Recent Trends in 4th Industrial Revolution for A Sustainable Future–A Review

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1 Introduction

Recent technology advances have led to "Industry 4.0". It surpasses mechanisation, industrialisation, and computerisation. Industry 4.0 covers data management, manufacturing processes, competitiveness, and efficiency. Industry 4.0 concept involves information and communication technologies, cyber-physical systems, artificial intelligence, big data analytics, IoT, autonomous robotics, cloud computing, and augmented reality. These technologies may be the main drivers of automated and digital industrial environments. These technologies enable intelligent manufacturing by allowing devices, machines, production modules, and products to autonomously share information, trigger action, and control each other [1]. Industry 4.0 also goals to integrate human personnels into industrial processes to enhance, add value, and reduce waste.

The steam engine sparked the first Industrial Revolution in England in the mid-eighteenth century. Steam and water power mechanised manufacturing [2]. Europe and the United States began the second Industrial Revolution in the late nineteenth century, harnessing electrical power for mass production [3]. The third Industrial Revolution employed electronics and computer technology to automate production in several industrialised countries in the late twentieth century [4, 5]. The steam engine, electricity, and digital technologies used in the first three Industrial Revolutions increased production and efficiency [6]. Industry 4.0's smart factory technologies

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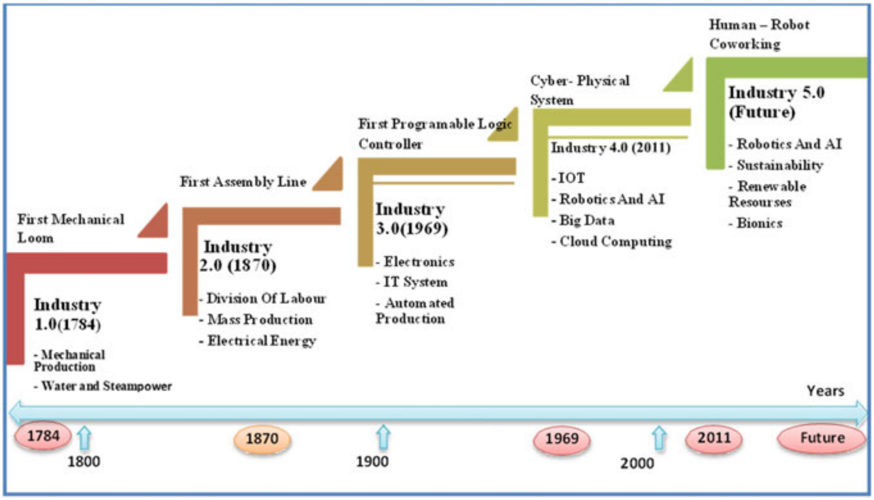

Fig. 1 From industry 1.0 to industry 5.0

have a huge impact on the industry. Figure 1 shows Industrial Revolution 1 to 5 (future) with special features and the year of revolution.

Germany's strategic plan coined "Industry 4.0". Hannover Messe, a German industrial expo, introduced Industry 4.0 in 2011. German Trade and Invest (GTAI) calls Industry 4.0 "a paradigm change enabled by technology innovations that reverses the previous industrial process logic". Industrial manufacturing equipment now "trains" products instead of just "processing" them [7]. As per experts, three potential areas of the industry's future are more clarity in energy system, demand flexibility, and energy efficiency. Industry 4.0 and the sustainable energy transition share basic qualities that might promote the transition. The sustainable development goal (SDG)'s energy, climate, and other aims might guide integrated approaches. Industry 4.0 prioritises energy efficiency.

2 Industry 4.0 Technologies

Industry 4.0 originally had nine pillars: big data, cyber-physical systems, the Internet of Things, 3D printing, robotics, simulation, augmented reality, cloud computing, and cyber security [8]. For better conceptual clarification, these technologies and their relevance have been explained in detail.

2.1 Big Data and Data Analytics

Data science analyses data sets using methods, scientific models, assumptions, and specialised equipment and software. Smart gadgets and advanced technologies like IoT, AI, social networking (SNS), and others have increased data sources, digital content, types, forms, and structure [9]. Five exabytes or five million terabytes of data are created daily [10]. Industry 4.0 generates data from sensors, log files, video/audio, network traffic, transactions, and social media [11].

Analysis complexity affects accuracy and quality. As firms receive more complicated data, they need technical, math/statistical, and business skills to design and provide an appropriate solution.

Thus, big data or heterogeneous data is generated daily and develops fast. Big data differs in volume, variety, honesty, velocity, and value [9, 12]. Big data gives industries and intelligent manufacturing several advantages, merits, and benefits via predictive and prospective insights. Therefore, to remain competitive, organisations should implement and apply contemporary advanced analytical tools, methods, methodologies, and applications for processing big data, obtaining insight, and recovering the value of each case's vital data. Big data analytics (BDA) uses parallel and analytic methods to analyse massive amounts of diverse, fast-changing data, making it easier to acquire, analyse, and manage vital information and statistics [9, 13]. The best method for companies to surpass competition, optimise operations, boost productivity, quality, and efficiency, and minimise operating costs is to use newly discovered information to deliver important insights and improve equipment servicing and maintainability [14]. Businesses must change their decision-making culture and remember that human understanding is still needed, even as big data and analytic technologies grow [12]. Figure 2 shows the data science model, Fig. 3 shows industry-wide applications and use cases, and Fig. 4 shows data analytics methodology, implementation, and measurement.

2.2 The Internet of Things (IoT)

Atzori et al. [16] describe IoT as "global network of uniquely addressable things employing standard communication protocols". Vermesan et al. [13] describe IoT as a self-configuring, global network architecture with open, standardised communication protocols. This network includes "things" with identities, physical traits, and virtual personalities [17]. Intelligent manufacturing uses the Industrial Internet of Things (IIoT). IIoT uses modern fundamental technologies to improve system efficiency [18]. IIoT services and apps increase industrial process and system planning, management, and scheduling [14, 19]. Networked devices will decentralise analytics and decision-making for real-time reactions [20]. Minimising unexpected downtime improves "availability, maintainability, operational efficiency, productivity, and new product time-to-market". It boosts industry [19]. Khan et al. [21]

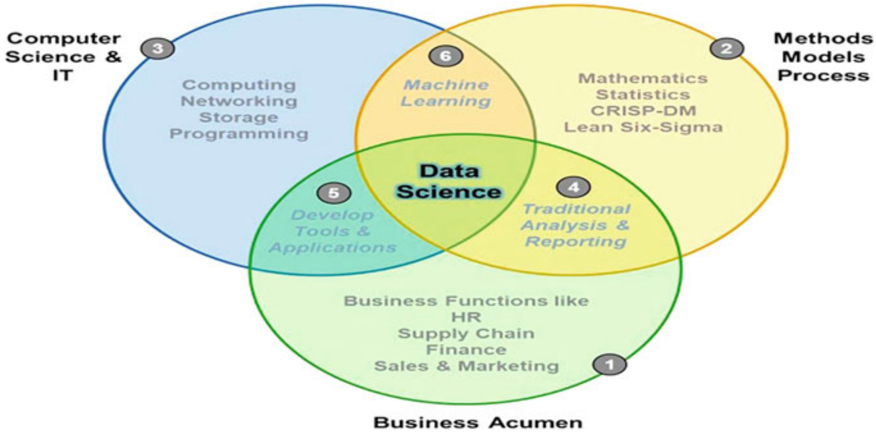

Fig. 2 The data science model [15]

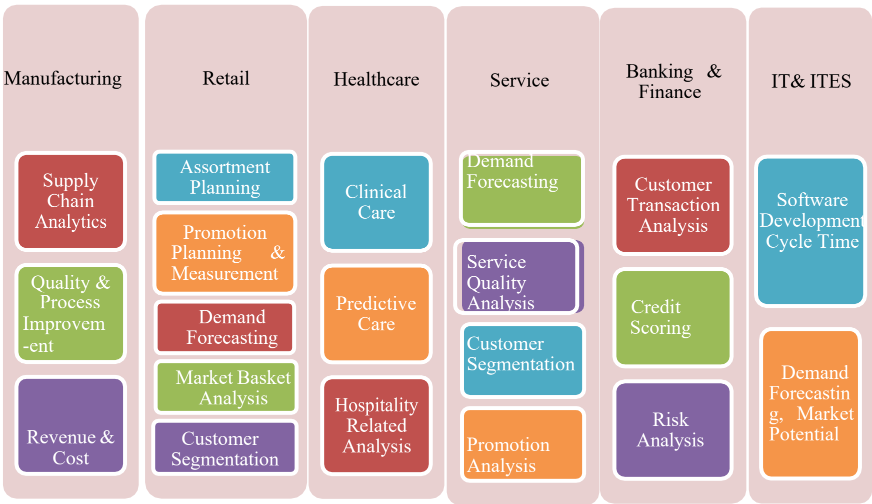

Fig. 3 Industry wide application and use cases [15]

examined "interoperability, standardisation, data and information secrecy, encryption, privacy, name and identity management, IoT greening, object and network security". Miorandi et al. examined communication, identification, distributed system, intelligence, security, data privacy, confidentiality, and trust [22]. Gubbi et al. studied "safe reprogrammable networks, privacy, QoS, energy-efficient sensing, architecture, and protocols, GIS-based visualisation, data mining, and cloud computing" [23]. Borgia includes "object mobility, M2M communications, device and data management, network architecture, system design, addressing, naming, traffic categorization, and security" [24]. As per Perera et al., privacy, data analytics, product and

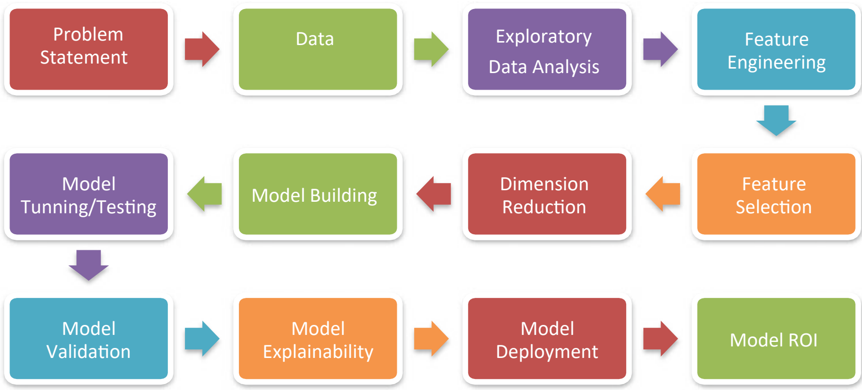

Fig. 4 A typical data analytics process, implementation, and measurement [15]

service interoperability, resource and energy management are key challenges [25]. AL-Faqaha et al. "examined IoT challenges and QoS demands such as availability, reliability, mobility, performance and management, scalability and interoperability, security, and privacy" [26]. Breivold and Sandstrom list IIoT problems as fault tolerance, functional safety, data latency and scalability, mixed-criticality, and secure real-time collaboration [27]. Lee considers data management, mining, security, and privacy the biggest IoT problems [28]. Sadeghi et al. [29] evaluated IIoT security, privacy, and attack weaknesses.

2.3 The Cloud

Benchmarking, colour management, and remote services utilise Cloud. Cloud computing, sometimes known as "Cloud", is a kind of outsourcing that uses many computer servers and resources to provide computer programmes, high-level services, and resources on demand or on a paper-cycle basis [30]. Wang et al. define cloud computing as "A set of network-enabled services that offer scalable, QoS-guaranteed, frequently customisable, and economical computing infrastructure on demand that can be accessed in a simple and broad way" [31]. Cloud computing services include SaaS, PaaS, and IaaS, which provide different levels of solution stack virtualisation and management [30]. Advanced apps and services that expand with users are one of the biggest benefits of cloud computing [32]. Consumers and companies may quickly access "Cloud" applications, programmes, and services with little administrative effort and from anywhere and at any time. Thus, industrial companies use cloud-based customer relationship management (CRM) and human resources management (HRM) apps to enhance critical processes. Cloud computing also eliminates the hassle of creating and maintaining an IT infrastructure and the upfront costs of the "Pay-as-you-go" approach [32]. Letting firms start as small and expand as demand rises [33, 34]. Due to cloud computing's fast growth, a wide range of applications and many advantages, businesses of all sorts are quickly adopting it to increase their capacity and capabilities at the lowest cost [34].

2.4 Autonomous Robots

Industry 4.0 relies on robotic manufacturing methods that prioritise safety, flexibility, diversity, and cooperation. More industrial robots are helping the Industrial Revolution with contemporary technologies. People and robots, work together using smart sensors and human–machine interfaces in Industry 4.0. Intelligent robots can be controlled by remote [35].

Industry 4.0 pioneers include some cutting-edge robotics. The lightweight Kuka LBR IIWA (Industrial Intelligent Work Assistant) is designed for human–robot cooperation on delicate tasks. It can independently check, optimise, and record its results while connected to the cloud [36]. Bosch also offers the APAS family robot system, which includes the APAS assistant, inspector, and base, for agile and flexible production based on a production system that can be easily retooled [37]. Rethink Robotics' Baxter makes interactive packages. BioRob Arm works near humans. Automated equipment performs repetitive operations quickly and accurately in locations where humans cannot reach easily [11].

2.5 Augmented Reality

Augmented Reality (AR) is used in computer and video games, social networking app filters, education, and learning to merge digital and real-world information. Milgram and Kishino [38] defined augmented reality as the interaction between real space, virtual space, and any intermediate mixed space in 1994. The AR Tool Kit was originally released outside US academic institutions at SIGGRAPH in 1999, launching the AR company. Two years later, it was released as open-source software. Smartphones and tablets have all the sensors and processing units needed to design and launch augmented reality apps. The Emacula contact lenses by Innoyega, the Vuzix blade 3000 AR glasses, and the Meta 2 AR headset are examples of emerging kinds of AR gadgets. Augmented reality's fast growth and widespread usage suggest a major social influence. AR in industry accelerates and improves product design and manufacturing development by boosting communication.

Some of the industrial AR applications: human–robot collaboration, maintenance-assembly-repair, training, product inspection, and building surveillance. Human–robot collaboration uses AR to create industrial robot interfaces. AR boosts maintenance-assembly-repair productivity. AR enhances skills in training. Inspectors may find product flaws using a sophisticated and adaptive AR system. Finally, augmented reality simplifies facility issues in building monitoring.

2.6 Cyber Security

Cyber-Physical Systems (CPS) underpin Industry 4.0 [39]. CPS automate physical reality operations using computer and communication infrastructures [40, 41]. A CPS are a network-capable embedded system. The "Internet of Things" includes internet-connected CPS. CPS connect devices, unlike standard embedded systems [41]. In today's digitally networked culture, CPS provide information and services everywhere.

CPS, the Internet of Things, and services have started the fourth Industrial Revolution. Germany leads CPS with almost 20 years of experience. Internet-enabled objects provide new services including cost-effective and efficient Internet-based diagnostics, maintenance, and operation. It also helps to adopt new business models, operational concepts, and intelligent controls while focussing on the user and their needs [42].

2.7 3D Printing

3D printing, known as additive manufacturing (AM) in Industry 4.0, can create complex metal or plastic structures [8]. AM, unlike subtractive manufacturing, combines materials to create a whole assembly using 3D model data created using particular software tools, frequently layer by layer [43, 44]. It allows varied production locations, reduced transportation, and inventories [11]. Due to technological breakthroughs, additive manufacturing in industry is growing despite worries about its mass production practicality. Since it can quickly produce precise, strengthened, and intricate items, it may replace traditional manufacturing procedures in the future. AM will improve technologies. Metal additive manufacturing is popular in this new age because metals are the most widely utilised industrial material [14, 16–19]. Digitalisation and the need to reduce product life cycles are attracting more sectors. Technologies like fused deposition, selective laser melting, and selective laser sintering are also covered [11].

2.8 Simulation

Product development and production are simulated using real-time data. Simulation can provide real-time data to speed up and improve testing. This optimises procedures and settings before production. It may speed up and improve product quality also. Plant operations need extensive simulation. Simulation may ensure product quality and reduce market price volatility [11]. It can decrease error-related downtime. Simulation helps Industry 4.0 to create exploratory and planning models for better decision-making, design, and operation of complex systems.

3 Opportunities, Issues, and Challenges in Industry 4.0

These new technologies enable real-time monitoring to improve product quality and encourage innovation across a wide range of applications, which has a stronger influence on economic growth. Automation and optimisation improve output, provide economic advantages through lower transaction and transit costs, predictive and remote maintenance, effective use of resources and staff, energy-efficient and ecologically friendly production system, and many more.

In the age of Industry 4.0, developing nations must keep up with the technology. Digital strategies demand technological knowledge and a business-friendly environment. Establishing places for discussion, information exchange and experience sharing would help society and government firms to boost up the development of emerging technologies for inclusive and sustainable industrial and economic progress.

These new technologies will have numerous benefits but also drawbacks. Researchers found many concerns and impediments, including: many present systems lack autonomy, most network protocols lack capacity, and many sectors have yet to secure data quality and integrity [45]. There is no standard technique for data entity annotations [46], complicated system modelling and analysis are not yet viable [45], and changing production routes to accept a big dynamical reconfiguration for individualised and customised goods is challenging [11], CPS stability, new talent development, privacy, ethics, and management change, outdated international laws, and data quality.

4 Conclusion and Future Work

The fourth Industrial Revolution of the twenty-firstst century enables intelligent, effective, personalised and tailored production. This study examines Industry 4.0, its development, and its components. Industrial progress has been extensively documented. The benefits, drawbacks, and challenges of Industry 4.0 are discussed with its nine pillars. Since Industry 4.0 is new, future challenges will undoubtedly rise. Industry 4.0 may change an organisation's value chain and provide it with a competitive edge in the global market. It promotes social growth, good governance, and transparency.

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