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SMART MANUFACTURING: THE ROLE OF IOT AND AI IN MODERN PRODUCTION SYSTEMS

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Abstract. Smart manufacturing, driven by the Internet of Things (IoT) and Artificial Intelligence (AI), is revolutionizing industrial production by enabling real-time monitoring, predictive maintenance, and autonomous decision-making. This article explores the integration of IoT and AI in manufacturing, highlighting key technologies, benefits, and challenges. The discussion underscores how these advancements enhance efficiency, reduce costs, and support sustainable production practices.

Keywords: Smart manufacturing, Internet of Things, Artificial Intelligence, Digital Twins, Data Security.

The Fourth Industrial Revolution (Industry 4.0) has transformed traditional manufacturing into a data-driven, interconnected ecosystem. Central to this transformation are Internet of Things (IoT) and Artificial Intelligence (AI), which empower machines to communicate, analyze data, and optimize processes autonomously (Fig. 1). This article examines their synergistic roles in smart manufacturing and their potential to redefine global production standards, emphasizing the urgent need for adaptation in today's competitive landscape.

A more detailed examination of IoT and AI will now follow.



Figure 1 – AI + IoT Architecture

IoT

IoT connects physical devices, such as sensors and actuators, to collect and exchange data seamlessly. In manufacturing, IoT enables:

- Real-Time Monitoring: Tracking equipment performance and product quality to minimize downtime.
- Predictive Maintenance: Identifying potential failures before they occur, thus enhancing reliability.
- Supply Chain Visibility: Improving logistics and inventory management through enhanced data sharing. In combination with digital twins—virtual replicas of physical assets—IoT allows for real-time simulation, diagnostics, and optimization of manufacturing systems, supporting informed decision-making and continuous improvement.

AI

AI algorithms analyze vast datasets

to derive actionable insights. Key applications include:

- Autonomous Robotics: Robots adapt to dynamic tasks such as assembly and packaging through machine learning.
- Quality Control: Advanced computer vision systems detect defects with greater accuracy than human inspection.
- Demand Forecasting: Machine learning models predict market trends, optimizing production schedules accordingly.

Digital Twins

Digital twins are virtual replicas of physical systems that simulate scenarios, such as equipment stress tests, to enhance design and operational efficiency. This technology facilitates proactive management and continuous improvement.

Smart technologies in manufacturing offer a number of significant advantages. Firstly, the automation of production operations allows for a substantial reduction in process cycle times and minimizes losses, thereby contributing to overall productivity optimization.

Secondly, the use of predictive maintenance reduces the frequency of unplanned equipment downtime and repair costs, ultimately resulting in considerable resource savings.

Moreover, smart technologies promote the adoption of energy-efficient processes and the reduction of waste, thus enhancing the environmental sustainability of manufacturing and aligning with the principles of sustainable development.

Finally, the implementation of cloud-based platforms provides flexibility in scaling production capacities and facilitates coordination across distributed manufacturing sites—an especially important factor in the context of globalization.

However, despite these evident benefits, smart manufacturing faces a number of challenges. One of the key issues is the increasing risk of cyberattacks due to the high degree of interconnectivity among digital systems. The use of blockchain technology ensures secure data transmission and access control, significantly mitigating the likelihood of external interference.

The growing application of high-tech solutions also demands new competencies from personnel, which exacerbates the problem of skill shortages. The implementation of upskilling programs, as well as the development of frameworks for human-machine collaboration, enables effective adaptation of the workforce to digital transformation.

Furthermore, the substantial investments required for the deployment of IoT and AI platforms can be prohibitive, particularly for small and medium-sized enterprises. A phased implementation approach and the availability of governmental support measures—including subsidies and grants – help alleviate the financial burden on organizations.

Conclusion

The integration of IoT and AI in smart manufacturing represents a paradigm shift toward agile, sustainable, and competitive production. While challenges exist, strategic investments and cross-industry collaboration can accelerate adoption. Future research should focus on establishing interoperability standards and ethical AI applications to maximize societal benefits, ensuring that technological advancements serve the greater good.

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