EDUZONE: International Peer Reviewed/Refereed Multidisciplinary Journal (EIPRMJ), ISSN: 2319-5045
Volume 8, Issue 2, July-December, 2019, Impact Factor: 5.679, Available online at: www.eduzonejournal.com

Cyber-Physical System (CPS) & Internet of Things (IoT) in Manufacturing

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ABSTRACT

Industry 4. 0 is the fourth industrial revolution, focused around the use of automation, data exchange, and processes such as Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Things (IoT) being used in the development of advanced and flexible manufacturing and production processes. It is aimed at creating an array of interconnected smart factories, with rapid communication and instant feedback between connected materials, machines, people, and processes. This gives greater control over production conditions and stronger, more integrated systems, allowing more effective and efficient production.Cyber-Physical System (CPS) is based on the integration of physical components (e. g. machines, robots, sensors) with software components and communication networks, providing a bridge between the virtual and real world. This technology enables a continuous exchange of information, allowing for more solid and reliable decision-making capabilities and control over processes. The CPS allows more efficient use of resources since conditions and parameters can be monitored and adjusted in real-time. IoT is a network of physical objects that are connected via the internet, enabling them to communicate with one another and exchange data, enabling users to monitor and control their applications, products and services at real-time. It is the integration of IT and operational technology (OT) of the factory or the production line, and allows the communication of all the machines, sensors and actuators. This allows for the collection and analysis of data from the different components, leading to better decision-making with regards to system performance. The combination of the CPS and IoT, combined with data analytics, gives manufacturers more visibility and control over their production, allowing them to make more informed and data-driven decisions, drive predictive maintenance and traceability, and optimize production processes. With Industry 4. 0 companies are able to move from product-oriented production to production-oriented products.This article provides an in-depth examination of the advances in technology related to the technological Revolution, such as CPS & IoT and how they can be used to increase productivity, drive predictive maintenance and traceability, and optimize production processes. It also provides examples from the literature as well as a real world case study from a manufacturing company to demonstrate how these technologies can be successfully implemented.

Keywords: Cyber-Physical System (CPS), Internet of Things (IoT), Artificial Intelligence (AI),Machine Learning (ML)

INTRODUCTION

The benefits of Industry 4. 0 and the development of automated and smart factories are numerous. One of the major benefits is the increased efficiency and accuracy, allowing for more effective and efficient production. This can be achieved through the use of AI and ML, which provide real-time insights and feedback to manufacturers. Additionally, the combination of CPS and IoT allow companies to monitor and control their applications, products and services in real-time, giving them more visibility and control over their production. This can lead to data-driven decision-making, predictive maintenance, and improved traceability of products. All of this can lead to cost savings and better customer experience, making companies more competitive in the market.

The first industrial revolution, aka the Scientific Revolution, was a period from the 18th to 19th centuries marked by the introduction and widespread adoption of mechanization and new power sources, such as steam engines and the use of coal. This revolution was responsible for moving production away from agricultural-based systems, leading to increased efficiency and productivity. The second industrial revolution began in the late 19th century with the widespread use of electricity and electric-powered machinery. This revolution brought manufacturers the ability to produce goods quickly and with more precision. The 3rd revolution allowed for the development of automated manufacturing processes, improved productive, and higher-quality products. All these industrial revolutions have drastically changed the way products are manufactured, increasing efficiency and quality.

IoT is a network of physical objects such as machines, vehicles and household appliances, which are connected to the internet. These devices use sensors and software to communicate with each other and exchange data with external systems. The combination of CPS and IoT allows machines and other devices to communicate directly with each other, ultimately allowing for increased efficiency and reduced costs.

Cyber-Physical Systems (CPS) are machines that combine physical components with computer software. They are able to sense the environment, process data, react to changes, and take autonomous actions. Examples of CPS include robots, industrial equipment and vehicles that are operated or monitored by computers.

Each object is equipped with sensors and software which allow them to collect and exchange data with other digital systems, such as computers and mobile phones. The IoT has the potential to reduce costs and increase efficiency by allowing machines and other devices to communicate directly with each other.

CPS offers more than just a conceptual framework, but a way to achieve decentralized decision making, set goals and modify behaviour for machines. For example, self-driving cars can be seen as an example of Cyber Physical Systems. Additionally, Cyber Physical Systems also offer real-time monitoring and controlling of machines on a factory floor.

The Internet of Things (IoT) is the network of physical objects, including appliances and machines, connected to the Internet. These physical objects can exchange data, which can be used to monitor the state of the device, send alerts and provide insights on their performance. The connected components of the IoT system can include sensors, software, analytics, and even human-machine interfaces, allowing machines and devices to communicate directly with each other. For example, in industrial settings, the IoT can allow for the efficient monitoring and optimization of manufacturing processes, reducing costs and improving production efficiency. It can also be used to monitor the condition of machinery, enabling preventive maintenance and reducing the risk of unexpected downtime. Additionally, IoT can be used to connect different sites in a distributed, global system, allowing the seamless exchange of data [1].

CURRENT ADVANCEMENT

Production

In the Industry 4. 0 concept, it's described as the fourth industrial revolution, where physical and digital elements converge to create a closed loop system. This approach uses Cyber-Physical Systems to provide real-time communication to machines and coordinating the entire process [2]. CPS is a system of interconnected computing and physical elements, where real-time data is collected and processed. These links allow decisions and connections between machines that autonomously respond to changes in their environment. By harnessing the power of the internet, sensors and actuators connected together, this creates highly efficient and intelligent factories. This increases productivity and speed due to the fact that decisions can be made in real time when things occur, or when their environment changes, thus helping facilitate automation and remotely managing components [3].

The fundamental element of CPS is that they are able toanalyze large amount of data and use this information to automate physical processes. For example, a robotic arm in an automotive factory pulling parts from a conveyor belt uses a complex computer system and programming to take into account the system dynamics and autonomously respond to different inputs [4].

CPS can contribute to the growth and development of many industries. For example, in healthcare, CPS can be used to monitor the health and vital signs of patients and respond to any changes autonomously. In energy distribution, CPS can be used to monitor and control the flow of energy and respond to different scenarios. In automotive manufacturing, CPS can be used to accurately locate parts on a conveyor belt and quickly assemble them into cars [5].

CPS has already become a reality in many areas. With the rise of smart devices and artificial intelligence, the potential of CPS is immense and will continue to be explored in different industrial and non-industrial applications. The key benefits of CPS are improved efficiency, robustness and cost-effectiveness [6]. Finally, CPS allows for greater accuracy and more flexibility in addressing varying conditions and scenarios, thereby, opening up the possibility of more efficient and autonomous operations.Physical elements such as sensors and actuators are used to collect input information and supply feedback from the system, while software algorithms parse this data to identify patterns, make decisions, and generate operational commands [7]. In addition, these elements might be connected through networks that enable a constant exchange of data among them. The resulting systems will be able to evaluate the system data, processes it and create responses autonomously, thus providing greater oversight of the process's parameters [8].

CPS is a complex system that involves a variety of disciplines, each of which has its own design thinking and practices. On the one hand, engineers must consider material properties, acoustic and electrical properties, mobility, power consumption, and other physical factors when designing physical components and communication technologies [9]. On the other hand, computer scientists must consider software architecture, structure, performance, scalability, and so on when designing networked and cloud-based technologies [10]. Both experts need to bridge these seemingly disparate perspectives to be able to develop truly interdisciplinary solutions to the challenges in CPS. Bridging these gaps requires a space for meaningful collaboration between these various disciplines in order to be able to develop successful systems [11].

Transportation

Autonomous vehicles are quickly becoming a reality, as cars and trucks are on the brink of being able to drive on roads without human intervention. This is an example of a Cyber-Physical System, as it requires integration of physical components with sensing and control systems, and embedded software that is connected to offboard computing and cloud-based analytics [12]. In addition, the system must be able to interact with and respond to real-world input in order to function properly. This requires close collaboration between mechanical and systems engineers and computer scientists who can develop hardware and software components that are tailored to the specific situation and intended applications. Automotive autonomous systems typically include sensors such as cameras, lasers, radars, and ultrasound emitters, which must be able to interact with and interpret their surrounding environment, as well as actuators that can respond as necessary [13]. On the software side, autonomous vehicles must be able to process and interpret input data in real-time and employ machine learning algorithms to enable more dynamic responses in the face of changing conditions. In order to have a successful autonomous driving system, everyone involved must have a unified understanding of each component of the system and the way all the pieces interact [14].

Artificial Intelligence

Artificial Intelligence (AI) is the name given to computer algorithms that are designed to mimic the cognitive processes that humans normally use when making decisions or solving problems. AI algorithms can learn by themselves, making the process of developing solutions more efficient and accurate [15]. By allowing machines to make decisions and solve problems in the same way that humans can, tasks can be completed more quickly and with fewer errors. Additionally, AI can have access to large data sets and quickly analyze them to make decisions or to optimize processes. AI also has the capability to learn from experience and generate complex solutions on its own [16]. This means that AI algorithms are becoming increasingly sophisticated, offering solutions that are both accurate and efficient. In the context of autonomous vehicles, AI is being used to enable autonomous vehicles to measure and respond to their environment in real-time in order to safely drive without human intervention [17].

Compared to strong AI, weak AI is limited to a specific set of tasks, such as playing chess or optimizing routes to a warehouse, while strong AI can complete multiple tasks with the same level of accuracy or higher as a human. While weak AI has shown to be efficient in specific tasks, strong AI has the potential to analyze data sets and develop insights, which can lead to more efficient decisions in operations research and supply chain management.In the context of supply chain management, strong AI systems can be used to automate entire processes or track the performance of entire systems, whereas weak AI systems can be leveraged to focus on specific tasks, such as driving optimization [18]. For example, weak AI can be used to automatically generate the best route to a warehouse or the optimal re-scheduling of deliveries when one shipment is delayed. Furthermore, AI can leverage large data sets to develop insights and make more intelligent, data-driven decisions that lead to better outcomes. This is especially useful in operations research and decision making processes such as inventory management, where AI systems can be used to analyze historic data to forecast future demand and make predictions about the optimal stock levels for specific products.At the deeper level, AI is being used for a wide range of business applications including data analysis, forecasting and decision support [19].

AI is revolutionizing the way we interact with machines and our lives. AI can be used to automate repetitive tasks, such as data entry, providing faster, more accurate results than manual methods. AI can also be applied to tasks such as detecting anomalies in large data sets, helping businesses, manufacturers, and retailers make sense of the vast and sometimes complicated data collected from customers and operations. AI can also be used for forecasting, providing an understanding of trends, customer preferences and identifying opportunities faster and more accurately than manual methods. AI can also be used for decision support and providing recommendations on what options to pursue based on historical data, predictions and other information. As AI techniques become more sophisticated, machines are increasingly capable of thinking, understanding and predicting what people are likely to do in any given situation. In short, AI is now being used to make our lives easier, more efficient and more productive [20].

CONCLUSION

The combination of CPS, IoT and AI enables businesses, organizations and individuals to create new, more efficient solutions to solve their challenges and problems. The convergence of CPS, IoT and AI allow developers to create apps, products and systems that uses machine learning algorithms to collect, store and analyze large volumes of data in order to generate insights and make better decisions in real-time. The analysis of the data gathered from CPS, IoT and AI devices is used to uncover patterns and trends in data streams like customer preferences or asset performance. This could then be used to make smarter decisions for the organization, such as better customer segmentation or optimized supply chains. In addition, AI technologies such as virtual agents and smart home solutions that offer automated solutions to customer service or home automation can be tailored to the user's needs and provide a more personalized experience. AI can further optimize processes and empower decision makers to do more with less time and resources. Such innovative solutions can revolutionize the way people interact with machines and benefit both humanity and the environment.

The human trait of anxiousness should remain in the upper hand over curiosity when it comes to global supply chains and their essential interlinks. This is because if these supply chains are disrupted or unmanaged, it can lead to a range of serious consequences such as food shortages, economic instability, and other related issues that can have serious implications on humanity's physical survival. Identity theft, data breaches, and other malicious activity can also arise from mismanagement of the global supply chain, which should also be avoided. For these reasons, anxiousness should take precedence in managing the global supply chain infrastructure. The use of CPS, IoT and AI can help automate and streamline the process of managing and monitoring the supply chain, thereby reducing the need for manual oversight and allowing decision makers to focus on other areas of the organization. This technology can also empower decision makers to make better and more informed decisions in order to take proactive measures and prevent potential issues from occurring in the supply chain.

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