Topics in Artificial Intelligence Applied to Industry 4.0

Edited by
Mahmoud Ragab AL-Refaey · Amit Kumar Tyagi
Abdullah Saad AL-Malaise AL-Ghamdi · Swetta Kukreja

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Preface

Industries, as we all know, are the ones that produce goods and services for society. Workers in the textile industry design, fabricate, and sell cloth. The tourist industry includes all the commercial aspects of tourism. The automobile industry makes cars and car parts. The food service industry prepares food and delivers it to hotels, schools, and other big facilities. "Industry" comes from the Latin "*industria*," which means "diligence, hard work," and the word is still used with that meaning. Generally, the industry has been through various evolutions during the last three decades. The industry started in the eighteenth century; that is, in 1784, the first power loom was developed. Hence, Industry 1.0 was all about mechanization with water and steam. In the next phase of the industry revolution, that is, Industry 2.0, the electrification of the industry took place. It started from 1900 to 1950. During this revolution, the "Assembly Line was developed." Further, Industry 3.0 is about the automation of data. During this revolution, the adoption of computers and automation, enhanced by smart and autonomous systems, is fueled by data and machine learning. All the data that was available manually began to be stored disks. Industry 3.0 was a major revolution in terms of automating things, and even operational technologies came into existence, but there was still a felt need to merge information technology with operational technology to truly digitize the world. This would be called "the Digital Transformation" in the true sense, and the resolution happening in Industry 4.0 is to move toward that direction.

Later, Industry 4.0 is to improve manufacturing efficiency; it is about transforming the way your entire business operates and grows. It is associated with cyber-physical system, in which digital technologies can create virtual versions of real-world installations, processes, and applications. This can then be robustly tested to make cost-effective, decentralized decisions. These virtual copies can then be created in the real world and linked via the Internet of Things (IoT), allowing cyber-physical systems to communicate and cooperate with each other and human staff to create a joined-up real-time data exchange and automation process for Industry 4.0 manufacturing. This should allow for digital transformation and automated and autonomous manufacturing with joined-up systems that can cooperate with each other. This technology will help solve problems and track processes while increasing productivity. It also primarily focuses on the use of large-scale machine-to-machine communication and IoT deployments to provide increased automation, improved communication, and self-monitoring, as well as smart machines that can analyze and diagnose issues without the need for human intervention. The idea of connected manufacturing or smart factories is becoming increasingly ubiquitous. Factories and their machines across the globe are getting smarter as connected products and systems operate as part of a larger, more responsive, and agile information infrastructure. The aim is to harvest benefits and improvements in efficiency and profitability, increased innovation, and better management of safety, performance, and environmental impact. This book will provide a complete experience of industrial revolution and its progress toward emerging technology.

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1

Introduction to Industry 4.0 and Its Impacts on Society

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1.1 Introduction

The ongoing Fourth Industrial Revolution (4IR) is characterized by the continuous transformation of society and the economy through technological advancements [1, 2]. This revolution encompasses breakthroughs in artificial intelligence (AI), robotics, the Internet of Things (IoT), and other digital technologies. What sets it apart from previous revolutions is not only the creation of new machines or processes but also the integration of these technologies into existing systems and the development of previously unimaginable systems [3].

The potential impacts of the 4IR on society and the economy are extensive and profound [4]. While these new technologies have the potential to improve productivity, efficiency, and quality of life for many, they also raise important questions regarding the equitable distribution of benefits and the potential exclusion of certain groups.

This chapter serves as an introduction to the 4IR and its societal impact. It explores the technological advancements driving this revolution, examines its potential effects on the economy and society, and addresses the ethical and governance considerations that arise in this era of technological progress.

The objective of this exploration is to deepen our understanding of the 4IR and its implications for society and the economy. Additionally, it explores how individuals, businesses, and governments can collaborate to shape this revolution in a way that maximizes its potential benefits while mitigating any negative consequences.

The 4IR refers to the current phase of technological advancements, encompassing AI, robotics, the IoT, and other digital technologies [5]. Coined by Klaus Schwab in his 2016 book *The Fourth Industrial Revolution*, it builds upon the transformative changes initiated by previous industrial revolutions [6].

The First Industrial Revolution introduced mechanization and steam power, while the Second Industrial Revolution brought electricity and mass production [7]. The Third Industrial Revolution, known as "the digital revolution," introduced computers and digital technology. However, the 4IR is distinctive because it integrates and converges technologies across all aspects of life [8]. It blurs the boundaries between physical, digital, and biological systems, enabling unprecedented levels of automation, connectivity, and data analysis. This integration has the potential to revolutionize industries, boost productivity, and create new avenues for economic growth.

The anticipated impact of the 4IR on society and the economy is profound. It is crucial for us to understand its implications and foster collaboration to ensure the equitable distribution of its benefits.

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1.1.1 Overview of the Major Technological Advancements Driving the Revolution

The ongoing 4IR is characterized by remarkable technological advancements that are profoundly reshaping our lifestyles and work dynamics [9]. These advancements include:

- Artificial Intelligence: AI encompasses machines capable of performing tasks that traditionally require human intelligence, such as speech recognition, decision-making, and experiential learning. It continues to evolve and finds applications in various fields, including autonomous vehicles, personalized medicine, and intelligent virtual assistants.
- Robotics: Robotics involves the use of robots and automated systems to perform tasks that typically require human intervention. Advances in robotics enable increased levels of automation in industries such as manufacturing, logistics, and more.
- Internet of Things: The IoT is a network that connects physical objects embedded with sensors, software, and other technologies, enabling data exchange and collection. It promotes connectivity and data analysis, leading to valuable insights and efficiencies in sectors such as health care, agriculture, and transportation.
- Big Data Analytics: Big data refers to vast amounts of data generated by the IoT, social media, and other sources. Big data analytics involves employing advanced analytical techniques to extract insights and value from this data. It empowers organizations to make informed decisions and optimize their operations.
- 3D Printing: 3D printing involves the layer-by-layer creation of physical objects. Advances in 3D printing technology allow to produce intricate and precise objects, unlocking new possibilities in health care, aerospace, manufacturing, and other industries.

These advancements in the 4IR are revolutionizing various sectors and presenting exciting opportunities for innovation and growth (refer to Figure 1.1). They have the potential to reshape our society and economy in profound ways, driving us toward a more interconnected and technologically advanced future.

1.1.2 Importance of Studying and Understanding the Impacts of the Fourth Industrial Revolution

Studying and understanding the impacts of the 4IR is critical for several reasons [6, 10]:

- Economic Growth: The 4IR has the potential to drive substantial economic growth by fostering innovation, creating new employment opportunities, and enhancing productivity. A deep understanding of the opportunities presented by these technological advancements enables businesses and governments to capitalize on them, leading to sustainable economic growth.

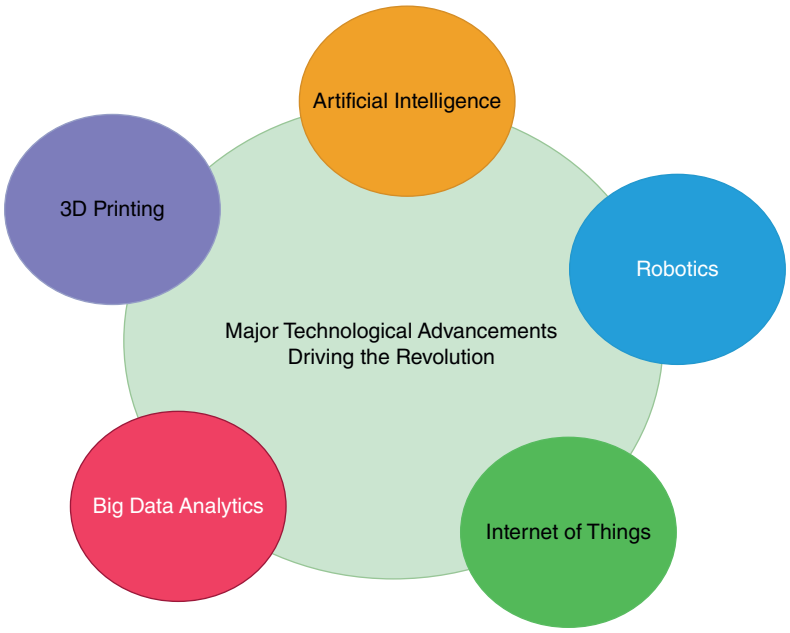

Figure 1.1 Major technological advancements driving the revolution.

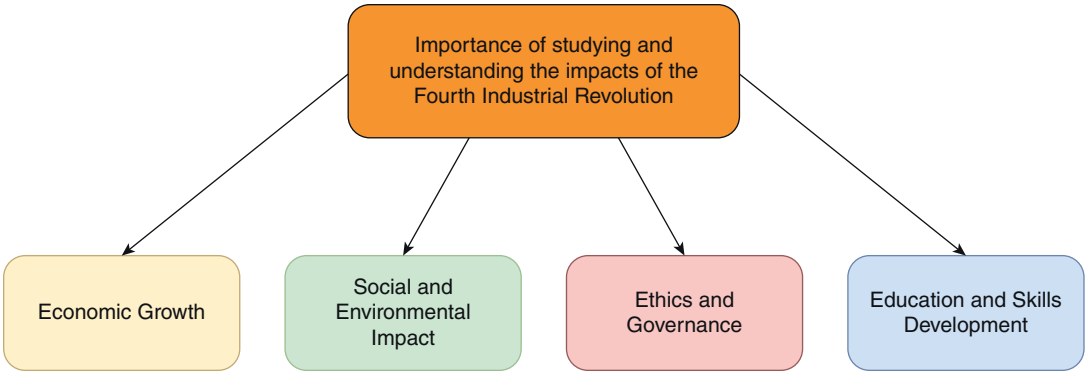

Figure 1.2 Importance of studying and understanding the impacts of the Fourth Industrial Revolution.

- Social and Environmental Impact: The 4IR carries the potential for significant social and environmental consequences. It may exacerbate income inequality, contribute to job displacement through automation, and have adverse environmental effects. By comprehending the potential negative impacts of these technologies, we can develop policies and strategies to address and mitigate these challenges effectively.
- Ethics and Governance: The 4IR raises crucial ethical and governance considerations. Privacy, security, and accountability become paramount concerns in a technologically advanced era. A thorough understanding of these considerations empowers us to establish ethical frameworks and governance structures that ensure responsible development and use of these technologies.
- Education and Skills Development: The 4IR transforms the skill sets and educational requirements needed for the workforce of the future. Understanding the evolving demands and identifying the necessary skills equip us to prepare individuals and communities for the changing nature of work, fostering adaptability and lifelong learning.

In summary, studying and comprehending the impacts of the 4IR are vital to optimize the benefits of these technological advancements while minimizing their negative consequences. By doing so, we can create a more equitable, sustainable, and prosperous future for all (refer to Figure 1.2).

1.2 The Technological Advancements of the Fourth Industrial Revolution

The 4IR represents a wave of transformative technological advancements that are fundamentally reshaping our lives and work dynamics [7, 11]. These advancements encompass a range of key technologies, which include the following:

- Artificial Intelligence: AI enables machines to perform tasks that traditionally require human intelligence, such as speech recognition, decision-making, and experiential learning. Ongoing advancements in AI have led to its application in various domains, including autonomous vehicles, personalized medicine, and intelligent virtual assistants.
- Robotics: Robotics involves the use of robots and automated systems to perform tasks that typically require human intervention. Advances in robotics have facilitated increased levels of automation in industries such as manufacturing, logistics, and beyond.
- Internet of Things: The IoT consists of a network of physical objects embedded with sensors, software, and other technologies for data collection and exchange. It enables enhanced connectivity and data analysis, leading to valuable insights and efficiencies in sectors like health care, agriculture, and transportation.
- Big Data Analytics: Big data refers to vast amounts of data generated by the IoT, social media, and other sources. Big data analytics involves employing advanced techniques to extract insights and value from this data. Organizations leverage these insights to make informed decisions and optimize their operations.
- 3D Printing: 3D printing is an additive manufacturing process that constructs physical objects layer by layer. Advancements in 3D printing technology enable the production of intricate objects with exceptional precision, unlocking new possibilities in health care, aerospace, manufacturing, and more.

- Blockchain: Blockchain is a distributed ledger technology that enables secure and transparent transactions without intermediaries. It has the potential to transform various industries, including finance, supply chain management, and real estate.
- Augmented Reality (AR) and Virtual Reality (VR): AR and VR technologies provide immersive experiences that blend the physical and digital realms. These technologies find applications in fields such as education, entertainment, and retail.

These technological advancements are reshaping industries, creating new opportunities for growth. However, they also give rise to critical ethical and governance considerations. Understanding these advancements and their potential impact is crucial for individuals, businesses, and governments as we navigate the 4IR and strive to maximize its benefits while addressing its challenges.

1.2.1 Discussion of the Potential Benefits and Drawbacks of Each Technology

The key technologies driving the 4IR present both potential benefits and drawbacks [12]:

- Artificial Intelligence
  Benefits: AI has the potential to enhance decision-making, improve efficiency, and enable better understanding of complex data. It offers applications in various fields, including health care and finance.
  Drawbacks: Ethical concerns regarding bias and discrimination in AI decision-making processes exist. There are also concerns about job displacement as AI and automation become more prevalent.
- Robotics
  Benefits: Robotics can increase efficiency, reduce costs, and improve safety in industries like manufacturing and logistics. It enables the completion of tasks that are dangerous or difficult for humans.
  Drawbacks: Job displacement is a concern as robotics and automation advance. Safety and ethical considerations in the development and deployment of robots require attention.
- 3D Printing
  Benefits: 3D printing enables faster, cheaper, and more customizable production of products. It has the potential to reduce waste and improve sustainability.
  Drawbacks: 3D printing is still relatively costly compared to traditional manufacturing methods. The quality of printed products may not always meet the standards of traditional manufacturing.
- Internet of Things
  Advantages: The IoT offers real-time insights and improved efficiency across industries. It enhances resource monitoring and management, promoting energy and water conservation.
  Disadvantages: Security and privacy concerns arise as more devices become interconnected, necessitating robust data protection measures. Increased energy usage associated with the IoT raises environmental concerns.
- Blockchain
  Advantages: Blockchain enhances transparency, security, and efficiency in industries like finance, supply chain management, and real estate. It enables peer-to-peer transactions, reducing reliance on intermediaries.
  Disadvantages: Energy consumption, especially with cryptocurrencies, poses environmental challenges. Scalability and interoperability of blockchain systems require attention.

Understanding the potential benefits and drawbacks of these technologies is crucial as we navigate the 4IR (refer to Figure 1.3). It allows for informed decision-making regarding their development and deployment, enabling us to harness their advantages while addressing the associated challenges.

1.2.2 Examples of How These Technologies Are Already Being Used in Various Industries

The key technologies of the 4IR are already being applied in various industries, leading to transformative outcomes [12]:

- Artificial Intelligence
  Health Care: AI assists in disease diagnosis, treatment development, and improving patient outcomes. It analyzes medical images, predicts high-risk individuals, and enables proactive interventions.
  Finance: AI enhances fraud detection, risk management, and customer service in the financial industry. AI-powered chatbots offer personalized financial advice and efficient customer support.