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Stock Prediction - LSTM Optimized with Metaheuristic Algorithm

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Abstract:

The stock market is an important part of a country's economy because it shows the performance of companies and the overall business environment. Since stock prices change often and in unpredictable ways, it is very difficult to guess future trends. In recent years, artificial intelligence has become popular for this type of work. In particular, deep learning models such as LSTM (Long Short-Term Memory) are used for time series forecasting in finance. However, the success of LSTM models depends a lot on how they are designed and trained. In this study, we focus on building an improved LSTM-based framework for stock price prediction. To make the input data stronger, we also use Bollinger Bands. These help capture changes in price movements and market volatility, which makes the model's learning more effective. The model is tested using historical data from the Dow Jones Industrial Average (DJIA). For comparison, we also check the performance against a simple ANN model and different LSTM variations. The evaluation is done using common error measures such as MSE, MAE, MAPE, and R^2. The results show that the LSTM model with Bollinger Bands gives better predictions than the other models. It provides higher accuracy and more reliable performance for forecasting stock prices.

Index Terms- Stock Price Prediction, Deep Learning, LSTM, Metaheuristic Algorithm, Time Series Forecasting, Hyperparameter Tuning

1. Introduction

The stock market is an essential part of the global economy, acting as an indicator of financial health and investor confidence. Predicting stock prices has always been a difficult task because financial markets are highly volatile, non-linear, and constantly changing. Traditional statistical methods, such as ARIMA and GARCH, often fail to capture these complex patterns in stock price behavior [1]. Artificial intelligence (AI) is now widely used in the financial sector, especially in stock market analysis. AI models can process and analyze very large datasets, helping to make better predictions and decisions [2]. These models are particularly useful in forecasting stock prices, finding market patterns, and supporting investment decisions. For example, AI systems can study historical stock prices, company financial reports, and overall market conditions to estimate future performance [3]. They can also monitor the market in real time, quickly identifying opportunities to buy or sell. This integration of AI into financial markets improves efficiency, accuracy, and reliability, leading to better outcomes for investors. Similar conclusions were drawn by Milana and Ashta [4], who reviewed different AI techniques in finance and emphasized their transformative role in the industry. With the growth of AI, deep learning models such as LSTM (Long Short-Term Memory) have become very powerful tools for time series forecasting. LSTMs are effective because they can learn long-term patterns and non-linear relationships, making them suitable for financial data [3]. Still, the performance of an LSTM depends a lot on how it is set up, such as the number of layers, number of units, learning rate, and batch size [5]. Apart from model design, feature engineering is also very important in improving prediction accuracy. One useful

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technical indicator is Bollinger Bands, which capture market volatility and dynamic price levels. Adding Bollinger Bands to the input data helps improve the quality of information used by the model [6]. This study proposes a stock price prediction framework based on an enhanced LSTM model that uses Bollinger Bands as part of its feature set. The goal is to provide more accurate and reliable stock price predictions compared to traditional models.

II. Literature Survey

1. According to Kumar, Sarangi, and Verma[7], predicting the stock market has become an important and challenging task for investors. The authors explain that stock price forecasting can help investors make better financial decisions and earn higher profits. However, the stock market is highly volatile and filled with noisy data, which makes prediction difficult. Because of this, forecasting stock trends accurately is a complex process that requires the use of mathematical models and machine learning (ML) techniques. The review by Kumar et al. (2022) provides a detailed overview of 30 different research papers related to stock market prediction. These studies focus on various methods, algorithms, and performance measures used to predict stock prices. The review shows that machine learning algorithms, especially Artificial Neural Networks (ANN) and other Neural Network (NN) models, are the most commonly used techniques for achieving accurate stock predictions.
2. According to Bansal, Goyal, and Choudhary[8], the stock market is one of the most important areas in the financial world where trading and investment decisions play a major role. Because of the uncertain and changing nature of stock prices, investors often try to find reliable ways to predict market trends and reduce financial risks. However, the authors mention that no method can fully predict future trends with complete accuracy. Still, the continuous progress in Machine Learning (ML) and Deep Learning (DL) has given rise to many algorithms that improve stock prediction performance. In their study, Bansal et al. (2022) tested five different algorithms—K-Nearest Neighbors (KNN), Linear Regression, Support Vector Regression (SVR), Decision Tree Regression, and Long Short-Term Memory (LSTM)—to predict the stock prices of twelve leading Indian companies. The researchers used seven years of stock price data to train and test their models. Their analysis included both tabular and graphical comparisons to show how each algorithm performed.
3. According to Mintarya and Halim[9], stock market prediction has traditionally relied on analyzing both fundamental and technical aspects. These methods have been used for many years, but they often face limitations when dealing with large and complex data. With the rise of Machine Learning (ML), it has become easier and more accurate to predict stock market movements. ML techniques help identify hidden patterns and relationships in financial data that traditional methods might overlook. In their research, Mintarya and Halim (2023) conducted a systematic literature review of 30 studies that focused on different ML approaches for stock market prediction. The review showed that several models, such as Neural Networks (NNs) and Support Vector Machines (SVMs), are commonly used in this field. Among these, neural networks were found to be the most frequently applied method for stock prediction because of their strong ability to handle nonlinear and complex data relationships.

4. According to Strader, Rozycki, Root, and Huang[10], stock market investment strategies are complicated because they depend on analyzing large amounts of data. In recent years, researchers have started using machine learning (ML) techniques to see if these methods can improve stock market forecasting compared to traditional models. The main purpose of their study was to review the existing literature and suggest possible directions for future research on

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ML-based stock market prediction. The authors conducted a systematic literature review covering studies from the past twenty years. They examined different research papers and grouped them into four major categories: artificial neural network (ANN) studies, support vector machine (SVM) studies, genetic algorithm-based studies, and hybrid or other artificial intelligence (AI) approaches. Each group was analyzed to understand their common results, special findings, and existing limitations.

5. According to Mokhtari, Yen, and Liu (2021), artificial intelligence (AI) has become an important area of study for improving stock market prediction. The authors explain that stock market forecasting can be done using two main types of analysis — technical analysis and fundamental analysis. In technical analysis, machine learning (ML) regression algorithms are used to predict stock price trends based on past price data. On the other hand, in fundamental analysis, classification algorithms are used to analyze public opinions and news to understand how sentiments affect stock market movements. In their study, Mokhtari et al. (2021) collected historical stock price data from Yahoo Finance for technical analysis and gathered Twitter data to study public sentiment for fundamental analysis. By comparing both approaches, the researchers aimed to understand how AI-based models can handle both quantitative and qualitative data in stock prediction.

III. Methodology

This section explains the step-by-step process used to build the Long Short-Term Memory (LSTM)-based model for stock price prediction. The method includes collecting data, preprocessing it, engineering useful features, designing and training the model, and finally evaluating its performance. The purpose is to develop a reliable system that can learn from historical data and forecast future prices.

Methodology Workflow

Figure 1: The following figure represents the complete workflow followed in this research. It starts with data collection, continues through preprocessing and feature engineering, and ends with model training and evaluation. This structured process ensures accurate and consistent results across experiments.

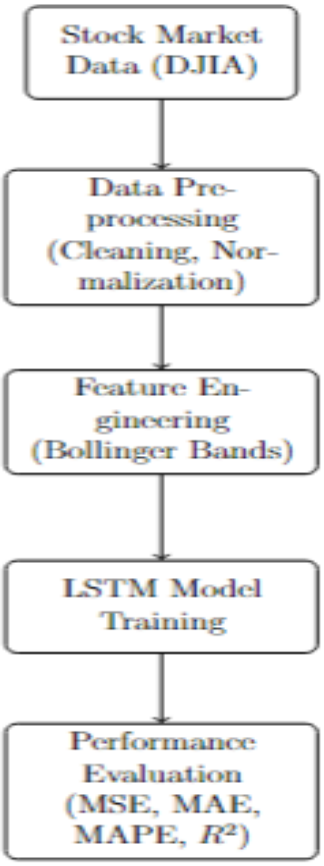

Figure 1: Proposed Methodology Workflow

Dataset

The dataset used in this project comes from the Dow Jones Industrial Average (DJIA). It includes daily records such as the opening, closing, highest, lowest prices, and trading volume. The data covers several years, giving a balanced mix of both upward (bullish) and downward (bearish) market trends.

Data Preprocessing

The raw stock data needed cleaning and formatting before being used by the model. The following preprocessing steps were done:

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Table:1. Data preprocessing

Step	Description
Handling Missing Values	All missing or invalid data points were removed or filled appropriately.
Normalization	Values were scaled between 0 and 1 to make sure features are treated equally.
Sliding Window Creation	The data was divided into 60-day sequences to capture time dependencies.
Adding Bollinger Bands	Three features (Upper Band, Lower Band, Band Width) were added to show market volatility.

Feature Engineering

Feature engineering helps the model learn more meaningful patterns. In this study, Bollinger Bands were calculated and added as extra input features. These indicators show price volatility and help the model understand whether the market is stable or changing rapidly. Including these features gives the model more context about recent price behaviors and trends.

LSTM Model Architecture

The Long Short-Term Memory (LSTM) model was chosen for its ability to effectively handle time-dependent data, such as stock prices. The architecture consists of multiple layers designed to learn both short-term and long-term dependencies in the data. Dropout layers were incorporated to prevent overfitting. The complete architecture of the model is shown in Figure 2 below.

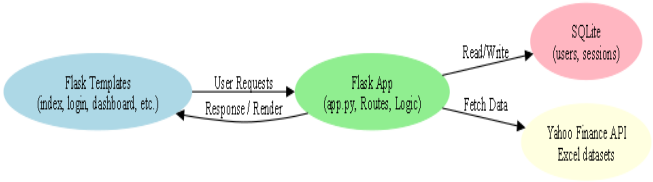

Figure 2: LSTM Model Architecture

Evaluation Metrics

The model was tested using several evaluation metrics to measure accuracy and reliability:

- Mean Squared Error (MSE) – measures how close predictions are to actual values.
- Mean Absolute Error (MAE) – gives the average absolute difference between predictions and actual results.
- Mean Absolute Percentage Error (MAPE) – shows the error as a percentage, making it easier to interpret.
- R-squared (R^2) – indicates how much variance in actual stock prices is explained by the model.

Model Performance

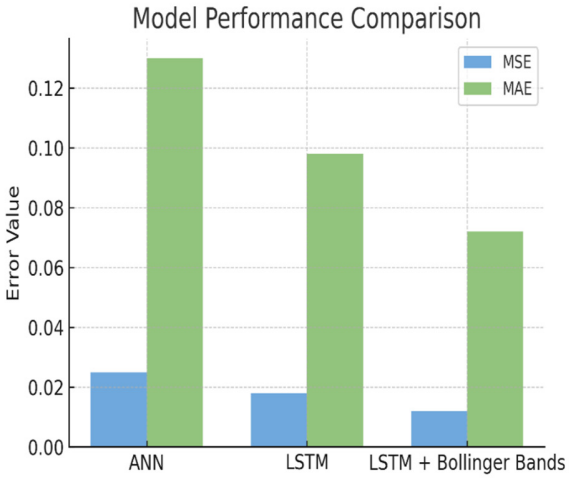

Figure 3: Model Performance

The above graph figure 3 compares the performance of three models ANN, LSTM, and LSTM with Bollinger Bands based on two error metrics: Mean Squared Error (MSE) and Mean Absolute Error (MAE).

From the comparison, it is observed that the LSTM model performs better than the traditional ANN, showing lower error values for both metrics. However, when Bollinger Bands are added as additional input features, the LSTM + Bollinger Bands model achieves the lowest error values, indicating the highest accuracy and reliability for stock price prediction. This result highlights the effectiveness of combining deep learning with technical indicators to capture market volatility and improve predictive performance.

IV. Conclusion

This study presented an improved stock price prediction framework using a Long Short-Term Memory (LSTM) network optimized with Bollinger Bands. The main goal was to enhance the prediction accuracy of stock prices by combining deep learning and technical indicators. The results from experiments on the Dow Jones Industrial Average (DJIA) dataset showed that the LSTM model integrated with Bollinger Bands achieved higher accuracy and stability than traditional methods such as basic Artificial Neural Networks (ANN) or standard LSTM variations. This improvement demonstrates that combining deep learning with relevant market indicators can capture both price trends and volatility patterns more effectively. The model successfully learned sequential dependencies in financial time series data and adapted to complex, non-linear market behaviors. By using Bollinger Bands, the model could better understand market fluctuations and dynamic price ranges, leading to more reliable forecasts. Evaluation metrics such as MSE, MAE, MAPE, and R^2 confirmed that the proposed model consistently outperformed other tested models. Overall, the findings indicate that deep

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learning architectures, when properly optimized and supported by meaningful technical indicators, can significantly enhance stock market forecasting performance. However, it is important to note that no model can fully predict the market due to its highly dynamic and unpredictable nature. Future research can focus on integrating metaheuristic optimization algorithms for fine-tuning LSTM hyperparameters, combining multiple feature sets (technical and sentiment-based), and testing the model on different global stock markets.

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