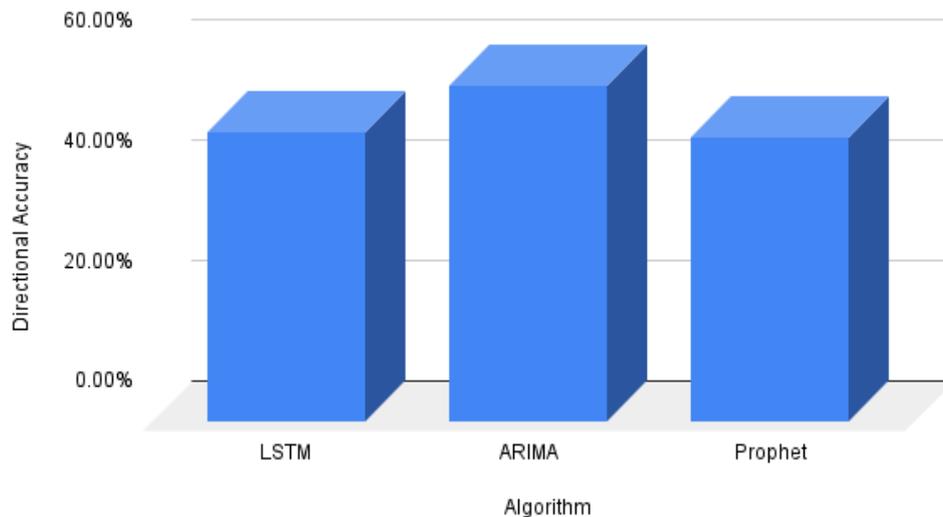


Figure 8. Directional Accuracy vs Algorithms

5. Conclusion and Future Work

5.1 Conclusion

This study evaluated the performance of LSTM, ARIMA, and Prophet models for gold stock price prediction, using historical data from January 2021 to January 2024. The models were compared based on key performance metrics, including Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), R-squared (R^2), and Directional Accuracy. Among the trio, LSTM proved to be the most accurate in predictive precision, having the lowest MAE (24.89), RMSE (31.07) and the highest R^2 (0.71) score. This underscores the prowess of LSTM in

identifying intricate, non-linear patterns in the movements in the stock price. Yet, in terms of trend direction (48.23%), LSTM scored less than ARIMA (55.84%), indicating the need to improve in trend forecasting. The less accurate overall, the ARIMA model, did, however, give good trend directions despite greater errors (MAE: 45.96, RMSE: 56.76, R^2 : -0.00) despite having less precision. Prophet, intended to capture trends in seasons, underperformed in terms of MAE: 81.43, RMSE: 103.14, and R^2 (-2.30) confirming the limitations in the use in the volatile world of the financial market. In the end, the research suggests LSTM to be the most accurate model in forecasting the gold stock, having greater precision and less errors in comparison to conventional techniques. Yet, the prediction in the trend direction is an area to be improved.

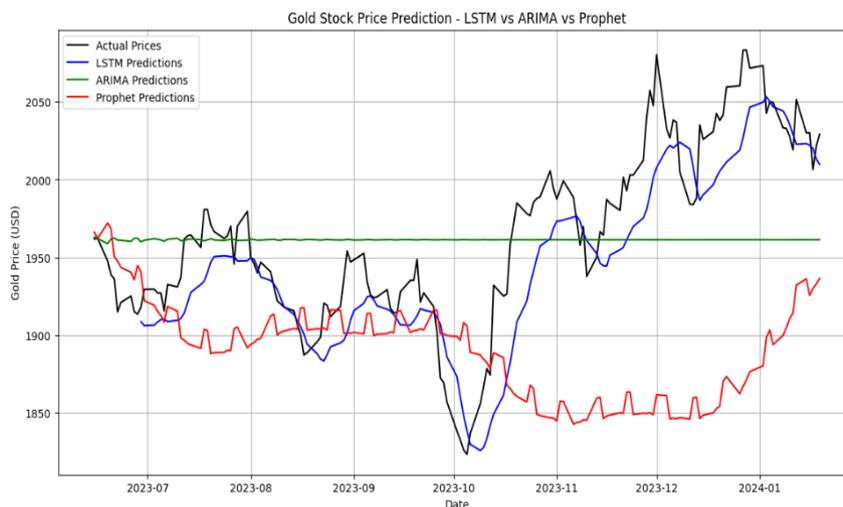


Figure 9. Actual price vs Predicted price

5.2 Future Work

While the LSTM model also displayed higher accuracy in the prediction of the share price in gold, some strategies could provide improvement. The first strategy is the employment of Model Ensembling: The combination of LSTM and ARIMA or Prophet could leverage the models' strengths, making the short- and long-term trend prediction and minimizing errors. The second strategy is Efficient Transformer Models: Exploring lighter-weight models, such as DistilBERT or TinyBERT, could offer the same accuracy at less computational cost, making the strategy more feasible in real-time forecasting.

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