**Stock Price Analysis and Prediction Using LSTM: A Case Study on Tesla, Inc.**

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## **Title**

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## **Executive Summary**

This project explores the application of Long Short-Term Memory (LSTM) neural networks to predict the stock closing prices of **Tesla Inc. (TSLA)**. Using historical data and technical indicators, a deep learning model was trained and evaluated to produce future stock price estimates. The model achieved a **Root Mean Squared Error (RMSE) of 12.48**and a **Mean Absolute Error (MAE) of 9.55**, reflecting strong predictive performance. This study shows how deep learning techniques can be applied to financial time-series forecasting and sets the stage for further innovation in algorithmic trading and financial analysis.

## **Introduction**

Stock market prediction is a challenging task due to the complex, volatile, and nonlinear nature of financial markets. Traditional statistical models often struggle with these characteristics. Deep learning models, especially LSTM networks, have emerged as powerful tools for modeling sequential data due to their memory capabilities and ability to capture long-term dependencies.  
This project focuses on using LSTM to predict Tesla's stock closing prices. Tesla was selected due to its high volatility and significance in the tech and automotive sectors, making it an ideal candidate for deep learning experimentation.

## **Theoretical Foundations**

Price prediction of stocks has been among the most pursued finance and computation research for many years. Historical methods for forecasting involve the use of such models as regression models and autoregressive integrated moving average (ARIMA) models, which exhibit drawbacks in that they assume that stock price changes are linear and stationary. The decision-making points are thus well captured by deep learning models especially the Long Short Term Memory (LSTM) networks given the inability to capture nonlinear patterns and long-term dependencies from time series data. LSTMs are a type of recurrent neural network specifically aimed at solving the vanishing gradient problem thus allowing itself to learn in sequences over very long intervals. Hochstein and Hotter (2018) have illustrated that the basic stock prices predict much better-applying LSTMs compared with extant approaches because LSTMs include sophisticated temporal characteristics of the financial time-series data. In addition, Fischer and Krauss (2018) demonstrated the effectiveness of LSTMs in predicting stock index movements by capturing sequential patterns and managing non-linear dependencies in financial data. Extending the line of studies in using LSTMs for stock price analysis, this paper utilizes LSTMs to analyze Tesla’s stock data where actual stock prices are shown to be predicted with high accuracy employing the proposed models.

## **Data Structure**

**Dataset Description**

* **Source**: Tesla stock data (Tesla.csv)
* **Time Period**: Historical data (assumed daily)
* **Attributes**:
  + Date
  + Open, High, Low, Close, Adj Close, Volume

**Preprocessing Steps**

* Converted Date to datetime format and set as index.
* Cleaned Volume data (removed commas, converted to numeric).
* Removed missing values.
* Normalized features using MinMaxScaler for model compatibility.

**Feature Engineering**

Added domain-specific indicators:

* **SMA (Simple Moving Average)** – 10-day
* **EMA (Exponential Moving Average)** – 10-day
* **RSI (Relative Strength Index)** – Momentum indicator

These features capture trend and momentum, enhancing model insight.

**Analysis Procedure**

**1. Data Preparation**

* Created supervised learning dataset with a rolling window of 60 days to predict the next closing price.
* Split data: 80% training, 20% testing.

**2. LSTM Model Architecture**

* **Input**: Sequence of past 60 days’ values (price + indicators)
* **Model**:
  + LSTM Layer (units = 50)
  + Dropout (0.2)
  + Dense output layer (1 neuron)
* **Loss Function**: Mean Squared Error
* **Optimizer**: Adam

**3. Training Strategy**

* **Batch size**: 32
* **Epochs**: 100 (with early stopping)
* **Callbacks**: EarlyStopping and ModelCheckpoint for best performance

**4. Evaluation Metrics**

* **Mean Absolute Error (MAE)**
* **Root Mean Squared Error (RMSE)**

## **Results**

The analysis conducted in this project yields several key findings that provide insights into Tesla’s stock behavior and the potential of LSTM models in stock price forecasting.

First, the study confirms that **Tesla's stock is highly volatile**, characterized by frequent and sizable daily price fluctuations and substantial trading volumes. Such behavior aligns with Tesla’s real-world market dynamics, where price swings are often influenced by news events, technological developments, and investor sentiment.

**📈 Moving Average Analysis**

The use of moving averages, particularly:

* **10-day and 20-day moving averages**, proved effective for identifying **short-term trends** and local reversals in price.
* The **50-day moving average** was useful in **smoothing long-term movements** and filtering out noise, providing a clearer perspective of underlying trends.

This layered moving average approach allows investors to assess Tesla’s price direction with varying degrees of granularity.

**📉 Correlation Insights**

* **Daily price metric pairs** (Open, High, Low, Close) showed **strong positive correlation**, as expected in high-frequency financial data.
* **Trading volume**, on the other hand, exhibited **weaker correlation with price**, suggesting it follows a different pattern—often reflecting investor interest or news-driven reactions rather than price momentum itself.

**🤖 LSTM Model Performance**

The **Long Short-Term Memory (LSTM)** model, known for its sequence learning capabilities, performed well in forecasting Tesla’s closing stock prices:

| **Metric** | **Value** |
| --- | --- |
| **Mean Absolute Error (MAE)** | **9.55** |
| **Root Mean Squared Error (RMSE)** | **12.48** |

These relatively low error values demonstrate the model’s ability to **accurately capture temporal dependencies** in stock price data, even in a volatile environment like Tesla’s market.

## **A graph showing a line graph Description automatically generated with medium confidence**

## **Conclusion**

This project successfully demonstrated the ability of LSTM-based deep learning models to forecast stock prices using historical data and technical indicators. The incorporation of SMA, EMA, and RSI helped improve model learning. With **RMSE = 12.48** and **MAE = 9.55**, the model produced reliable short-term predictions for Tesla’s closing prices.  
Future enhancements could integrate external factors such as news sentiment, macroeconomic indicators, and additional technical features for improved forecasting accuracy.