Chapter 1
A Systematic Review on the Emergence and Applications of Industry 4.0

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Abstract The transition from traditional manufacturing to intelligent manufacturing is evolving as a result of technological advancement. Industry 4.0 has a broader spectrum of the domain and has brought a radical shift to innovative activities, though it is still at an early stage of maturity. The need to embrace emerging techniques and technology is imperative more than ever. This article presents a review on the emerging industrial fourth revolution called Industry 4.0 (14.0). The research noticed no consensus among researchers on the number of technologies responsible for the radical industrial transformation. However, it highlights and discusses some unique enabling technologies of Industry 4.0 with applications areas. The study realized that in the future, robotics would take over the activities of manufacturing more intelligently and thus, leading to Industry 5.0. The article contributes to the bank of literature on Industry 4.0

Keywords Industry 4.0 · Smart manufacturing · Cyber-physical systems · Big data analytics · Industrial internet of things · Industrial robotics

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1 Introduction

Industry 4.0 is the radical change in goods and services due to technology referred to as the fourth industrial revolution. It emerges from market expansion, globalization, and competitiveness growth (Piccarozzi et al. 2018). It is, therefore, a technology-driven revolution for smart production, automation in business communications, and manufacturing (Zheng et al. 2021). Information technology (IT) advancement will lead the fourth industrial revolution to integrate manufacturing and service delivery in an automated and digital fashion (Rüßmann et al. 2015). Industry 4.0, in other words, is an intelligent production/manufacturing consisting of the Internet of things (IoT), cloud computing, and cyber-physical systems (CPS). In manufacturing, for instance, the whole system is adaptable via the CPS. In CPS, the communication is between the processing unit and the computer serving as a head connected as a network. Any change in the input parameter will adjust to the output parameter, thereby creating a feedback loop in the decision-making process (Schwab 2016; Kamble et al. 2018). The second part of the industry 14.0 component is cloud computing related to IT service delivery such as storage, databases, and servers located remotely and easily accessible from everywhere within a short possible time. The IoT is entirely human-free operations. It is a system or machine that connects and interacts without third-party intervention (Yu et al. 2017). Each machine has its unique code identifier connecting the other device and controls remotely at a higher speed and efficiency, making the entire operation bright and more intelligent, leading to the fourth industrial revolution (Lee et al. 2017).

Industry 4.0 brings new industrial perspectives on adding value chain products in the manufacturing system via different technologies and using little resources to realize maximum output. The innovations of industry 4.0 mainly affected the growth and employment sector (Piccarozzi et al. 2018). The application of technology in industries will improve and enhance productivity in the manufacturing, investment, revenue generation, and employment sectors (Rüßmann et al. 2015, Kamble et al. 2018). Therefore, industry 4.0 is a revolutionary shift from the traditional manufacturing norms (machine dominant) to the technological-based practice (intelligent manufacturing) (Oztemel and Gursev 2020).

One of the essential parts of any research is the literature review, through which a research gap can be identified and possibly bridge. Research is a continuous process; a thorough review of existing works, new ideas emerge and widen the research cycle's scope. Many authors studied industry 4.0 from different dimensions and perspectives. A corporate social responsibility studied industry 4.0 and the youth generation via a sustainable human resources management framework (Scavarda et al. 2019). This chapter seeks to review the literature extensively due to the growing interest surrounding industry 4.0. the paper will retrospect the kind of industry 4.0 revolutions such as virtual manufacturing, artificial intelligence (AI), cybernetics (man–machine interactions), machine interactions, industry 4.0 technologies, sustainability, blockchain, and Big data analytics.

2 Industry 4.0 Technologies

As mentioned earlier, technology is the back-born of industry 4.0. It is an essential aspect of the fourth industrial revolution. Nowadays, combining digital and manufacturing technologies integrates organizations' system vertically, horizontally, and end to end across the value chain (Klingenberg et al. 2019). The enabling industry 4.0 technologies are enormous, and there is no consensus on the number among researchers as it varies from one domain to another (Fettermann et al. 2018; Riel and Flatscher 2017). The enabling technologies include but are not limited to Cyber-physical systems, IoT, big data analytics, cloud servers, enterprises resource planning software, blockchain technology, visualization technology, artificial intelligence, and modelling and simulation, automation, and industrial robot system. The applications of these technology enablers for industry 4.0 has been studied extensively (Piccarozzi et al. 2018; Zheng et al. 2021; Rüßmann et al, 2015; Schwab 2016; Kamble et al. 2018; Yu et al. 2017; Lee et al. 2017; Oztemel and Gursev 2020; Scavarda et al. 2019; Klingenberg et al. 2019; Fettermann et al. 2018; Riel and Flatscher 2017; Nascimento et al. 2019; Alguliyev et al. 2018; Monostori et al. 2016; Nagy et al. 2018; Wong and Kim 2017; Yang et al. 2017; Li et al. 2017; Rao and Prasad 2018).

2.1 Cyber-Physical Systems

The CPS is the underlying technology representing Industry 4.0. It is a system that integrates the aspect of computation, automation, networking, and processing. It serves as a modular for manufacturing systems and can massively manufacture highly customized products (Nascimento et al. 2019). It encompasses mobile device technologies, robotics, AI, IoT, 3D printing, and cyber-security (Piccarozzi et al. 2018). It enables the fusion between the virtual and physical world via IoT connectivity. It has been applied in new smart product development and sensing (Alguliyev et al. 2018; Monostori et al. 2016). Additionally, it captures and exchanges data in real time. The companies employing CPS tend to satisfy customers and partners more efficiently (Nagy et al. 2018).

2.2 Internet of Things

Internet of Things improves efficiency and productivity through the combination of predictive analytics and intelligent machines. It can disseminate data and information significantly faster and accurately and provide sensing ability (Wong and Kim 2017). Data are collected, analyzed, and managed using IoT. It is also helpful in the manufacturing system as a control process (Yang et al. 2017). It helps synchronize

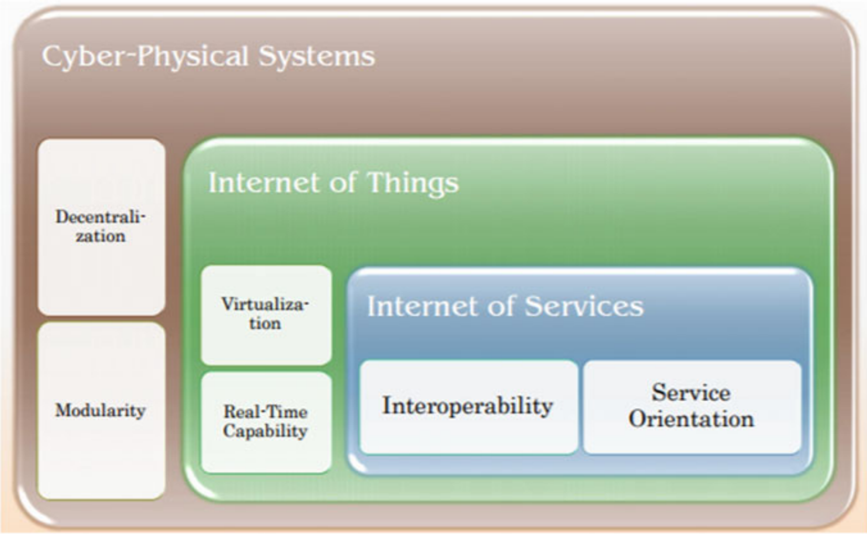

Fig. 1 Industry 4.0 framework (adapted from Oztemel and Gursev 2020)

and coordinate product and information flow effectively. The advantages of IoT in Industry 4.0 is enormous. Using RFID, the IoT provides more flexibility in logistics processes (Fig. 1).

2.3 Big Data and Analytics

Big data and analytics (BDA) is another technology enabler for Industry 4.0. The BDA technology collects and analyzes many available data with several filtering, capturing, and insights reporting techniques. It processes voluminous data with higher velocity and variability (Zheng et al. 2021). For any digital transformation in manufacturing sectors, powerful data analytics is imperative; therefore, expert skills to analyze massively available data are mandatory (Lee et al. 2017). The BDA technologies are real-time data collection tools; they support real-time decision-making, improving product quality, manufacturing flexibility and overall, predictive maintainability of equipment (Li et al. 2017). It has been used widely for finding fault and monitoring processes in manufacturing industries. Manufacturing agility can be derived from the big data intelligence exploitation and the high data quality and analytics expertise required to fulfil the task. However, there is a challenge of data confidentiality and consistency over the complex supply chain in the long run.

2.4 Artificial Intelligence

Artificial intelligence is a system that thinks like a human being. It rationally behaves under neural language processing, knowledge-based representation, machine learning, automated reasoning, robotics, and computer vision. Artificial intelligence technologies are helpful in product design, planning, control, scheduling, and quality improvement, among others (Rao and Prasad 2018). It has been used in the manufacturing industry for unmanned training, unmanned vehicles, aeroplanes, developing intelligent factories, and automatic prediction. Nowadays, AI system based is taking part in the enterprise decision-making process as robots, solving healthcare human resource crisis. Typical AI technologies include fuzzy logic, genetic algorithms, neural networks, random forest, expert systems, etc.

2.5 Cybernetics and Human–Machine Interactions

Cybernetics or man–machine interactions is an old interdisciplinary science. It studies control and communication concepts in living organisms, machines, and organizations, including self-organization (Novikov 2016). Its inherent feature focuses on how mechanical, biological, or digital systems process information and respond to it or change it based on feedback for better functioning. The feature is typical in industry 4.0 nowadays as modern manufacturing comprises the human component, the CPS, and cyber. IoT integrates all the parts as a connecting element. The human-cyber-physical interactions are regarded as one of the tools for intelligent manufacturing implementation (Qian et al. 2017). The cybernetic interactions with different systems and their originated year depicted in Fig. 2. The significant challenges of deploying IoT-based CPS in an organization is the fear of cyber-attacks and data theft due to malware that could defect the product quality. The cyber-attacks issues need to be addressed to improve the systems' trustworthiness and acceptability and guarantee industrial data safety.

2.6 Blockchain Technology

A blockchain is a database with a distributed and tamper-proof digital ledger of transactions based on a chain of linked blocks, including timestamps maintained by participating nodes that enable sharing of information among peers and provide a double-spending problem solution (Zheng et al. 2021; Ghadimi et al. 2019). Blockchain technology is applied in an integrated supply chain effectively with real-time material identification and tracking system. It automatically enables cross-

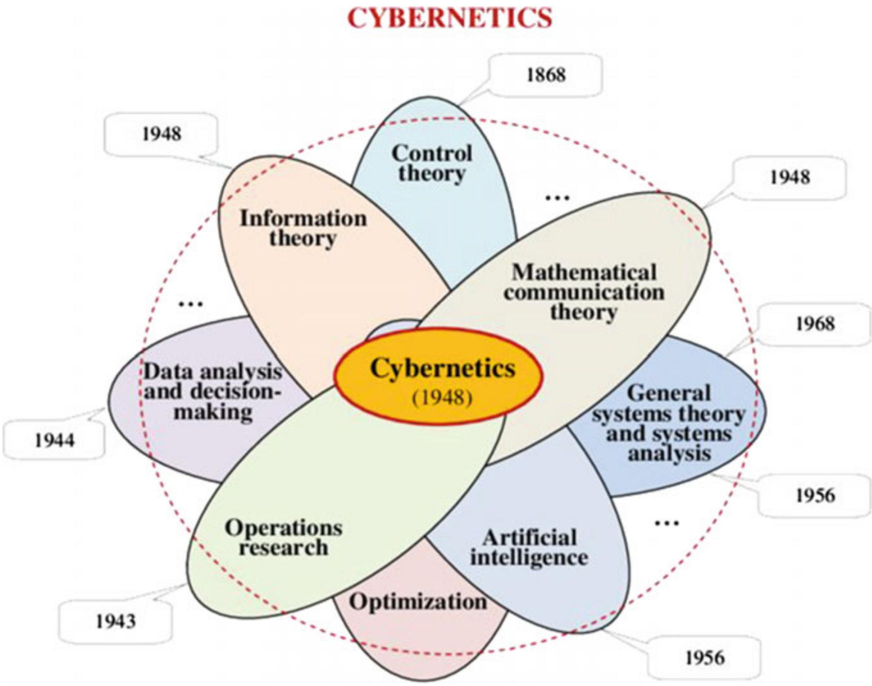

Fig. 2 The structural composition of cybernetics system (adapted from Novikov 2016)

organizational collaboration among stakeholders (Zheng et al. 2021; Ghadimi et al. 2019). Also, it is applicable in smart purchasing and supply chain management, smart contracts in negotiating energy supply agreement among enterprises (Fraga-Lamas and Fernández-Caramés 2019; Mohamed et al. 2019).

2.7 Visualization Technology

Visualization Technology (VT) is an indispensable part of automation. Softwares such as computer-aided design (CAD) are used in printing a three-dimensional object in a 3D printer. Visualizing a production process in 3D gives a clear picture or image of the process and makes understanding better. It is known as additive manufacturing, unlike the traditional manufacturing of drilling, cutting, grinding, etc. The VT is automated. The VT can be either augmented reality (AR) or virtual reality (VR). The AR is a set of humanly innovative techniques to interact with a computer capable of embedding virtual objects to interact and co-exist in the natural environment. The AR helps visualize the end product, thereby giving proper assessment and supporting the developmental product process.

On the other hand, VR is an interactive world created by a computer technology application. The user can control the virtual object and the entire virtual scene in real time (Zheng et al. 2021; Cohen et al. 2019). The VT has been applied in intelligent procurement and supply management, shop floor visualization, automated manual tasks guidance for operators, staff training, products alignment, etc.

2.8 Automation and Industrial Robot System

The operational process in manufacturing systems is mainly automated. Humans and machines share similar learning environment. For instance, robotics collaborate and learn from human. It has been said, in the future industrial robotics and robots will take over most if not all of the human activities. Modern robots exhibit some level of flexibility and autonomy, and they can interact with one another and human beings. Industrial robots reduce the cost of operations and are faster and intelligently do factory work. With an increase in programming knowledge, several researchers proposed different robots for industry 4.0 (Wang et al. 2016).

3 Conclusion

This article discusses and investigated the industry 4.0 current state-of-art—the primary industry 4.0 enabling technologies identified and discussed briefly to understand the subject matter. Applications areas of these technologies also elaborated. The study presents the scope of industry 4.0 in recent years. The study discovered no consensus on the different technologies enabling the fourth industrial revolution. However, it found the major players in the era of intelligent manufacturing and the digital economy. It understands that robotics will take over the performance of activities more intelligently shortly. The paper is limited because the number of growing research papers in industry 4.0 has not reported due to its diverse approaches and concept used by several authors in the literature. In future, more robust statistical tools will be employed with graphs and figures in illustrating the trend and the kind of research conducted on Industry 4.0.

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