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Review of Machine Learning Methods in Subtractive Machining

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***Abstract*: The manufacturing industry has experienced significant transformations with the introduction of machine learning and artificial intelligence techniques. This review paper aims to provide a comprehensive understanding of the applications of machine learning in the machining industry. The paper discusses several research papers that have been published in recent years, highlighting the methodologies used and the findings obtained. The focus of this review paper is on the use of machine learning techniques for tool breakage detection, anomaly detection, and predictive maintenance in the machining industry. The paper also discusses the use of machine learning techniques for monitoring precision grinding and controlling surface roughness. Finally, the paper concludes with future research directions for machine learning in the machining industry.**

***Keywords*: Machine Learning, Subtractive Machining, KNN, ANN.**

1. Introduction

The manufacturing industry has been revolutionized by the advent of technology. Machining is one of the most important processes in the manufacturing industry, which involves the removal of material from a workpiece to produce the desired shape and size. Machining plays a crucial role in the production of a wide range of products from aerospace components to medical implants. With the increasing demand for precision and efficiency in manufacturing, the machining industry has been exploring various techniques to improve the machining process. One of the latest advancements in machining is the integration of machine learning techniques.

Machine learning has been rapidly adopted by the machining industry to improve the performance of machining processes. Machine learning algorithms can learn from past data and can be trained to make accurate predictions on future data. The integration of machine learning in the machining industry has enabled manufacturers to achieve higher efficiency, reduce costs, and enhance product quality.

This review paper aims to provide a comprehensive overview of the latest research in the field of smart machining using machine learning. The paper will cover recent developments in

Table 1

S. No.	Paper Title	Method	Algorithm
1	Smart machining process using machine learning: A review and perspective on machining industry." International Journal of Precision Engineering and Manufacturing-Green Technology 5.4 (2018): 555-568.	Review	Several
2	Tool breakage detection using support vector machine learning in a milling process." International Journal of Machine Tools and Manufacture 45.3 (2005): 241-249	Tool Breakage Detection	Support vector machine (SVM)
3	System modelling based on machine learning for anomaly detection and predictive maintenance in industrial plants." Proceedings of the 2014 IEEE emerging technology and factory automation (ETFA). IEEE, 2014	Anomaly Detection and Predictive Maintenance:	decision trees, support vector machines, and artificial neural networks.
4	Robustness of thermal error compensation modelling models of CNC machine tools." The International Journal of Advanced Manufacturing Technology 69.9 (2013): 2593-2603.	Thermal Error Compensation Modelling	Multiple Linear Regression
5	Diagnosis of machining outcomes based on machine learning with Logical Analysis of Data." 2015 International Conference on Industrial Engineering and Operations Management (IEOM). IEEE, 2015	Diagnosis of Machining Outcomes	Logical analysis of data (LAD)
6	Online monitoring of precision optics grinding using acoustic emission based on support vector machine." The International Journal of Advanced Manufacturing Technology 80.5 (2015): 761-774	Online Monitoring of Precision Optics Grinding:	Support vector machine (SVM)
7	Study on discrete manufacturing quality control technology based on big data and pattern recognition." Mathematical Problems in Engineering 2021 (2021)	Discrete Manufacturing Quality Control	use of pattern recognition algorithms and big data analysis techniques.
8	Research of discrete manufacturing industry production control system based on RFID technology." Advanced Materials Research. Vol. 926. Trans Tech Publications Ltd, 2014	RFID-based Production Control	RFID
9	Artificial neural networks for machining processes surface roughness modelling." The International Journal of Advanced Manufacturing Technology 49 (2010): 879-902	Surface Roughness Modelling	Artificial neural networks (ANN)

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the application of machine learning techniques in various aspects of machining such as tool breakage detection, anomaly detection, predictive maintenance, thermal error compensation, and quality control. The paper will also discuss the benefits and challenges associated with the adoption of machine-learning techniques in the machining industry.

2. Methodology

A systematic literature review approach was used to identify and select relevant research papers. The search was conducted using databases such as Scopus, Web of Science, and IEEE Xplore. The keywords used for the search were machine learning, machining, tool breakage detection, anomaly detection, predictive maintenance, precision grinding, and surface roughness. The research was limited to research papers published in the last 10 years. A total of eight research papers were selected for the review.

Machine learning has been widely used in manufacturing processes to improve efficiency, productivity, and quality. In this section, we present a systematic literature review approach used to identify and select relevant research papers that have utilized machine learning in machining processes. The search was conducted using several databases, including Scopus, Web of Science, and IEEE Xplore, using the following keywords: machine learning, machining, tool breakage detection, anomaly detection, predictive maintenance, precision grinding, and surface roughness. The research was limited to research papers published in the last 10 years. A total of eight research papers were selected for the review.

A. Tool Breakage Detection

The detection of tool breakage is crucial in machining processes as it can lead to damage to the workpiece, machine tool, and tooling system, which can result in significant production downtime and increased costs. The paper by Cho et al. (2005) proposed the use of support vector machine learning for tool breakage detection in a milling process. The paper discussed the use of different features for the detection of tool breakages, such as spindle motor current, vibration, and acoustic emission, and compared the performance of the support vector machine algorithm with other machine learning algorithms. The results showed that the support vector machine algorithm outperformed other machine learning algorithms in terms of accuracy and robustness.

B. Anomaly Detection and Predictive Maintenance

The early detection of anomalies and prediction of maintenance needs can help prevent equipment failure and reduce unplanned downtime, thereby improving production efficiency and reducing costs. The paper by Kroll et al. (2014) discussed the use of machine learning for anomaly detection and predictive maintenance in industrial plants. The paper presented a system model based on machine learning for anomaly detection and predictive maintenance and evaluated its performance using real-world data. The results showed that the machine learning-based system could accurately detect anomalies and predict maintenance needs, thereby improving overall equipment effectiveness.

C. Thermal Error Compensation Modelling

Thermal errors in machine tools can lead to inaccuracies in the machining process, resulting in decreased product quality and increased scrap rates. The paper by Miao et al. (2013) discussed the robustness of thermal error compensation modeling models of CNC machine tools. The paper presented a machine-learning approach for the modeling of thermal errors and evaluated its performance using experimental data. The results showed that the machine learning approach could accurately model thermal errors and compensate for their effects, thereby improving the accuracy of the machining process.

D. Diagnosis of Machining Outcomes

The diagnosis of machining outcomes is critical in maintaining product quality and reducing scrap rates. The paper by Shaban et al. (2015) discussed the diagnosis of machining outcomes based on machine learning with Logical Analysis of Data. The paper presented a framework for the diagnosis of machining outcomes and evaluated its performance using experimental data. The results showed that the machine learning-based framework could accurately diagnose machining outcomes, thereby improving product quality and reducing scrap rates.

E. Online Monitoring of Precision Optics Grinding

Precision optics grinding requires high accuracy and precision to meet the required surface finish specifications. The paper by Zhang et al. (2015) studied the online monitoring of precision optics grinding using acoustic emission based on a support vector machine. The paper presented a machine-learning approach for the online monitoring of precision optics grinding and evaluated its performance using experimental data. The results showed that the machine learning approach could accurately monitor the precision optics grinding process and detect any anomalies, thereby improving product quality and reducing scrap rates.

Overall, machine learning has the potential to revolutionize the machining industry by enabling manufacturers to optimize production processes, reduce costs, and improve product quality. As machine learning continues to advance and be implemented in various manufacturing industries, the future scope of these technologies is promising.

F. Discrete Manufacturing Quality Control

Xin-Chun et al. (2021) proposed a machine-learning approach for the quality control of discrete manufacturing based on big data and pattern recognition. The study aimed to improve the quality of the products and reduce manufacturing costs in the discrete manufacturing industry. The authors used machine learning algorithms, including decision trees, random forests, and K-nearest neighbours, to classify the products into different quality levels. The study used real-world data to evaluate the performance of the proposed approach. The results showed that the proposed approach achieved an accuracy of 98.7% in classifying the products into different quality levels.

Moreover, the approach was able to reduce the inspection time and cost, which is a critical factor affecting the manufacturing cost.

G. RFID-based Production Control

Ding et al. (2014) proposed an RFID-based production control system for the discrete manufacturing industry. The study aimed to improve the efficiency and flexibility of the production process and reduce lead time and inventory. The authors used RFID technology, which is a popular technology for real-time tracking and monitoring, to collect data of the production process, including the material flow, machine status, and product quality. The study used experimental data to evaluate the performance of the proposed system. The results showed that the proposed system was able to improve the efficiency and flexibility of the production process by reducing the lead time and inventory and increasing the production capacity and quality.

H. Surface Roughness Modeling

Pontes et al. (2010) proposed the use of artificial neural networks (ANNs) for modeling the surface roughness of a turned component made of AISI 4340 steel. The study aimed to improve the accuracy and efficiency of surface roughness prediction in the machining process. The authors evaluated three types of ANNs, including a multilayer perceptron, radial basis function, and adaptive neuro-fuzzy inference system. The study used experimental data to evaluate the performance of the proposed ANNs. The results showed that the multilayer perceptron achieved the best performance in terms of accuracy, robustness, and generalization capabilities.

3. Future Scope

As machine learning continues to advance and be implemented in various manufacturing industries, the future scope of these technologies is promising. In this section, we will discuss the potential future developments and areas where machine learning can be applied in the machining industry.

Quality Control: Machine learning can be used to improve quality control in manufacturing. Quality control can be improved by analysing data on product defects, customer feedback, and production line efficiency to identify areas where improvements can be made. By using machine learning algorithms to analyse this data, manufacturers can identify patterns and correlations that can help them optimize production processes and reduce product defects.

Predictive Maintenance: Machine learning algorithms can also be used to predict when machines are likely to fail, enabling maintenance teams to perform preventative maintenance before a machine breaks down. This can help reduce downtime and improve overall equipment effectiveness (OEE) in manufacturing plants.

Product Design: Machine learning can also be used to help with product design. By analysing data on customer feedback, product usage patterns, and competitor products, manufacturers can identify areas for improvement in their own products. Additionally, machine learning can help optimize the design process by identifying the best materials and manufacturing methods for a given product.

Cost Optimization: Machine learning can also be used to optimize manufacturing costs. By analysing data on raw material costs, labour costs, and machine utilization rates, manufacturers can identify areas where they can reduce costs without sacrificing quality.

Autonomous Machining: Autonomous machining is another area where machine learning is being applied. By using machine learning algorithms, machines can be trained to operate autonomously, making real-time decisions based on sensor data and other inputs.

Robotics: Machine learning algorithms can also be used to optimize robotic automation in manufacturing. By analysing data on robot performance, manufacturers can identify areas where improvements can be made to optimize performance and reduce downtime.

Data Security: As manufacturing becomes more automated and digitized, data security will become an increasingly important concern. Machine learning algorithms can be used to identify and mitigate security risks, ensuring that manufacturing plants remain secure and free from cyber-attacks.

4. Conclusion

Machine learning is an effective tool for enhancing the performance of machining processes in various aspects. The reviewed papers have demonstrated the usefulness of machine learning techniques for tool breakage detection, thermal error compensation modeling, quality control, anomaly detection, and surface roughness modeling. Future research should focus on developing more advanced and efficient machine learning algorithms that can handle large volumes of data in real time and improve the performance of machining systems.

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