Research on Apple's Stock Price Trend Forecasting

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Abstract. As the world's largest company by market capitalization, Apple has attracted the attention of many investors. Many investors have developed a strong interest in Apple stocks. However, it is not easy to study the trend of Apple stocks. Because there are many factors affecting Apple's stock price changes, it is very complicated and difficult to review the details of all these factors. Predicting and analyzing stock prices can provide investors with practical tools to raise funds and reduce investment risks. This paper starts with the time series research method of stock prices, which has proved to be a relatively effective method. Through this method, this paper can have an in-depth understanding of the fluctuation of stock prices, so as to better grasp market trends and make more informed investment decisions. By using CNN and LSTM models for prediction, the author finds that it rose by an average of 4% per trading day, and its MSE value was basically below 10, The MSE of other stocks has been optimized from more than 1900 shares predicted in less than 10 a share. This paper splits and analyzes the adjusted data to obtain more reasonable and accurate prediction results. Finally, this article aims to provide valuable reference for those who are interested in stock forecasting or studying the trend of Apple's stock price.

Keywords: Apple's stock, ARIMA, LSTM, CNN.

1. Introduction

Predicting the trend of Apple stocks is very meaningful. Apple has long been a legend in the American technology category. After leading the personal computer (PC) revolution in the 1970s, Apple has repeatedly launched traditional and highly creative products in recent years, including smartphones and wearable devices. In addition, as a company with a market value of more than $3 trillion, Apple is currently the most valuable company in the world. This has made many investors interested in Apple stocks. According to Jordan (2018), "Apple's health predicts the health of the whole industry and industries that rely on Apple." Apple's stock price is an indicator of its health. Therefore, it is particularly meaningful to have a good model to predict the stock price of such an iconic company. However, it is not easy to study Apple's stock trends. Because there are many factors that affect the price change of Apple's stock, including the trend of stock price data, the operation status of the company corresponding to the stock, the evaluation of the stock, national policies, unexpected news events, etc., will have an impact on stock prices. It is very complicated and difficult to review all the details of these factors. In order to make the changing trends and influencing factors of problems clearer and more transparent, it is necessary to predict the trend of Apple's stock price by using R language and comparing stock price statistics and trends. Finally, this article aims to provide a reasonable reference for people who are interested in stock forecasting or interested in studying Apple's stock price trends.

The theme of this article is to predict Apple's future stock trends. According to Mo Jiawei's paper concluded with the development of modern financial engineering theory, quantitative investment strategies are receiving increasing attention. Technical analysis, fundamental analysis and quantitative strategy analysis are currently known as three mainstream investment methods in the investment field [1], quantitative strategy investment. It can not only effectively collect, sort out, study, evaluate and predict the current financial environment, but also quickly and effectively adjust the finance portfolio and discover potential investment opportunities, which greatly improves the risk management level of contemporary investors [2]. In recent years, however, reports on Apple's stock price have tended to focus on the news or fundamentals such as the company's financial health. Few reports have reliably predicted Apple's stock price with time-series models, which is unfriendly to

long-term value investors. And that's what this project is trying to contribute to. It has won wide recognition from investors for its accurate investment strategy, flexible investment methods, timely return on investment and stable return on investment.

In the same direction, Peng et al. used in the stock price prediction based on the AP-SVM combination model [3], while others used the RNN-CNN model to predict [4], Wang and associates forecasted the stock price index using the hidden Markov model [5]. Ariyo et al. shown that the ARIMA model can be effectively used in this field [6]. Wang et al. used the time series model of BiLSTM-SA-TCN in stock forecasting [7]. There are so many different ways to predict stock price trends, the most popular of which are the CNN-LSTM and ARIMA models to improve the clarity and intuitiveness of stock trend analysis. Through the empirical study of the LSTM model, it is found that it can more accurately predict the rise and fall of the Shanghai 50 stock index. By using the LSTM model, no matter what the market situation is, our quantitative stock selection strategy will bring better returns than expected. This shows that despite the simple division of the market, the strategy still has good performance in different market stages and can better quantitative selection, thus providing more investment opportunities [8]. Therefore, these two methods are the main prediction methods.

In short, the project will use the ARIMA model, long-term memory (LSTM) model and convolutional neural network (CNN) model to analyze Apple's stock price from 2012 to 2023 and predict Apple's stock price in 186 trading days before 2023 [9]. The project obtained data from the Kaggle website. The series contains two data sets, both including the opening price, closing price, high price, low price and quantity of Apple stocks in 1984-2023. This study only analyzed the data from 2012-2023 [10]. But the closing prices of 660 days and 2180 days have changed dramatically. These dramatic changes are the result of artificial division of stocks. Therefore, this study chooses to analyze the split-adjusted data to obtain more reasonable and accurate prediction results.

2. Methods

2.1. Data Source

To model Apple’s stock price, this research collected data from the Kaggle website, which selects the data of Apple stocks from 1980 to 2022.

2.2. Model Selection

ARIMA model is a time series analysis method. Its modeling process is relatively simple. It only needs to determine the difference order, the number of autoregressive terms and the number of moving average items of the timing data. Compared with other time series analysis methods, such as neural network models, ARIMA models are more convenient to use. In addition, based on previous stock prices, the ARIMA model can be used to predict the future stock value, which provides a strong basis for enterprise decision-making.

LSTM, as a special cyclic neural network, has its strong memory ability to better capture the long-term dependence in sequence data, which is particularly critical in the processing of time series data such as stock prices. By learning and simulating past stock price dynamics, the LSTM model can predict future price trends. This undoubtedly provides an important reference for investors when formulating investment strategies, enabling them to make more informed investment decisions.

Through a unique design combination, the CNN model can automatically mine features, which significantly enhances the representation ability of neural networks and surpasses traditional linear classification models, such as support vector machines. In addition, CNN is a nonlinear model whose complex stacking structure makes it more able to identify the nonlinear characteristics of the stock market than a linear model, thus more accurately simulating and predicting the ups and downs of stock prices. In addition, CNN makes the output sensing field wider through the structure of the convolutional layer and pooling layer, and shares the weights of the convolution kernel, thus effectively reducing the number of parameters. The CNN model has significant advantages in

processing nonlinear financial time series data with a large amount of noise. Most importantly, the CNN model can predict the trend of stock prices and provide investors with reference for buying and selling stocks to obtain profits.

2.3. Method Introduction

ARIMA model, LSTM model, and CNN model were used. Hence, it is essential to comprehend the fundamental ideas of the models.

LSTM and CNN models have good flexibility and extensibility, which can be adjusted and optimized according to specific situations. Model performance can be improved by increasing the number of network layers, adjusting the amounts of neurons, and using different activation functions.

2.3.1. ARIMA model

Time series data prediction and modeling can be done using the ARIMA model, a widely used time series analysis method. By analyzing and fitting historical data time series, it is possible to forecast future trends and changes. The basic idea is to build a model that can describe data characteristics through self-regression, moving average and differential transformation of time series data, and use this model to predict future data changes.

Time series analysis can be done using the ARIMA model, which is a statistical model. AR (p) model is a model that describes the influence of the previous p values on the current value in the time series. Non-stationary time series refers to the trend or periodic sequence of data that changes rapidly, which will lead to the predicted effect of the model is poor. The integrated model is a model used to deal with non-stationary time series. It can convert non-stationary time series into stable sequences through d-order differences, making the model easier to describe. The moving average model, or MA (q) model, is a model that describes the relationship between the error value of a point in a time series and the error value of the past q points.

AR and MA are combined to obtain the ARMA (p, q) model with the expression

$$y_t = \mathbf{c} + \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i} + \varepsilon_t \quad (1)$$

In the formula: y_t is the t-th value of the time series, representing the value of the current moment; $\mathbf{c}$ is the constant term; ϕ_i is the autoregressive term coefficient, which is used to describe the impact of the value of the past p moments of the current moment; θ_i is the moving average term coefficient. It is used to describe the impact of past q error terms of current moment error terms; ε_t is a random error term.

2.3.2. LSTM model

The LSTM model consists of 3 doors and a memory unit. The forgotten door is used to determine whether the memory information of the previous time step will be discarded. The discard of information is determined by the forgotten door Ft.

$$f_t = \sigma(\boldsymbol{W}_f \cdot [h_{t-1}, x_t] + b_f) \quad (2)$$

In the formula: f_t is the output of the forgotten door; $\boldsymbol{W}_f$ is the weight matrix of the forgotten door; h_{t-1} is the hidden state of the previous moment; x_t is the input of the current moment; b_f is the bias vector of the forgotten gate; σ is the sigmoid function.

LSTM is a cyclic neural network suitable for processing timing data. Apple's stock data is sequential, that is, the price and trading volume of the previous time may have an impact on the price of the following time. LSTM can capture and memorize this timing relationship to help predict future stock prices. This called LSTM 's timing modelling ability.

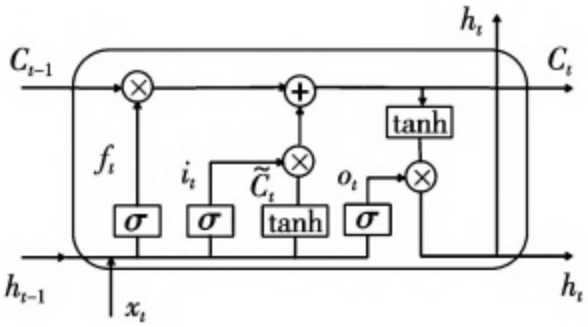

Figure 1. Schematic diagram of LSTM cell structure [11]

2.3.3. CNN model

CNN model is a feedforward neural network. Figure 2 demonstrates the inclusion of convolutional and pooling layers in CNN. And CNN is MLPs (multi-layer perceptrons) inspired by biological thinking. They have different category levels, and each layer works in different ways and functions. Figure 3 shows the structure of CNN network.

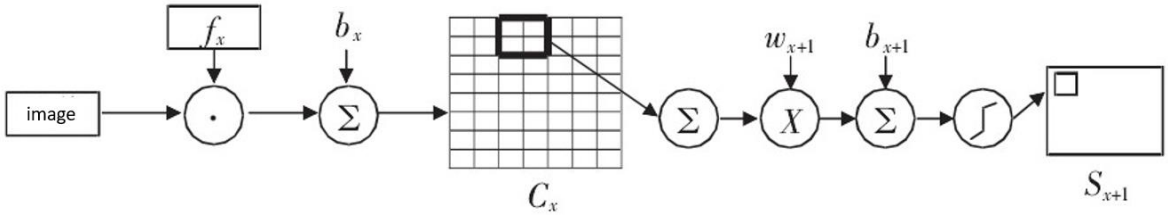

Figure 2. Convolution and sampling process in CNN [12]

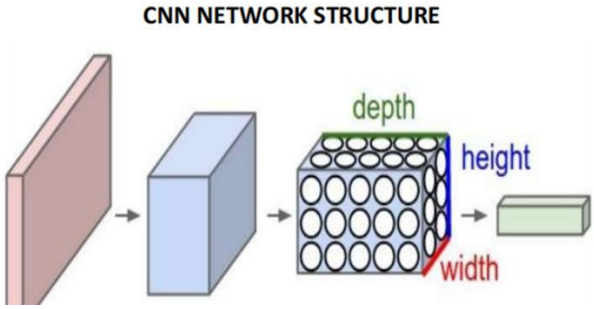

Figure 3. CNN network structure [13]

Additionally, CNN is a commonly used neural network model in the field of image processing. In stock data, features such as price and trading volume can be regarded as an image representation of time series data. By using CNN, the spatial and temporal characteristics in these image data can be effectively extracted to help identify and predict the pattern and trend of stock prices [14]. This is called CNN's feature extraction ability.

3. Results and Discussion

This project firstly used the ARIMA model for analysis. As shown in Table 1, taking the CLOSE part of the data as an example, the study used the difference method on the data, and the ADF test can be seen that the CLOSE variable is a smooth series with $P<0.05$ at the 1st order difference, but the values of the AIC are all relatively large, which indicates that the model's goodness of fit is low. Figure 4 is the optimal difference sequence plot also known as the first order difference sequence plot.

Table 1. ADF Retrieval table

Variable	Difference Order	t	P	AIC	Threshold 1%	5%	10%
close	0	-0.401	0.910	10081.971	-3.433	-2.863	-2.567
	1	-10.649	0.000	10077.339	-3.433	-2.863	-2.567
	2	-16.781	0.000	10168.223	-3.433	-2.863	-2.567

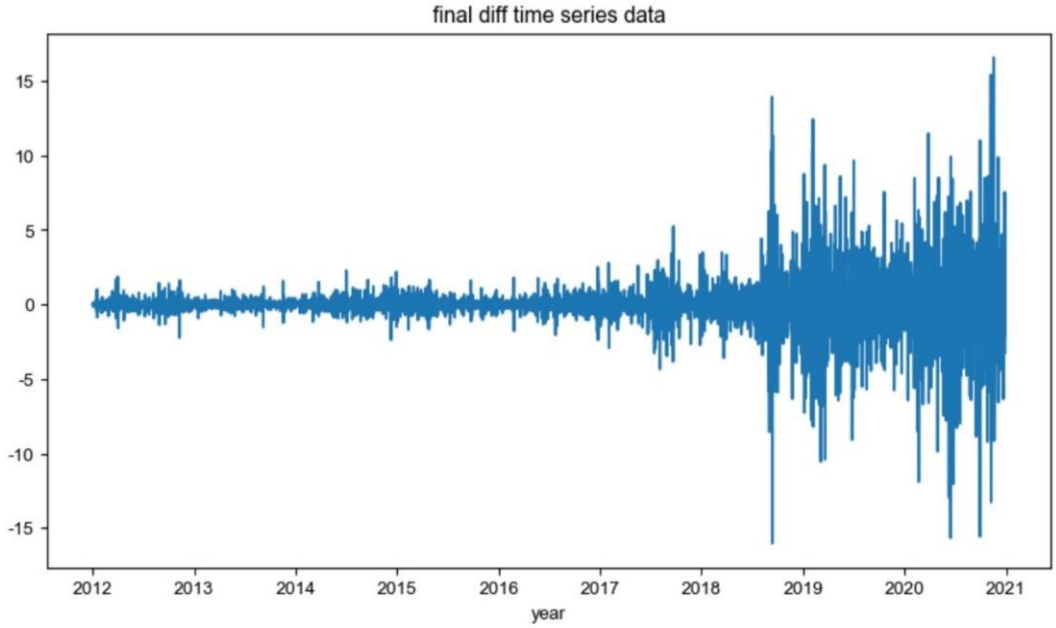

Figure 4. Differential sequence

The research then analyzed the final difference data by its ACF and PACF as shown in Figure 5 and 6. The results of the model are ARIMA (1, 1, 1), by examining the results of the Q statistic, it is possible to determine that Q6 is not that important at the level, and the hypothesis that the model's residuals are a white noise sequence cannot be disproven, but the AIC and BIC are larger. This is shown in Table 2.

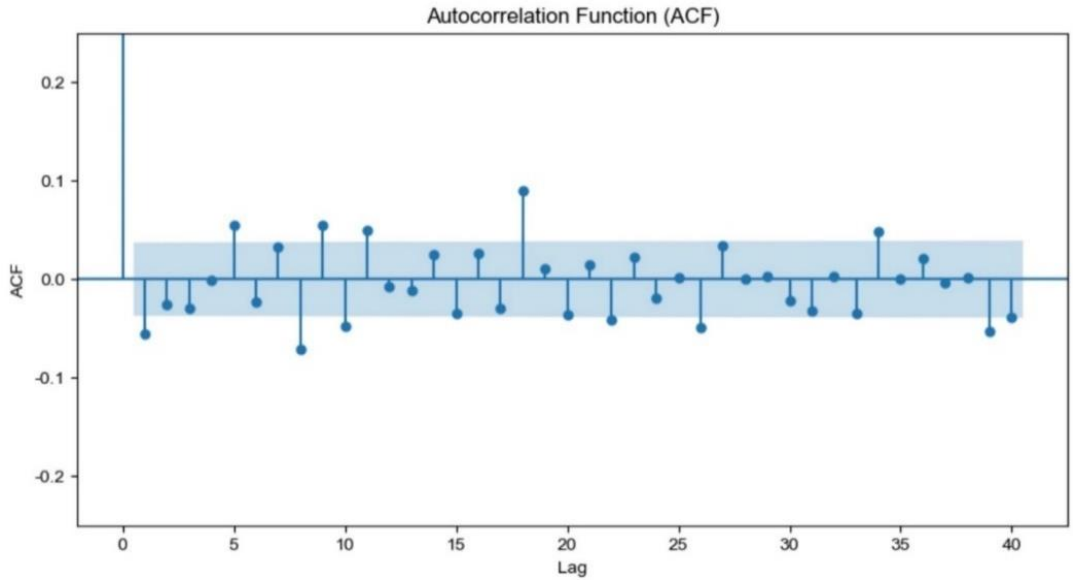

Figure 5. ACF plot

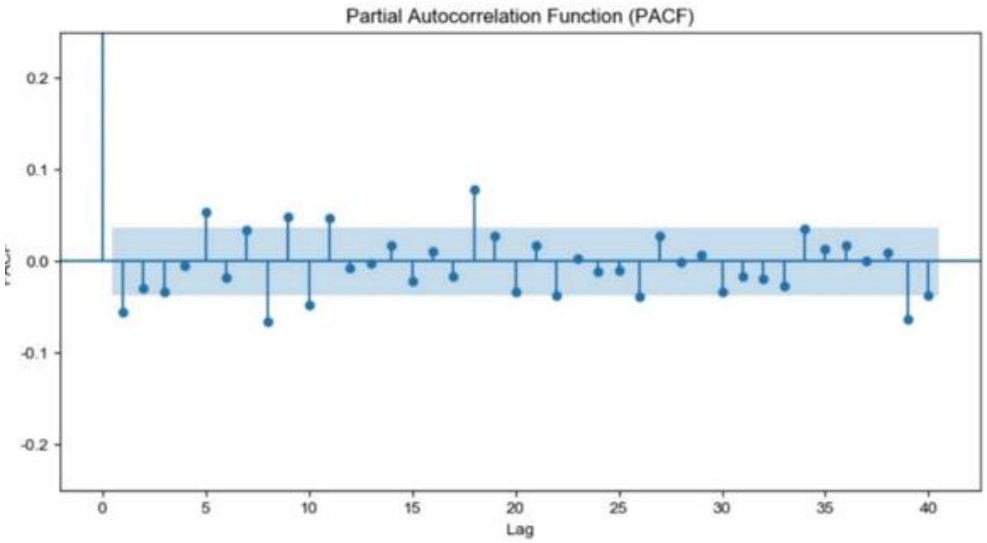

Figure 6. PACF plot

Table 2. ARIMA model Retrieval table

Item	Symbol	Value
	Df Residuals	2764
Samples Sizes	Q6	2768
Q Statistics	Q12	0.017(0.124)
	Q18	42.654
	Q24	72.679
	Q30	83.781
Information Criterion	AIC	10192.591
	BIC	10216.293
Goodness of Fit	R^2	0.999

Figure 7 shows, model equations and model predictions. The green line represents the true value. The orange line represents the fitted value. The blue line represents the predicted value. The project determined that Apple's stock price will remain in a continuous upward trend for some time to come, rising an average of $0.04 per trading day. But the study wanted to learn to understand that there are more accurate predictive models, so the CNN+LSTM model was used.

$$y(t) = 0.042 + 0.413^{\star}y(t-1) - 0.473^{\star}\varepsilon(t-1) \quad (3)$$

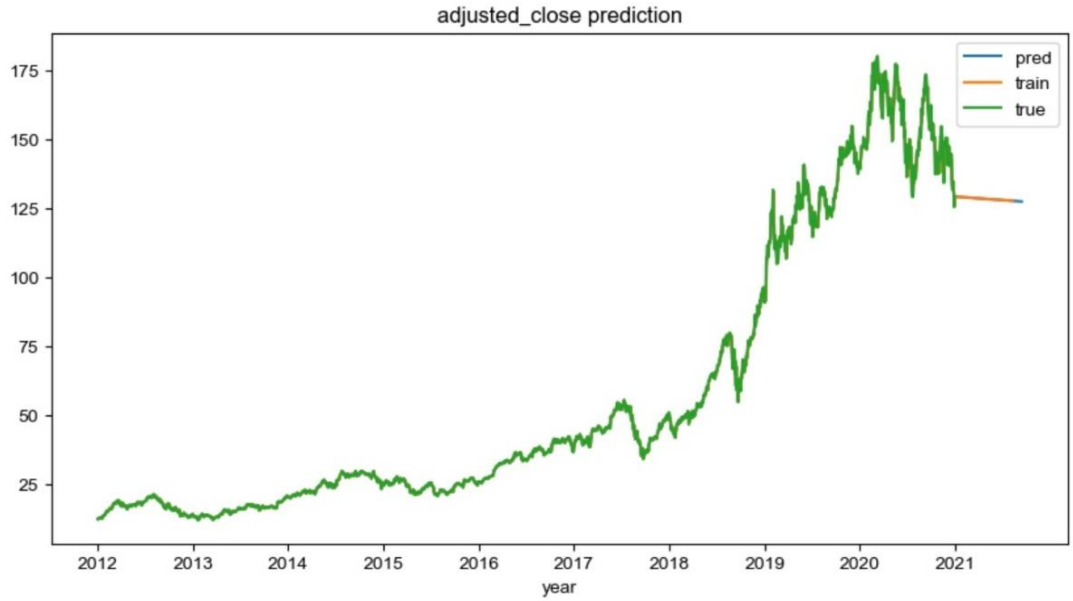

Figure 7. Predictive renderings

As shown in Figure 8, taking the "close" variable as an example again, the research input 4 close variables, which equals to the time step in LSTM, and then through two convolution layers of the same size, convolution kernel of 1, CNN processing, output a one-dimensional array, and then input it into the LSTM of 6 layers containing 64 hidden dimensions for processing. Finally, the study output the next data. Then the researchers removed the first “close” variable and add the new one, and continue the output section.

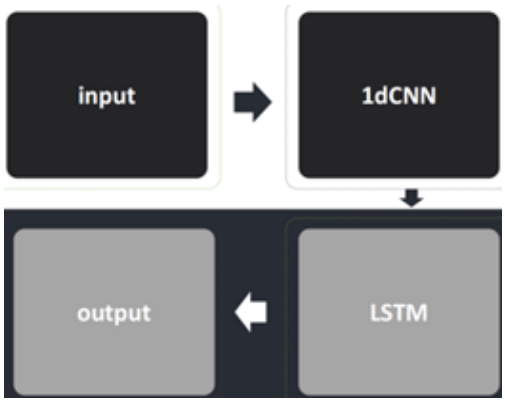

Figure 8. The model procedure

The loss function the research used is Mean-square error, and this is its formula:

$$\mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n} (Y_i - \widehat{Y}_i)^2 \tag{4}$$

And the following are some of the important parameters in the model: Percentage: The percentage of the training set data of total data. Conv_input: The number of input channels for each convolution layer. Num layers: Layers of the LSTM model. Hidden size: LSTM Hidden status dimension. Num epochs: Training cycle. Batch size: The number of each training sessions (Table 3, 4, 5).

Figure 9 and 10 show the adjustment experiment parameters and model structure. Taking hidden size as an example, the hidden size parameter of the LSTM model refers to the quantity of cells in the LSTM hidden layer or the dimension of the hidden state. It determines the mount of complex patterns and information that the LSTM model can learn and represent. This quantity is usually 2 to the power of n. The research picked 16, 32 and 256 in addition to 64. It can be seen that 64 is the optimal solution when other parameters are optimized at that time. Both images and MSE results indicate this. And Table 3-5 shows other parameters.

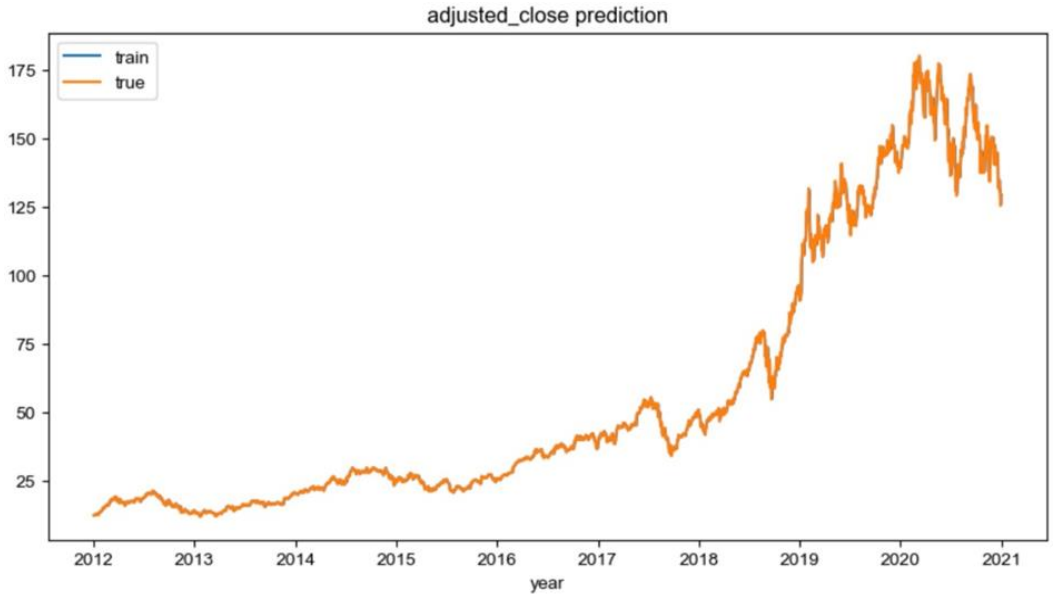

Figure 9. Prediction results of closing price

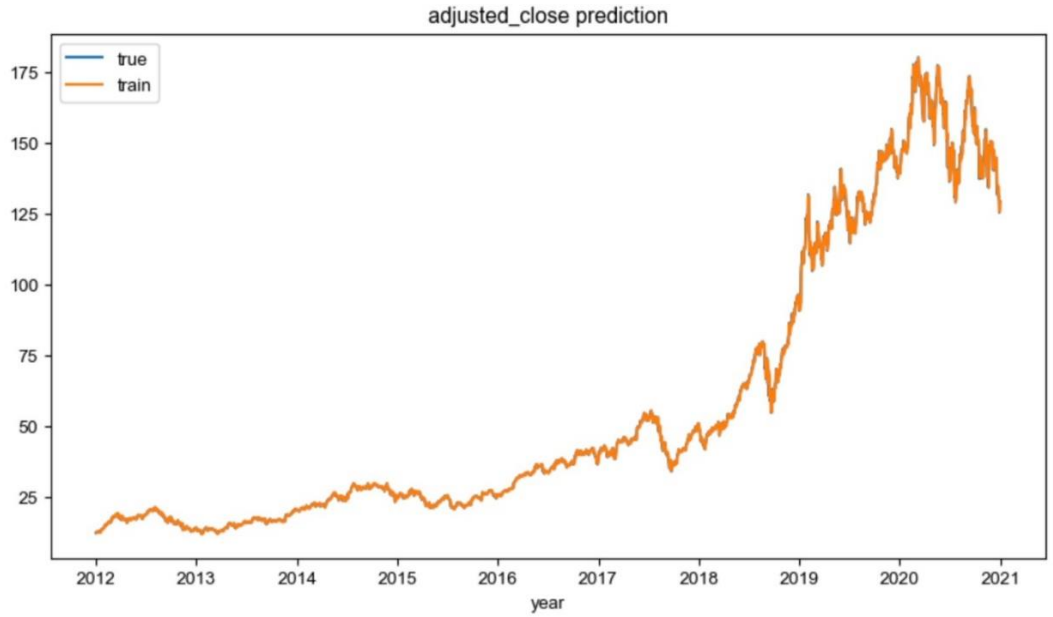

Figure 10. Prediction results of adjusted closing price

Table 3. LSTM (change: time_step)

Time_step	CNN_layers	Num_layers	Hidden_size	Num_epoch	Batch_size	time	mse
7	2	6	64	1000	64	25.7	14.42
6	2	6	64	1000	64	23.2	12.0426
5	2	6	64	1000	64	20.3	13.9228
4	2	6	64	1000	64	17.4	8.1984
3	2	6	64	1000	64	14.6	12.4234
2	2	6	64	1000	64	10.8	18.6477

Table 4. LSTM (change: num_layers)

Time_step	CNN_layers	Num_layers	Hidden_size	Num_epoch	Batch_size	time	mse
4	2	4	64	1000	64	11.7	9.8072
4	2	5	64	1000	64	14.5	8.3793
4	2	6	64	1000	64	17.4	8.1984
4	2	7	64	1000	64	19.5	24.7693
4	2	8	64	1000	64	22.5	30.3575

Table 5. LSTM (change: Hidden_size)

Time_step	CNN_layers	Num_layers	Hidden_size	Num_epoch	Batch_size	time	mse
4	2	6	16	1000	64	9.13	432.532
4	2	6	32	1000	64	11.6	26.4785
4	2	6	64	1000	64	17.4	8.1984
4	2	6	128	1000	64	30.5	9.736
4	2	6	256	1000	64	91	15.837

4. Conclusion

The ARIMA model predicted the long-term trend of Apple's stock price and concluded that it rose by an average of 4% per trading day. At the same time, when using CNN and LSTM models for prediction, the performance is better, and the MSE value is basically lower than 10. If further research is done, the author hopes to find a more accurate stock trading volume prediction model. Compared with last week, MSE of other stock prices has been optimized from forecasting more than 1900 shares to less than 10 shares, but the result of stock trading volume has increased, so it is hoped that later scholars can further study it.

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