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LSTM-Based Deep Learning Model for Financial Market Stock Price Prediction

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Abstract: Through methods such as machine learning and deep learning, artificial intelligence models can process and analyze large amounts of complex financial data to assist financial institutions in rapid and accurate analysis and decision-making, thereby improving the efficiency and quality of financial services. In this paper, a prediction model of gold stock price based on Bayesian network optimized Long short-term memory neural network (BO-LSTM) is proposed. By introducing Bayesian network to optimize the hyperparameters of LSTM model, the prediction accuracy and robustness of the model are improved. The empirical results show that the BO-LSTM model has a significant advantage in the gold stock price prediction task, which is better than the traditional LSTM model and the benchmark model. The results of this study strongly support the effectiveness of Bayesian networks in optimizing deep learning models, and demonstrate the potential and application prospect of BO-LSTM model in financial market forecasting. In addition, the study also points out future improvement directions, including optimizing data selection and improving model structure to more accurately describe the complex and volatile stock market.

Keywords: Financial Market Forecasting, Deep Learning Models, LSTM, Stock Price Prediction, Bayesian Optimization

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1 Introduction

Over the past few decades, intelligent computing in finance has been the focus of intense attention in academia and the financial industry. Researchers are constantly exploring models and applying them in financial markets to improve trading efficiency and risk management capabilities. With the development of the field of machine learning [1] (ML), deep learning (DL) has received widespread attention in recent years, and its performance advantages have gradually become prominent. The continuous emergence of DL algorithm has brought new opportunities and challenges to the financial field. In the financial field, the application of DL model has special significance. [2] The complexity and highly dynamic nature of financial markets make it difficult for traditional statistical methods to capture their inherent laws. The nonlinear characteristics of deep learning and the efficient processing of large-scale data provide new ideas and tools for solving forecasting and decision-making problems in financial markets.

As one of the important tasks in the financial field, stock market forecasting covers stock trend forecasting, stock price forecasting, portfolio management and trading strategy. In this area, deep learning techniques are rapidly emerging. In particular, deep learning models based on Long Short-Term Memory (LSTM) have shown excellent performance and potential in stock market prediction.

Based on LSTM model in deep learning, this paper discusses its application in stock price prediction of financial market. Through the theoretical analysis, empirical research and case analysis of the model, it aims to provide a new way of thinking and method for financial practitioners and researchers to deal with the complexity and uncertainty of the financial market.

2 Related work

2.1 Deep learning

Deep learning is a special ML model that consists of multiple ANN layers. It provides a high dimensional representation for data modeling. In the literature, there are different DL models: Deep Multilayer Perceptrons (DMLP), CNNS, RNN, LSTM, Restricted Boltzmann machines (RBM), Deep trust networks (DBN), and autoencoders (AE), among others.

Depth Multilayer Perceptron (DMLP): [3] A DMLP

network consists of input, output, and hidden layers, just like a normal multilayer perceptron (MLP); However, the number of layers in a DMLP is greater than in an MLP. In addition, each neuron has a nonlinear activation function that generates the output of that neuron by accumulating the weighted inputs of the previous layer of neurons. Compared with multi-layer shallow neural networks, multi-layer deep artificial neural networks can achieve more efficient classification and regression performance. The learning process of DMLP is implemented through backpropagation. The amount of output errors in the output layer neurons is also reflected back to the neurons in the previous layer. In DMLP, the stochastic gradient Descent (SGD) method is mainly used to optimize learning (updating the weights of connections between layers). The DMLP structure is as follows:

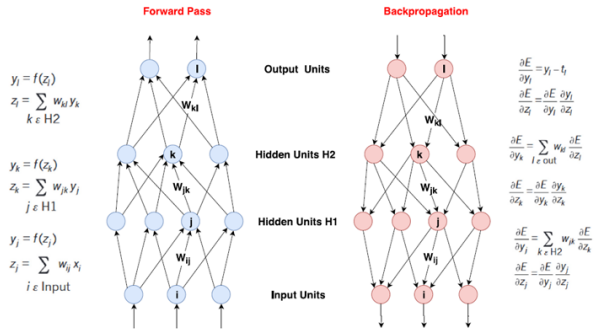


Figure 1. Deep multi layer neural network forward pass and backpropagation

Convolutional Neural Network (CNN) [4]: A CNN is a deep neural network (DNN) primarily used for image classification and image recognition problems. The whole image is mainly scanned by filter. In the literature, most use 1×1, 3×3, and 5×5 size filters. In most CNN architectures, the types of layers vary: convolution layer, pooling layer (mean layer or maximum layer), fully connected layer. CNN consists of convolutional layers based on convolution operations. The following diagram shows a common CNN architecture with different layers: a convolutional layer, a subsampling layer (pooled layer), and a fully connected layer, whose structure is as follows:

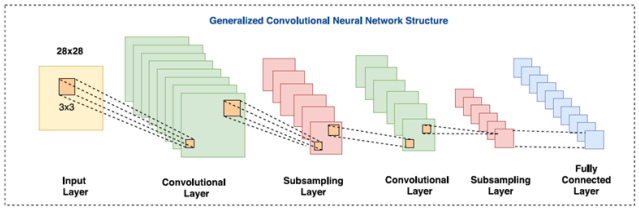


Figure 2. Generalized convolutional neural network architecture.

Long short-term Memory Neural Network (LSTM) : LSTM networks are another type of DL network that is specifically used for sequential data analysis. The advantage of LSTM networks is that both short - and long-term values in the network can be remembered. DL researchers are therefore primarily using LSTM networks for sequential data analysis (automatic speech recognition, language translation, handwritten character recognition, time series data prediction, etc.). The LSTM network consists of LSTM units. LSTM cells consist of cells with input, output, and forget gates. These three gates regulate the flow of information. Using these features, each cell can remember the desired value at any time interval. LSTM cells merge to form the neural network layer. The following diagram illustrates the composition of an LSTM cell.

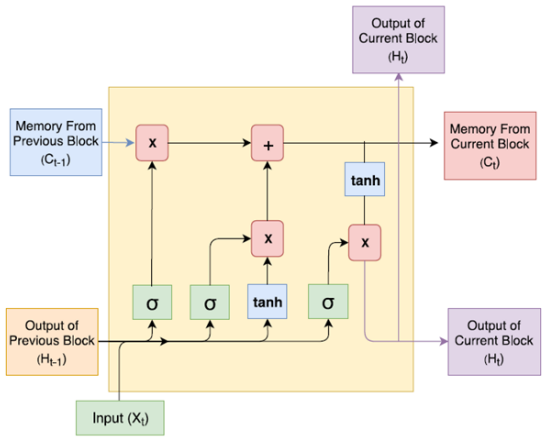


Figure 3. Basic LsTM unit

2.2 Finance and deep learning models

2.2.1 Algorithmic trading

Algorithmic trading (or Algorithmic trading) is defined as buying and selling decisions made solely by algorithmic models. These decisions can be based on some simple rules, mathematical models, optimized processes, or in the case of machine/deep learning, highly complex function approximation techniques. [5] With the introduction of electronic online trading platforms and frameworks, algorithmic trading has taken over the financial industry over the past two decades. As a result, algorithmic trading models based on DL have also begun to attract attention. Most Algorithmic trading applications are combined with price prediction models to predict market timing. Therefore, most price or trend prediction models based on their predictions trigger buy and sell signals are also considered algorithmic trading systems. However, there are also studies that propose independent algorithmic trading models that focus on the dynamics of the trade itself by optimizing buy and sell parameters (e.g., bid-ask spread, limit order book analysis, open position size, etc.). High-frequency trading (HFT) researchers are particularly interested in this area. Therefore, DL model also began to appear in HFT research.

2.2.2 Risk assessment

Another area of research that [6] DL researchers are interested in is "risk assessment," which identifies the "risk" of any given asset, company, individual, product, bank, etc. There are several different versions of this general problem, such as bankruptcy prediction, credit scoring, credit

evaluation, loan/insurance underwriting, bond rating, loan application, consumer credit determination, business credit rating, mortgage selection decisions, financial crisis prediction, business failure prediction. In this context, it is critical to correctly identify the risk status, as asset pricing is highly dependent on these risk assessment measures. The mortgage crisis, based on poor assessment of the risk of credit default swaps (CDS) [7] between financial institutions, caused the housing bubble to burst in 2008 and contributed to the Great Depression. Most risk assessment research focuses on credit scores and bank distress classification. However, there are also papers dealing with the possibility of mortgage default, risk trading detection or crisis prediction. At the same time, there are a number of anomaly detection studies for risk assessment, most of which also fall into the "fraud detection" category.

2.2.3 Fraud detection

Financial fraud is one of the areas where governments and authorities are desperately seeking permanent solutions. There are several different cases of financial fraud, such as credit card fraud, money laundering, consumer credit fraud, tax evasion, bank fraud, insurance claim fraud. There are many studies devoted to identifying credit card fraud. LSTM model for credit card fraud detection. [8] Implemented a DMLP network to sort credit card transactions for fraud. [9] Anomaly detection using deep AE to identify financial fraud and money laundering by Brazilian companies in export tax claims. [10] An anomaly detection model is proposed that also uses deep AE to identify anomalies in parliamentary spending in Brazilian elections. [11] Using text mining and DMLP models to detect auto insurance fraud [12] A DMLP model was developed to detect fraud in online payment transactions. [13] A sequence of characters and the response of the other party are used in financial transactions to detect whether the transaction is LSTM fraud. [14] Reinforcement learning (RL) is used to predict tax evasion by risk-averse companies. Finally, they offer recommendations for states to maximize their tax revenues.

2.3 Financial stock price forecasting

Common models for stock market prediction include RNN based model, GNN based model, CNN based model, reinforcement learning model, Transformer based model and some other innovative methods. Figure 3 shows an overview of the mainstream deep learning models used for stock market forecasting.

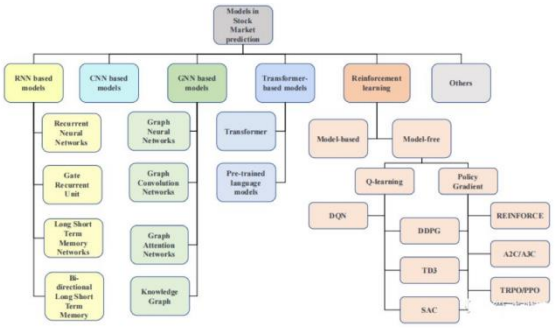


Figure 4. Structure of financial neural network

Since there is a belief in the stock market that stock prices change randomly and independently of each other, this is known as the random walk theory. [15-17] According to the random walk theory, stock prices take random and unpredictable paths, so all attempts to consistently predict stock prices are futile. This means that none of the previous stock prices, trends, or information can be used to accurately predict future movements. However, it is important to note that not everyone fully agrees with the random walk theory.

Input features are extracted and organized based on prediction targets and data set composition, which can be roughly divided into four groups: time series, text, knowledge graph, etc.

(1) Time series [18]. Because many models rely on modeling stock prices over time, time series data is a ubiquitous input in stock forecasting. The specific time range of the forecast, such as intra-day or cross-day, determines the granularity of the data used, ranging from the minute level to the day level. In addition, in the context of reinforcement learning, time series data can be transformed into environments where features can be used to create states and rewards. This allows the agent to interact with the environment and constantly improve its decision-making strategy.

(2) Text. [19] Text information includes a variety of information sources, such as news and articles. This type of information is thought to have a knock-on effect on investor sentiment. However, text information must be pre-processed and structured before it can be used in a model, as text information may come from different languages and sources.

(3) Figure. The industry knowledge graph is the most commonly used graph, not only to show the direct connections between partners, but also to explore their internal relationships, such as upstream and downstream supply chains.

(4) Others. Different data sources are used in the stock prediction task, each providing a unique perspective, including image data and audio data. [20-21] This data is used as supplementary information, for example, vocal features, such as intonation, can indicate the emotion of the speaker.

3 Methodology

This paper introduces an innovative gold stock price prediction model, which is based on Bayesian network optimized Long short-term memory neural network (BO-LSTM). Based on the traditional LSTM neural network, Bayesian network is introduced in this model, and the prediction accuracy is improved by optimizing the hyperparameters of the LSTM model. In the empirical study, we conducted extensive experimental validation of the BO-LSTM model to evaluate its performance in the gold stock price prediction task.

The experimental results show that the BO-LSTM model has a significant advantage in the task of gold stock price prediction. Compared with the traditional LSTM model and the benchmark model, the BO-LSTM model has achieved better results in terms of prediction accuracy and robustness. [22-24] These experimental evidences strongly support the effectiveness of Bayesian networks in optimizing deep learning models, as well as the potential and application prospects of BO-LSTM models in financial market forecasting.

3.1 Experimental design

This paper proves the advantages of the LSTM prediction model in the stock prediction market by forecasting the stock price of the gold market. BO-LSTM model consists of two parts [25]:

1.LSTM neural network: responsible for modeling and forecasting gold stock price time series data.

2. Bayesian network: responsible for optimizing the hyperparameters of the LSTM model.

The nodes in the Bayesian network represent the hyperparameters of the LSTM model, such as the learning rate, the number of hidden layer nodes, etc[26]. The connected edges between nodes represent dependencies between hyperparameters. With Bayesian networks, we can deduce the hyperparameters based on historical data to obtain the optimal combination of hyperparameters.

(1) Bayesian Optimization (BO)

Bayesian optimization is a global optimization algorithm that uses fewer iterations and known data to obtain the best solution, and is now mostly used to adjust the hyperparameters of machine learning algorithms. The idea of Bayesian optimization algorithm is to use the prior probability distribution of the objective function and known observation points to update the posterior probability distribution, and then find the next minimum point according to the posterior probability distribution, so that the minimum value is constantly reduced, and finally get the optimal hyperparameter. [27] Observed data = prior distribution - Posterior data According to Bayes' theorem:

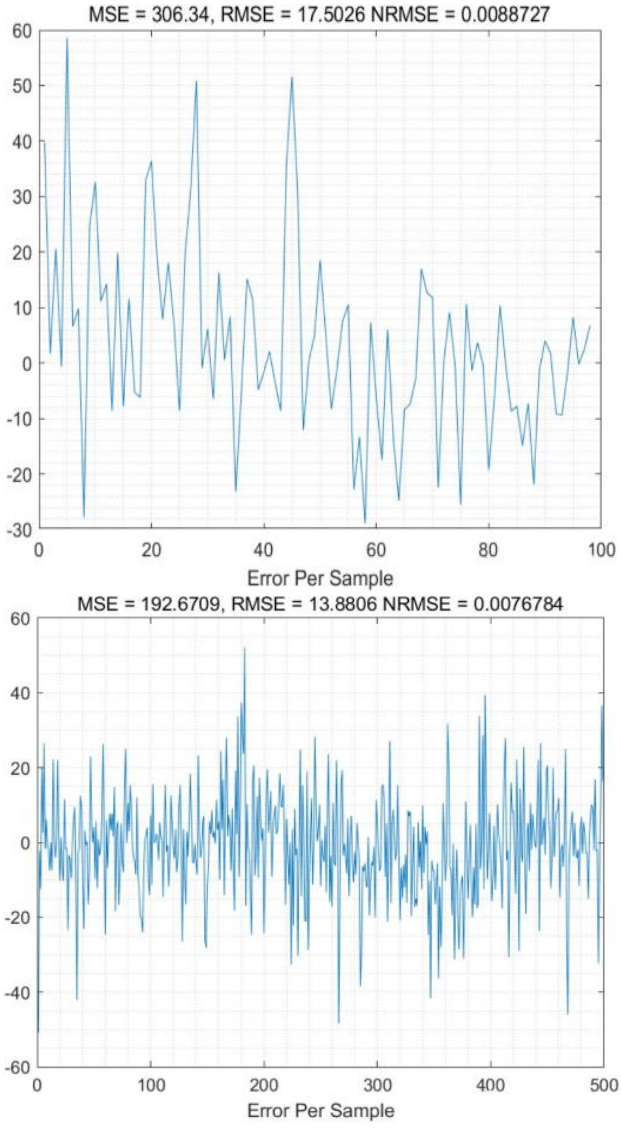
$$p(f \mid D) = \frac{p(D \mid f)p(f)}{p(D)} \quad (1)$$

(2) LSTM

LSTM is a special type of RNN (Recurrent Neural Network). Compared with RNN, it is more suitable for processing and prediction.

Data with long intervals in intermediate sequences. The traditional RNN tructure is a "loop" consisting of many repeating neurons, each of which can receive input information and thus produce output, and then pass the output result as the input of the next neuron, which in turn is passed on. This structure has a short-term dependence on the sequence data, but because of the influence of gradient vanishing and gradient explosion, it is difficult for RNN to perform well in the processing of long sequence data. To solve these problems, LST network is introduced in this paper.

3.2 Result model



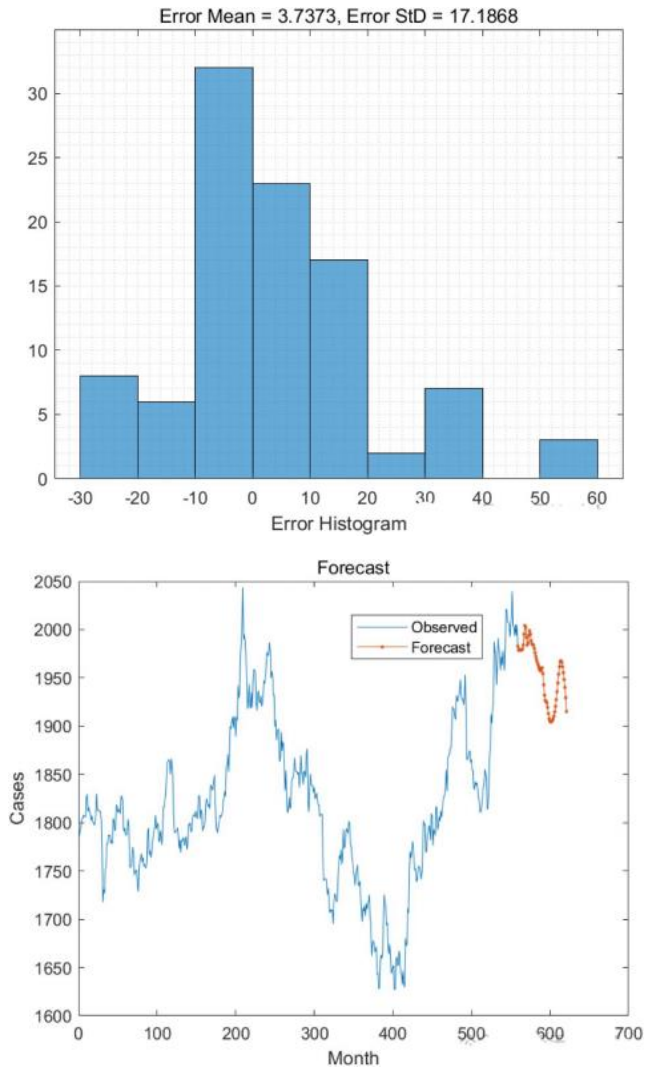


Figure 5. Resulting model diagram

The results of this experiment are shown in Figure 5, clearly demonstrating the advantages of the BO-LSTM model in the task of gold stock price prediction. First, we observed that the BO-LSTM model showed a significant improvement in forecasting accuracy. By comparing the traditional LSTM model with the benchmark model, we find that the BO-LSTM model can capture the trend of gold stock price more accurately, so that the prediction results are more accurate and reliable [28].

Further analysis of the experimental results shows that the BO-LSTM model not only has advantages in forecasting accuracy, but also has obvious improvement in robustness. In a highly dynamic and uncertain environment such as financial markets, model robustness is particularly important. By introducing Bayesian network optimization mechanism, BO-LSTM model effectively improves the robustness of the model and makes it better resistant to market fluctuations and data noise.

In addition, the experimental results also reveal the role of the traditional [29] LSTM model in this experiment. Although the LSTM model does not perform as well as the BO-LSTM model in some cases, it still provides us with a valuable benchmark for comparison. By comparing the performance of the traditional model and the optimized model, we can more clearly evaluate the advantages and improvements of the BO-LSTM model, and further guide the model optimization and application practice. Based on the above results, this experiment strongly supports the effectiveness of Bayesian networks in optimizing deep learning models, as well as the potential and application prospect of BO-LSTM [30] model in financial market forecasting. This research result provides important theoretical support and practical guidance for intelligent forecasting and decision-making in the financial field, and is expected to promote the development and innovation in the field of financial technology.

4 Conclusion

In the field of computer, the related research on stock price prediction has also attracted extensive attention of scholars. In order to build efficient and accurate prediction models for stock prices, researchers first tried to explore linear models, and then explored related machine learning models, until today's more popular deep learning models, which have made more contributions to predicting factors related to stocks. In recent years, deep learning models in theory can greatly improve the accuracy and timeliness of stock prediction tasks, and in large-scale calculation with the support of resources, part of the model can also be applied in practice, so as to improve the stock prediction task more accurately and efficiently [31].

For the research of stock prediction, this paper proposes the method of calculating self-attention with multi-module data to improve the prediction accuracy of deep learning model. Although the final experiment shows that the improved method has a certain effect, there are still many shortcomings.

First, the selection of data has yet to be optimized. The data determines the upper limit of the prediction effect, if the selected data does not provide enough market information, then no model or algorithm can get accurate prediction effect. The main factor of this paper is the model, and the research on the data set needs to be in-depth, and the data set used in this paper is not enough to [32] fully reflect the market situation. In future studies, the relevant data sets can be further expanded so that the data sets can more reflect the influence of other factors such as public opinion, investor sentiment, policy and environment on stock prices.

Second, the model used in this article leaves much room for improvement. From the perspective of deep learning, this study uses rich training sets and complex model structures to explore the law of stock price rise and fall. In contrast, finance studies usually start from the aspects of market rules, etc. [33] Many scholars use multi-factor models to study the factors affecting stock prices, and the models are more explainable. Compared with the multi-

factor models in finance, the complexity of deep learning models is greatly increased, and the corresponding interpretation of experimental results is lacking. If we can combine financial theory and deep learning theory, construct an improved combination model, make full use of the empirical theory of finance and the nonlinear fitting ability of deep learning, we will be able to describe the complex and changeable stock market more accurately.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

[1] Duan, Shiheng, et al. “Prediction of Atmospheric Carbon Dioxide Radiative Transfer Model Based on Machine Learning”. Frontiers in Computing and Intelligent Syste vol. 6, no. 3, Jan. 2024, pp. 132-6.

[2] He, Zheng & Shen, Xinyu & Zhou, Yanlin & Wang, Yong. (2024). Application of K-means clustering based on artificial intelligence in gene statistics of biological information engineering. 10.13140/RG.2.2.11207.47527.

[3] Pan, Linying & Xu, Jingyu & Wan, Weixiang & Zeng, Qiang. (2024). Combine deep learning and artificial intelligence to optimize the application path of digital image processing technology.

[4] Wan, Weixiang & Sun, Wenjian & Zeng, Qiang & Pan, Linying & Xu, Jingyu. (2024). Progress in artificial intelligence applications based on the combination of self-driven sensors and deep learning.

[5] Sun, Wenjian & Xu, Jingyu & Pan, Linying & Wan, Weixiang & Wang, Yong. (2024). Automatic driving lane change safety prediction model based on LSTM.

[6] Wang, Yong & Ji, Huan & Zhou, Yanlin & He, Zheng & Shen, Xinyu. (2024). Construction and application of artificial intelligence crowdsourcing map based on multi-track GPS data. 10.13140/RG.2.2.24419.53288.

[7] Zheng, Jiajian & Xin, Duan & Cheng, Qishuo & Tian, Miao & Yang, Le. (2024). The Random Forest Model for Analyzing and Forecasting the US Stock Market in the Context of Smart Finance.

[8] Yang, Le & Tian, Miao & Xin, Duan & Cheng, Qishuo & Zheng, Jiajian. (2024). AI-Driven Anonymization: Protecting Personal Data Privacy While Leveraging Machine Learning.

[9] Cheng, Qishuo & Yang, Le & Zheng, Jiajian & Tian, Miao & Xin, Duan. (2024). Optimizing Portfolio Management and Risk Assessment in Digital Assets Using Deep Learning for Predictive Analysis.

[10] He, Yuhang, et al. “Intelligent Fault Analysis With AIOps Technology”. Journal of Theory and Practice of Engineering Science, vol. 4, no. 01, Feb. 2024, pp. 94-100, doi:10.53469/jtpes.2024.04(01).13.

[11] Du, Shuqian, et al. “Application of HPV-16 in Liquid-Based Thin Layer Cytology of Host Genetic Lesions Based on AI Diagnostic Technology Presentation of Liquid”. Journal of Theory and Practice of Engineering Science, vol. 3, no. 12, Dec. 2023, pp. 1-6, doi:10.53469/jtpes.2023.03(12).01.

[12] Xin, Q., He, Y., Pan, Y., Wang, Y., & Du, S. (2023). The implementation of an AI-driven advertising push system based on a NLP algorithm. International Journal of Computer Science and Information Technology, 1(1), 30-37.0

[13] “Machine Learning Model Training and Practice: A Study on Constructing a Novel Drug Detection System”. International Journal of Computer Science and Information Technology, vol. 1, no. 1, Dec. 2023, pp. 139-46, https://doi.org/10.62051/ijcsit.v1n1.19.

[14] Cheng, M. Tian, L. Yang, J. Zheng, and D. Xin, “Enhancing High-Frequency Trading Strategies with Edge Computing and Deep Learning”, Journal of Industrial Engineering & Applied Science, vol. 2, no. 1, pp. 32–38, Feb. 2024.

[15] “Unveiling the Future Navigating Next-Generation AI Frontiers and Innovations in Application”. International Journal of Computer Science and Information Technology, vol. 1, no. 1, Dec. 2023, pp. 147-56, https://doi.org/10.62051/ijcsit.v1n1.20.

[16] K.Tan and W. Li, "Imaging and Parameter Estimating for Fast Moving Targets in Airborne SAR," in IEEE Transactions on Computational Imaging, vol. 3, no. 1, pp. 126-140, March 2017, doi: 10.1109/TCI.2016.2634421.

[17] K. Tan and W. Li, "A novel moving parameter estimation approach offast moving targets based on phase extraction," 2015 IEEE International Conference on Image Processing (ICIP), Quebec City, QC, Canada, 2015, pp. 2075-2079, doi: 10.1109/ICIP.2015.7351166.

[18] Duan, Shiheng, et al. "THE INNOVATIVE MODEL OF ARTIFICIAL INTELLIGENCE COMPUTER EDUCATION UNDER THE BACKGROUND OF EDUCATIONAL INNOVATION." The 2nd International scientific and practical conference “Innovations in education: prospects and challenges of today”(January 16-19, 2024) Sofia, Bulgaria. International Science Group. 2024. 389 p.. 2024.

[19] Liu, B., Zhao, X., Hu, H., Lin, Q., & Huang, J. (2023). Detection of Esophageal Cancer Lesions Based on CBAM Faster R-CNN. Journal of Theory and Practice of Engineering Science, 3(12), 36–42. https://doi.org/10.53469/jtpes.2023.03(12).06

[20] Gao, Longsen, et al. "Autonomous multi-robot servicing for spacecraft operation extension." 2023 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). IEEE, 2023.

[21] Qian, Wenpin, et al. "NEXT-GENERATION ARTIFICIAL INTELLIGENCE INNOVATIVE APPLICATIONS OF LARGE LANGUAGE MODELS AND NEW METHODS." OLD AND NEW TECHNOLOGIES OF LEARNING DEVELOPMENT IN MODERN CONDITIONS (2024): 262.

[22] Tan, Kai, et al. “Integrating Advanced Computer Vision and AI Algorithms for Autonomous Driving Systems”. Journal of Theory and Practice of Engineering Science, vol. 4, no. 01, Jan. 2024, pp. 41-48, doi:10.53469/jtpes.2024.04(01).06.

[23] Chen, Wangmei, et al. “Applying Machine Learning Algorithm to Optimize Personalized Education Recommendation System”. Journal of Theory and Practice of Engineering Science, vol. 4, no. 01, Feb. 2024, pp. 101-8, doi:10.53469/jtpes.2024.04(01).14.

[24] “Exploring New Frontiers of Deep Learning in Legal Practice: A Case Study of Large Language Models”. International Journal of Computer Science and Information Technology, vol. 1, no. 1, Dec. 2023, pp. 131-8, https://doi.org/10.62051/ijcsit.v1n1.18.

[25] Cai, J., Ou, Y., Li, X., Wang, H. (2021). ST-NAS: Efficient Optimization of Joint Neural Architecture and Hyperparameter. In: Mantoro, T., Lee, M., Ayu, M.A., Wong, K.W., Hidayanto, A.N. (eds) Neural Information Processing. ICONIP 2021. Communications in Computer and Information Science, vol 1516. Springer, Cham. https://doi.org/10.1007/978-3-030-92307-5_32

[26] Yimin Ou, Rui Yang, Lufan Ma, Yong Liu, Jiangpeng Yan, Shang Xu, Chengjie Wang, Xiu Li,UniInst: Unique representation for end-to-end instance segmentation,Neurocomputing,Volume 514,2022,Pages

551-562,ISSN 0925-2312,https://doi.org/10.1016/j.neucom.2022.09.112.

[27] Gong, Yulu, et al. "RESEARCH ON A MULTILEVEL PRACTICAL TEACHING SYSTEM FOR THE COURSE'DIGITAL IMAGE PROCESSING." OLD AND NEW TECHNOLOGIES OF LEARNING DEVELOPMENT IN MODERN CONDITIONS (2024): 272.

[28] "The Application of Artificial Intelligence in Medical Diagnostics: A New Frontier". Academic Journal of Science and Technology, vol. 8, no. 2, Dec. 2023, pp. 57-61, https://doi.org/10.54097/ajst.v8i2.14945.

[29] Pan, Yiming, et al. "Application of Three-Dimensional Coding Network in Screening and Diagnosis of Cervical Precancerous Lesions". Frontiers in Computing and Intelligent Systems, vol. 6, no. 3, Jan. 2024, pp. 61-64, https://doi.org/10.54097/mi3VM0yB.

[30] Shen, Zepeng, et al. "EDUCATIONAL INNOVATION IN THE DIGITAL AGE: THE ROLE AND IMPACT OF NLP TECHNOLOGY." OLD AND NEW TECHNOLOGIES OF LEARNING DEVELOPMENT IN MODERN CONDITIONS (2024): 281.

[31] Wei, Kuo, et al. "Strategic Application of AI Intelligent Algorithm in Network Threat Detection and Defense". Journal of Theory and Practice of Engineering Science, vol. 4, no. 01, Jan. 2024, pp. 49-57, doi:10.53469/jtpes.2024.04(01).07.

[32] Pan, Yiming, et al. "Application of Three-Dimensional Coding Network in Screening and Diagnosis of Cervical Precancerous Lesions". Frontiers in Computing and Intelligent Systems, vol. 6, no. 3, Jan. 2024, pp. 61-64, https://doi.org/10.54097/mi3VM0yB.

[33] Zhang, Yufeng, et al. "Manipulator Control System Based on Machine Vision." International Conference on Applications and Techniques in Cyber Intelligence ATCI 2019: Applications and Techniques in Cyber Intelligence 7. Springer International Publishing, 2020.