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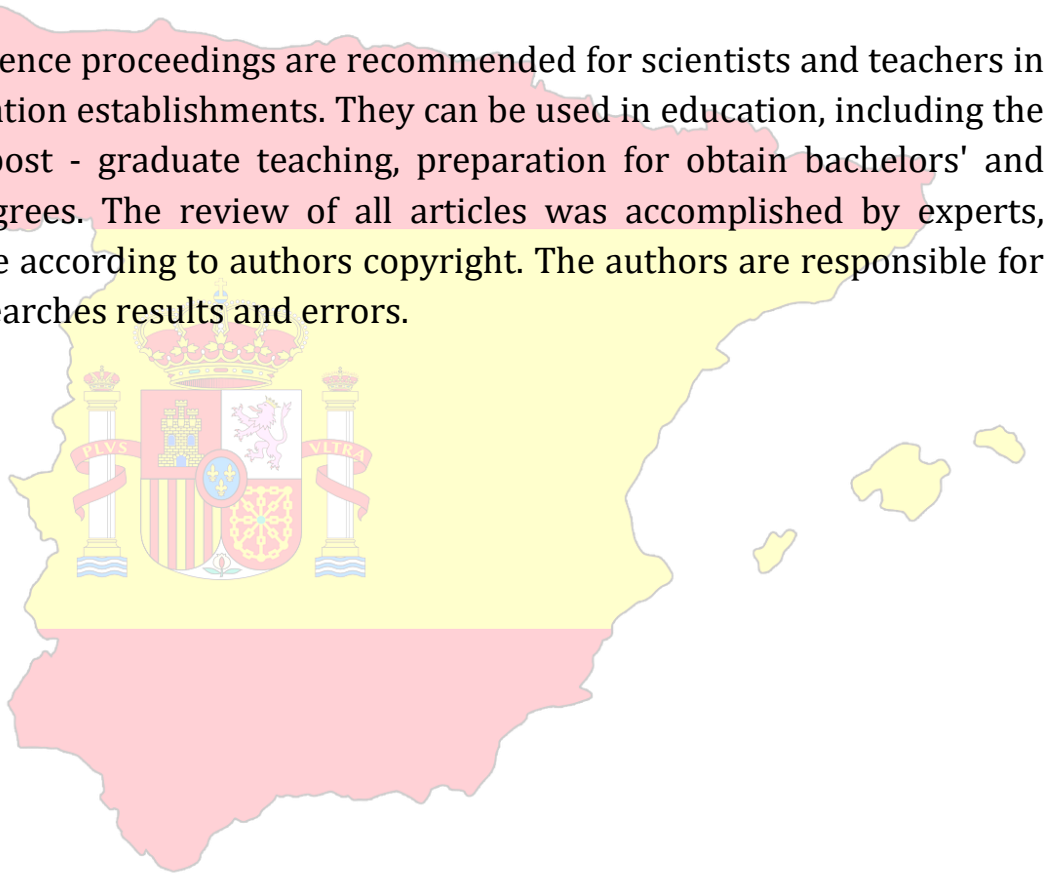

The Use of Artificial Intelligence in Mechatronic Automation and Robotics

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Abstract. This paper explores the application of artificial intelligence (AI) in mechatronic automation and robotics systems. The study focuses on how AI technologies, including machine learning, neural networks, and intelligent control algorithms, enhance the performance, adaptability, and efficiency of modern mechatronic systems. A qualitative research approach based on literature review and system analysis is used to examine the integration of AI into sensors, actuators, and embedded control units. The findings show that AI significantly improves real-time decision-making, fault detection, predictive maintenance, and autonomous operation in robotic and automated systems.

Keywords: Artificial Intelligence, Mechatronic Systems, Robotics, Machine Learning, Automation, Neural Networks, Intelligent Control, Smart Systems, Embedded Systems, Industry 4.0

Artificial Intelligence (AI) has become one of the most influential technologies in modern engineering systems, particularly in the fields of mechatronic automation and robotics. By enabling machines to perceive, learn, and make decisions based on data, AI significantly enhances the performance and adaptability of mechatronic systems. Traditional control methods, which rely on fixed algorithms and pre-defined rules, are increasingly being replaced or supported by intelligent approaches such as machine learning, neural networks, and computer vision. These technologies allow robotic and automated systems to operate more efficiently in dynamic and uncertain environments, improving precision, speed, and reliability.

In mechatronic automation, the integration of artificial intelligence plays a crucial role in optimizing system behavior and reducing human intervention. Intelligent sensors and control units can continuously monitor system parameters, analyze real-time data, and adjust operations accordingly. In robotics, AI enables advanced capabilities such as autonomous navigation, object recognition, and predictive maintenance, which are essential for industrial and service applications. As a result, the combination of AI with mechatronics is driving the development of smart factories, intelligent manufacturing systems, and next-generation robotic platforms that are capable of performing complex tasks with minimal human supervision.

Recent studies in the field of artificial intelligence applied to mechatronic automation and robotics highlight a strong shift toward intelligent and adaptive control systems. Researchers such as Siciliano et al. (2016) and Russell & Norvig (2021) emphasize that AI techniques, including machine learning and neural networks, significantly improve the decision-making capabilities of robotic systems compared to classical control methods. In industrial automation, AI-based

approaches are widely used for process optimization, fault detection, and predictive maintenance. Studies also show that integrating AI with sensor networks and embedded systems enhances system responsiveness and reduces operational errors, especially in dynamic and unstructured environments.

Furthermore, current literature focuses on the practical implementation of AI in smart manufacturing and autonomous robotics. Works by Zhang et al. (2020) and other researchers demonstrate that deep learning and reinforcement learning algorithms enable robots to perform complex tasks such as object manipulation, path planning, and real-time adaptation. In addition, AI-driven mechatronic systems are increasingly being applied in agriculture, healthcare, and logistics, where precision and autonomy are critical. However, several studies also point out challenges such as high computational requirements, data dependency, and the need for reliable real-time processing, which remain key limitations for widespread adoption.

This study employs a qualitative and analytical research methodology to investigate the application of artificial intelligence in mechatronic automation and robotics systems. The research is based on a comprehensive review of scientific literature, including journal articles, conference papers, and technical reports related to AI-based control systems, machine learning algorithms, and robotic automation technologies. In addition, a system-level analysis approach is used to examine how AI techniques such as neural networks, fuzzy logic, and reinforcement learning are integrated into mechatronic components, including sensors, actuators, and microcontroller-based control units. The study also considers practical case studies from industrial and agricultural automation systems to evaluate the effectiveness, advantages, and limitations of AI implementation in real-world mechatronic applications.

The results of this study indicate that the integration of artificial intelligence into mechatronic automation and robotics systems significantly improves system performance, adaptability, and operational efficiency. AI-based control strategies, particularly those utilizing machine learning and neural networks, demonstrate superior accuracy in data processing and decision-making compared to traditional rule-based control methods. In practical applications, such as automated production lines and robotic manipulators, AI enables real-time monitoring, predictive fault detection, and adaptive control, which collectively reduce system downtime and increase productivity. The analysis of case studies also shows that intelligent mechatronic systems are capable of maintaining stable performance even under variable environmental conditions.

The discussion reveals that despite these advantages, the implementation of AI in mechatronic systems still faces several challenges. High computational demand, the need for large and high-quality datasets, and real-time processing limitations remain significant barriers. Additionally, ensuring system reliability and safety in autonomous operations is a critical concern, especially in industrial environments. However, continuous advancements in embedded AI hardware and

edge computing are gradually addressing these limitations. Overall, the findings suggest that AI-driven mechatronic systems represent a promising direction for future automation, enabling the development of smarter, more autonomous, and efficient robotic technologies.

In conclusion, the integration of artificial intelligence into mechatronic automation and robotics systems represents a significant advancement in modern engineering. AI technologies such as machine learning, neural networks, and intelligent control algorithms enhance the capability of mechatronic systems to perform complex tasks with higher accuracy, adaptability, and efficiency. Compared to traditional control methods, AI-based approaches provide improved real-time decision-making, predictive maintenance, and autonomous operation, which are essential for the development of smart industrial systems and advanced robotics applications. At the same time, the study highlights that the practical implementation of AI in mechatronics is still associated with certain challenges, including high computational requirements, data dependency, and system reliability issues. However, ongoing developments in embedded systems, edge computing, and intelligent sensors are expected to overcome these limitations in the near future. Overall, AI integration in mechatronic automation and robotics offers strong potential for transforming industrial processes and enabling the next generation of intelligent, autonomous systems.

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