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The Current Status and Developing Trends of Industry 4.0: a Review

Yang Lu[1]

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Abstract
The core concept of Industry 4.0 is to integrate advanced information technologies, especially emerging technologies, such as the Internet of Things, 5G & 6G, data analytics and management, artificial intelligence, cloud computing, and blockchain, to achieve a consistent transformation and upgrade of manufacturing and to reshape the value chain of industry and society. More research focuses on the integration of informatization and industrialization, the digital integration and governance of the industry, and specific technical and operational objects. This paper conducts a survey trying to depict an overview of Industry 4.0, specifically a bibliographic analysis, the extant review and status, the enabling technologies, the major drivers, implementing policies in major countries, and developing trends and challenges. Furthermore, the next generation of industrial revolution Industry 5.0 is discussed. This study theoretically and practically provides a good foundation of the industrial revolution from the information systems perspective.

Keywords Industry 4.0 · Industry 5.0 · IoT (internet of things) · Cloud computing · Artificial intelligence (AI) · Blockchain

1 Introduction

In recent years, countries have promulgated national and regional innovation strategies related to the new generation of manufacturing. For example, "Industry 4.0" was proposed by Germany, "Made in China 2025" was proposed by China, and "Re-Industrialization" was proposed by the United States. Industry 4.0 is an intelligent transformation of traditional manufacturing. It has gradually become an integrated framework for related concepts and technologies, such as the transformation and upgrading of global manufacturing, intelligent manufacturing, and the industrial Internet of Things (IIoT). In 2011, the term "Industry 4.0", also known as smart manufacturing, was proposed in Hanover, Germany. It is a cyber physical system (CPS) based on traditional manufacturing, the Internet, and the Internet of Things (IoT), and it is associated with various high technologies, such as cloud computing, artificial intelligence, blockchain, etc. It aims to realize the smart factory, thereby seamlessly connecting the individual needs of customers to the production process. A smart factory is an intelligent automatic system that allows sensors, machines, and facilities to communicate with each other among different institutions and industries (Li, 2018; Xu et al., 2018; Zheng & Lu, 2021).

Industry 4.0 is regarded as the fourth industrial revolution. In the first industrial revolution, humans got rid of the limitations of many physical properties and employed water and steam as power for manufacturing and transportation. The second industrial revolution was brought about by the development of the electrical system. Electricity replaced water and steam as the power for production, and machines were first used for manufacturing. The third industrial revolution centred on the era of production automation and precision, using electronic equipment and information technology to increase production capacity (Lu, 2017a; Xu & Duan, 2019).

The revolution of Industry 4.0 connects IoT, cloud computing, big data analysis, AI, blockchain, and other high technologies into a high degree of automation and production. It can offer the production environment the capabilities of self-awareness, self-learning, autonomous decision-making, self-execution, and adaption for production. Industry 4.0 integrates the manufacturing systems of different smart factories into the value chain in the form of CPS, in order to obtain real-time data and make decision for manufacturing. The manufacturing system of CPS has a high degree of flexibility,

✉ Yang Lu
ylu12@uco.edu

[1] Department of Information Systems and Operations Management, University of Central Oklahoma, Edmond, OK 73034, USA

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adaptability, and agility. Industry 4.0 can produce customized products with higher quality, lower cost, and higher interoperability (Osterrieder et al., 2020; Xu, 2020a, b).

1.1 Features of Industry 4.0

The characteristics of Industry 4.0 are mainly reflected in the integration of three aspects: (1) Vertical integration with networked manufacturing systems; (2) Horizontal integration through value networks; (3) Future value chains across product life cycles through engineering processes end-to-end digital integration. The smart factory is the core component and key function of Industry 4.0. Horizontal integration refers to multiple smart factories and integrations between different smart factories through a value network. Vertical and horizontal integration can achieve end-to-end integration in the smart system (Lu, 2017a; Liao et al., 2017; Hofmann & Rüsch, 2017).

Smart products are another key concept in the Industry 4.0 system. In a smart factory, products and machines communicate with each other to promote performance. The term "smart products" refers to objects, equipment, and machines that are equipped with sensors, controlled by software, and connected to the Internet. Industry 4.0 is the fourth industrial revolution, which means that many other problems may yet arise in this new era, among them standardization, safety and security, resource allocation efficiency, new social infrastructure, work organization and design, training, and the regulatory framework (Zhong et al., 2017; Wang, et al., 2016a, b; Davis et al., 2012).

1.2 Principles of Industry 4.0

The core of Industry 4.0 is a cyber physical system (CPS). CPS is the integration of calculation analysis, interconnection communication, and precise control. According to potential data, CPS analyses and modifies data and then predicts results to dynamically connect the virtual and the physical worlds, aiming to form a unified system of things, data, products, and services. The integrated system combines production, logistics and services to monitor, coordinate, and control manufacturing in real time (Jin et al., 2012; Lu 2017b; Oztemel & Gursev, 2020).

Its basic principle is its ability to provide all relevant information in real time through the establishment of a network in the value chain, and its ability to obtain the best value from data transaction. Industry 4.0 connects people, objects, and systems, and creates dynamic, self-organizing, cross-organizational, and real-time optimized value networks based on cost, availability, and resource consumption. In the smart factory of Industry 4.0, CPS monitors the actual process, creates virtual objects in the physical world, and makes further decisions (Fig. 1). Through IoT and cloud computing, CPS can communicate and cooperate with people in real time. Participants have great opportunities to share and use intra-organizational and inter-organizational services within the system value chain (Fatorachian & Kazemi, 2018; Oztemel & Gursev, 2020; Culot et al., 2020).

Industry 4.0 makes all of its production factors in the physical world and reflects the corresponding models in the virtual world. This seamless connection between the real and the virtual world establishes the global production optimization of the smart factory. In addition, multiple factories in the value network are horizontally integrated; that is, the actual production factors and models are separately integrated in order to achieve the best decision of the entire value network. Through the CPS platform, IoT, services, data, and human effort can be connected and interacted via the Internet (Wang et al., 2016a, b; Oztemel & Gursev, 2020).

Covering the rapid development of Industry 4.0, this article presents a comprehensive overview of Industry 4.0. To depict the complete picture, a total of 2032 papers, published between 2011 and 2021 from WoS (Web of Science), were chosen for the study. This article is structured as follows. Section 1 presents an introduction of Industry 4.0. Section 2 provides a comparison among the extant popular review articles showing the potential that this study addresses. Section 3 illustrates the bibliographic analytics of Industry 4.0, while Section 4 introduces the enabling technologies of Industry 4.0. Section 5 explains the major drivers of Industry 4.0, and Section 6 lists policies towards Industry 4.0 in major countries. Section 7 describes development trends and challenges of Industry 4.0, Section 8 depicts foundations of Industry 5.0, and Section 9 is the conclusion.

2 The Extant Prominent Studies of Industry 4.0

This section considers the top ten highly influential and cited review/survey papers of Industry 4.0, ordered by the number of their comprehensive citations from Google Scholar as of August 31, 2021. Among the 10 papers, the total number of citations reached 11,645, which reflects that Industry 4.0 and the relevant topics attract a lot of attention in the real world. It also means that Industry 4.0 prompts the development of the whole society.

Specifically, Lu (2017a, b), Xu et al. (2018), Liao et al. (2017), Hofmann & Rüsch (2017), and Oztemel & Gursev (2020) offer general reviews, such as Industry 4.0's present status, as well as enabling technologies, viable applications, encountering challenges, developing trends, and potential research. Zhong et al. (2017); Wang et al. (2016a, b; Davis et al. (2012)) illustrate smart manufacturing and smart factories, reporting on enterprise architecture, the cyber physical

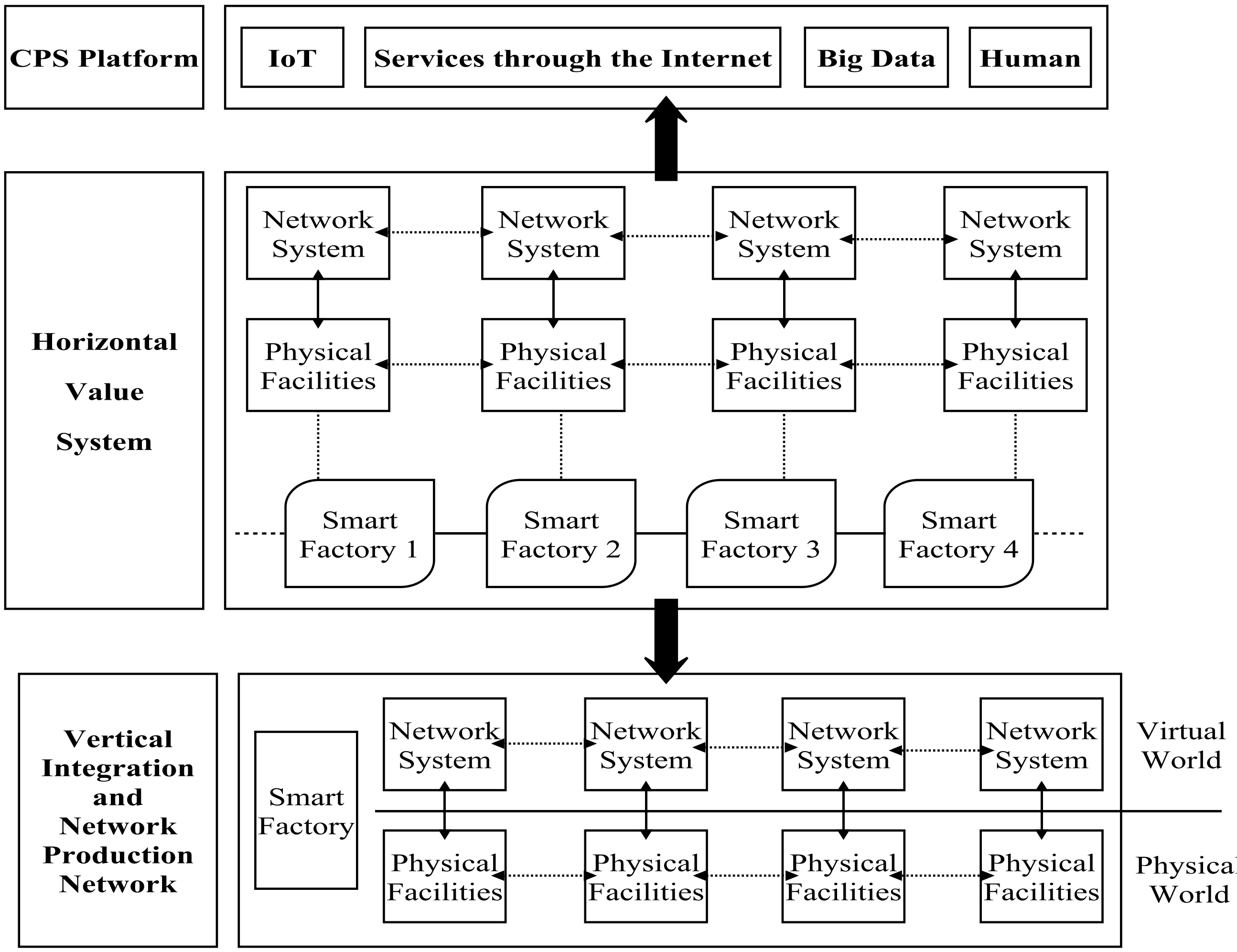


Fig. 1 The principle of industry 4.0

system, enterprise integration, data analytics, innovation, and performance. Jin et al. (2012) discusses implementation of the smart city and IoT within the context of Industry 4.0. Their detailed perspectives are listed in the following table (Table 1).

The top ten review papers serve to depict most of the potential from different angles; however, there is still the lack of a comprehensive overview of Industry 4.0. This paper describes Industry 4.0 from its more comprehensive aspects: those associated with bibliographical analytics, descriptive and prescriptive analytics, and the relevant prospects.

3 Bibliographic Analysis of Industry 4.0

3.1 Methodology

Aiming to seek popular and relevant articles, this study searched the major database, Web of Science (WoS). In addition, Google Scholar was used to double check the comprehensive citations of the selected articles. The keywords, "Industry 4.0", "smart manufacturing", and "smart factory", were used to search among articles' titles, keywords, or abstracts within the time frame of 2011 through 2021 (Table 2). The articles selected from the WoS database were from categories that are relevant to Industry 4.0, such as Business, Computer Science Information Systems, Economics, Management, Operations Research management Science. Articles consist of journal papers and conference proceedings. Eventually, the number qualified papers related to Industry 4.0 was 2032, after culling out duplicate papers from different search results or papers published beyond the designated year range of 2011 to 2021.

Table 1 Top 10 Reviews of industry 4.0

Article	Google Citation	<1>	<2>	<3>	<4>	<5>	<6>	<7>	<8>	<9>
Lu, 2017a, b	1904	●	●	●		●	●		●	
Xu et al., 2018	1454	●	●	●		●	●		●	
Zhong et al., 2017	1373	●	●			●		●	●	
Wang et al., 2016a	1283	●	●				●		●	
Jin, et al., 2012	1262					●	●		●	
Liao et al., 2017	1262	●		●	●	●			●	
Hofmann & Rüsch 2017	1155	●				●	●		●	
Wang et al., 2016b	1132		●				●		●	
Davis et al., 2012	672	●				●			●	
Oztemel & Gursev 2020	610	●		●		●	●	●	●	
This Paper		●	●	●	●	●	●	●	●	●

Notes:

1. The order of the Top 10 reviews is substantially based on the comprehensive citations of each article from Google Scholar, as of the counts on September 30, 2021.

2. KEY: <1> Features of Industry 4.0; <2> Principles of Industry 4.0; <3> The Prominent Studies of Industry 4.0; <4> Bibliographic Analysis of Industry 4.0; <5> The Enabling Technologies of Industry 4.0; <6> The Major Drivers of Industry 4.0; <7> Policies towards Industry 4.0 in Major Countries; <8> Development Trends and Challenges of Industry 4.0; <9> Foundations of Industry 5.0.

Table 2 Literature selection summary

Subject	A survey in industry 4.0
Time Period	2011 - 2021
Database	Web of Science (Paper selection)
	Google Scholar (Citations checking)
Search Fields	Title, Keywords, or Abstract
Search Criteria	Business, Computer Science Information Systems, Economics, Management, Operations Research management Science
Search Keywords	"Industry 4.0" (1472 papers)
	"Smart Manufacturing" (666 papers)
	"Smart Factory" (279 papers)
Quantity	Total Selected (2417)
	Identical Paper (358), Year Out of Range (27)
	Finalized Paper (2032)

3.2 Descriptive Analysis

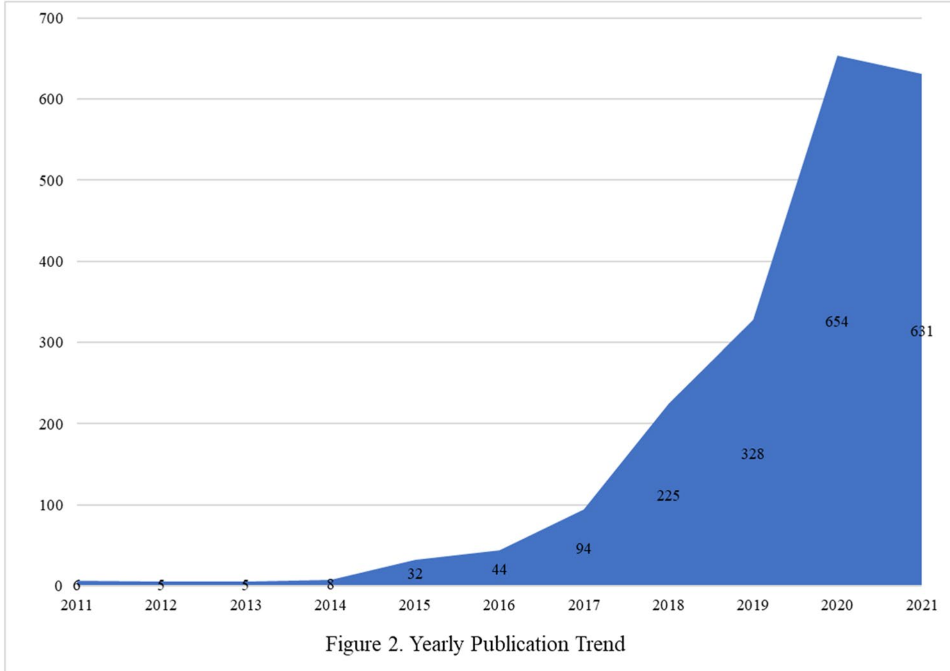
3.2.1 The Trend of Publication (2011 - 2021)

Within the current decade, research on Industry 4.0 has been increasing tremendously; since 2018, the number of publications has increased by an exponential level (Fig. 2). For the year 2021 through the writing of this article, as many as 631 papers have been published. Based upon the statistics, Industry 4.0 is not only a hot topic, but it is becoming mature, especially as regards the development of the relevant technologies and disciplines. Industry 4.0 will last for many years attracting the attention from practitioners, scholars, and other researchers.

3.2.2 Distributions of Journals

The selected 2032 articles were published in 408 journals. This indicates that Industry 4.0 covers a broad array of disciplines, such as agriculture, architecture, artificial intelligence, business, chemistry, computing, ecology, economics, education, engineering, ergonomics, geography, history, hospitality, humanities, information systems, management, manufacturing, material sciences, mathematics, mechanics, nanoscience, nutrition, operations, optics, physics, political science, psychology, quantum information science, robotics, sciences, social sciences, sociology, surgery, telecommunication, transportation, thermodynamics, and urban studies. The following table

Fig. 2 Yearly publication trend



(Table 3) lists the top 37 journals that have published at least ten papers related to Industry 4.0. The journal with the most is IEEE Access, with 244 publications, an open-source platform that has attracted more and more attention. Another top tier journal is the International Journal of Production Research that has also compiled more than 100 articles. Furthermore, as new journals, Journal of Management Analytics and the Journal of Industrial Integration and Management-Innovation and Entrepreneurship has had 21 and 12 articles published on the topic respectively, as well.

There are 373 journals that have published at least one but less than ten papers related to Industry 4.0 since 2011. Among them, IEEE (Institute of Electrical and Electronics Engineers) is the major organization that has developed several different journals that have covered Industry 4.0; in total, the quantity of published papers is 377. The journals, along with the number of Industry 4.0 papers published in them, are IEEE Access (244), IEEE Internet of Things Journal (64), IEEE Latin America Transactions (13), IEEE Network (13), IEEE Communications Surveys and Tutorials (12), IEEE Systems Journal (9), IEEE Cloud Computing (4), IEEE Transactions on Engineering Management (3), IEEE Journal of Biomedical and Health Informatics (2), IEEE Transactions on Computational Social Systems (2), IEEE Transactions on Emerging Topics in Computing (2), IEEE Transactions on Network and Service Management (2), IEEE Transactions on Services Computing (2), IEEE Pervasive Computing (1), IEEE Security & Privacy (1), IEEE Transactions on Dependable and Secure Computing (1), IEEE Transactions on Multi-Scale Computing Systems (1), and IEEE Wireless Communications.

3.3 Intellectual Relationship Analysis

3.3.1 Keywords Analytics

The keyword was first analysed by "Biblioshiny for Bibliometrix" of the R Project. This paper focuses on the authors' keywords. In total, the selected 2032 articles include 6375 keywords. The keywords that occurred most frequently were identified, and they are illustrated in the following picture (Fig. 3). The minimum frequency of a keyword is 20. There are four clear groups of keywords that indicate the research on Industry 4.0 from different angles.

For instance, the first (largest) cluster consists of illustration of the attributes of Industry 4.0. The keywords are "Industry 4.0", "intelligent manufacturing", "supply chain management", "digital transformation", "big data analytics", "sustainability", "circular economy", and "digitalization." The second cluster consists of a discussion of the ecosystems in smart manufacturing, such as "smart manufacturing", "smart factory", "digital twin", "industrial Internet of Things", "innovation", "cyber physical system", "fourth industrial revolution", "simulation", and "technology." The third and fourth clusters are mainly key technologies and applications used in Industry 4.0. These keywords include "blockchain", "IoT", "security", "cloud computing",

Table 3 Journal distribution

Source title	Count
IEEE Access	244
International Journal of Production Research	122
Journal of Industrial Information Integration	81
International Journal of Computer Integrated Manufacturing	72
Journal of Manufacturing Systems	71
Journal of Manufacturing Systems	71
IEEE Internet of Things Journal	64
Technological Forecasting and Social Change	48
Journal of Manufacturing Technology Management	44
Electronics	42
International Journal of Production Economics	42
Production Planning & Control	38
Journal of Ambient Intelligence and Humanized Computing	34
Benchmarking-An International Journal	25
Enterprise Information Systems	24
Journal of Management Analytics	21
Systems Research and Behavioral Science	19
Logforum	18
Polish Journal of Management Studies	18
International Journal of Productivity and Performance Management	16
Future Internet	15
Brazilian Journal of Operations & Production Management	13
IEEE Latin America Transactions	13
IEEE Network	13
Information	13
Annals of Operations Research	12
IEEE Communications Surveys and Tutorials	12
International Journal of Operations & Production Management	12
Journal of Asian Finance Economics and Business	12
Journal of Industrial Integration and Management-Innovation and Entrepreneurship	12
Multimedia Tools and Applications	12
Regional Studies	12
Wireless Communications & Mobile Computing	12
Expert Systems with Applications	11
Computer Communications	10
Concurrent Engineering-Research and Applications	10
Wireless Networks	10

Notes: In the database, the industry 4.0 relevant articles published among more than 400 journals and conference proceedings. The table include the main 37 journals that has published at least 10 papers since 2011.

"machine learning", "edge computing", "wireless sensor network", "monitoring", "augmented reality", "data models", "5G", "optimization", and "automation".

3.3.2 Collaboration Structure

For the selected 2032 articles, we built a keyword word cloud (Fig. 4). The word cloud consists of the 50 most frequent words from all the potential keywords of 3032 papers. The most used keyword for the research of Industry 4.0 was "Internet", used 278 times, and the least used, "quality" was found as a keyword in only 32 papers.

The top 50 most frequent keywords (Table 4) are: Internet (278), management (272), future (258), systems (230), framework (208), industry 4.0 (195), design (192), model (179), performance (176), big data (172), things (152), innovation (144), system (132), challenges (129), architecture (99), optimization (98), impact (95), implementation (93), cyber-physical systems (78), technology (75), integration (74), technologies (74), smart (72), networks (67), algorithm (64), information (64), security (63), supply chain (57), IoT (52), knowledge (50), big data analytics (48), context (47), opportunities (47), research agenda (47), service (47), logistics (45), cloud, (42), information-technology (41), supply chain management (41), models (40), strategy (40), perspective (39), firm performance (38), industry (37), capabilities (35), analytics (34), simulation (34), sustainability (34), of-the-art (33), and quality (32).

According to the co-citation network (Fig. 5), the influencing scholars are easily classified to two major groups. One eminent scholar, Dr. Li D. Xu of Old Dominion University (USA) has made a strong contribution to the research on Industry 4.0. In each group, he has published at least one paper that plays an important role. Also, as might be expected, among all of the influencing papers between the two groups, there is a high degree of cross-citing between scholars. It is clear that Industry 4.0 is not a separate discipline but rather a multiple subject that requires researchers to get familiar with the knowledge bases of different fields associated with the combined methodology to further seek values and to improve the overall development of the entire society.

3.3.3 Country Collaboration Map

The following figure (Fig. 6) depicts the studies on which researchers have collaborated, from countries all over the world. Until now, the major research has still been concentrated in the countries that have greatly developed Industry 4.0. For instance, in Asia, those countries are China and Korea; in North America, that country is USA; in South America, that country is Brazil; in Europe, those countries are Germany and the UK; in Oceania, those countries are Australia and New Zealand. China is the most developed country in the consideration of Internet 4.0, and it plays a dominant role around the world; its number of total citations is almost double the number of citations from the US.

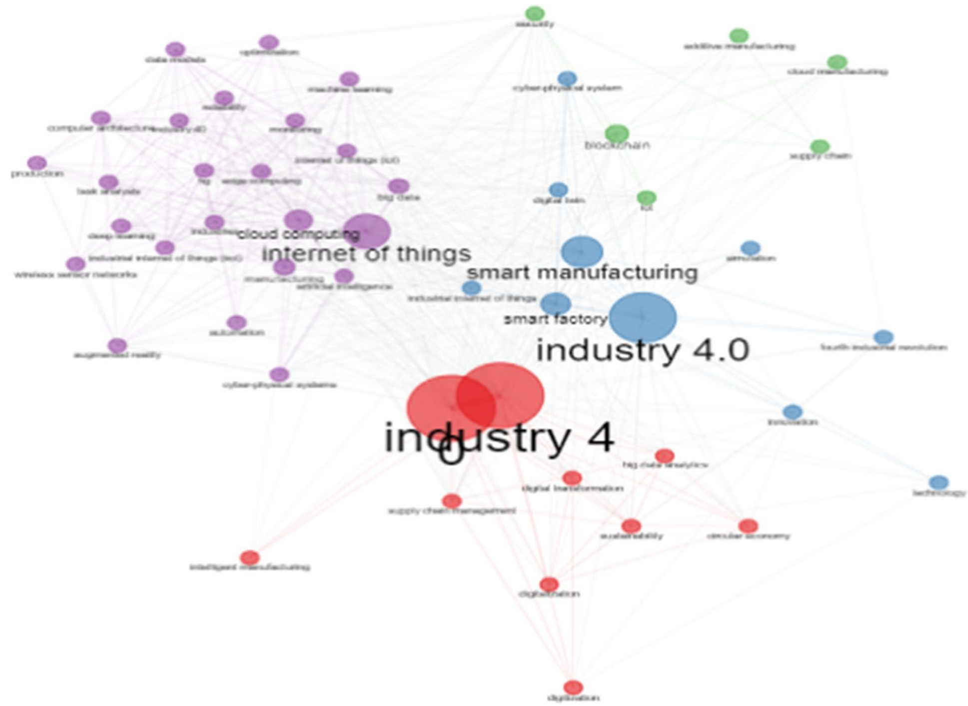


Fig. 3 Keywords network

Fig. 4 Word cloud

Europe is one of the major areas that has been enriching research and developing Industry 4.0. Among the top 20 most cited countries (Table 5), 12 countries are from Europe, Germany, UK, Italy, France, Sweden, Spain, Austria, Norway, Hungary, Poland, Russia, and Turkey.

3.4 Cluster Analysis of Research

For cluster analysis, two levels of measurement, density and centrality, were employed. The centrality of a cluster points out the importance of a theme in a research field, while density signifies a theme development status (Waltman et al., 2010; Callon et al., 1983). Figure 7 shows that the themes around industry technologies, supply chain, and manufacturing are the largest and most central to the research field. These themes are those that mainly drive research in the field. However, theme of supply chain-related research is comparatively less developed than the theme that focuses on manufacturing. The lean production and operational performance-related research is significantly developed, but it is not much central to the overall discussion. Smart factory and manufacturing-related discussions are not much developed or central to the overall research of Industry 4.0. Hence, smart manufacturing and cloud computing-related research need to be further developed in the future. In addition, within the scope of Industry 4.0, other topics, like IoT (Internet of Things), system cybersecurity, AI (artificial intelligent), 5G, and 6G, are becoming more and more popular in both academia and practice.

4 The Enabling Technologies of Industry 4.0

With the implementation of Industry 4.0, manufacturing and other relevant industries have been improved to a higher level of development. But without the support of foundational facilities and technologies, Industry 4.0 cannot be fulfilled as the strategical expectation. The development of Industry 4.0 is the comprehensive integration and interoperability of the enabling technologies. This section addresses the enabling technologies within Industry 4.0, including AI technology, IoT, cloud computing, and blockchain technology.

Table 4 The top 50 keywords

Terms	Frequency	Terms	Frequency	Terms	Frequency
internet	278	implementation	93	service	47
management	272	cyber-physical systems	78	logistics	45
future	258	technology	75	cloud	42
systems	230	integration	74	information-technology	41
framework	208	technologies	74	supply chain management	41
industry 4 0	195	smart	72	models	40
design	192	networks	67	strategy	40
model	179	algorithm	64	perspective	39
performance	176	information	64	firm performance	38
big data	172	security	63	industry	37
things	152	supply chain	57	capabilities	35
innovation	144	IoT	52	analytics	34
system	132	knowledge	50	simulation	34
challenges	129	big data analytics	48	sustainability	34
architecture	99	context	47	of-the-art	33
optimization	98	opportunities	47	quality	32
impact	95	research agenda	47		

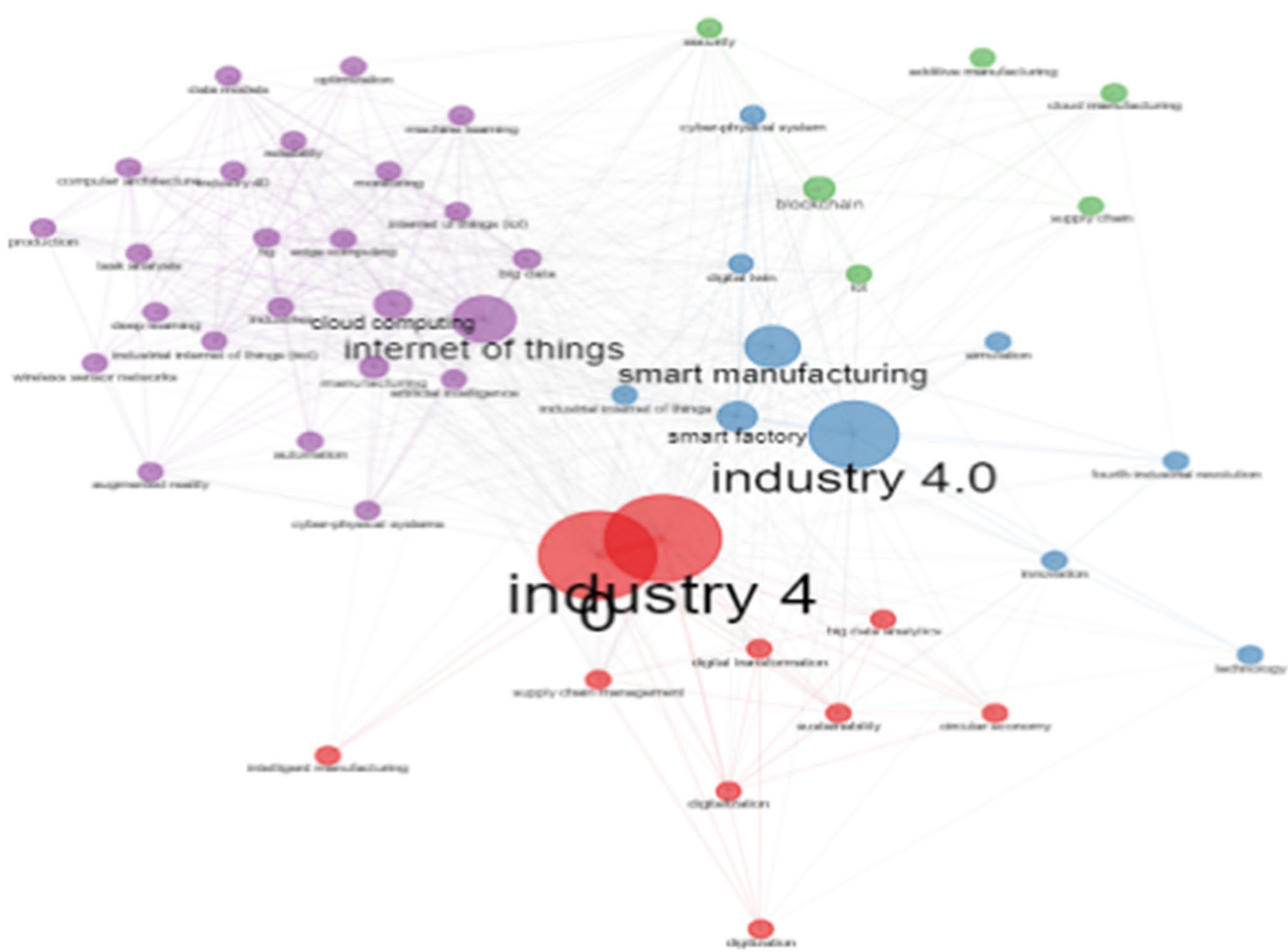


Fig. 5 Most influenced papers

Fig. 6 Country collaboration map

Table 5 The top 20 most cited countries

Country	Total citations	Average article citations
China	11,314	24.12
USA	5846	40.04
Brazil	2784	24.00
Germany	2313	21.42
United Kingdom	1925	16.31
Italy	1764	12.97
France	1688	31.26
Korea	1203	8.41
Sweden	1040	29.71
India	882	5.73
Spain	780	8.30
Australia	548	11.66
Austria	413	15.88
Iran	402	28.71
New Zealand	385	29.62
Norway	329	19.35
Hungary	310	12.92
Poland	308	5.70
Russia	290	8.29
Turkey	264	5.87

4.1 The AI Technology

AI (artificial intelligence) is a branch of computing and is known as one of the three cutting-edge technologies in the world. Its main directions are the principle of human intelligence activities, the construction of artificial systems with a certain degree of intelligence, and the study of basic theories and technologies on how to use computers to simulate certain human intelligent behaviours (Muhuri et al., 2019; Zhang & Lu, 2021).

With the penetration of artificial intelligence technology, machines have the capabilities of self-acquisition, self-adjustment, self-determination, and self-control. Machines can achieve collaborative cooperation, interconnection, and mutual sharing. This parallel status is a breakthrough in achieving intelligent manufacturing (Lu 2019b; Culot et al., 2020; Azeem et al., 2021).

Large data centres and huge storage capacity make AI a reality. For AI, the two branches of machine learning and deep learning use big data analysis to optimize processes and to seek new solutions and ideas. Based upon various mathematical algorithms, from small and medium-sized companies to large multinational companies, every organization accumulates usable data. Machine learning, the major development of AI in Industry 4.0, allows for the recognition of features and relationships and uses algorithms to find solutions. Generally, machine learning consists of four categories (Table 6): supervised learning, unsupervised learning, semi-supervised learning, and reinforcement learning (Lu, 2019b; Tortorella et al., 2020; Zhang & Lu, 2021).

AI technology appears in our daily lives in the form of unmanned driving and industrial robots. Technology in manufacturing applications may become the new standard for analyzing large amounts of data and for performing predictive maintenance. AI will have a huge impact on manufacturing and automation. For example, AI-related algorithms can be used to optimize the manufacturing supply chain to help companies predict market changes. AI can be linked together by location search, weather patterns, consumer behavior, political status, and socioeconomic and macroeconomic factors to estimate market demand (Tao & Zhang, 2017; Müller et al., 2018b; Chen et al., 2021).

Fig. 7 Clustering coupling

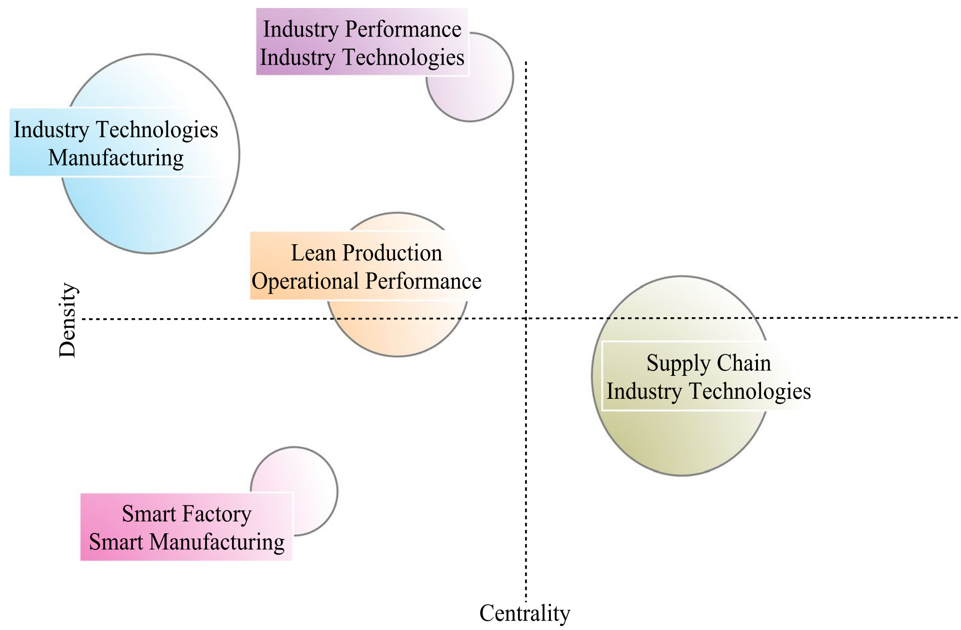


Table 6 Machine learning categorizations and explanations

Supervised learning
All data have something in common. A supervised models can learn the characteristics of the data set as the basis for prediction and classification. The model output can be used to calculate the error value through the standard answers.
Unsupervised learning
There is no standard answer for all data. The machine (computer) has to find the answer. This method does not require manual classification. The accuracy of the prediction is not high.
Semi supervised learning
A few pieces of data have something in common, but most of the data does not. This is equivalent to combining the advantages of supervised and unsupervised models. This approach requires only a small amount of manual classification to make the prediction more accurate.
Reinforcement learning
The machine will try to find the best solution with risks or errors. In order to make a decision, the answers and results need to be further revised.

AI attempts to understand the nature of intelligence and produces a new type of intelligent machine that can react in a way similar to that of human thinking. Research in this field includes robotics, speech understanding, image recognition, natural language processing, and expert systems. The theory and technology of AI have matured gradually, and the field of AI application has also been expanding. In the future, technological products engendered by AI will embed human wisdom. AI can simulate the process of human consciousness and thinking (Tao et al., 2018; Diez-Olivan et al., 2019; Wang et al., 2021).

4.2 IoT

IoT is an important emerging technology. According to pre-agreed communication protocols and exchange and communication standards, IoT uses radio frequency identification (RFID) and barcode recognition and smart sensors, as well as other information sensing devices, to transmit data to the Internet in order to achieve human-computer interaction, intelligent identification management, and decision-making control between things. In an environment constituted by the Industrial Internet of Things (IIoT), through machine-to-machine communication, machines can interact and communicate with other machines, objects, and infrastructure. As a result, a large amount of data can be generated. After processing and analysis, how to use these data to optimize factory management and control to further solve the problem of global manufacturing upgrades is the key to the success of Industry 4.0 and manufacturing (Kim, 2017; Zhang & Chen, 2020).

In recent years, IoT has developed rapidly. In the network, sensors and devices collect and analyse data related to the production environment, and then modify and improve the operation of the production line based on the results of the data analytics. This offers the potential to understand the real-time operating status of the machine, to monitor or predict when the machine needs maintenance, and to avoid damage caused by downtime. Among those potentials, communication technology is a critical part of IoT. At present, manufacturers and organizations are vigorously promoting the relevant communication standards and specifications of IoT, so it will have easy-to-build, low-cost, and universal technology, to integrate and communicate with each entity (Xu et al., 2021; Manavalan & Jayakrishna, 2019; Khan & Javaid, 2021).

Before Industry 4.0, the manufacturing industry developed a mature manufacturing execution system (MES), which could arrange, manage, and track the operation of each step in the production process by using Internet of Things technology to provide a management foundation. Specifically, IoT, in industrial production, focuses more on the expansion and use of industrial applications. Under the influence of Industry 4.0, after a period of exploration, the development of the global Industrial IoT (IIoT) has gradually shown its performance. IIoT explores more machine-to-machine communication, collects big data in the production process, and implements machine learning to make production operations more effective and reliable (Boyes et al., 2018; Reyna et al., 2018; Kim, 2021).

IIoT is the integration of sensor networks, the Internet, and massive data collection and analysis. It can effectively improve the production efficiency of existing industries and create new business opportunities. Since the goal of intelligent manufacturing is to establish a self-sensing production environment, IIoT is an indispensable part of the integration of network entity systems and production processes. IIoT can collect data generated from various sensors and production equipment in real time. After artificial intelligence embeddedness, IIoT can help industrial production equipment and infrastructure in making decisions, predicting real-time and accurate production, or scheduling existing resources to improve efficiency and to reduce unnecessary costs. It can further increase profits and complete automation tasks that could not be handled before (Li et al., 2018; Sisinni et al., 2018; Reyna et al., 2018).

4.3 Cloud Computing

Cloud computing is part of the era of big data. With the exponential growth of data, a grid computing model based on Internet technology, distributed computing, and information resource sharing management technology has been proposed. It provides users with scalable and configurable on-demand services and resource sharing computing models, and it offers users convenient, fast, stable, reliable, economical, practical, and interactively configurable personalized services. The cloud platform can access, monitor, and obtain the resources needed by individuals in real time (Yang, 2019; Rajput & Singh, 2019; Aceto et al., 2020).

Cloud computing is an Internet-based calculating and resources system. Shared resource and information are transmitted through cloud computing. It is characterized by distributing calculations in different locations on the structured computer. This enables companies to switch resources to the required applications and allows them to access them as needed. Cloud computing provides a reliable and safe data storage system in which users no longer need to worry about data loss, virus intrusion, or other troubles (Moeuf et al., 2018; Kim, 2017; Reinhardt et al., 2020).

Based on the application of cloud computing business models, cloud technology is a general term for network technology, information technology, integration technology, management platform technology, application technology, etc. Cloud computing is an emerging technology that can form a resource pool which can be used on demand, flexibly and conveniently. Since it is not maintained locally, and since traditional methods cannot be used for storage, monitoring, or protection, it allows remote and more effective real-time collaboration for companies to process operating modes (Pace et al., 2018; Mittal et al., 2018, 2019; Xie et al., 2021).

Compared with traditional data systems, one of the advantages of cloud technology is that the cloud reduces maintenance and improves manageability. For example, the SaaS model (Software as a Service) of cloud computing allows customers to pay service fees on demand based on different combinations of factors, such as the number of concurrent users, the number of functions used, the data storage capacity, and the length of use time. There is no need to pay various fees, such as software license fees, servers and other hardware devices operating systems, databases and other platform, the cost of customization, the development and implementation of software project, and the cost of IT maintenance. The most important function of only charging for services is the ERP product that transacts the service (Liao et al., 2017; Machado et al., 2020).

4.4 Blockchain Technology

As an emerging technology, blockchain is gradually leading a new round of technological and industrial revolution across the globe. Its application scenarios have penetrated from digital currency into finance, supply chain, medicine, and other fields, promoting the transformation of the Internet of Information into the Internet of Value. Traditional manufacturing has also begun to have a strong interest in blockchain technology. Companies have begun to apply blockchain to accounting, logistics, and production activities (Lu, 2018; Lin et al., 2018; Dev et al., 2020; Gorkhali et al., 2020).

Intelligent manufacturing is a human-machine integrated system composed of intelligent machines and human experts. It can perform intelligent activities in the manufacturing process, such as analysis, reasoning, judgment, conception, and decision-making. Through the cooperation between humans and intelligent devices, the mental work of human experts in the manufacturing process has been expanded, extended, and partially replaced. Intelligent manufacturing updates the concept of manufacturing automation and flexible integration. Intelligent manufacturing combines with a wide range of social production networks to realize value transfer. Blockchain and its relevant technologies will play an important role in intelligent manufacturing (Jin et al., 2014; Reyna et al., 2018; Xu & Viriyasitavat, 2019).

In the implementation of intelligent manufacturing, the key task is to realize both the vertical integration of the internal information system of the manufacturing enterprise and the horizontal integration based on the value chain and information flow between different manufacturing enterprises. Since manufacturing equipment and information systems involve multiple manufacturers, the original centralized system mainly uses manual or central computer control, and it is difficult to obtain all of the information in the manufacturing process in real time. At the same time, all information, such as order demand, production capacity, inventory level changes, and sudden failures, are monitored by the independent systems. The technical architecture, communication protocol, and data storage format of these systems are different from each other. This affects the efficiency of interconnection and intercommunication, and it also restricts the application of intelligent manufacturing in the actual manufacturing process (Lu, 2019a; Viriyasitavat et al., 2020; Nanayakkara et al., 2021).

Blockchain technology is characterized by the ability to connect sensors, control modules and systems, communication networks, ERP systems, and other systems by manufacturing companies. Through a unified ledger infrastructure, blockchain can assist equipment manufacturers and safety production supervision departments to maintain long-term maintenance and to continuously monitor all aspects of manufacturing in order to improve the safety and reliability of manufacturing. The traceability and the non-tampering modification of blockchain ledger records are also conducive to the development of corporate auditing, facilitating system discovery, tracking, and problem solving and optimization, as well as improving the manufacturing process of intelligent manufacturing. The use of blockchain technology can effectively collect and analyze the information generated by all sensors and other components in the originally isolated system, can use big data analysis to evaluate its actual value, and can perform the expected analysis on production. It can help companies quickly establish a safer operating mechanism, a more efficient workflow, and better service (Lu, 2018; Reyna et al., 2018; Qi & Tao, 2018; Viriyasitavat et al., 2019).

5 Major Drivers of Industry 4.0

Currently, the manufacturing industry is undergoing a transition from manual assistance to fully automated operations such as industrial automation and smart factories. Modern massive production is completed through automated operations, and the production process nearly requires no manual assistance. To meet the needs of modernization, industry that is automatic and intelligent is an inevitable trend. The development of a diversified economic market is the main factor that is driving this industrial revolution (Lu 2017a; Wang et al., 2016a; Ivanov et al., 2019).

The continuous growth of the industry is attributed to the continuous development of technical support. The key drivers of modern manufacturing include the IIoT (Industrial Internet of Things), robotics, big data, network security, and other drivers, such as 3D, modeling, simulation, visualization, and immersion. Industry 4.0, supported by these technologies, has the advantages of high productivity, accuracy, safety, high quality, and intelligence (Wang et al., 2016b; Wan et al., 2016; Frank et al., 2019a, b).

5.1 IIoT (Industrial Internet of Things)

IIoT is the continuous integration of various acquisition and control sensors or controllers with sensing and monitoring functions, as well as with mobile communications, intelligent analysis, and other technologies, into all aspects of the industrial production process. IIoT has potential to improve the quality and the productivity of manufacturing, to reduce product costs and resource consumption, and to reach a new stage in the intelligence of industries. The application of IIoT in Industry 4.0 has the characteristics of real-time, automation, embeddedness, security, and information interoperability (Xu et al., 2014; Lu & Xu, 2018; Boyes et al., 2018; Zheng et al., 2018; Frank et al., 2019a).

IIoT can use relevant information to complete basic tasks through the use of tablets, smartphones, and other intelligent devices. For example, a company can use data analysis to change its business to use a leaner and more adaptable method, in order to achieve long-term or short-term goals. Through this connection, all departments can speed up their response speed and can improve the agility of operations (Wan et al., 2016; Zhong et al., 2017; Zhang & Chen, 2020; Li & Xu, 2021).

Smart devices not only perform well in capturing and analyzing data in real time, but they are also more accurate and time-sensitive in terms of the strategies that drive business decisions. Therefore, IIoT integrated with smart devices plays a huge role in quality control, traceability, sustainability, supply chain efficiency, predictive maintenance, asset tracking, customer satisfaction, and facility management (Ivanov et al., 2016; Yin et al., 2018; Manavalan & Jayakrishna, 2019).

5.2 Robotics

A robot is a machine that realizes various functions through its own power and control capabilities. It can accept manual commands, run pre-arranged programs, or take actions based on principles established by AI technology. Its mission is to assist or replace labor, such as production, construction, or high-risk work (Roblek et al., 2016; Zhang et al., 2019; Haleem & Javaid, 2019).

As more and more physical factories become smarter and more efficient, robots will occupy a more important position in manufacturing. With the advancement of robotics, these machines can exhibit more complex and outstanding functions, including machine learning and storage, greater flexibility, and more effective collaboration functions. Robots have been regarded as an important part of Industry 4.0 (Peruzzini & Stjepandić, 2018; Fraga-Lamas et al., 2018; Yli-Ojanperä et al., 2019).

5.3 Big Data

Big data requires new processing models with stronger decision-making capabilities, insight and discovery capabilities, and process optimization functions to adapt to the high growth rate and the diversified information assets. Big data requires special techniques to effectively process large amounts of data that can be tolerated over time. Technologies applicable to big data include massively parallel processing (MPP) databases, data mining, distributed file systems, distributed databases, cloud computing platforms, the Internet, and scalable storage systems (Chen et al., 2016; Qi & Tao, 2018; Birkel et al., 2019; Aceto et al., 2020; Duan & Xu, 2021; Javaid et al., 2021).

In terms of product type and depth, manufacturing is the most complex industry. Companies that use big data in manufacturing can respond to global development challenges, such as opening new factories in new locations and transferring production to other countries. The way in which we store and capture data changes every day, so new standards for sharing, transmission, updating, searching, visual query, and information privacy have emerged. Industry 4.0 needs to adopt more powerful technologies to keep up with the pace of data updates. Therefore, the emergence of enterprise resource planning (ERP) has provided a vital role for the business development of enterprises (Buer et al., 2018; Jiang, et al., 2019; Hämäläinen & Inkinen 2019; Sahal et al., 2020; Faheem et al., 2021).

5.4 Network Security

As more and more business operations turn to cloud-based solutions and rely more and more on robotic labor, maintaining the integrity and safety of the system will become a critical issue. As manufacturing companies simultaneously build and integrate their systems through the IIoT, more information security threats and vulnerabilities will appear (Li et al., 2017; Dalenogare et al., 2018; Fragapane et al., 2020).

In addition, manufacturing companies are the basis for the continuous development of automated processes. In the increasingly insecure digital environment of Industry 4.0, the level of security needs to be urgently considered. To address these vulnerabilities, manufacturing and other industries are paying close attention to cloud-based systems. Perhaps cloud-based security is one of the important components of future modern integrated system functions. However, dealing with the security issues of the cloud-based system is a challenging and complex process (Wang et al., 2016b; Lin et al., 2018; Dolgui et al., 2019).

5.5 Other Drivers

3D printing is one of the emerging advanced manufacturing technologies. 3D printing can now construct large and complex structures in less than a day. In the past, it usually took weeks to complete this process. The use of new special consumable materials is the main development direction of 3D printing. This technique is easier for metals, but it is relatively difficult for high-strength alloys, ceramics, and nano-ceramics (Kang et al., 2016; Longo et al., 2020; Ghobakhloo, 2020).

Companies can immerse themselves in new forms of modeling, simulation, visualization, and interaction, and they can use new technologies to present and to predict scenarios more effectively. Some innovative technologies such as modeling, immersive tools, and visualization can be used by companies that rely on big data, including those in the manufacturing, medical, energy, and financial fields. These innovative displays are not only data, but they also offer effective methods to help teams develop technology and increase their mission success rates (Luthra & Mangla, 2018; Ghobakhloo & Fathi, 2019; Machado et al., 2020).

6 Policies of Industry 4.0 Among Countries

How to implement the related strategies and modules is critical to the success of Industry 4.0. Most of the major countries have developed policies regarding their use of Industry

4.0. In this section, we briefly address unique policies in major countries, such as China, the US, and Germany.

6.1 China

In 2015, China issued the "Made in China 2025" action plan, which not only heralded the arrival of a new round of industrial revolution but pointed out that China's manufacturing industry will strive to build a new generation of information technology industry. The intelligent development of manufacturing, high-end equipment manufacturing, and new energy industries is accelerating the transformation of China from a large manufacturing country to a powerful manufacturing country. To smart manufacturing, China is using "Internet + Industry" to integrate the Internet into the manufacturing industry and using the Internet to lead the transformation and the upgrading of China's manufacturing industry to intelligent development (Li, 2018; Reischauer, 2018; Kuo et al., 2019).

6.2 The US

As a traditional manufacturing powerhouse, the US proposed "Achieving Domestic Competitive Advantage in Advanced Manufacturing Industry" (AMP 1.0) and "Accelerating American Advanced Manufacturing Industry" (AMP 2.0) in 2012 and 2014, respectively. These two projects aim to promote the development of a national reindustrialization associated with the industrial Internet of Things. To realize the safety of "Industry 4.0", two conditions need to be fulfilled: one is to ensure that the smart factories and industrial products themselves do not cause danger to the environment or to personnel. The other is to prevent data loss and abuse. With the increasing integration of the virtual machine and the real world, the challenge of network information security has become more and more severe. Therefore, it is necessary to facilitate cybersecurity system to achieve Industry 4.0 (Reischauer, 2018; Lin et al., 2017; Kuo et al., 2019).

6.3 Germany

As the birthplace of Industry 4.0, Germany identified Industry 4.0 as one of the top ten future projects through it "High-Tech Strategy 2020" as early as 2006, and now, it has upgraded Industry 4.0 to a national strategy. The goal is to promote Germany to become a supplier of a new generation of industrial revolution, and then to help it to dominate the manufacturing market. Germany uses innovative ideas to efficiently and quickly transform products and services in order to promote the transformation of the industry. Innovation includes not only technological innovation, but also social innovation. Social development is also an important factor affecting innovation in Industry 4.0 (Reischauer, 2018; Kuo et al., 2019).

6.4 Comparison and Summary

According to the development characteristics and the innovation output of the manufacturing industry, the US has obvious advantages in R&D and technology accumulation in manufacturing. Germany maintains a leading global position in certain advanced equipment manufacturing. There is a certain gap in the layout of manufacturing and in the proportion of high-end manufacturing between China and the two developed countries (Kamble et al., 2018; Reischauer, 2018; Kuo et al., 2019; Beier et al., 2020; Aceto et al., 2020).

The US and Germany have established public infrastructure, innovation platforms, and innovation networks, and have strengthened popular science and scientific communication regarding the new industrial innovation. Meanwhile, China is focusing on policy and institutional reform, aiming to fulfill transformation of scientific and technological achievements (Sung, 2018; Horváth & Szabó, 2019; Kuo et al., 2019; Birkel et al., 2019; Alcácer & Cruz-Machado, 2019).

7 Development Trends and Challenges of Industry 4.0

Driven by Industry 4.0, the productivity and the profit margins of the manufacturing industry have been improved to an unprecedented degree. In this process, many challenges will inevitably be encountered. Among them is likely to be the growing demand for personalized and customized products, the ability to reduce waste, and the handling of resources in a more responsible manner. However, with creativity and originality, these and other difficulties will be solved. The developing trends and challenges of Industry 4.0 are (1) standard and seamless operation, (2) an AI-relevant process and system improvement and management, (3) the cooperation of human and robots, and (4) 5G communication technology.

7.1 Standards and Seamless Operation

Due to the lack of unified standard software and hardware support, industrial software is usually limited by platforms with different technical specifications. Since many things inside and outside the factory are connected to services, communication methods and data formats require a unified architecture. "Interconnectivity" refers to the dynamic reorganization of the machines and modules in a factory. It is necessary to ensure seamless interoperability between devices from different vendors, and standardized protocols will play a key role. It is likely that the cumbersome wiring and cables will disappear without a trace, replaced by wireless protocols such as 5G and its derivative technologies. These machines are not only connected to each other but are connected to the cloud system. In cloud systems, flexible computing functions are used to run powerful algorithms to process various types of data (Chen et al., 2017; Ardito et al., 2019; Yadav et al., 2020).

7.2 AI relevant Process and System Improvement & Management

After reinforcement learning (RL) training, AI will play a greater role in Industry 4.0. RL helps engineers implement controllers and decision-making algorithms in complex systems, such as robotics and automatic systems, autonomous driving, and control design. RL will become an important part of improving large-scale systems. The key goal is to provide engineers with easy-to-use tools to build and train RL strategies and to generate large amounts of simulation data for training. Then, the RL agents are integrated into the system simulation tool to generate code for the embedded hardware. RL can achieve major breakthroughs in the industrial field, can improve the automation level of mobile factory equipment, and can even realize unmanned operation (Oesterreich & Teuteberg, 2016; Ghobakhloo, 2018; Büchi et al., 2020).

In view of the continuous development of edge computing equipment and industrial controllers, computing capabilities have rapidly improved. With the strong collaboration of the cloud system, the software functions of the production system will be continuously updated. The AI algorithms will dynamically optimize the output of the entire production line while minimizing energy and other resource consumption. This can not only help companies reduce waste and fulfill corporate social responsibility policies, but it will save a lot of resources. Predictive maintenance will continue to improve; it will no longer be limited to investigating the data of one machine or one site, but it will comprehensively consider the equipment data of multiple factories and even multiple different suppliers (Davis et al., 2012; Peruzzini & Stjepandić, 2018; Olsen & Tomlin, 2020).

7.3 The Cooperation of Human and Robots

However, there is still the question of how to generate customized samples through multiple production lines without having to spend a long conversion time or having to tolerate other inefficiencies. In the age of Industry 4.0, this vision will finally be realized to meet the needs of achieving a full range of personalized production. Traditionally, we have employed a fixed and inflexible way to set up machines in the workshop. After setting and adjusting the parameters, you could use it to produce specific products for months or even years. However, future production lines will contain multiple reconfigurable electromechanical modules and will be equipped with more and more collaborative robots that can communicate and interact with humans. At the same time, AI technology will be used to set parameters and to adjust the machine according to the next personalized product produced on the production line (de Sousa Jabbour, et al., 2018a, b; Tortorella & Fettermann 2018).

7.4 5G and Industry 4.0

The application scenarios that support 5G have expanded, from the mobile Internet to the mobile Internet of Things, and a new generation of high-speed, mobile, secure, and ubiquitous information infrastructure will be built. 5G will accelerate the digital transformation of many industries, and it will be used more in the industrial Internet, in automotive networks, and in other fields to expand the market, to bring new opportunities, and to support the vigorous development of the digital economy (Hofmann & Rüsch, 2017; Rossit et al., 2019; Lu & Ning, 2020).

Real-time communications between people, robots, factory logistics, and products are the basic conditions of Industry 4.0. Real-time data will generate transparency and actionable insights, while edge analytics will help maximize value and optimize production. These factors require standardization and data security. 5G is the right tool to take advantage of digital transformation, since it relies on standardized network functions, with built-in security, guaranteed service levels, and distributed cloud and network slicing concepts (Nascimento et al., 2019; Ivanov & Dolgui, 2020; Raj et al., 2020).

The trend of personalized product customization is growing. The current process needs to be adjusted to make it more flexible and customizable, while still protecting the initial investment in the production line. The high-speed wireless infrastructure of the 5G network can facilitate the rapid and flexible modification of OEM (original equipment manufacturer) machines, with less impact and higher efficiency (Müller et al., 2018a; Tao et al., 2019; Kamble et al., 2020).

By collecting data from the production line and transmitting the data to the cloud system, a combination of wireless sensors and a large-capacity communication network (5G) can be used for continuous monitoring. Compared with traditional systems, the ability to combine control, data logging, and alarms into a virtual controller in the cloud platform will help to simplify digital processes and to save on costs. In addition, the cloud platform can control various production tools and is a solution for remote machines and portable systems that can run independently (Yin et al., 2018; Aazam et al., 2018; Lu & Zheng, 2020).

8 Prospects for Industry 5.0

Industry 4.0 has spread to major countries all across the globe, with each country conducting the industrial revolution associated with its own features and environment of manufacturing, as well as other relevant fields. With the emergence of high technologies and the foreseeable future of industry and society, the next generation of industrial revolution, Industry 5.0, is described. However, there exist a numberof fuzzy issues. This section presents several fundamental points, such as a look at Industry 5.0, the notable features of Industry 5.0, and human values achievement in Industry 5.0 (Lu, 2017a, b; Nahavandi 2019; Leong et al., 2020; Longo et al., 2020).

8.1 What is Industry 5.0?

In the modern world, the factory environment of the future is destined to be smarter than ever. During the past few years, we have gradually become familiar with a new concept, Industry 4.0, the combination of sensors, data processing, connectivity, and production facilities. Slowly, the new generation of industry, Industry 5.0, is appearing. It is expected to bring new advantages in areas such as mass customization (Li, 2018; Nahavandi, 2019; Culot et al., 2020; Fernandez-Viagas & Framinan, 2021).

But what is Industry 5.0? In an increasingly interconnected world, what value will it bring to manufacturers? In short, Industry 5.0 will allow people to rejoin the automated process, thereby strengthening the collaboration between humans and machines (robots). In a symbiotic relationship, humans will be able to cooperate with a new generation of collaborative robots in order to add value to products. In this more diverse environment, production lines will become more intelligent; for example, humans will be able to supervise product customization at a higher level (Longo et al., 2020). Automation systems are commonplace in today's manufacturing environment; the starting point of the Industry 5.0 revolution stems from the shift in the relationship between human and intelligent systems. The following table (Table 7) illustrates several definitions of Industry 5.0 from other scholars.

8.2 The Notable Feature of Industry 5.0: Personal Customization

The unique feature of Industry 5.0 is "personalized customization": various sensor data are directly connected to design and production, in order to provide customers with personalized products in real time. The high degree of automation brought by Industry 5.0 will not compress the human value, but it will lift the human value throughout the process of human-machine collaboration and integration (Moeuf et al., 2018; Leong et al., 2020; Haleem & Javaid, 2019; Javaid & Haleem, 2020; Choudhary & Mishra, 2021).

Personal customization is based on the Internet, which integrates enterprises, collaborative partners, suppliers, and customers to customize personalized products according to the needs and preferences of those consumers. It seeks to explore the personalized needs of consumers and to design personalized products through high technologies and algorithms, i.e., AI-relevant mechanisms (Nahavandi, 2019; Machado et al., 2020; Echchakoui & Barka 2020; Bellini et al., 2021).

8.3 Human Value Achievement in Industry 5.0

In the factory of Industry 5.0, the working space of workers will not shrink; rather, it will increase. Compared to current conditions, workers will have a more spacious, friendly, and secure working environment. At the same time, the production operations in the manufacturing will begin to participate more and more in the design process, not just in the manufacturing procedure (Li, 2018; Leong et al., 2020; Longo et al., 2020; Kumar et al., 2021).

Industry 5.0 will realize closed-loop design and will break through the physical boundaries of manufacturing.

Table 7 Definitions of industry 5.0

Definition	Article
"Industry 5.0 will be a synergy between humans and autonomous machines. The autonomous workforce will be perceptive and informed about human intention and desire. The human race will work alongside robots, not only with no fear but also with peace of mind, knowing that their robotic co-workers adequately understand them and have the ability to effectively collaborate with them. It will result in an exceptionally efficient and value-added production process, flourishing trusted autonomy, and reduced waste and associated costs".	Nahavandi, 2019
"A new revolutionary wave—Industry 5.0—is emerging as an 'Age of Augmentation' when the human and machine reconcile and work in perfect symbiosis with one another. Industry 5.0. Unlike Industry 4.0, the new revolutionary wave combines the diverging strengths of CPPS and human agents to create symbiotic factories".	Longo et al., 2020
"Industry 5:0, a symmetrical innovation and the next generation global governance, is an incremental advancement of Industry 4:0 (asymmetrical innovation). It aims to design orthogonal safe exits by segregating the hyperconnected automation systems for manufacturing and production".	Leong et al., 2020

For example, to produce a new generation of aircraft, we are still be limited by existing manufacturing and data operation capabilities. In the era of Industry 5.0, we will be able to better automate the manufacturing process. This means that real-time data can be better implemented and used. The data, design, and manufacturing process can be seamlessly connected (Moeuf et al., 2018; Nahavandi, 2019; Abdirad et al., 2021).

9 Conclusions

Technological development in the industry will continue to develop rapidly. Industry 4.0 and Industry 5.0 illustrate changes in the way we design, produce, and maintain products and services in a highly intelligent manner. This transformation will increasingly promote the symbiotic interaction between machines and humans. The interweaving and the integration provide the potential to create more intelligent and efficient facilities and factories in the future. Industry 4.0 aims to realize the visualization and the real-time production through the use of big data, massive production, and personalized and uninterrupted seamless connection. By introducing a new generation of ICT (Information and Communication Technology), Industry 4.0 is a new era in the transformation and upgrading of industry and society.

This study conducts a comprehensive survey study into Industry 4.0. The study covers a broad range of Industry 4.0 topics including its bibliographic analytics, its enabling technologies, its major drivers, the policies of major countries, the development trends and challenges associated with Industry 4.0, and the foundations of Industry 5.0. The future research of industry revolution in Information Systems will move forward to its adoption and absorption; furthermore, both companies and institutions will seek approaches that will transform industry to a higher level for business profits and value exchange.

Declarations

Conflict of interest There is no conflict interest. Any ideas and insights expressed in this paper are those of the authors.

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Yang Lu is an Assistant Professor of InformationSystems & Operations Management Department, College of Business, Universityof Central Oklahoma, United States. He received his B.S. degree from JilinUniversity, China, in 2004 and the M.S. degree from the University ofManchester, UK, in 2006. He received his Ph.D. degree in ICT (Information andCommunication Technology) from ODU in USA. He is a Senior Member of IEEE.

He has made significant contributions to thefield, as evidenced by my three ESI Highly Cited papers and my ranking amongStanford's Top 2% of Scientists. He has published research papers in refereedjournals published by major publishers such as Elsevier, IEEE, Taylor &Francis, and World Scientific.