# Stock Price Prediction Using Deep Learning Methods.

**Sanjana Singh[1] , Akshra Singh[2], Rachita Jha[3], Aditya Kunal Bhate[4], Prof. Anand Motwani[5]**

(1,2,3,4) Department of Computer Science and Engineering; VIT Bhopal University

Sehore, Madhya Pradesh, India

(5) Assistant Professor; Department of Computer Science and Engineering;

VIT Bhopal University;Sehore, Madhya Pradesh, India

## Abstract

Stock market prediction is the way to determine the future value of a company's stock and the successful prediction of a stock's future price could produce profits. For effective prediction of the stock price, the researchers have explored both the linear and machine learning tools for the past few years. However, currently Deep learning applications are found to yield better accuracy and return for financial predictions. For this survey, we selected papers from the Digital Bibliography & Library Project (DBLP) database for comparison and analysis. The purpose of this survey is to review the latest work on deep learning models for stock price prediction. Based on the deep learning methods we classified the paper into Convolutional neural network (CNN); Long Short-Term Memory (LSTM); Deep neural network (DNN); Recurrent Neural Network (RNN). In this survey paper, we also study the dataset, variable, model, and results of all the different deep learning methods. In this paper, we identified that the deep learning based method for stock price prediction is rising exponentially.

**Key words**

**Stock price prediction; deep learning; convolution neural network; recurrent neural network; long short-term memory; deep neural network;survey**

# 1. INTRODUCTION

In developing countries like India, the stock market plays an important role in broadening and growing the country economically in a much faster way. Study of the stock market is an interesting and attractive way to gain knowledge about opportunities to traders, investors, analysts, merchants and researchers in different ways it offers. Stock indexes, predictions, trends, deep learning, machine learning, LSTM are the major terminologies that are explored during all this project. Country's development and growth is directly proportional to stock i.e. increase in stock market will result in country's economic development. Stock prediction can be defined as a combined process of investment, gambling, mind games, transaction,potentially suffering of gaining or losing all together at a gigantic level. According to CNN Business, countries like Argentina, Hungary, Jamaica tops the rankings as the best performers from year 2015 having success rate of 37.48%, 30.78%, 28.5% respectively in stock markets have used several statistical methods for deep studying and doing research on it whereas India is on 41st position with a success rate of 2.58%. The trend and pattern of the stock market may differ from an individual to a country's perspective. For example, understanding the behavioral changes in stock prediction, identifying suitable and profitable trading periods and by looking at past datas, to invest in those organizations that can result in maximum profit, etc. Because of such uncertain and dynamic behavior of stock, very few people of any country gain attraction towards the stock market. As this field is very much unpredictable, people find this field extremely challenging. So, to change people's mindset and to reduce the risk of losing, analysis of market prediction methods come into play to bring much better results.

Our main aim of this survey is to have a detailed study on how to apply deep learning methods in stock price prediction which have been researched in past few years. This survey will be analyzing the existing work in the field of stock price prediction on the basis of the dataset and the variables used. It will also analyze what kind of deep learning model is adopted and the result of the corresponding prediction model.

This paper is organized in the following manner: at first, we have the introduction of different deep learning models; second, the criteria and the research method in the paper;third, the impact and analysis of different deep learning methods on stock price prediction and at last the conclusion of the entire paper.

## 1.1 Stock Price/Trend prediction

One of the first concerns towards the stock exchange is prediction of stock price. A substantial amount of work has been administered that analyses market etiquettes and predicts the longer term price and/or trend. A highly volatile stock exchange experiences large fluctuations and thus, forecasting the worth values and estimating whether the market would move upwards, downwards, or remain steady is difficult. Such predictions require study of varied influential data

also as derivation of the previous patterns of price movements. Therefore, to study these varied influential data we have used the different deep learning methods that will be discussed further.

# 2. INTRODUCTION TO DEEP LEARNING METHODS

## 2.1 CONVOLUTION NEURAL NETWORK

CNN (Convolutional Neural Network)

CNN is made up of multiple neurons that are linked together in a hierarchical structure, and the weights and bias between layers can be trained. The weight of the neurons in each layer of the network can be distributed. As a result, the model significantly reduces network weight while avoiding dimensional disaster and local minimization. Because of its powerful pattern recognition ability, CNN was widely used in the field of image recognition; its use was also extended to the field of economic prediction.

If the characteristics of the stock market at a specific time point are thought of as a feature graph, CNN can extract the characteristics of the stock market at the corresponding period from these feature graphs. As a result, CNN can be used to create a timing-selection model, which can then be used to complete the timing-selection strategy.

## 2.2 RECURRENT NEURAL NETWORK

RNN (RECURRENT NEURAL NETWORK)

RNN can remember the previous state, which can then be used to calculate the current state. RNN is particularly good at dealing with sequential data. The different hidden layers are not independent of one another. The current hidden layer's input includes the output of the input layer and the output of the previous hidden layer. The advantage of RNN is that it considers the context of data during the training process, which is ideal for the scenario of stocks because the fluctuation at a given time frequently contains some connection to the previous trend.

## 2.3 LONG SHORT-TERM MEMORY

LSTM (Long Short-Term Memory) networks are an advanced form of RNN i.e, Recurrent Neural Networks. It was used in the problems where RNN failed. The biggest drawback of RNN was the exploding and the vanishing gradient problem which occurs during the training process of a network during backtracking and therefore LSTM was introduced to primarily solve this vanishing gradient problem in backpropagation.

LSTM is used for classifying,processing and making predictions based on time series data[1]. LSTM uses the gating mechanism that manages the memoizing process. Information can be stored, written or read through these gates. These gates store the

memory in the analog format and analog being differential in nature is suitable for backpropagation. These gates execute element-wise multiplication by sigmoid ranges between 0-1. The stock prediction model based on LSTM uses the corresponding data characteristics from the stock history dataset.

## 2.4 DEEP NEURAL NETWORK

DNN may be a neural network with a minimum of one hidden layer. It provides modeling for complicated nonlinear functions and has a high-level abstraction ability, which means that the fitting power of the model is significantly improved. Meanwhile, it is a kind of discriminant model which might be trained through the backpropagation algorithm.
Since the DNN is appropriate with prediction problems with sizable data and complicated nonlinear mapping relations, a stock prediction system can be designed based on a DNN to predict stock trends[2].

# 3. RESEARCH METHODS AND THE CRITERIA OF DIFFERENT DEEP LEARNING MODELS

## 3.1 PAPER SELECTION METHODS

In the past few years, there are many deep learning model papers on stock prediction methods. The articles analyzed during this paper were all from the Digital Bibliography & Library Project (DBLP) computing bibliography and Microsoft Academic database.
Firstly, the keywords were searched in DBLP: “CNN stock/Forex”, “LSTMstock/Forex”,“Deep learning stock/Forex”, “RNNstock/Forex”.
These keywords are necessary to make sure the papers reviewed are relevant to our topic. The keywords were taken from Microsoft Academic, and then, the filters “2015–2021” and “Deep learning” were applied.
Secondly, the standard of the chosen articles from DBLP was ensured by excluding all journals and conferences that were informally published, and therefore the quality of the chosen articles from Microsoft Academic was controlled by excluding all journals and conferences that were informally published also as those without a minimum of 5 citations. Filtering on citations because the search method was designed to detect understudied areas within this field; a paper with 5 or more citations is often a sign that the world might be potentially explored. Furthermore, it should be noted that we only considered papers with a completely unique model, with the implementation of existing models not analyzed during this review.

At an equivalent time, the timeliness of the survey was provided by those specialized in publications after 2015. Among them, there have been 4 papers in 2015, 1 paper in 2016, 14 papers in 2017, 29 papers in 2018, 28 papers in 2019, and 10 papers in 2020; in total, 86 existing papers were reviewed.

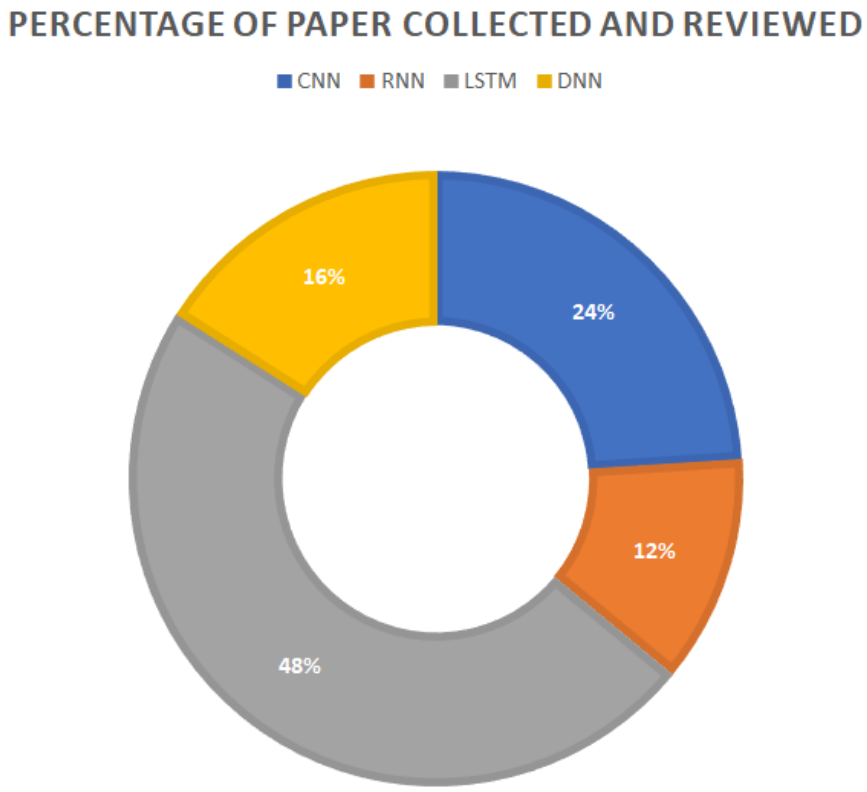
## 3.2 SELECTED PAPER STATISTICS

In this paper, our main aim is to give a detailed survey on the four different models of deep learning with different dataset, input variables and model types. After analyzing each model of deep learning all the results will be compared and discussed for conclusion.
Figure 1 shows the annual distribution of the papers collected and reviewed.

Table 1. The distribution of different types of articles reviewed for this paper

| Types of methods | Total papers | Number of papers in Journals | Number of papers in conferences |
|---|---|---|---|
| CNN | 18 | 6 | 12 |
| RNN | 38 | 13 | 25 |
| LSTM | 9 | 5 | 4 |
| DNN | 5 | 2 | 3 |

Figure 1. Distribution of  different methods used in this paper




## 4. IMPACT AND ANALYSIS OF DIFFERENT DEEP LEARNING MODELS

### 4.1 CNN

The following are brief descriptions of five articles that used CNN for stock prediction. Table- lists the papers' authors,models, datasets and variables.

Table-Papers that used the Convolutional Neural Network (CNN) model are listed here.

| Author | Model | Dataset | Variables | Reference No. |
|---|---|---|---|---|
| Selvin, S. | CNN sliding-window | Companies listed under | Close price | [3] |

| | | | | |
|---|---|---|---|---|
| | model | NSE:TCS,Infosys and CIPLA | | |
| Cai, S. | CNN-LSTM | 1. Crawling financial news<br>2. Baidu Index | 1. word vector; headline and keyword training set in the news<br>2. Close price | [4] |
| Maqsood, H. | CNN | 1. Top 4 performing companies of US, Hong Kong, Turkey, and Pakistan<br>2. Twitter dataset | 1. Open price, high price, low price, AdjClose price, volume, and close price<br>2. Sentiment (positive, neutral, and negative sentiments). | [5] |
| Yang, H. | CNN with MICFS | S&P 500 Index ETF (SPY) | High, low, and close price; volume, RSI, KD, WR, ROC, and CCI | [6] |
| Sim, HS. | CNN | S&P 500 min data | Close price | [7] |

Selvin, S. compared the performance of CNN, LSTM, and RNN architectures in forecasting the price of NSE-listed companies. The final results demonstrated that CNN is the best architecture for predicting stock price because it can identify the trend of directional change.[3]

Cai, S. proposed a CNN and LSTM forecasting system using financial news and historical stock market data. It generated seven different prediction models. The ensemble learning method was used to combine the seven models into one ensemble model in order to obtain an aggregated model. Sadly, all of the models had lower prediction accuracy.[4]

Maqsood, H. proposed a CNN model with price and sentiment analysis as input and compared it to linear regression and support vector machines (SVM). He came to the conclusion that not all significant events have a significant impact on stock exchange prediction. However, more significant local events may have an impact on the performance of prediction algorithms.[5]

Yang, H.M. proposed the MI-CNN framework, which is a multi-indicator feature selection framework for stock index prediction based on a multichannel CNN structure without subsampling. The maximal information coefficient feature selection (MICFS) approach was used to select candidate indicators in this method to ensure correlation with stock movements while reducing redundancy between different indicators.[6]

Sim, H.S. proposed a CNN network that uses 9 technical indicators to validate the CNN method in the stock market (close price, Simple moving average (SMA), Exponential moving average (EMA), Rate of change (ROC), Moving average convergence/divergence (MACD), Fast%K, Slow%D, upper band, and lower band).He came to the conclusion that CNN's use of technical indicators in stock market prediction seems to have no positive effect.[7]

## 4.2 RNN

The following are brief descriptions of four articles that used RNN technology for stock and Forex prediction. Table 3 lists the papers' authors, variables, datasets, and models.
Table 3 lists the papers that used the Recurrent Neural Network (RNN) model.

| Author | Model | Dataset | Variables | Reference No. |
|---|---|---|---|---|
| Chen,W | RNN-Boost | HS300 | 1. Technical features: open price, high price, low price, close price, volume, price change, price limit, volume change, volume limit, amplitude, and | [8] |

| | | | | |
|---|---|---|---|---|
| | | | difference. 2. Content features: sentiment features and LDA features | |
| Zeng, Z. and Khushi | Attention-based RNN-ARIMA | USDJPY exchange rate | Momentum indicators: average directional movement index, absolute price oscillator, Aroon oscillator, balance of power, commodity channel index, Chande momentum oscillator, percentage price oscillator, moving average convergence divergence,Williams, momentum, relative strength index, stochastic oscillator, and triple exponential average Volatility indicators: average true range, normalized average true range, and true range | [9] |

| | | | | |
|---|---|---|---|---|
| Ni, L. | C-RNN | EURUSD, AUDUSD, XAUUSD, GBPJPY, EURJPY, GBPUSD, USDCHF, USDJPY, and USDCAD | Open price, close price, highest price, and lowest price | [10] |
| Li, C. | Multi-task RNN with MRFs | China Security Index: CSI300, CSI200, and CSI500 | Open price, high price, low price, close price, volume, and amount | [11] |

Chen, W. proposed an RNN-Boost model that used technical indicators and sentiment features, as well as Latent Dirichlet allocation (LDA) features, to predict stock prices. Its findings revealed that the proposed model outperformed the single-RNN model.[8]

Zeng. Z proposed a novel Attention-based RNN (ARNN) in which wavelet denoised input was fed into the ARNN. The forecast was created using the Autoregressive integrated moving average (ARIMA) and the ARNN model output.[9]

Ni, L. proposed a CRNN model to forecast the price of nine different Forex pairs. The results showed that the proposed model outperformed both the LSTM and CNN models.[10]

Li, C. proposed an RNN model with Markov Random Fields for multi-tasking (MRF). The multi-multilayer perceptron (MMPL) was proposed to automatically extract diverse and complementary features from individual stock price sequences, removing the need for technical indicators. To use intra-cli, features learned by MMPL were passed to a binary MRF with a weighted lower linear envelope energy function.
MMPL-learned features were fed into a binary MRF with a weighted lower linear envelope energy function to take advantage of intra-clique higher-order consistency between stocks.[11]

## 4.3 LSTM

The following are brief descriptions of four articles that used LSTM for stock prediction. Table- lists the papers' authors,models, datasets and variables.

Table 4 lists the papers that used the Long Short Term Memory (LSTM) model.

| Author | Model | Dataset | Variables | References |
|---|---|---|---|---|
| Lakshminarayanan, S.K. | LSTM | Dow Jones Industrial Average (DJIA) | Close price, moving average, crude oil price, and gold price | [12] |
| Achkar, R. | RNN with LSTM | Facebook stocks, Google stocks, and Bitcoin stocks collected from Yahoo finance | Close price | [13] |
| Skehin, T. | ARIMA-LSTM-Wavelet | Facebook Inc. (FB), Apple Inc. (AAPL), Amazon.com Inc (AMZN), Netflix Inc. (NFLX), and Alphabet Inc. (GOOG) in NASDAQ of S&P 500 | Close price | [14] |
| Jin, Zhigang, et al. | LSTM with sentiment analysis model | Apple stock price | Sentiment and stock price data | [15] |

Lakshminarayanan, S.K. proposed an LSTM model combined with crude oil price, gold price, and moving average, which performed much better than the LSTM model without them and the SVM model. It showed that the crude oil and gold prices had some impact on stock price prediction [12].

Achkar, R. proposed an approach to predict stock market ratios using artificial neural networks. It considered two different techniques—Best performance algorithm (BPA)-Multilayer perceptron (MLP) and LSTM-RNN—their potential, and their limitations. And the LSTM-RNN model outperformed the other one slightly [13].

Skehin, T. proposed a linear Autoregressive Integrated Moving Average (ARIMA) model and LSTM network for each series to produce next-day predictions. Wavelet methods decomposed a series into approximation and detail components to better explain behavior over time. He combined these techniques in a novel ensemble model in an attempt to increase forecast accuracy [14].

Jin, Z., et al. proposed to incorporate a sentiment analysis model into LSTM; they successfully created a novel model which delivers a reasonable result [15].

## 4.4. DNN

The following are brief descriptions of five articles that used DNN for stock prediction. Table- lists the papers' authors,models, datasets and variables.

Table 5 lists the papers that used the Deep Neural Network (DNN) model.

| Author | Model | Dataset | Variables | Reference |
|---|---|---|---|---|
| Naik, N. | DNN | NSE<br>ICICI Bank<br>SBI Bank<br>Kotak Bank<br>Yes Bank | SMA, exponential moving average, momentum indicator, stochastic oscillator, moving average | [16] |

| | | | | |
|---|---|---|---|---|
| | | | convergence divergence, relative strength index, Williams R, accumulation distribution index, and commodity channel index | |
| Yong, Bang Xiang, et al. | DNN | Singapore stock market | Intraday prices | [17] |
| Chatzis, S.P. | DNN | FRED database and the SNL | Stock price, exchange rates, VIX index, gold price, TED spread, oil price, effective federal funds rate, and high yield bond returns | [18] |
| Chong, E. | DNN with autoencoder | KOSPI | Close Price | [19] |
| Yu, Pengfei, and Xuesong Yan | DNN with phase-space reconstruction (PSR) and LSTM | Hang Seng index (HSI), the China Securities index 300 (CSI 300), and the ChiNext index | Closing price | [20] |

Naik, N. proposed a DNN model that used the Boruta feature selection technique to solve the problem of technical indicator feature selection and identification of the relevant

technical indicators. The results showed that his model performed much better than the ANN and SVM models [16].
Yong, B.X., et al. proposed a DNN model with 40 nodes which showed reasonable results and appeared to be a highly profitable model [17].

Chatzis, S.P. proposed a DNN model which used Boosted approaches to predict stock market crisis episodes. According to his research, it was meaningful to know the stock market crisis to predict the price, even though his research was not specific to certain prediction methods [18].

Chong, E. proposed DNN networks and examined the effects of three unsupervised feature extraction methods including principal component analysis, auto-encoder, and the restricted Boltzmann machine on the network's overall ability to predict future market behavior. The empirical results suggested that DNNs could extract additional information from the residuals of the auto-regressive model and could improve prediction performance; the same could not be said when the auto-regressive model is applied to the residuals of
the network [19].

Yu, P. and Yan, X. proposed a novel DNN model which incorporated LSTM as well as phase-space recognition. The model had produced promising results [20].

## FUTURE WORK

The previously described machine learning models demonstrate how SVM and LSTM are highly preferred by investigators due to their high accuracy results in text classification and market prediction, whereas many other machine learning methods like decision tree, random forest (RF),K-nearest neighbors, linear regression, artificial neural networks (ANN), etc. show promising results for text mining and sentiment analysis tasks for market analysis but are least frequently used and therefore should be looked into further.Future work should concentrate on predicting stock market movement using structured data (past stock prices) as well as textual data from various sources such as financial news and social media. Furthermore, in order to achieve better results in stock market prediction, the text mining

procedure should improve feature selection, feature representation, and dimensionality reduction methods.

In future we might consider combining various other models for predicting stock prices. Although LSTM has been widely used these days for predicting the stock price/trends. But despite of LSTM there are a number of various other methods that are exponentially rising to predict the stock price/trends i.e, reinforcement learning, hybrid approach and ARIMA model etc. Hence all these models will be very beneficiary in future for predicting the stock price/prediction.

## CONCLUSION

Stock market predictions have been appealing to both investors and researchers; an enormous amount of work has been done at various levels where different aspects of market dynamics are explored in order to make reliable predictions.

To investigate the significance of neural network prediction in the stock market, we conduct a thorough survey and review the approaches for various stock market applications.

The existing stock models were evaluated by examining data sets, variables, and the application of various models. The research review covered a wide range of techniques, including CNN, LSTM, DNN, and RNN. Besides that, the data sets, variables, and models, as well as the various outcomes, were analyzed and compared within each technique.

This paper aimed to contribute to the research on stock market prediction by analysing the various deep learning prediction models mentioned above.As per the review, there is a scarcity of studies on the combination of multiple deep learning methods, particularly when compared to other deep learning methods. The LSTM Models are showing promising results in terms of future research.

## REFERENCES


1. He, T.; Droppo, J. Exploiting LSTM structure in deep neural networks for speech recognition. In Proceedings of the 2016 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Shanghai, China, 20–25 March 2016; pp. 5445–5449.
2. Souma, W.; Vodenska, I.; Aoyama, H. Enhanced news sentiment analysis using deep learning methods. J. Comput. Soc. Sci. 2019, 2, 33–46.
3. Selvin, S.; Vinayakumar, R.; Gopalakrishnan, E.A.; Menon, V.K.; Soman, K.P. Stock price prediction using LSTM, RNN and CNN-sliding window model. In Proceedings of the 2017 International Conference on Advances in Computing, Communications and Informatics (ICACCI), Manipal, India, 13–16 September 2017.
4. Cai, S.; Feng, X.; Deng, Z.; Ming, Z.; Shan, Z. Financial news quantization and stock market forecast research based on CNN and LSTM. In Proceedings of the International Conference on Smart Computing and Communication, Tokyo, Japan, 10–12 December 2018; Springer: Berlin/Heidelberg, Germany, 2018.
5. Maqsood, H.; Mehmood, I.; Maqsood, M.; Yasir, M.; Afzal, S.; Aadil, F.; Selim, M.M.; Muhammad, K. A local and global event sentiment based efficient stock exchange forecasting using deep learning. Int. J. Inf. Manag. 2020, 50, 432–451.
6. Yang, H.; Zhu, Y.; Huang, Q. A multi-indicator feature selection for CNN-driven stock index prediction. In Proceedings of the International Conference on Neural Information Processing, Siem Reap, Cambodia, 13–16 December 2018; Springer: Berlin/Heidelberg, Germany, 2018.
7. Sim, H.S.; Kim, H.I.; Ahn, J.J. Is deep learning for image recognition applicable to stock market prediction? Complexity 2019,1–10.
8. Chen, W.; Yeo, C.K.; Lau, C.T.; Lee, B.S. Leveraging social media news to predict stock index movement using RNN-boost. Data Knowl. Eng. 2018, 118, 14–24.
9. Zeng, Z.; Khushi, M.Wavelet denoising and attention-based RNN- ARIMA model to predict forex price. In Proceedings of the 2020 International Joint Conference on Neural Networks (IJCNN), Glasgow, UK, 19–24 July 2020.
10. Ni, L.; Li, Y.; Wang, X.; Zhang, J.; Yu, J.; Qi, C. Forecasting of forex time series data based on deep learning. Procedia Comput. Sci. 2019, 147, 647–652.
11. Li, C.; Song, D.; Tao, D. Multi-task recurrent neural networks and higher-order markov random fields for stock price movement prediction: Multi-task RNN and higher-order MRFs for stock price classification. In Proceedings of the 25th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining, Anchorage, AK, USA, 4–8 August 2019; Association for Computing Machinery: Anchorage, AK, USA, 2019; pp. 1141–1151.

12. Lakshminarayanan, S.K.; McCrae, J. A comparative study of svm and lstm deep learning algorithms for stock market prediction. In Proceedings of the 27th AIAI Irish Conference on Artificial Intelligence and Cognitive Science (AICS 2019), Galway, Ireland, 5–6 December 2019.
13. Achkar, R.; Elias-Sleiman, F.; Ezzidine, H.; Haidar, N. Comparison of BPA-MLP and LSTM-RNN for stock prediction. In Proceedings of the 2018 6th International Symposium on Computational and Business Intelligence (ISCBI), Basel, Switzerland,27–29 August 2018.
14. Skehin, T.; Crane, M.; Bezbradica, M. Day ahead forecasting of FAANG stocks using ARIMA, LSTM networks and wavelets. In Proceedings of the 26th AIAI Irish Conference on Artificial Intelligence and Cognitive Science (AICS 2018), Dublin, Ireland, 6–7 December 2018.
15. Jin, Z.; Yang, Y.; Liu, Y. Stock closing price prediction based on sentiment analysis and LSTM. Neural Comput. Appl. 2020, 32, 9713–9729.
16. Naik, N.; Mohan, B.R. Stock price movements classification using machine and deep learning techniques-the case study of indian stock market. In Proceedings of the International Conference on Engineering Applications of Neural Networks, Athens, Greece, August 2019; Springer: Berlin/Heidelberg, Germany, 2019.
17. Yong, B.X.; Rahim, M.R.A.; Abdullah, A.S. A stock market trading system using deep neural networks. In Proceedings of the Asian Simulation Conference, Melaka, Malaysia, 27–29 August 2017; Springer: Berlin/Heidelberg, Germany, 2017.
18. Chatzis, S.P.; Siakoulis, V.; Petropoulos, A.; Stavroulakis, E.; Vlachogiannakis, N. Forecasting stock market crisis events using deep and statistical machine learning techniques. Expert Syst. Appl. 2018, 112, 353–371
19. Chong, E.; Han, C.; Park, F.C. Deep learning networks for stock market analysis and prediction: Methodology, data representations, and case studies. Expert Syst. Appl. 2017, 83, 187–205.
20. Yu, P.; Yan, X. Stock price prediction based on deep neural networks. Neural Comput. Appl. 2020, 32, 1609–1628.