THE DESIGN OF DIGITAL PRODUCTION SYSTEMS IN THE CONTEXT OF INDUSTRY 4.0

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SUMMARY: The Industry 4.0, also known as the fourth industrial revolution, involves the integration of cyber-physical systems such as IoT, computing, data analytics, robotics, and AI. Digital production systems help companies collect and analyze production data, make better decisions, optimize production processes, reduce downtime, and minimize production errors. The paper aims to present the crucial role of digital production systems in Industry 4.0, examining their benefits and challenges, as well as current trends in this continuously evolving field. The technologies used in Industry 4.0 include IoT, data analytics, smart factories, virtual and augmented reality, and blockchain. While these technologies offer advantages such as increased efficiency, reduced costs, and better user experience, they also come with challenges such as high implementation and maintenance costs, data security concerns, and lack of common standards.

KEYWORDS: Internet of Things, Artificial Intelligence, Blockchain, Smart Factories.

1. Introduction

The term "Industry 4.0" was coined in 2011 by a German project led in collaboration with universities and businesses by the federal government. Specifically, the development of sophisticated production techniques to increase productivity and efficiency in domestic industries was a strategic initiative. [5]

Industry 4.0 represents the fourth industrial revolution, characterized by cyber-physical systems, the Internet of Things (IoT), cloud computing, and artificial intelligence (AI). When it comes to manufacturing companies, Industry 4.0 entails a major transformation of the entire production process by integrating digital technologies and the Internet with conventional industry. [4]

The aim of this paper is to present the crucial role of digital production systems in the context of Industry 4.0, analyzing both their benefits and challenges, as well as current trends in this continuously evolving field.

2. The classification of technologies used in Industry 4.0

The Internet of Things (IoT) is a network of interconnected devices that can collect and share data in real-time without human intervention. These devices are equipped with sensors and communication modules that allow them to communicate with each other and with other internet-connected systems. IoT is used in a variety of fields, from smart homes and transportation to agriculture and manufacturing industries. [7]

Data analysis collected through IoT is the process of extracting and analyzing data collected through IoT devices to gain valuable insights and make informed decisions. This analysis may involve data analysis technologies such as machine learning to identify patterns and trends in the collected data. [7]

The smart factory is a concept that involves the use of digital technologies, such as IoT, data analysis, and automation, to create an efficient and adaptive production environment. The smart factory utilizes data collected from IoT devices to optimize processes and make real-time informed decisions. [6]

Virtual reality and augmented reality are technologies that allow users to interact with the virtual or real environment through digital devices. Virtual reality creates a completely virtual environment, while augmented reality adds digital elements to the real environment. [8]

Blockchain in Industry 4.0 is a technology that enables secure and decentralized storage and sharing of information without the need for an intermediary. Blockchain can be used in Industry 4.0 to create a trusted network among different parties involved in the production process. [9]

3. The advantages and disadvantages of using technologies in Industry 4.0

IoT can improve efficiency by connecting and automating devices, thereby reducing costs and the time required to complete tasks. The real-time monitoring and control offered by IoT can optimize activities and prevent issues, while the enhanced experience and comfort it brings can be beneficial for users. In the business environment, IoT can increase productivity by optimizing processes, but implementing and maintaining IoT technologies can be costly. Additionally, data collected through IoT can be vulnerable to cyber-attacks, so security and data protection are essential. The lack of common standards for IoT implementation can lead to fragmentation and difficulties in interoperability between devices and systems. [7]

Fig. 1 The connection between devices and ”things” (Internet of Things)

The data collected through IoT can improve business decisions and help identify trends and patterns, enabling a better understanding of the market and consumers. Data analysis can assist in eliminating unnecessary or redundant activities, which can increase efficiency. However, implementing and maintaining data analytics systems can be costly. Additionally, managing a large volume of data available through IoT can be challenging, and the use of appropriate analytics technologies is important to effectively manage and utilize the data. [7]

A smart factory can provide increased efficiency through the connection and communication between devices, enabling process automation and reducing time and costs. Furthermore, a smart factory can offer flexibility by quickly adjusting processes and workflows to market changes or customized customer requirements. Improving product quality is possible through real-time quality control, data monitoring, and analysis. The smart factory can reduce delivery time by eliminating unnecessary or redundant activities, optimizing processes, and improving efficiency. Additionally, the smart factory can enhance safety and security by monitoring and controlling critical processes and alerting users in case of issues. However, implementing and maintaining systems in the smart factory can be costly, and the need for specialized workforce training can be challenging. Additionally, smart factories can be vulnerable to cyber-attacks and hacking, so ensuring data security and protection is important. [6]

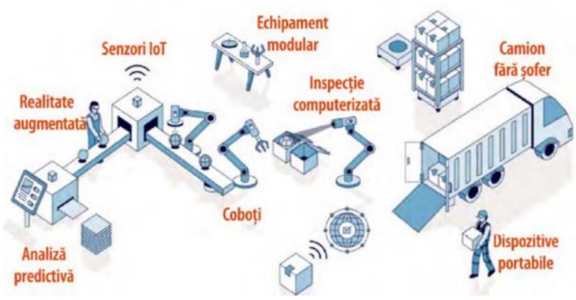

Fig. 2 Smart Factory

Virtual and augmented reality can enhance the user experience and reduce training costs, thereby increasing process efficiency and productivity. However, the implementation and maintenance of these systems can be expensive and require specialized resources. Excessive use of virtual and augmented reality technology can lead to dependency and negatively impact mental and physical health. Additionally, there are technical limitations such as battery capacity and device size that can affect the functioning of these systems. [8]

Fig. 3 Augmented and Virtual Reality

Blockchain is one of the emerging digital technologies that will play a role in the discoveries of the fourth industrial revolution. The use of blockchain technology has the potential to greatly benefit businesses of all sizes by increasing integrity, confidentiality, and openness for the reuse or redistribution of their data. [10]

Customizing products and services for each customer is possible using blockchain technology. However, the scalability issue may arise with many users or transactions, and implementing and maintaining a blockchain system can be complex and costly. Furthermore, the regulation of blockchain technology is still under development, which can lead to uncertainty or confusion in certain jurisdictions. [9]

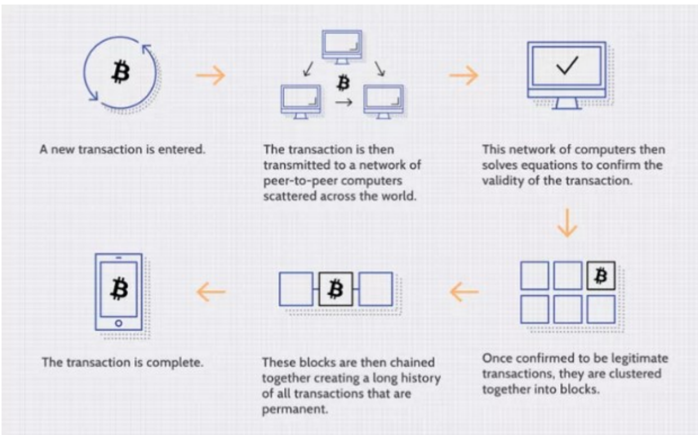

Fig. 4 The process of Blockchain technology

4. Integration of IoT technology in the CNC machining environment

CNC machines are numerically controlled devices that utilize computer programming to control the machining motion and achieve automated production of parts. These machines are used in a wide range of industries and enable the efficient and repeatable production of complex and precise parts. By connecting to the Internet of Things (IoT), CNC machines can be monitored and controlled in real time, thereby enhancing efficiency and productivity. The data collected from CNC machines can be used to optimize production processes and perform maintenance and troubleshooting activities more efficiently.

The Haas VF-2SS is a CNC milling machine manufactured by the American company Haas Automation. This vertical milling machine offers fast and precise milling capability for parts. The VF-2SS is equipped with an advanced control system, a through-spindle coolant system, and an automatic tool changer to ensure efficient and precise production. The machine is used in a wide range of applications, including the production of components for the aerospace industry, automotive industry, and many others. [2]

Fig. 5 Milling machine Haas VF-2SS

Another example of a CNC machine is the "TruLaser 3030," a laser cutting machine produced by the German company TRUMPF. This laser cutting machine offers a cutting capacity of up to 25 mm for a wide range of materials such as stainless steel, aluminum, copper, and many others. The machine is equipped with state-of-the-art technology, including high-precision sensors and advanced control software to ensure precise and fast cutting. The CNC laser cutting machine consists of a powerful laser light source, a system of mirrors and lenses that direct and focus the laser beam, a motion system that controls the position and speed of the machine, and a worktable that supports the material to be cut. Modern CNC laser cutting machines are also equipped with sensors and advanced control software, which enable them to work with high precision and perform complex cuts. [3]

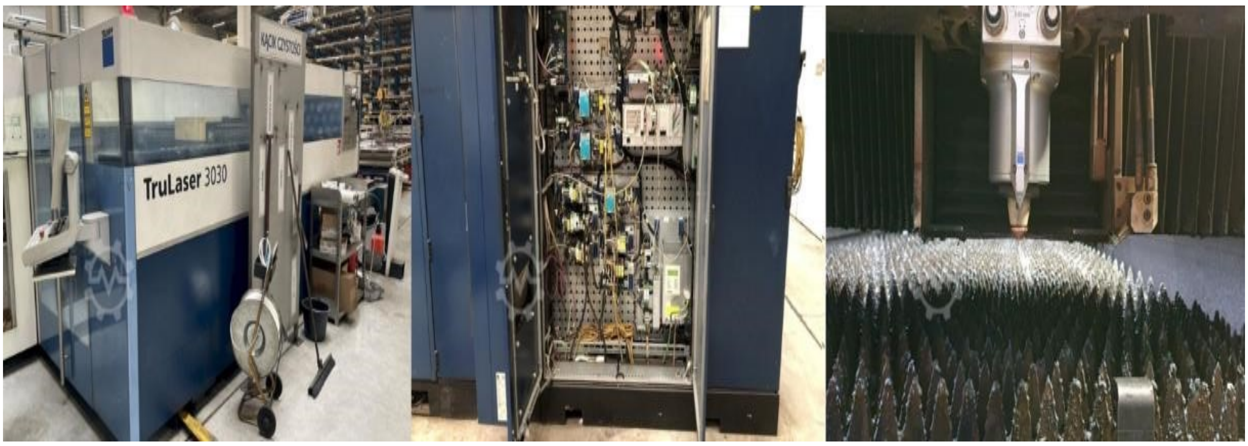

Fig. 6 Laser cutting machine TruLaser 3030

5. Case study

Employees in standard production are supported and assisted by artificial intelligence (AI). With the help of this fast, efficient, and reliable technology, employees are no longer required to manually check model inscriptions against order data, for example, during the final inspection. This task is now handled by AI, which alerts the employee if an inscription is incorrect. This, along with other AI applications, provides significant added value to the BMW Group production system. [1]

Fig. 7 Control panel using Artificial Intelligence

Virtual reality is used to simulate an interactive 3D environment in real time. Technology provides both players and companies with real added value. The international team at the BMW Group Virtual Reality Lab creates virtual spaces and scenarios that can be used to optimize processes and safety, for example, in the logistics sector. [1]

Fig. 8 Control panel that utilizes Artificial Intelligence

Intelligent transport robots are capable of independently transporting components weighing up to 0.5 tons from point A to point B. Once wireless transmitters have determined their location, they can calculate the best route to their destination on their own. Powered by recycled BMW i3 batteries, they have a battery life of approximately eight hours. [1]

Fig. 9 Transport robot

Currently, it is possible for people to work directly with conventional industrial robots on a large scale. Of course, safety is also paramount here: if a person approaches a robot dangerously, the latest safety technology intervenes to stop the movement of the robot's arm. [1]

Fig. 10 Industrial Robot

6. Conclusions

The purpose of this paper is to present the crucial role of digital production systems in the context of Industry 4.0, analyzing both their benefits and challenges, as well as the current trends in this continuously developing field.

This process of automation and interconnection of processes relies on an integrated system of equipment, machines, employees, mobile devices, and IT systems, which can communicate with each other both within and outside the factory.

By utilizing digital production systems, companies can collect and analyze production data, enabling them to make better decisions and optimize production processes. These systems can also help reduce downtime and minimize production errors through continuous monitoring of production processes and quick issue identification.

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