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Healthcare 4.0

Next Generation Processes with the Latest Technologies

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CHAPTER 1

An Introduction to Healthcare 4.0

Abstract The Industry 4.0 revolution is already redefining how companies manufacture "things" today. It sets out the concepts for how companies can achieve faster innovation and increase efficiencies across the value chain. But, in the world of healthcare devices and services, which is burdened with regulatory compliance and is still largely dependent on paper-based processes, what does Industry 4.0 really mean? If healthcare services are to incorporate Industry 4.0 core principles, they require proper guidelines or a framework within which to incorporate the core principles. Based on the key factors determined from our research and based on the knowledge acquired from literature reviews, a set of emerging technologies is proposed for implementation in the healthcare sector.

Keywords Industry 4.0 • Healthcare 4.0 • Internet of Things (IoT) • Internet of Services (IoS) • Interoperability • Cyber-physical systems (CPS)

1.1 Introduction

New opportunities and challenges emerge in an industry as a result of customer demand and the desire for advanced technology to further enhance sophisticated technological services. Such transformation promotes new context configurations, new environments and new motivations which will

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eventually impact upon a company's performance. Today, technical advancements and innovations are gaining serious importance in several industries such as the biotech industry, IT industry and automotive industry. These industries are incorporating new technologies which make use of automation and provide intelligent solutions. These transformations are the precursors to the rapid changes which are leading us towards a new industrial revolution, or Industry 4.0 as it is known. This "revolution" will have an industry-wide impact (Tjahjono, Esplugues, Ares, & Pelaez, 2017).

Society itself is being influenced by this revolution. Our general operational structure, man–machine interaction optimization, economic views and patterns, and other significant circumstances are all affected. Industry 4.0 enhances the ability to accurately interpret and recognize progressions, along with an awareness and understanding of market trends. The organizational structure of a firm can be streamlined and made more cohesive by utilizing new discoveries in Industry 4.0. This revolution is promoting new models such as social networks, additive manufacturing, collaborative innovation, digital platforms and a shared economy that initiates change in organizations. Production in the manufacturing industry has been completely modernized and automated. Industry 4.0, with its technical advancement, has not only promoted improvements but in itself is a concept that promotes transformation (Lu, 2017).

There has been a great deal of research into Industry 4.0 and its benefits, challenges and opportunities with regard to the healthcare industry. The internet has been a revolutionary technology for the healthcare sector and it has helped in optimizing the entire supply chain and provided more detailed patient outcomes. However, incorporating Industry 4.0's core principles into healthcare practices is still not widespread enough to have created the transformation that is possible.

Industry 4.0 is not just a technical advancement; it is a profound concept that can enhance the performance of any industry. The six core principles of virtualization, modularity, interoperability, decentralization, service orientation and real-time capabilities constitute the concepts contained within Industry 4.0. Industry 4.0 core principles are driven by emerging technologies such as blockchain, Internet of Things (IoT), big data and Artificial Intelligence (AI) (Manogaran, Thota, Lopez, & Sundarasekar, 2017). The main aim of this book is to demonstrate the benefits of implementing Industry 4.0 in healthcare services and to recommend a framework to support this implementation.

1.2 Industry 4.0

In 2011, German manufacturing industries were strengthening their competitiveness in the sector by promoting a new concept, with the help of pioneers from different fields such as politics, academia and business. This concept was proposed at the Hanover Trade Fair 2011 as Industry 4.0. The concept was widely supported by the German government with the view that Industry 4.0 would develop into a high-level competitive strategy in the future.

The "virtual marketplace" is expected to influence the connection of the physical world (people, products, machines and systems) to a constant virtual world. In this way, service platforms and software-based systems will play a significant part in future manufacturing processes. These virtual connections are the optimal way of analysing and providing data that supports the communication between product and machine. In other words, virtual connection is the process of connecting physical and digital processes to "smart" products.

1.2.1 Key Components of Industry 4.0

The fundamental components of Industry 4.0 are cyber-physical systems (CPS) and Internet of Services (IoS). These components are equipped with *actuators* and sensors which help in effective communication and support factories to work autonomously and in a decentralized way (Zezulka, Marcon, Vesely, & Sajdl, 2016).

Cyber-Physical Systems (CPS)

CPS are fundamental elements of Industry 4.0 that connect the physical and virtual world. CPS are characterized by remarkable coordination of distributed ledgers and internet services. In other words, the systems that connect physical processes with computations are called cyber-physical systems, or CPS. Computation is influenced by physical processes such as feedback loops, embedded networks and computers, and physical process controls (Poovendran, 2010). The physical process is also influenced by computation. High-level transparency, efficiency, surveillance and control in the operations process are a few of the noteworthy advantages of CPS. CPS consist of two parallel networks such as cyber networks and physical networks, and constitute communication linkages between these networks. The cyber network includes intelligent controllers while a physical network incorporates infrastructure of manufacturing. Using several controls, actuators, communication devices and sensors, CPS connect these two networks (Garibaldo & Rebecchi, 2018).

Internet of Things (IoT)
The internet has allowed technical advancements and had an unprecedented impact on both communication systems and data-sharing systems. Moreover, it has facilitated the exchange of and access to real-time data from any place in the world and at any time. It also enhances the coordination required between the customer, the supplier and the company, along with the interaction of man and machine. IoT has served as an Industry 4.0 initiator since the 1990s (Gubbi, Buyya, Marusic, & Palaniswami, 2013). Smart products can allow us to overcome or cut across the traditional boundaries of a product, providing greater reliability, new functionality, expanded opportunities and high-level product utilization. IoT promotes an environment where every individual can be connected to web service provided by smart technology, which is self-managing, self-aligning and self-organizing anywhere and at any time. IoT constitutes the most dominant and conservative technology that can stimulate numerous opportunities for economic growth (Wortmann & Flüchter, 2015).

Internet of Services (IoS)
Concerning the idea of a "service society" and IoT, web-orientated services have also been developed. These services are called IoS and they allow private users and companies to connect, develop and promote advanced value-added services. Future industries are expected to rely upon internet value-added services. From a technical point of view, ideas such as BPO (business process outsourcing), SOA (service-oriented architecture) and SaaS (software as a service) are more similar to IoS. In essence, IoS is a business service transaction between two parties. The aim is to perform the required activities and the result is to gain advantage from that performance. To perform such activities, one party temporarily uses the resources of the other (Drăgoicea, Pătraşcu, & Bucur, 2012).

Smart Factory
According to the literature, Industry 4.0's core components are IoS, CPS and IoT. CPS connects to IoS and IoT through cyber and physical networks and communication linkages, thus promoting a Smart factory

set-up. This points to these core components as the initiators of a Smart factory. Smart factories are being developed with the aim of building a social network set-up in which resources, human beings and machines communicate with each other easily. A decentralized manufacturing system can also be built with the help of this social network. Existing complex production processes and production logic can be altered by integrating human beings with transport systems, machinery and products at sophisticated levels, and this goal can be effectively achieved by a Smart factory (Zuehlke, 2010). A cost-effective manufacturing Smart factory provides a highly flexible, distinct and individualized production process along with availability, positioning and locating of the product. A Smart factory reduces complexity in production and provides effective tracking of both process and product. It not only promotes changes in the production process, it also minimizes the duties and responsibilities of employees. The advantages of a decentralized manufacturing system encourage employees to act independently and instantly (Radziwon, Bilberg, Bogers, & Madsen, 2014).

1.2.2 Core Principles of Industry 4.0

Industry 4.0 is not just a technological development; it is a concept that could disrupt many industries. The concept is developed by integrating six core principles, namely interoperability, decentralization, virtualization, modularity, service orientation and real-time capabilities (Qin, Liu, & Grosvenor, 2016).

Interoperability

Interoperability is the primary principle or the key initiator of Industry 4.0. The system's capacity to communicate with various other systems to coordinate distinct functions and to exchange data is termed interoperability. Interoperability provides man and machine the ability to obtain real-time data, which enables faster and more effective decision-making. Without Interoperability, immense amounts of data gathered in warehouses every day remain unused, or are not exchanged with other systems for processing. To develop opportunities and to increase the presence of man and machine integration, facilities should be linked with IoT. Interoperability enables the integration of software such as Enterprise Resource Planning system (ERP), Electronic Medical Records (EMRs), Laboratory Information Management system (LIMS) and other software, thereby minimizing the transaction cost between the software systems in analysing and consolidating the data. The data gathered from distinct systems and devices is processed and consolidated into knowledge which can assist in and improve decision-making (Lu, 2017).

There are a few procedures which enhance the ability of interoperability. The standard and proprietary protocols of current processes and systems require analysis and evaluation. Protocols that require costly custom-coding or that promote a single supplier strategy should be eliminated. Where there are several business issues, the issue that requires more consideration should be prioritized. Uptime, productivity, cost, speed and accuracy are some significant business issues. Business issues can be prioritized using real-time business case research, and this prioritization enhances the ability of interoperability. The aim is to develop long-term guidelines for real-time decision-making and man and machine integration in the future. Long-term guidelines also promote improvements in interoperability and the ability to adopt other core principles. Interoperability is also used to allow IoT to intersect with other Industry 4.0 components (Wollschlaeger, Sauter, & Jasperneite, 2017).

Modularity

Today's software companies would benefit greatly from anticipating future risks and being able to "disable" uncertainty. The goals of enhanced productivity and profitability competitiveness may be achieved by the adoption of new technologies. Yet the companies which adopt this technology still face difficulties in upgrading, since various disruptive changes cannot necessarily be anticipated, nor the changes incorporated into the new technology. A system which intrinsically adapts to change and new advancements is termed a "modular system". Modular systems enable a company to respond quickly to demand fluctuation and ensure the security of initial investments during fluctuation.

Virtualization

Some functions that cannot be executed in the physical world may be performed in the digital world. Data obtained from facilities, along with their equipment and processes, is simulated with virtual simulation models to develop a digital view of operations. This digital view is termed Virtualization and it provides the ability to minimize equipment downtime, enhance processes and handle complex situations. The virtualized view is helpful in coordinating and monitoring the physical and digital world.

Remote services are performed using Augmented Reality. Augmented Reality is one of the key components used to incorporate virtualization capabilities. Providing remote services and monitoring the condition and location of the product are just some of the tangible benefits of Virtualization. Many organizations face challenges in understanding the benefits and impact of incorporating new technology into their processes. Virtualization provides an exact view of activities performed by "human and machine", along with the capability of optimizing processes and using preventative measures to mitigate risk. The combined benefits of mobile robots, virtual reality and Augmented Reality equipment may provide us with great opportunities in the future (Klement, 2017).

Real-Time Capabilities
To obtain ongoing or real-time information on equipment and its processes is the ultimate aim of the core principles. Thus the Virtualization and Interoperability principles of Industry 4.0 promote real-time capabilities. CPS is used to collect real-time data across an entire supply chain. Robots, Auto Guiding Vehicles (AGVs) and equipment which interfaces with computerized devices such as scanners, sensors and Radio Frequency Identification (RFID) tags and which connects with IoT provide visibility and real-time data. In such cases, man and machine can make real-time decisions with the help of real-time data. Adequate data can be collected to enhance current operations. In summary, real-time data is collected to optimize operations and to enable real-time decision-making (Wittenberg, 2016).

Decentralization
In the traditional manufacturing process, several subsystems in each stage of the process were supported by a centralized system. In a centralized structure, a central computer embedded with business logic is used to provide solutions to other subsystems. With Industry 4.0, there are certain restrictions around having a centralized structure. A centralized structure limits scalability. It is also difficult to adapt to upcoming advancements or respond to fluctuations, as the structure cannot be altered once it reaches its maximum capacity.

In a distributed structure, logic nodes can be used to help or handle the subsystems or remote components. To enhance intelligence and functionally in a distributed structure, the data collected is shared with every node and the capabilities of every node are combined. Components or subsystems are programmed with business logic in a completely decentralized structure. This capability enhances the intelligence required to execute necessary functions and allows coordination with other subsystems to manage more complicated tasks. From the Industry 4.0 perspective of decentralization, more robots and AGVs can be added to enhance the easy scalability of the operation, and decentralized decision-making enhances speedier execution of operations. The subsystems and workers are coordinated with the help of CPS. Improvement in intelligence and functionality can only be fully realized when the subsystems and their operations are distributed or decentralized.

Service Orientation

The activities or services carried out by machines and humans are optimized by connecting to the internet. IoS is used to optimize the service and this is performed in order to enhance service orientation. From the initial stage of movement of merchandise to the final stage of data analytics, every service involved is overseen via the internet to mitigate specific business issues (Jiang, Ding, & Leng, 2016).

To illustrate the preceding point, if a modular assembly station equipped with AGVs is subjected to a service-oriented approach, IoS serves as a platform for the AGVs and modular stations to perform necessary services. The RFID tags on merchandise contain design procedures, and the services required with respect to the design are decided autonomously by the machines. At that point, the machine formulates the required procedure and directs the services to be performed through IoS. In spite of collecting and storing large amounts of data, the exchange of information between various systems becomes too complex. Yet, service orientation empowers more liberated data streams between and within systems. Software used by a company serves as a tool to manage internal services, which in turn maximizes the benefits of external functionality. The supporting software serves as a well-grounded platform to optimize and execute business processes. Finally, a greater capacity to alter processes and give higher scalability is provided by service orientation (Stock & Seliger, 2016).

1.3 Challenges in Implementing Information Technologies in Healthcare

Despite healthcare delivery services having much to gain from implementing information technologies, they have been the slowest of all industries in the adoption of such technology. There are many reasons for IT failures in the healthcare environment, but the single most important cause is a technology capability mismatch in addressing work processes within healthcare service organizations (Yusof, Stergioulas, & Zugic, 2007). For over 20 years Information and Communication Technology (ICT) and healthcare service organizations have been unable to find a comprehensive solution. It may be necessary to research less into design and implementation and further into how an end user reacts to already implemented IT solutions (Morrow, Robert, Maben, & Griffiths, 2012).

IT investment will only be successful if the fit between IT and clinical processes is a comfortable one, reflected best by the acceptance or rejection by end users (Yusof, Kuljis, Papazafeiropoulou, & Stergioulas, 2008). In the short history of IT, the emergence of new, disruptive technologies plays a crucial role in closing the capability gap and in gaining more acceptance from the main users.

The latest innovations are changing or disrupting how medical care is organized, practised and delivered. They are also redefining a host of other aspects such as changing the patient-physician model and facilitating the emergence of new industry players within the value chain. It is hoped that these innovations will be successful in delivering better, smarter care.

1.4 Stages in Healthcare IT Transformation

Between 1970 and 1990, we saw the emergence of modular or silo IT systems in the healthcare industry. This period could safely be called Healthcare 1.0. Throughout the next decade and a half, most IT systems commenced networking, and Electronic Health Records (EHRs) that were being generated started integrating with clinical imaging, giving doctors a better perspective. This was Healthcare 2.0.

From the year 2000 onwards, we saw the development of genomic information, along with the emergence of wearables and implantables. The integration of all the resultant data, along with networked electronic patient records, saw the emergence of Healthcare 3.0. However, due to data incompatibility and resistance from healthcare providers, the adoption of IT in Healthcare 3.0 did not produce significant improvements for the community.

What we are seeing today is the emergence of Healthcare 4.0. Its intention is to apply some of the principles of Industry 4.0 by integrating technologies with IoT for data collection, increasing the use of AI for analysis and using the overlay of a blockchain for patient medical records. The focus on collaboration, coherence and convergence should make healthcare more predictive and personalized.

The enhanced amount of data available to doctors should be of great benefit; however, the critical advantage may be found in the ability to extract insights from the data being captured, and the portability of this data using blockchain.

Data portability and interoperability would allow patients and their physicians to access information anytime, anywhere. Enhanced analytics would allow for differential diagnoses and medical responses that can be predictive, timely and innovative (Chawla & Davis, 2013). Healthcare 4.0 allows valuable data to be used more consistently and effectively. It can pinpoint areas of improvement and enable people to make more informed decisions. What it also does is help move the entire healthcare industry from a system that is reactive and focused on fee-for-service to a system that is value-based, which measures outcomes and encourages proactive prevention. Table 1.1 shows the transition from Healthcare 1.0 to Healthcare 4.0.

Table 1.1 Transition from Healthcare 1.0 to Healthcare 4.0

	Healthcare 1.0	*Healthcare 2.0*	*Healthcare 3.0*	*Healthcare 4.0*
Main objective	Improve efficiency and reduce paper work	Improve data sharing and productivity	Provide patient-centred solutions	Provide real-time tracking and response solutions
Focus	Simple automation	Connectivity with other organizations	Interactivity with patients	Integrated real-time monitoring, diagnostics with AI support
Information sharing	Within an organization	Within a cluster of healthcare providers	Within a country	Global healthcare supply chain
Key technologies used	LIMS and administrative systems	EDI and cloud computing with HL7 messages for exchange	EMR, Big data, wearable devices, optimization system	IoT, Blockchain, AI, Data analytics
Limitations	Stand-alone systems with limited functionality	Sharing of critical information only but not interacting with patients	Different standards used within the community with limited interoperability	New and untested technologies with concerns about data privacy

1.5 Drivers for Healthcare 4.0

There are several factors influencing the drive towards improved healthcare. First, in some developed countries such as Singapore, the USA and the UK, central governments have proposed a national IT "backbone" that will help in integrating EMRs and making them portable. For governments, initiatives like this are key in meeting such societal objectives as enhanced access to healthcare and improved patient outcomes (Qin et al., 2016; Sligo, Gauld, Roberts, & Villa, 2017).

The second factor is the rise of an IT-savvy population that is more informed and as such demands better service from its healthcare providers. The healthcare providers themselves—diagnosticians, physicians, surgeons and hospitals as a whole—are realizing that with the increased use of Healthcare 4.0-enabled tools, their efficiency is enhanced and outcomes are becoming more effective (Eysenbach et al., 2013).

The third factor is the emergence of integrated care. The move from patient-centred to integrated care will shift the primary focus from disease and treatment to wellness and prevention. Truly integrated care will take into consideration not just the individual but also factors like medical history of their family, the patient's lifestyle, demographics and their ability to access healthcare. Taking all these factors into account, healthcare plans can be developed with a focus on providing care that is personalized, enabling and coordinated, and that treats people with compassion and respect.

The final factor that is driving this change is the data revolution that is currently taking place in many countries (Chawla & Davis, 2013). Access to affordable, high-speed data connectivity—as a result of some governments' initiatives and private sector competition—makes it possible for both doctors and patients from smaller towns to access some of the benefits of Healthcare 4.0. To sum up, the focus is shifting to integration of capabilities, integrated care and ownership of clinical outcomes.

One key issue that requires tackling is the need expressed by patients and even doctors for a physical presence. This need calls for a hybrid model that combines hi-tech with hi-touch. What may provide a solution is a platform that connects the entire ecosystem (integrated and connected devices), one that extracts valuable patient information, mines the derived intelligence, innovates with predictions and delivers blended (hi-tech and hi-touch) services across the entire spectrum of wellness, prevention, cure and care.

1.6 Recommendations

If healthcare services are to incorporate Industry 4.0 core principles, they require proper guidelines or a framework within which to incorporate the core principles. Based on the key factors determined from research and the knowledge acquired from literature reviews, a set of emerging technologies is proposed for implementation in the healthcare sector. Table 1.2 demonstrates how these emerging technologies are fulfilling the core principles of Industry 4.0.

The benefits of adopting these emerging technologies for Healthcare 4.0 include:

1. *IoT and wearable devices*—Empowering patients to perform self-management of medical needs, and provide channels for more interactive communication with healthcare professionals;
2. *Blockchain technology*—Providing real-time capturing of patient clinical records;
3. *Artificial Intelligence*—Providing more accurate predictive models of a patient's condition; and
4. *Big data and mobile applications*—Maximizing healthcare resources, and increasing the preventive and predictive components of care with the expectation of keeping individuals as healthy as possible and less dependent on curative care.

Table 1.2 Emerging technologies to support Industry 4.0

Core principles of Industry 4.0	*Internet of Things/ wearable devices*	*Big data and mobile Apps*	*Blockchain*	*Artificial Intelligence*
Interoperability	Yes		Yes	
Decentralization	Yes		Yes	
Virtualization		Yes		Yes
Modularity		Yes		Yes
Service orientation			Yes	Yes
Real-time capabilities	Yes	Yes		Yes

1.7 Conclusion

Industry 4.0 is not just a technological advancement; it is a concept that may be used to enhance the "intelligence" and functionality of any industry. This concept comprises six core principles which demonstrate Industry 4.0's capabilities and which can be applied to the healthcare industry. The author has summarized the evolution of IT implementation over the decades and how Industry 4.0 can help to transform the healthcare industry. The following chapters of this book will explain in more detail the use of IoT and big data analytics, blockchain, Artificial Intelligence and optimization techniques in healthcare. The book concludes by highlighting the innovative health technologies and start-up process in the healthcare industry and recommending processes to transform and manage healthcare. We hope that the adoption of these emerging technologies will raise the level of the healthcare industry towards Industry 4.0.

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