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A Parameter Based Comparative Study of Deep Learning Algorithms for Stock Price Prediction

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Abstract—Stock exchanges are places where buyers and sellers meet to trade shares in public companies. Stock exchanges encourage investment. Companies can grow, expand, and generate jobs in the economy by raising cash. These investments play a crucial role in promoting trade, economic expansion, and prosperity. We compare the three well-known deep learning algorithms, LSTM, GRU, and CNN, in this work. Our goal is to provide a thorough study of each algorithm and identify the best strategy when taking into account elements like accuracy, memory utilization, interpretability, and more. To do this, we recommend the usage of hybrid models, which combine the advantages of the various methods while also evaluating the performance of each approach separately. Aim of research is to investigate model with the highest accuracy and the best outcomes with respect to stock price prediction.

Keywords- Accuracy, Algorithms, CNN, Comparison, GRU, LSTM, Prediction, Stock.

I. INTRODUCTION

Accurate forecasting of the stock market can be challenging due to its complexity and dynamic nature. For financial organizations and investors trying to make wise judgments, the capacity for precise prediction is essential. To forecast stock market patterns and movements, a variety of algorithms and methods have been created over time [1] [2]. The purpose of this research article is to examine and assess the performance of three widely used stock market prediction algorithms. We'll be evaluating and contrasting the performance of several methods, including LSTM (Long-short Term Memory), GRU (Gated Recurrent Unit), CNN (Convolutional Neural Network), and their hybrid models, on a dataset of historical stock market data. The ability of each algorithm to forecast future stock prices and market movements will be assessed [3][4]. By comparing the performance of these algorithms, we hope to provide insights into which techniques are most effective in predicting stock market movements. Overall, the results of this study will be of interest to investors, financial analysts, and anyone looking to gain a better understanding of how different stock market prediction algorithms compare in terms of accuracy and reliability.

The proposed work has the following contribution:

1. The proposed research work is a detailed analysis of LSTM, GRU, CNN, LSTM-GRU, and LSTM-CNN models for publicly available stock datasets for 12 years.
2. The proposed research work compares the algorithms over two metrics i.e., RMSE and MSE values.
3. The proposed research work in turn will be valuable for professionals and organizations looking to adopt deep learning in their operations and also will guide the readers in making informed decisions regarding which algorithm is most suitable for their specific needs and criteria.

The remaining section of this paper is structured as follows: Section 2 discusses the related work done by the authors earlier. Section 3 focuses on the proposed work with the datasets and the various models and algorithms related to our work with respective graphs and tables. In section 4 authors discuss a comparative analysis of all the models. Section 5 concludes the work and is followed by the references for this paper.

II. RELATED WORKS

There is a lot of research on stock market forecasting and

LSTM. Almost all data mining and forecasting techniques have been used to predict stock prices. Many different functions and attributes were used for the same purpose.

Authors in [5] have proposed a CNN-LSTM-based model for predicting stock prices. In this, the stock price has been predicted using LSTM using feature data that has been mined [21][22][49]. The studies' findings indicate that CNN-LSTM can offer accurate stock price predictions that are trustworthy. The experimental results show that CNN-LSTM has the best

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prediction accuracy and performance [23]. The shortcomings of this method are that it doesn't consider the impact of the data on stock prices[24] and their closing prices do not take into account psychological considerations [25][26] [48] like news and national policies and forecasting.

Authors [6] have proposed a cutting-edge model for predicting the price of cryptocurrencies using GRU, LSTM, and bi-LSTM [27][28]. The study found that a gated recurrent unit (GRU) model performed better in predicting the prices of three cryptocurrencies (Bitcoin (BTC), Litecoin (LTC), and Ethereum (ETH)) than the bidirectional LSTM (bi-LSTM) and LSTM models. GRU's forecast for LTC was the most precise, coming in at a mean absolute [29] [30] percentage error of 0.2454%. However, bi-LSTM showed the lowest prediction results compared to the other two algorithms. The results indicate that AI algorithms [31][32] can be reliable for cryptocurrency price prediction and the GRU model can be considered the best for the targeted cryptocurrencies[33][34]. The authors recommend further investigation into other elements, such as trade volume, tweets, and social media, which may also have an impact on cryptocurrency values[35][36].

In this paper [7] the effectiveness of three stock price prediction models is compared. This study compares the performance of three models for stock price prediction: Support Vector Machines (SVM)[37], Artificial Neural Networks (ANN) and Long Short-Term Memory (LSTM), and Gated Recurrent Unit (GRU) models. The study found that the LSTM model had the best performance with the ratio of optimism [38] to pessimism with the lowest average value, highest R2 score, and RMS error. The GRU model had almost similar results to the LSTM model but with a larger optimism ratio, which denotes a greater degree of forecast uncertainty [39][40]. The ANN model performed the worst, showing worse performance and greater volatility with a higher RMS error and a lower R2 score [41][42]. The study found that standardization of the data improved the performance of the models and introduced the use of GRU models and Independent Component Analysis (ICA) for price predictions, which have not been use before [43].

Authors [8] have a graph-based CNN- LSTM stock price prediction algorithm to achieve a more accurate stock price prediction. It creates an array of historical data sequences and their primary indicators (futures and options), using the array as input to the CNN structure and extracting certain feature vectors through the convolution layer and the pooling layer, and using the extracted feature vectors as input to the LSTM vector. As a result, The SACLSTM is designed to employ a range of news sets, including futures, options, historical data, and the LSTM stock sequence table convolution algorithm to predict stocks. It has been confirmed that the neural network structure in combination with convolution and long-term memory units leads to improved performance of statistical methods and traditional CNNs and LSTMs in prediction tasks.

In this research work [9] analysis has been done in the use of regularized GRU-LSTM in stock price prediction. In this, the authors have proposed a GRU-LSTM model fitted and applied to a short-term prediction of the closing price of two stocks. The experimental results have shown that the proposed model has better results in short-term forecasts with high prediction accuracy and high convergence speed but sometimes the stability is relatively poor hence, the neighbour step is to find an optimization method to improve the stability of the model.

The research work of [10] includes stock price predictions based on optimized LSTM and GRU models. A new model has been designed to optimize inventory forecasting. A variety of technical indicators have been considered, including indicators of Using LASSO and PCA deep learning techniques, dimensionality reduction of numerous aspects affecting the resultant stock price has been carried out, including investor sentiment and financial data. Also, a comparison of the effectiveness of LSTM and GRU for stock market projections based on different metrics has been carried out. The According to experimental findings, both LSTM and GRU models may be used to accurately predict stock values. For various resizing techniques, the prediction outcomes of two neural network models employing LASSO resizing are often superior to those using PCA resizing data. There were no financial or commercial ties present during the research's execution.

The paper [11], [12] contains the study of stock price prediction using Bi-LSTM and GRU-based Hybrid Deep Learning Approaches. The paper describes a proposed hybrid deep learning model for predicting stock market prices, which combines a Bi-LSTM network and a GRU network with a 1D CNN. The performance of this hybrid model is compared to individual models of LSTM, Bi-LSTM, GRU, and traditional neural network (NN) using NIFTY-50 stock market data. The results showed that the suggested hybrid Bi-LSTM-GRU [46] model outperformed the individual models for predicting the opening prices of the ASIANPAINT Company. The model was also able to accurately predict future prices for 100, 300, 500, and 1000 days. The authors plan to further improve the model by incorporating both traditional and deep learning-based methods and considering low-frequency and high-dimensional data.

In all the above works various algorithms have been used, each with a different outcome. In each of them, one algorithm is taken and they have analyzed the algorithms concerning

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their datasets. Some have proposed their methodologies as well. But there was no room for comparison in those works. A comparative analysis has become important as no such work was encountered by us during our research.

III. PROPOSED WORK

We have covered several stock prediction algorithms in this work, including LSTM, GRU, and CNN. Using datasets from various companies, each method and hybrid model is used, and a graph is produced. We compared the outcomes of all the models in the end and concluded.

First, the pre-processed dataset has been taken and the dataset is run through various algorithms. Based on the value obtained after the execution of each dataset a graph has plotted on RMSE and MSE metrics. figure 1 describes the workflow of the proposed comparative study.

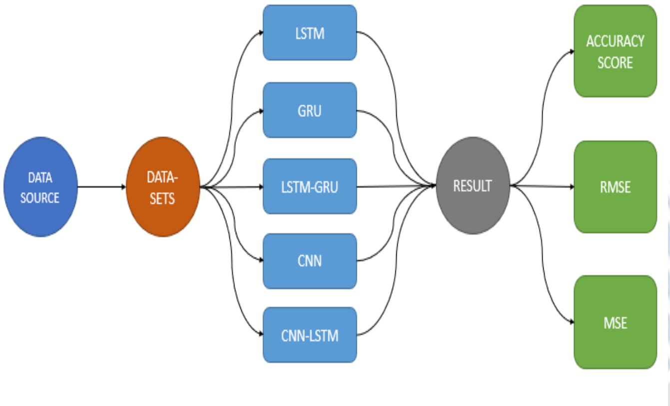

Figure 1. Workflow of approach

IV. DATASETS

The datasets that have been used in this proposed comparative study are APPLE AND NYSE. The datasets have been taken from the year 2006 to the year 2018 i.e., 12 years. TABLE-1 shows the details about the datasets.

4.1 LSTM

The Recurrent Neural Network (RNN) architecture known as LSTM is used to analyse sequential data.[10] [45] By taking the past stock prices as a sequential dataset and developing a predictive model on LSTMs applied to the forecasting of stock prices. The model attempts to forecast the following price in the sequence given a series of previous stock prices as input. To learn the patterns and interactions between the prices over time in this instance, the LSTM network is trained using historical stock price data.[13] [44] Using the most current prices as input, the model predicts the upcoming time step during the prediction phase[14].

The influence of numerous intricate and unpredictable factors on stock prices, however, must be noted.

TABLE-1

DATASETS

Stock prices dataset	**Feature**	**Training Set**	**Testing set**
Apple Stock Price	'Open', 'High', 'Low', 'Close', 'Volume'	1stJan 2006 to 1st Jan 2018	1st Jan 2017 to 1st Jan 2018
NYSE (New York Stock Price)	'Open', 'High', 'Low', 'Close', 'Volume'	March 2006 to March 2018	March 2017 to March 2018

Table 2 contains the data regarding the parameters used while doing the prediction using the LSTM model. Figure 2 shows the real and predicted value of the LSTM of Apple stock price. The red line shows the actual price and the blue line shows the predicted price. Figure 3 shows the real and predicted value of the LSTM of the NYSE stock price. The red line shows the actual price and the blue line shows the predicted price.

TABLE-2

LSTM PARAMETERS

No. of epochs	50
No. of layers	3
Type of activation function	Sigmoid, tanh, Rectified Linear Unit
Batch Size	32
Optimizer	Stochastic gradient descent
Loss functions	Mean Square Error
No. of Input Neurons	Open, High, low, close, volume
No. of Output Neurons	High

4.2 CNN

Machine learning includes convolutional neural networks, also known as convnets or CNNs. It is a subset of the several artificial neural network models that are employed for diverse purposes and data sets. A CNN is a particular type of network design for deep learning algorithms that are utilized for tasks like image recognition and pixel data processing, in-depth learning a convolutional layer, a pooling layer, and a fully connected (FC) layer are the three layers that make up CNN. The first layer is the convolutional layer, while the final layer is the FC layer. The complexity of the CNN grows from the convolutional layer to the FC layer. The CNN can identify increasingly larger and more intricate aspects of an image until

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it successfully recognizes the complete thing as a result of the rising complexity.

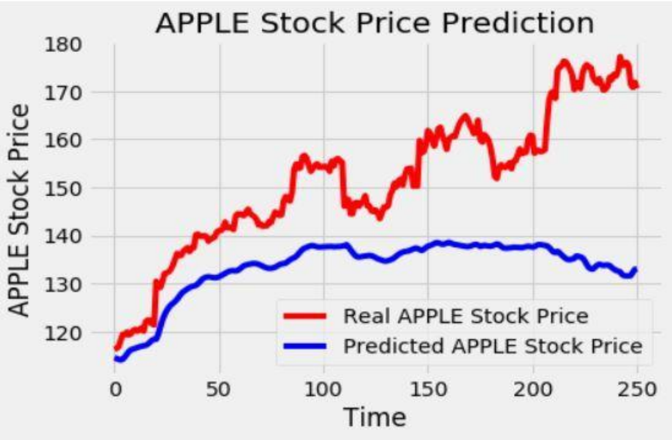

Figure 2. LSTM of apple

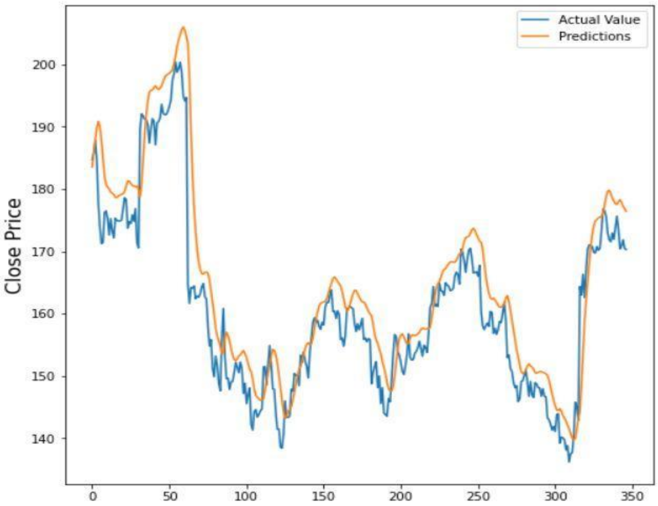

Figure 3. LSTM of NYSE

Table 3 contains the data regarding the parameters used while doing the prediction using the CNN model [15].

Figure 4 shows the real and predicted value of the CNN of Apple stock prices. In this, the black line shows the actual price and the green line shows the predicted price.

Figure 5 shows the real and predicted value of the CNN of NYSE stock prices. In this, the blue line shows the actual price and the yellow line shows the predicted price

TABLE-3 CNN Parameters

No. of epochs	30
No. of layers	5
Type of activation function	SoftMax, Rectified linear unit
Batch size	86
Optimiser	RMSprop
Loss function	Categorial cross entropy
Number of Input Neurons	ImageId, label
No. of Output Neurons	Label

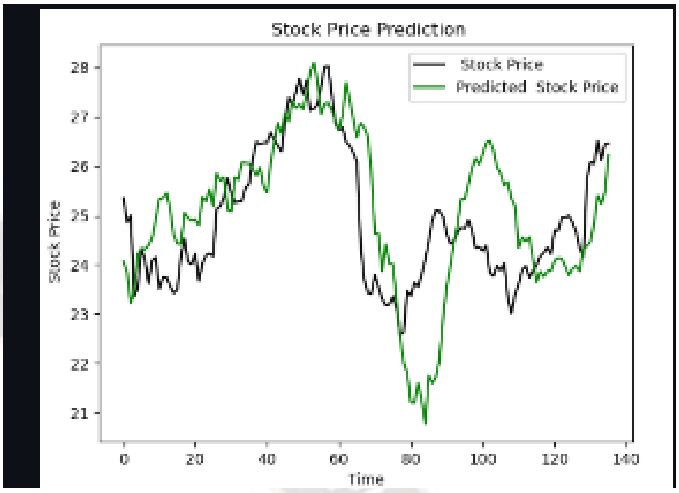

Figure 4. CNN of apple

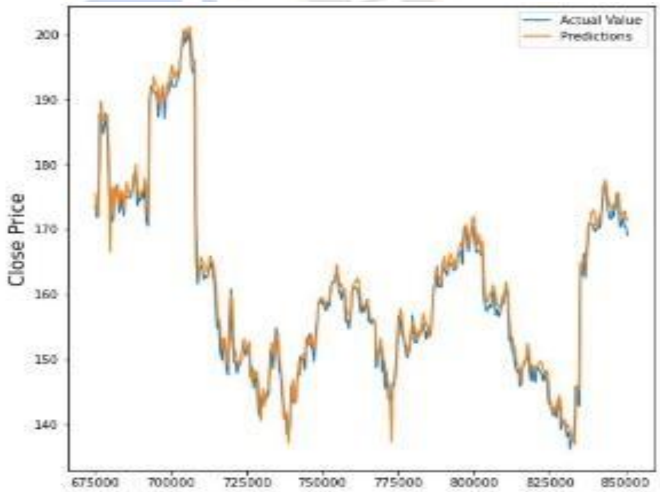

Figure 5. CNN of NYSE

4.3GRU

GRUs can be used in stock prediction by treating the historical stock prices as a sequential dataset and training a predictive model on it. The model attempts to forecast the following price in a series of prior stock prices given as input. To learn the patterns and interactions between the prices over time in this instance, the GRU network is trained on historical stock price data. During the prediction phase, the model takes the most recent prices as input and generates a prediction for the next time step. Like LSTMs and Bi-LSTMs, the use of GRUs in stock prediction can help capture important trends and dependencies in the Stock price data.

Table 4 contains the data regarding the parameters used while doing the prediction using the GRU model. Figure 6 shows the

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real and predicted value of the GRU of Apple stock prices. The red line shows the actual price and the blue line shows the predicted price. Figure 7 shows the real and predicted value of the GRU of NYSE stock prices. The red line shows the actual price and the blue line shows the predicted price.

TABLE-4 GRU PARAMETERS

No. of epochs	50
No. of layers	2
Type of activation function	Sigmoid, tanh
Batch size	150
Optimiser	Stochastic Gradient descent (SGD)
Loss function	Mean Square error
Number of Input Neurons	Open, high, low, Close, Volume
No. of Output Neurons	High

Figure 6. GRU of apple

Figure 7. GRU of NYSE

4.4 LSTM-GRU

The LSTM (Long Short-Term Memory) and GRU (Gated Recurrent Unit) are well-known recurrent neural network architectures for sequential data processing tasks like speech recognition, natural language processing, and time-series analysis. An LSTM cell has three gates that control the information flow into and out of the cell, allowing it to selectively forget or remember information from earlier time steps. The gates are the forget gate, the input gate, and the output gate. One advantage of LSTM is its ability to handle long-term dependencies in sequential data. A GRU cell is made up of two gates: the update gate and the reset gate. The update gate governs how much of the current input is remembered while the reset gate controls how much of the prior hidden state is erased. An LSTM-GRU hybrid model combines both architectures to take advantage of their strengths. For example, the LSTM part can be used to capture long-term dependencies and the GRU part can be used to process short-term dependencies in the sequence. The hybrid model may also use fewer parameters than a pure LSTM model while still achieving good performance.

Table 5 contains the data regarding the parameters used while doing the prediction using the Hybrid LSTM-GRU model. Figure 8 shows the real and predicted value of the LSTM-GRU of Apple stock prices. The red line shows the actual price and the blue line shows the predicted price. Figure 9 shows the real and predicted value of the LSTM-GRU of Apple stock prices. The red line shows the actual price and the blue line shows the predicted price.

4.5 LSTM-CNN

A well-liked neural network design for sequence classification applications, such as speech recognition, natural language processing, and picture captioning, is the LSTM-CNN hybrid model. The approach combines the benefits of CNN and LSTM, two different kinds of neural networks. The CNN serves as a feature extractor for the input sequence in the LSTM-CNN hybrid model, while the LSTM is utilized to process the retrieved features and create predictions. The CNN is first used to process the input sequence, producing a collection of feature maps [16], [17], and [18]. Following flattening, an LSTM layer receives the feature maps and uses them to process the sequential data and produce a prediction for the entire series. It is possible to employ this hybrid model for applications like speech recognition, picture captioning when the input is an image, or waveform captioning, where the input is an audio waveform. The LSTM can be used to create a string of words that characterize the input, and the CNN can be used to extract features from the audio waveform or image [19], [20].

TABLE-5 LSTM-GRU PARAMETERS

No. of epochs	50
No. of layers	5
Type of activation function	Sigmoid, tanh, Rectified Linear Unit
Batch Size	32

Optimizer	Stochastic gradient descent
Loss functions	Mean Square Error
No. of Input Neurons	Open, High, low, close, volume
No. of Output Neurons	High

Figure 8. LSTM-GRU of APPLE

Table 6 contains the data regarding the parameters used while doing the prediction using the Hybrid LSTM-CNN model. Figure 10 shows the real and predicted value of the LSTM-CNN of Apple stock prices. In figure 10 the black line shows the actual price and the green line shows the predicted price Figure 11 shows the real and predicted value of the LSTM-CNN of Apple stock prices. In this figure the red line shows the actual price and green line shows the predicted price.

Figure 9. LSTM-GRU of NYSE

TABLE-6 LSTM-CNN PARAMETERS

No. of epochs	40
No. of layers	6
Type of activation function	Sigmoid, tanh
Batch Size	40
Optimizer	Adam
Loss functions	Mean Square Error
No. of Input Neurons	Open, High, low, close
No. of Output Neurons	Close

Figure 10. LSTM-CNN of apple

Figure 11. LSTM-CNN of NYSE

V. COMPARATIVE ANALYSIS

Our proposed work is a comparison of the four different algorithms for Stock prediction prices. We have compared LSTM, GRU, LSTM-GRU, and LSTM-CNN over the two datasets of Apple and NYSE. We are comparing these algorithms on two different metrics i.e., RMSE and MSE. A measure of the discrepancies between actual values and values predicted by regression analysis is called RMSE (Root Mean Square Error). This formula is used to compute it:

RMSE = *sqrt(sum((y_pred - y_actual)^2)/n) ..eqn-1*

In eqn-1(equation-1) y_pred, y_actual, and n are the variables where n is the dataset's total number of observations. In the equation, the average of the squared discrepancies between the expected and actual values is calculated.

Mean Squared Error, sometimes known as MSE, is a regularly used metric to assess the discrepancy between expected and actual results in regression analysis. This formula is used to compute it:

MSE = *sum((y_pred - y_actual)^2)/n* ...*eqn-2*

In eqn-2(equation-2) Y_pred stands for the predicted value, Y_actual for the actual value, and n for the dataset's total number of observations. By squaring the discrepancies

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between the expected and actual values, the formula determines the average of those disparities.

Figure 12 shows the comparison among the algorithms, LSTM, GRU, LSTM-GRU, and LSTM-CNN respectively on the RMSE value on Apple and NYSE dataset. Figure 13 shows the comparison among the algorithms, LSTM, GRU, LSTM-GRU and LSTM-CNN respectively on the MSE value on Apple and NYSE dataset.

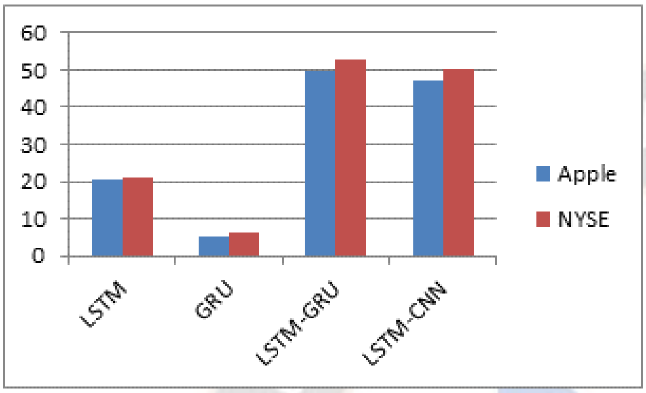

Fig. 12. RMSE graph of Apple and NYSE

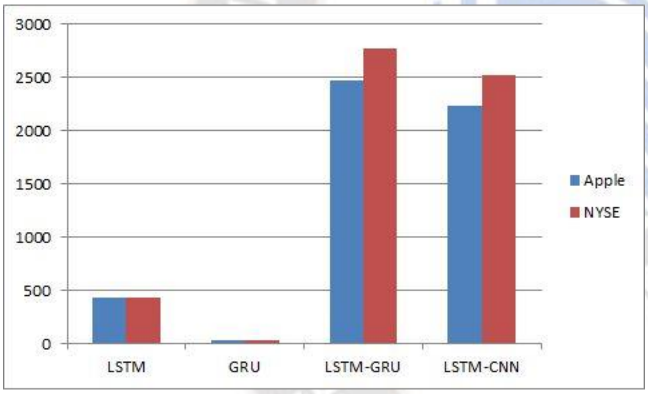

Fig. 13. MSE graph of Apple and NYSE

VI. CONCLUSION

In this research work, we delve into the comparison of three popular deep learning algorithms, LSTM, GRU, and CNN. Our objective is to provide a comprehensive analysis of each algorithm and determine the most effective approach when considering factors such as accuracy, memory usage, interpretability, and more. The proposed research work concludes that as GRU has the low RMSE and MSE values and hence it proves to be the better algorithm till now.

A recurrent neural network architecture called a GRU (Gated Recurrent Unit) has demonstrated success in modelling sequential data, such as text and speech.. It works better on smaller datasets due to its simpler architecture, faster training, and lower risk of overfitting compared to LSTMs (Long Short-Term Memory) network. GRUs have fewer parameters and are less likely to overfit. Additionally, they can be trained faster with less data and less computation. Therefore, GRUs may be a better choice for smaller datasets, but the effectiveness of the model depends on the specific characteristics of the dataset and the task at hand.

Implementation results through the graph depict that LSTM is found to be the second-best machine learning algorithm for the prediction of stock market prices because of its low RMSE and MSE values.

Our research is valuable for professionals and organizations looking to adopt deep learning in their operations. By presenting a comprehensive analysis of the separate and hybrid models, we hope to guide our readers in making informed decisions regarding which algorithm is most suitable for their specific needs and criteria.

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