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COMPARISON OF THE CNN, RNN AND LSTM MODELS FOR HIGH-FREQUENCY STOCK PRICE FORECASTS

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Abstract: We think stock price is a long-term research topic and find that stock price forecasts are very important. And found that the changes in the stock price often show no linear and the current traditional stock price forecast can not well reflect the forecast results. So the deep learning method to predict stock prices. And explored three of the mainstream methods, RNN, working principles of the CNN and LSTM models. We then tried to use three models for TSLA, NFLX, LLY, AAPL share price data from four companies in different sectors. Finally, by comparing the MSE obtained by different companies through different models. The MAE and MAPE standards were compared. Finally, the most applicable general model is obtained. The experiment and final comparison found that the RNN model is higher than the other two models. At the end of the study, we considered the RNN model as a general model with higher comprehensive ability to predict stock prices in different fields.
Keywords: CNN; RNN; LSTM; Forecast stock price

1 INTRODUCTION

The stock market provides opportunities for capital appreciation. By buying stocks, investors can directly participate in the corporate growth and economic development, and share the economic results. Many listed companies distribute some of their profits to shareholders in the form of dividends, which provides investors with additional income sources, so more and more people tend to participate in the stock market.Stock prices are affected by a variety of factors, including macroeconomic conditions, corporate performance, and political events, which lead to high volatility in stock prices, and the personal selection and emotional uncertainty of market participants further increases stock volatility and makes stock forecasts more challenging.

Nowadays, more and more people use deep learning models to predict the trend of stock prices because of its stronger adaptability and generalization ability.Like Ding G, and Qin L has made stock price predictions by using the LSTM model [1]. Jahan I and Sajal S. forecast price prices using the RNN algorithm on time series [2]. Elvin, S has also used the sliding window models of RNN, LSTM and CNN to predict different corporate stock prices, respectively [3]. It can be seen that the deep learning model has a considerable effect on the stock prediction of non-linear characteristics, and it is the mainstream method and hot topic of the stock prediction in the current era. Until now, many scholars are still exploring appropriate advanced general models to achieve more accurate prediction ability.

2 ARTICLE REVIEW

The rise and fall of the stock market are related to the macro economy of the country, so the accurate prediction of the future of the stock market is conducive to the introduction of policies to maintain the stability of the market and the harmony of the society, so the prediction of the stock market has always been a hot topic.In the traditional statistical method, the commonly used [4-5] statistical analysis and the stock image (stock chart) method are combined to judge the development trend of the stock market, often can achieve better results.However, statistical methods usually rely on historical data to predict future trends, but historical data do not guarantee that the future will repeat the past trend and the stock market tends to show non-linear characteristics, and traditional statistical methods may not capture this nonlinear relationship well.

Later, with the development of science and technology, the research began to develop into the field of machine learning, in an attempt to build a prediction model more in line with the market model.There came improved models like support vector machines (SVM), artificial neural networks (ANN), XGBOOST, random forests (Random Forest, RF), and their improved models.In this course of development,Lin [6] uses SVM to select multiple factors to predict stock markets in several countries.Mizuno [7] Using ANN to predict the rise and fall of the Japanese stock market, and found that ANN's prediction accuracy of the stock price rise is significantly higher than that of the decline, which can reach more than 60%.Kumar M et al. [8] discuss how random forests can function in the stock market and find that random forests can improve the generalization performance and avoid overfitting problems.

Later, with the development of deep learning, people found that deep neural networks could capture more abstract and complex relationships between data. Therefore, the research of building the model to predict the stock price is conducted towards RNN (Recurrent Neural Networks) LSTM (Long Short-Term Memory) and CNN (Convolutional Neural Networks)Zhang [9]. used the two hottest methods, ——, BP neural network model and ARMA-GARCH model to analyze and predict stock prices.Li Yong [10] constructed an LSTM model to identify stock trends; Nikou M. [11] compared the LSTM model with SVR, RF, and ANN models, confirming that deep networks like LSTM have better feature capture capabilities than other shallow models.Yang Qi [12] et al. also adopted the innovative ARMA-GARCH model to analyze and predict the prices of different stocks; Huang Ying [13] et al. used XGBoost and LSTM models to further compare and analyze the prices of time financial series including different stocks;Zhang Kanglin [14] uses different software pytorch to build the LSTM model and then analyze it by classifying the stock prices.Song Gang [15] et al. used the LSTM model optimized by the adaptive particle swarm to predict the different stock prices in Shanghai, Shenzhen and Hong Kong.Li Xiongying [16] et al. used three models to analyze and predict the stock prices of the four major banks respectively, and obtained that different models have different characteristics, among which LSTM is more practical.Chen W [17] proposed an RNN-Boost model that uses technical indicators, emotional characteristics and Latent Dirichlet allocation characteristics to predict stock prices;Maqsood H. [18] proposed a CNN model with price and sentiment analysis as input and compared it with linear regression and SVM.

Until now, people still try to build a variety of different deep neural network models to achieve the methods that can best adapt to the nonlinear change problem of stocks and achieve higher accuracy.Now as China's financial market constantly mature, the center of gravity and trend is moving to the domestic market, considering the prediction and analysis of stock data is a nonlinear, time-varying problem, this paper will build the CNN, RNN and LSTM three kinds of deep neural network prediction and comparative analysis judge which model for stock price prediction applicability is higher.

3 LITERATURE REVIEW

In this paper, the comparison and investigation of the prediction ability of RNN, CNN and LSTM for non-linear high-frequency data.We chose to analyze the interdependence between the stock price and the stock quantity of the 3 companies. The focus of this article is to use deep learning algorithm to predict stock prices. Deep neural networks can be considered as nonlinear functional approximators capable of mapping nonlinear functions. Based on the application types, various types of deep neural network architecture are adopted. These systems include, recurrent neural network (RNN), long and short-term memory (LSTM), and CNN (convolutional neural network), etc. They have been applied in various fields, including image processing, natural language processing, and time series analysis. The deep learning model can well solve the problem of non-linearity of the outcome stock data, so this paper uses CNN, LSTM and RNN models to predict the company's stock price and compare the accuracy to find the general model with higher applicability of comprehensive prediction ability.Experimental model

3.1 Model Principle

LSTM is a special type of recurrent neural network. It avoids the problem of gradient vanishing and exploding caused by traditional recurrent neural networks by carefully designing the "gate" structure, and can effectively learn long-term dependency relationships. Therefore, in dealing with time series prediction and classification problems, LSTM models with memory function exhibit strong advantages.The following is the model principle for LSTM [19].

$$f_t = \sigma\left(w_t \cdot \left[h_{i-1},\ x_t\right] + b_f\right) \tag{1}$$

$$i_t = \sigma\left(w_i \cdot \left[h_{i-1},\ x_t\right] + b_i\right) \tag{2}$$

$$\tilde{C}_t = \tan h\left(w_c \cdot \left[h_{i-1},\ x_t\right] + b_c\right) \tag{3}$$

$$C_t = f_t C_{t-1} + i_t \tilde{C}_t \tag{4}$$

$$o_t = \sigma\left(w_o \cdot \left[h_{i-1},\ x_t\right] + b_o\right) \tag{5}$$

$$h_t = o_t \tan h\left(C_t\right) \tag{6}$$

In the formula, the input vector of the LSTM unit is x; H is the cell output vector; C represents the unit status; The subscript t represents the time; f. I and o represent forget gates, input gates, and output gates, respectively; σ. Tanh represents sigmoid and tanh activation functions, respectively; W and b represent the weight and deviation matrices, respectively.

As shown in Figure 1, multiple isomorphic cells can form LSTM, which can store information for a long time to update internal states. A represents that the three cells have the same unit structure, and each cell is composed of four elements: input gate, forget gate, outputs, and unit structure.

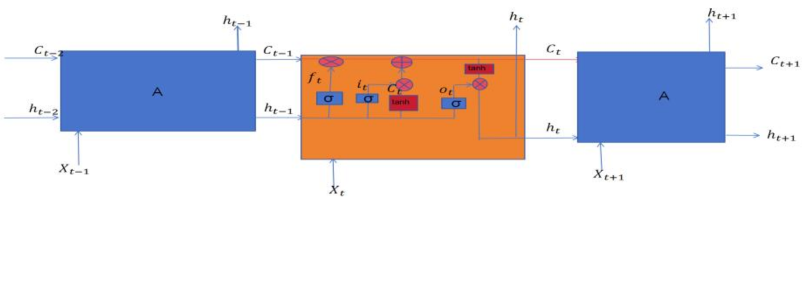

Figure 1 LSTM Schematic Diagram

The key to LSTM lies in the cell state. The flow of information between cell states remains unchanged. Simultaneously using three gates to control the long-term state c [20].
The output of the gate is a real number vector between 0 and 1. When the gate output is 0, any vector multiplied by it will result in a 0 vector, which is equivalent to nothing passing through; When the output is 1, any vector multiplied by it will not change in any way, which is equivalent to everything passing through[21].
CNN is a feed forward artificial neural network that includes an input layer, an output layer, and one or more hidden layers. Its structure is shown in Figure 3 [4]. The hidden layer of CNN usually consists of pooling layer, convolutional layer, and fully connected layer. The convolutional layer is responsible for reading small segments of data and using the kernel to read inputs such as two-dimensional images or one-dimensional signals, and scanning the entire input field. The pooling layer adopts feature projection, and the final output of the pooling layer is sent to one or more fully connected layers, which will interpret the read content and map this internal representation to class values. CNN is similar to a regular neural network (NN) composed of a set of neurons with learnable weights and biases, with the difference being that the convolutional layer uses convolution operations as input and then transmits the results to the next layer. This operation allows for more efficient implementation of forward functionality with fewer parameters[5].The working principle of the cnn is formulated as follows:

$$Y = f(w^{x} + b) \tag{7}$$

Where w is the weight matrix, x represents the input value, b represents the offset, f represents the activation function, and Y represents the output value.
The RNN receives the input and a hidden state at every time step, and outputs a hidden state and a (optional) output. The hidden state contains the sequence information until the current time step, which is passed to the next time step, and the entire sequence can thus maintain the continuity of the information.

$$h_t = \sigma(w_{ih}x_t + b_{ih} + w_{hh}h_{t-1} + b_{hh}) \tag{8}$$

h_t represents the hidden state of the current time step t, σis an activation function, such as tanh or ReLU, which is used to introduce a nonlinearity. w_{ih} and b_{ih} The weight matrix and bias terms from the input layer to the hidden layer, respectively. w_{hh} and b_{hh} the weight matrix and bias terms respectively from the hidden layer to the hidden layer (i. e, the hidden state of the previous time step to the hidden state of the current time step). x_t represents the input for the current time-step. h_{t-1} represents the hidden state of the last time step

4 EXPERIMENTAL ANALYSIS

In this experiment, we used CNN, RNN, LSTM models to predict the high-frequency data of TSLA, AAPL, NFLX and LLY stock prices from 2019 to 2024, and compared the accuracy of each model for different companies by comparing MSE (mean square error) MAE (average absolute error) and MAPE (average absolute percentage error).The principles of MSE, MAE and MAPE are as follows:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y_i})^2 \tag{9}$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y_i}| \tag{10}$$

$$MAPE = \frac{100\%}{n}\sum_{i=1}^{n}\left|\frac{y_i - \hat{y_i}}{y_i}\right| \tag{11}$$

Where, n is the number of samples, $y_i$and is the i th observation (true value), $\hat{y_i}$ is the corresponding predictive value.
For comparison, we used MSE, MAE, MAPE. The rates of error obtained by these four companies are as follows:

Table 1 Error Percenatge - Mse

	TSLA	NFLX	LLY	AAPL
CNN	958.71	2956.26	1877.20	317.30
RNN	107.10	141.36	280.34	11.26
LSTM	169.70	425.42	21648.04	35.74

Table 2 Error Percenatge - Mae

	TSLA	NFLX	LLY	AAPL
CNN	27.45	50.02	35.48	15.04
RNN	7.60	8.59	11.63	2.47
LSTM	9.96	15.11	105.22	4.54

Table 3 Error Percenatge - Mape

	TSLA	NFLX	LLY	AAPL
CNN	12.44	9.26	5.11	7.86
RNN	3.61	1.66	1.74	1.33
LSTM	4.73	2.97	13.69	2.43

From the table, we can find that the prediction error value of the four companies is minimal when using RNN, and the prediction error value of CNN and LSTM models is large.

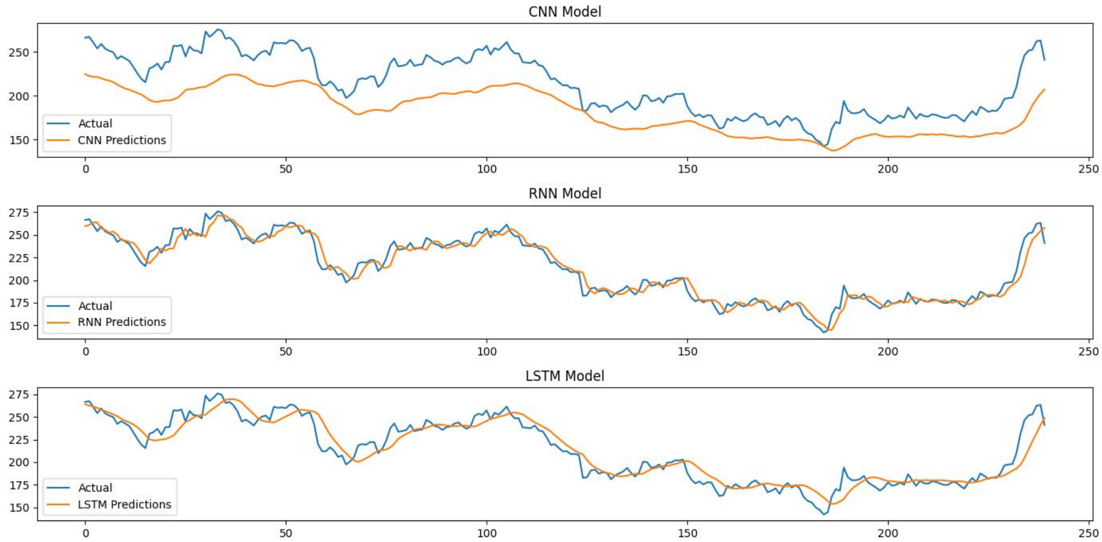

Figure 2 The TSLA Share Price, as Predicted by the CNN,RNN.LSTM

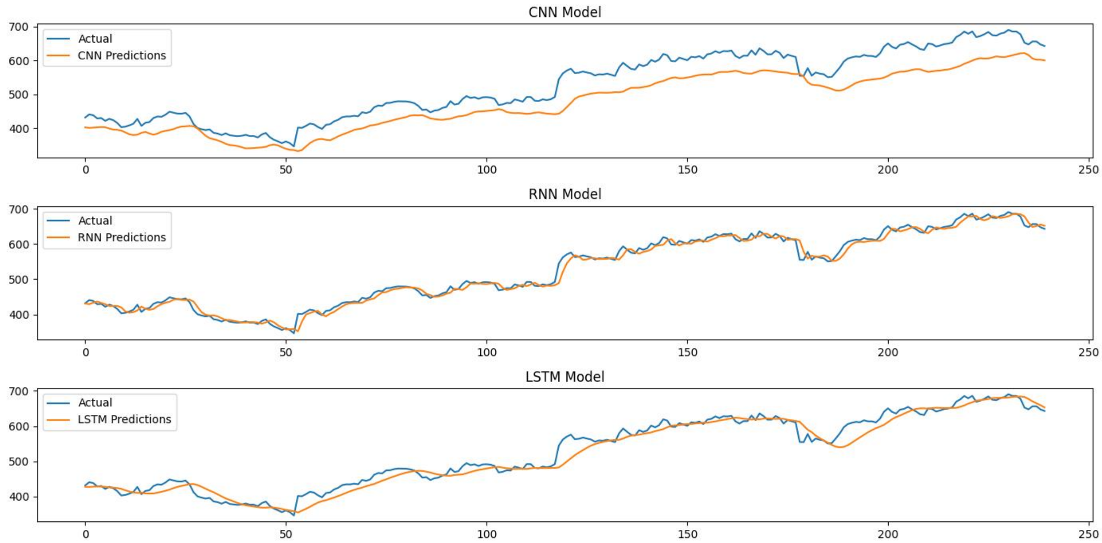

Figure 3 The NFLX Share Price, as Predicted by the CNN,RNN.LSTM

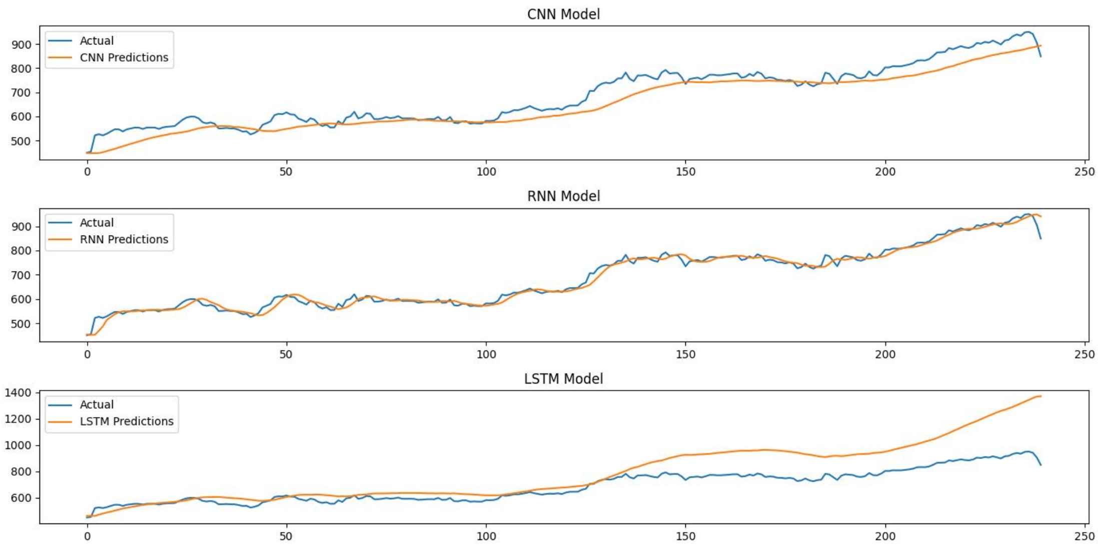

Figure 4 The LLY Share Price, as Predicted by the CNN,RNN.LSTM

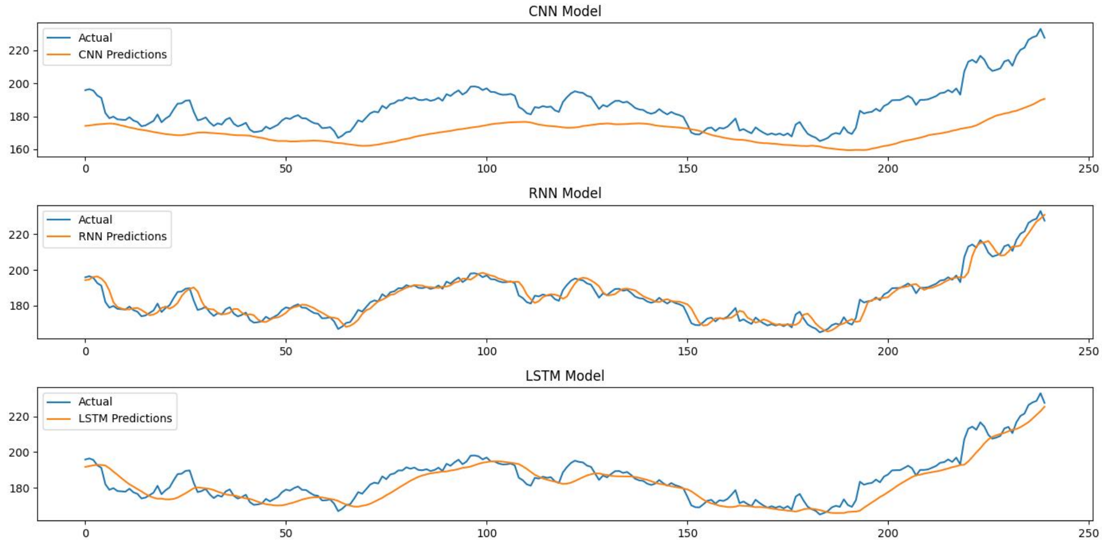

Figure 5 The AAPL Share Price, as Predicted by the CNN, RNN. LSTM

From Figure 2 to Figure 5, we can find that the data of different companies predicted by CNN are generally lower than the true value and have low prediction accuracy, because CNN (convolutional neural network) is usually good at processing data with spatial hierarchy, while stock price prediction is the prediction of time series, so the accuracy of CNN is not high. This is because CNN may not be as effective as RNN or LSTM in processing the long-term dependence and sequence patterns of time series.LSTM predicted somewhat better than CNN but the effect of predicting data changes is not high and from Figure 4 we found that the its predictions after LLY's 125 are clearly inconsistent with the original data. This may be because the LSTM model, as a type of recurrent neural networks, is good at handling long-term dependencies in sequence data. However, the change of LLY stock price is not completely dependent on the long-term trend in the historical data and there are sudden factors, so the LSTM model may not fully capture these characteristics, resulting in the prediction results are inconsistent with the actual data.Finally, we combined the results of Figure 2 to Figure 5 and found that RNN predicted the best.The reason for this result is that the RNN structure simpler reduces the effect of overfitting, and the RNN model is more suitable for short-or medium-term time series prediction, so it is more accurate.

5 CONCLUSION

This article delves into the complexity of the ability of deep learning models to predict linear-free stock price predictions for companies in different fields, and presents valuable insights and perspectives. We first discuss the current situation of economic development and the linear limitations of the traditional method of predicting stock price, and finally propose the use of deep learning model to predict stock price to solve the nonlinear problem of stock price change. Then, we screened the three models of deep learning RNN in the deep learning, CNN and LSTM as the objects of this study. We first examine how the three models work, The advantage of the different models was analyzed, Then, by selecting the TSLA, NFLX, LLY and AAPL, four companies from different sectors, Finally, by the LSTM, The RNN and CNN models train and forecast each company's stock price data. Then we also drew images through the results of the three deep learning models of CNN, RNN and LSTM making the prediction results visualized and convenient to judge the prediction ability of the three deep learning prediction models for companies in different fields.
Finally we, by comparing MSE, The MAE and MAPE values found that the RNN model is much smaller than the CNN and LSTM models for the three criteria of different companies, at the same time, we also found that the RNN model fits the prediction line map of the stock price forecast of TSLA, NFLX, LLY and AAPL to the actual data more closely than that predicted by the CNN and LSTM models.So ultimately we decided that the RNN model was slightly more comprehensively predictive.Finally, we conclude that the RNN model predicts less regression loss of stock prices in different fields, which means that the RNN model has the highest prediction accuracy, so we choose the RNN model as a more suitable general model in the ability of deep learning to predict stock prices.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Ding G, Qin L. Study on the prediction of stock price based on the associated network model of LSTM. International Journal of Machine Learning and Cybernetics, 2020, 11(6), 1307-1317.
[2] Jahan I, Sajal S. Stock price prediction using recurrent neural network (RNN) algorithm on time-series data. In 2018 Midwest instruction and computing symposium, 2018.

[3] Selvin S, Vinayakumar R, Gopalakrishnan EA, et al. Stock price prediction using LSTM, RNN and CNN-sliding window model. In 2017 international conference on advances in computing, communications and informatics (icacci) , 2017, 1643-1647.

[4] Li Haitao. The Markov forecasting method is used to predict stock prices. Statistics and Decision-making, 2002, (5): 25-26.

[5] Prado HD, Ferneda E, Morais LCR, et al. On the Effectiveness of Candlestick Chart Analysis for the Brazilian Stock Market. Procedia Computer Science, 2013, 22: 1136-1145.

[6] Lin Y, Guo H, Hu J. An SVM-Based Approach for Stock Market Trend Prediction. The 2013 International Joint Conference on Neural Networks (IJCNN), 2014, 4-9.

[7] Mizuno H, Kosaka M, Yajima H, et al. Application of Neural Network to Technical Analysis of Stock Market Prediction. Studies in Informatic and Control, 1998, 7: 111-120

[8] Kumar M, Thenmozhi M. Forecasting Stock Index Movement: A Comparison of Support Vector Machines and Random Forest. Social Science Electronic Publishing, 2006.

[9] Zhang Rumeng, Zhang Huamei. Comparative analysis of BP neural network and ARMA-GARCH model in stock prediction. Journal of Science, 2021: 41(4): 14-20.

[10] Li Yong. Design and Implementation of an Intelligent Stock Prediction System Based on Deep Neural Networks: [Master's Thesis] Xi'an: Northwest University, 2019.

[11] Nikou M, Mansourfar G, Bagherzadeh J. Stock Price Prediction Using Deep Learning Algorithm and Its Comparison with Machine Learning Algorithms. Intelligent Systems in Accounting, Finance and Management, 2019, 26: 164-174. DOI : 10.1002/isaf.1459.

[12] Yang Qi, Cao Xianbing. Analysis and prediction of stock prices based on the ARMA-GARCH model. The Practice and Understanding of Mathematics, 2016, 46(6): 80-86.

[13] Huang Ying, Yang Huijie. Financial time series prediction based on the XGBoost and LSTM models. Technology and Industry, 2021, 21(8): 158-162.

[14] Zhang Kanglin. Analysis and prediction of the stock price by the LSTM model based on pytorch. Computer Technology and Development, 2021, 31(1): 161-167.

[15] Song Gang, Zhang Yunfeng, Bao Fangxun. Stock prediction model based on particle swarm optimization of LSTM. Journal of Beijing University of Astronautics, 2019, 45(12): 2533-2542.

[16] Chen W, Chai KY, Lau CT, et al. Leveraging Social Media News to Predict Stock Index Movement Using RNN-Boost. Data & Knowledge Engineering, 2018, 118: 14-24. DOI: 10.1016/j.datak.2018.08.003.

[17] Maqsood H, Mehmood I, Maqsood M, et al. A Local and Global Event Sentiment Based Efficient Stock Exchange Forecasting Using Deep Learning. International Journal of Information Management, 2020, 50: 432-451. DOI: 10.1016/j.ijinfomgt.2019.07.011.

[18] Song Gang, Zhang Yunfeng, Bao Fangxun, et al. A stock prediction model based on particle swarm optimization LSTM, 2019.

[19] Cui Guochao. Research on the Characteristics of Neural Network Models and Packet Size. Wireless Internet Technology, 2012 (3): 105.

[20] Gu Yongpeng, Qin Dibo, Zhang Xiang, et al. Tourist prediction based on LSTM Advances in Applied Mathematics, 2023, 12: 2143.

[21] Qiao Ruoyu. Neural network-based stock prediction model. Operations research and Management, 2019, 28 (10): 132-140.