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Machine Learning Analysis in Mechanical Engineering

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Abstract

Despite the rapid development of the AI industry and the programming industry in the machinery manufacturing or production industry, there is no systematic explanation as to why the use of machine learning can enhance the development of related industries. This paper summarizes the reasons for the industry's development direction from the three aspects of machine learning's automation design, expected maintenance, and production efficiency improvement. The learning types are briefly introduced to indicate the application of machine learning in mechanical engineering. By providing relevant examples, the superiority of machine learning in mechanical engineering is reflected, and specific practical cases are given to show the development trend of machine learning in the manufacturing industry in the future. Finally, we make predictions on the main development directions of machine learning in the future industry.

Keywords

data-driven, neural network, machine learning, artificial intelligence

1. Introduction

In recent years, because of the continuous upward development of the domestic industrial level, the industrial structure has gradually been updated and upgraded. Industrial production has remained stable on the path toward high-end, intelligent, and greenization, with the supporting role of equipment manufacturing and high-tech manufacturing becoming increasingly prominent. Together, these factors have promoted the continued growth of domestic industrial development. In the manufacturing process, optimizing the use efficiency and production efficiency of machine learning is a way worth exploring (Shi, 2024). This method not only improves efficiency but also improves product design, maintenance and management methods, injecting new vitality into the transformation of the traditional machinery manufacturing industry. This paper comprehensively reviewed the application of machine learning in mechanical engineering, discussed the theoretical basis and practical effects, and proposed future developments.

2. Machine Learning Basics

2.1 Summary of Machine Learning Methods

Computer technology is "data-driven" disciplinary research that aims to endow computers with learning ability and computer programs that absorb historical experience through performance evaluation. Additionally, it covers techniques that can automatically discover patterns in data and make predictions about future data. Its basic concepts cover information collection, data analysis, and optimization of problem-solving methods.

In the computer field, the influence of statistics is very significant, laying the foundation of a probabilistic model for the foundation of machine learning and providing important support for decision-making.

2.2 Main Types of Learning

In the past few years, traditional machine learning methods such as the backpropagation algorithm and the deep learning of convolutional neural networks have been popular research topics (Zhang & Wang, 2016). Today, with the continuous development of machine learning methods, the application areas include artificial intelligence applications, image generation, autonomous driving, and large language models. Currently, machine learning models include various types, such as the K-nearest neighbor algorithm (KNN) and linear regression (LR). On the basis of its different characteristics, it can also be classified into supervised learning (using labeled data for classification and prediction; for problem detection and state assessment), unsupervised learning (identifying patterns and anomalies through unlabeled data, suitable for sensor data analysis and fault detection), and reinforcement learning, which learns the best behavior through interaction with the environment and is suitable for optimizing maintenance plans and decision-making (Meng & Li, 2020).

3. Machine Learning in Mechanical Engineering

3.1 Automation Design

In the engineering field, the use of big data analysis and machine learning technologies can help engineers discover design patterns, thus supporting them in design optimization. For example, the deep learning neural network model is used to automatically analyze the relationship between design parameters and performance, to provide improvement plans, to shorten design time, and to increase design quality (Zhu, 2024). With the collection and analysis of large amounts of design data, such as historical design cases, simulation results, and experimental data, AI technology can reveal the intricate relationship between design parameters and product performance. The sources of these data span multiple fields, including modeling software, engineering analysis tools, and enterprise resource planning systems. This information is integrated via a machine learning algorithm to establish a comprehensive design knowledge base. In the field of automation design, the neural network model constructed via deep learning technology plays a key role (Hu et al., 2024). This type of model can identify the nonlinear relationship between parameters and performance and can automatically adjust the network weights through adaptive training data, thereby realizing the prediction and optimization of novel design schemes. For example, in a manner similar to that of Mencius, in the field of auto parts design, Lai et al. (2019) proposed a method that uses neural networks to analyze the relationships between different materials, sizes, and shapes (such as strength, durability, fuel efficiency, and horizontal automation, and an improvement scheme is proposed.

3.2 Anticipated Maintenance

In the field of mechanical engineering, machine learning is widely used in predictive maintenance, with the purpose of predicting and preventing equipment failure in advance. At the core of this method is the use of AI algorithms and data analysis techniques, including methods such as clustering algorithms and random forest (Li & Hu, 2020). AI networks have a wide range of applications in the predictive maintenance field. Through the combination of known failure modes and potential failure modes, early warning and preventive maintenance of equipment failure are realized. This solution has achieved significant results in improving equipment safety. The real-time monitoring mechanism enables various sensors (vibration, temperature, pressure, etc.) to be installed on the equipment, and the machine learning model can capture the operation data of the equipment in real time. This information can reveal the current status and performance fluctuations of equipment, laying the foundation for the further implementation of predictive maintenance. The machine learning algorithm can be used to detect abnormal patterns in equipment operation data; thus, signals that deviate from the normal state can be discovered. This abnormal condition may be a symptom of equipment failure, and timely detection and handling can effectively reduce the possibility of fault propagation. Using historical fault data and real-time monitoring data, the machine learning model can predict the probability and time distribution of future equipment failure. This predictive function helps enterprises plan maintenance plans in advance and rationally allocate maintenance resources to reduce the risk of production interruption and loss

caused by equipment failure. By evaluating the prediction results and maintenance cost analysis, machine learning technology helps companies develop optimal maintenance plans. For example, when a part is about to fail, the company can choose to replace the part to prevent failure and adjust the production plan to reduce the impact of the failure on production.

3.3 Improvement in Production Efficiency

In the manufacturing process, AI technology involves summarizing and analyzing manufacturing data to automatically optimize production parameters, thereby improving production efficiency and product quality. At this stage, research has focused mainly on the importance of hyperparameter selection and adjustment to production. All kinds of data on the production line can be collected by the machine learning model, including but not limited to machine operating speed, raw material consumption rate, product quality indicators, etc. These data shed light on the efficiency and efficiency of the production process. In terms of data analysis and modeling, through in-depth study of the collected information, machine learning technology can identify bottlenecks and waste of resources in the production process. In addition, with the help of the combination of past and current data, machine learning algorithms can be used to build mathematical models to predict and optimize future production performance. The results of data analysis can be used by machine learning algorithms to automatically adjust production parameters, such as equipment speed, ambient temperature, and pressure, to adapt to various production needs and conditions. This technology ensures that the production process continues to run smoothly and efficiently, with less human intervention and errors. Machine learning also plays a critical role in the optimization of production processes, ensuring consistent product quality. By monitoring product quality parameters in real time and adjusting the corresponding parameters, the machine learning model can continuously ensure that products meet the quality standards, thereby reducing the defect rate and the number of reworks.

4. Practical Case Analysis

4.1 Predictive Maintenance in the Manufacturing Industry

In the manufacturing field, machine learning technology is used to monitor the real-time operation status of equipment to predict possible failures, thus effectively reducing the downtime and maintenance costs of the production line. For example, a furniture factory uses a machine learning model to continuously monitor production equipment and identify the problem of component wear and tear in a timely manner. To maintain the continuity of large-scale production, maintenance work was arranged in advance, and necessary preventive measures were taken to ensure the stable operation of the equipment. Airlines use advanced technology to monitor the performance status of aircraft engines. In this method, sensors are used to acquire all the data when the engine is running, and machine learning algorithms are used for data analysis. Through the implementation of real-time monitoring and analysis, airlines can discover signs of potential engine failure in a timely manner and take corresponding maintenance measures. In these two cases, because predictive maintenance detected equipment problems in advance, maintenance measures were taken quickly, effectively reducing the company's losses.

4.2 Optimization of the Automatic Assembly Line

A company that manufactures electronic equipment has successfully applied machine learning technology to achieve an intelligently optimized automatic assembly line. Through the optical identification system, machine tools can accurately identify the part and use the machine learning program to plan the route and execute the operation strategy, thereby significantly improving the accuracy and efficiency of the installation. In addition, the ability to autonomously adjust the assembly sequence enables the machine learning model to better adapt to production needs, thereby improving the flexibility and strain capacity of the production line. They conducted process analysis on the processing plane layout and production process of the GL’s core products, optimized and redesigned important links, and reviewed the layout of the processing shop to develop a more optimized production process (Zhang, 2012).

Through real-time data analysis and intelligent decision-making, the production process can be continuously optimized and flexibly adjusted. Cross-scientific integration: Similarly, the organic combination of artificial intelligence with the Internet of Things, cloud computing and other technologies is promoting the development of mechanical engineering in a more intelligent and networked direction.

5. Conclusions

With the growth of the Internet of Things, the growth of data volume and the continuous development of artificial intelligence technology, machine learning will have more extensive applications in the engineering field and have a profound impact on various industries. In future development, machine learning will exert a more significant influence in the field of intelligent design by integrating advanced algorithms and models to achieve a more accurate and efficient production process (Li, 2024). With the wide application of sensor technology and the enhancement of data processing capability, the application of predictive maintenance in different fields has gradually increased in popularity.

Machine learning has demonstrated considerable application potential and value in the field of mechanical engineering, and machine learning has performed prominently as one of the core technologies of artificial intelligence. In the actual application process in the fields of automation design, maintenance prediction, and production process optimization, the application of machine learning technology not only improves work efficiency and product quality but also accelerates the development of the mechanical engineering industry toward intelligence (Wei et al., 2024). In the future, with the continuous improvement of technology and the expansion of the scope of application, machine learning will play a more important role in the machinery field, bringing new impetus to the progress of the industry. In addition, during this stage of the academic journey, our understanding of machine learning and some programming skills improved and deepened. At this stage, I was very grateful for the guidance of Teacher Zhuang, as well as for the opportunity.

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Conflicts of Interest

The authors declare no conflict of interest.

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