Application of Big Data and the Internet of Things in Industry 4.0

Cleiton R. Mendes, Rapfael Y. Osaki and Cesar da Costa

Abstract—Recent technological developments have altered the working conditions in manufacturing industries. Currently, the term Industry 4.0 is used to describe the fourth industrial revolution that has enabled the digitization of the value chain. This revolution has also enabled the connection of production sites via intelligent information systems, which means that machines can communicate with other machines and products. In addition, more accurate data can be delivered, and information can be processed in real time. However, history says that technological development takes time. The complete adoption and realization of the potential of Industry 4.0 will likely require about 20 years. Our discussion in this paper is based on a particular example of an automation integration platform. To understand the potential of big data and the Internet of Things in manufacturing companies, we investigated the production process of an auto parts company. Currently, data is collected manually and automatically. Other types of data are automatically recorded by an information system. Depending on where in the production process the data is collected, the data are logged and processed using different systems.

Index Terms—Industry 4.0; Big Data; Internet of Things (IoT); Cloud Computing; Manufacturing Cell; Production Logic.

I. INTRODUCTION

Greater efficiency and reduced costs are two possible outcomes of the use of product and value chain scanning. Digitization is also a key factor in maintaining or increasing competitiveness in the manufacturing industry. It is vital to both digitize the information related to services and products that are already in a company's portfolio as well as develop new digital services. As such, the business models of manufacturing companies are challenged by the rapid progress of digital development [1]-[3]. Whereas industrial digitization yields several opportunities, it also comes with several new challenges and risks. These challenges must be addressed as companies work to realize the potential of Industry 4.0.

Industry 4.0 is expected to have a profound impact on manufacturing processes, design, operations, and production systems. These changes will include the establishment of intelligent plants that will be interconnected via the Internet of Things (IoT). This represents a significant change from the current situation and will involve automated manufacturing cells, following the ISA 95 Reference Model [3].

The introduction of digitization is increasing the demand for new-generation automation systems. Concepts such as the Industry Reference Architecture Model 4.0 (RAMI 4.0) provide models, but do not address their actual implementation [3]. The changes in industrial production associated with Industry 4.0 are driven by some important advances in technology, two of the most important of which are big data and the IoT, which facilitate the sharing of information and improve the flexibility of the production chain [2].

Big data can be described as the collection of massive volumes of data, which is made possible by advanced analytical capabilities for monitoring and analyzing several digital data streams [4]. The IoT, on the other hand, comprises several connected data sources that generate data and communicate with each other effectively [5]. When implementing an IoT, a company must first establish a big data strategy for dealing with the huge volumes of data generated [6].

Thus, big data and the IoT are closely related and are both contributing to the transformation of industrial production. As such, we investigated both in this research. In addition, big data and the IoT are recent advances [2] and it is difficult for manufacturing companies to know how to realize their inherent potentials. It is also difficult to predict the threat level of new actors in the marketplace who are able to compete with fully digitized businesses rather than traditional physical products [6].

Over the last decade, a large volume of research has been conducted regarding Industry 4.0 [1]-[4]. Intelligent manufacturing has attracted huge interest from researchers in the government, business, and academic sectors and the implementation patterns of intelligent plants are widely discussed. However, standards for the implementation of intelligent factories have not yet been established. To address this specific need, several techniques have been proposed [5]-[7].

Benkamoun et al. [5] proposed a class diagram for use in representing manufacturing systems from the perspectives of the entities involved and the functions performed. Radziwon et al. [6] considered the intelligent factory concept and stated that the intelligent factory is in fact an adaptable and flexible manufacturing case.

According to Delsing [3], the transition from ISA-95-based automation systems to distributed-IoT-based automation systems has begun. Pan and McElhannon [7] investigated the motivations, state of the art research efforts, key enabling technologies, and possible future use cases for
the edge cloud environment. The authors provided an overview of this topic in comprehensive discussions.

Bera and Vasilakos [8] presented an overview of the current state of IoT development and highlighted some of the future research directions and open research issues, considering the limitations of existing software-defined networking-based technologies. Cheng et al. [9] characterized Industry 4.0 as having four main features: interconnectedness, data, integration, and innovation. Furthermore, they listed nine technological pillars of Industry 4.0: virtual reality, artificial intelligence, the industrial Internet, industrial big data, industrial robots, 3D printing, cloud computing, knowledge-work automation, and industrial network security. The authors predicted that these nine pillars will generate numerous future business opportunities.

Our research objective in this study was to investigate the adoption of big data and IoT technologies. Our findings make two contributions. First, we categorize the technologies used in Industry 4.0 as relating either to the human-machine interface (HMI) or connectivity. The HMI includes devices that assist operators in manufacturing activities such as touch screens and augmented reality. Connectivity includes systems that connect devices and collect and analyze data from a scanned factory, which includes both big data and IoT technologies. Our second contribution concerns the study of Industry 4.0 with respect to the state of the art of different theories related to technological transition and the management of innovation.

This paper is organized as follows. In section 2, we briefly describe intelligent manufacturing in Industry 4.0, big data, the IoT, and cloud computing. In section 3, we present a general scenario of where big data and IoT technologies will be applied. In section 4, we present our methodology and discuss our findings. In section 5, we make concluding remarks.

II. INTELLIGENT MANUFACTURING

A. Intelligent Factory

The world has observed several industrial revolutions throughout history. The 1st industrial revolution introduced production using water and steam; the second industrial revolution focused on mass production facilitated by electricity; and 3rd industrial revolution applied electronics and information technology (IT) to promote and automate production. Currently, the world is moving into the next industrial revolution - Industry 4.0, which allows manufacturers to connect with supplier, manufacturing resources, distributor and final product [10].

Industry 4.0 is part of the Internet of Things (IoT), but it is industry oriented. The core industry 4.0 core includes intelligent factory, cybernetic physical system, advanced analysis, big data, cloud computing and augmented reality [11], [12]. The intelligent factory is the factory that applies Information Technology to improve the management of production resources and service quality, based on the factory's scanning and automation [11]-[14].

The intelligent factory models are widely discussed, but the standards for the implementation of the intelligent factory, in practice, have not yet been established [14]. The changes in industrial production associated with Industry 4.0 are driven by nine major advances in technology. Two of the most important technological developments are Big Data and Internet of Things (IoT). Fig. 1 illustrates the nine technologies that make up the Industry 4.0 concept. [3].

Due to the current structure of the manufacturing industries, it is necessary to model an intelligent factory to upgrade the manufacturing industry. The intelligent factory adopts the combination of physical technology and cybernetic technology and deeply integrates previously independent discrete systems, making the technologies involved more complex and accurate than they are now. To understand the general concepts of these technologies, this work is based on the consolidation of the various definitions of Industry 4.0.

B. Big Data

Big data and the IoT are considered to be essential components of Industry 4.0, which are enabling this new industrial revolution as did steam energy in the first revolution and electricity in the second. Big data technology
is characterized by three fundamental attributes: volume, speed, and variety [15].

To better understand the terms volume, speed, and variety, here, we give an example related to time and location. With a sufficient volume of sensor data, for example, the locations of misplaced product can be identified. Speed gives the ability to determine the current location and movement of product. Data variety enables the estimation of both the exact location of the product, as well as who is nearby, who is working on it, and its intended path [15], [16]. However, big data represents a new technological breakthrough, and there are numerous variations in its characteristics.

C. Internet of Things

The IoT can be defined as a conceptual dynamic information network with global reach. Its structure involves configurations of autonomous capacities based on standardized communication protocols, whereby virtual and physical entities use intelligent interfaces and are perfectly integrated. In addition, the IoT increases the value of the information generated by affiliated entities, and transforms this processed information, such as by providing knowledge that facilitates product manufacture [15], [17].

D. Cloud Computing

The Internet of Things will inevitably have to deal with all these issues already presented and there is an assumption in the scientific community that it can use the capabilities of cloud computing to manage, store and process a virtual processing platform. Cloud computing is one of the building blocks in the foundations of the internet of the future, which enables the management of all systems in a dynamic, fast and comprehensive way, in the most varied volumes and proportions. This interaction reveals a paradigm shift in the integration of the use and application of different systems. The new generation of applications in the industrial arena can be quickly generated by selecting and combining new services and capabilities to accomplish their goals and tasks, which are offered in cloud computing. Applications are being dynamically allowed and accessible to other industrial management subsystems [18]. Fig. 2 illustrates a cloud computing system.

To build the intelligent manufacturing in Industry 4.0, enterprises must improve process control, production processes and reduce manual intervention in the factory [19], [20]. Lin et al. [21] proposed an architecture for manufacturing systems in cloud computing oriented to the aerospace industry, that facilitates the ideal configuration of the manufacturing resources. The authors provided an intelligent factory orientation architecture. In summary, the intelligent factory is based on the digital and automated factory, using information technology such as cloud computing, big data and IoT, to improve the management of the manufacturing resources.

III. GENERAL SCENARIO

As referenced, previous research suggests that big data and IoT technologies can be applied in the manufacturing process to increase their flexibility and efficiency. To understand which applications are best suited to the specific needs of a manufacturing company, it is essential to understand what the company expects to achieve with the implementation of Big Data and IoT. In other words, it is vital to understand the company's supply chain strategy as well as its products, requirements, and production processes. In this scenario, the methodology to be developed is based only on a comprehensive overview of the manufacturing process and its performance. Finally, it allows you to collect data from machines, sensors or other devices connected to the corporate network. This data can then be used and combined with analytical tools to monitor certain information. This provides an opportunity to identify certain patterns that help develop an understanding of which specific factors may result in errors or failures in the production chain.

It is considered that the company under study will be digitally integrated in the next five years. This integration will be both internal and external. Internal integration considers integration within the enterprise, as well as across departments and functions. In contrast, external integration considers aspects such as customers and partners. Fig. 3 illustrates the general scenario of the application of Big Data and IoT.

IV. METHODOLOGY AND DISCUSSION

The main objective of this research is to develop a new methodology to investigate the adoption of the Big Data and Internet of Things (IoT) technologies related to Industry 4.0, in a Brazilian auto parts industry, located in São Paulo, Brazil. The methodology developed in this project was divided into two parts: (i) human-machine interface (HMI) and (ii) Connectivity.

- Human Machine Interface – HMI: includes embedded devices to assist operators in manufacturing activities, with touch screens, virtual reality, industrial tablets, etc.
Connectivity: includes systems for connecting RFID devices to collect factory data, Internet of Things - IoT, Big data, data analysis, cloud computing, and M2M interfaces.

![Diagram of Big Data and IoT](image)

Fig. 3. General scenario for the application of Big data and IoT.

HMI technology incorporates interactive touchscreens, exoskeletons and collaborative robots in manufacturing processes and digitalizes operator tasks. The technology of touch screens and robots able to interact with humans has been available at the consumer market for some years, industrial applications have been feasible and available.

Many technologies affect all these priorities and they are connected to each other. Therefore, we have identified them as technology bundles, in which several technologies are interconnected. The two bundles of technologies are the Connectivity bundle, which refer to the digitalization of manufacturing, and the HMI bundle, which are technologies for operator guidance. This means that implementing these technologies can lead to better quality, flexibility, ergonomics and delivery time all together. Fig. 4(a) illustrates the HMI technology and Fig. 4(b) the Connectivity technology.

![Diagram of Connectivity and HMI bundles](image)

Fig. 4. Overview of HMI (a) and Connectivity (b) technologies.

Depending on the production logic of the auto parts company to be studied, the adoption of technologies is different. If flexibility is dominant tends to implement HMI technology to a greater degree. At the other extreme, if the company has a few product variations, where quality and efficiency dominate the production logic, it tends to implement Connectivity technology to monitor and improve the quality of its manufacturing regardless of the logic of production.

V. CONCLUSION

The purpose of this research was to develop a categorization of the different Industry 4.0 technologies based on how they are applied in industrial settings as well as determine where there is a need for elements from each of the technology bundles. An auto parts industry was studied in particular. In the study, the Industry 4.0- technologies were described. This included identifying the emerging technologies within Industry 4.0 and how they apply throughout certain industries as well as identifying patterns in their spread and the connection with logic of production.

REFERENCES


**Cléiton R. Mendes** was born in São Bernardo do Campo, SP, Brazil. He received the B.Sc. degree in Industrial Mechatronic Technology from the SENAI of São Caetano do Sul, SP, Brazil in 2009. He received the B.Sc. degree in Pedagogy from the South University of the Santa Catarina of Palhoça, SC, Brazil in 2010 and currently is student of Post Graduated (M.Sc.) in Automation and Control in IFSP – Federal Institute of São Paulo. His research interest includes PLC – Programmable Logic Control, IoT – Internet of Things, CPS – Cyber Physical System and Industry 4.0.

**Raphael Y. Osaki** was born in São Paulo, SP, Brazil. He is currently student of Automation and Control Engineering from the IFSP – Federal Institute of São Paulo, SP, Brazil. His research interest includes PLC – Programmable Logic Control, IoT – Internet of Things, CPS – Cyber Physical System and Industry 4.0.

**César da Costa** was born in Rio de Janeiro, RJ, Brazil. He received the B.Sc. degree in electronic and electrical engineering from the CEFET-RJ, Federal Center of Technological Education Center Ceelho Suckow da Fonseca and Nuño Lisboa University in 1975 and 1980 respectively. He received the M.Sc. degree in mechanical engineering from Taubate University, Taubate, SP, Brazil, and the Ph.D. degree in mechanical engineering from UNESP- Universidade Estadual Paulista Julio de Mesquita Filho, Guaratinguetá, SP, Brazil in 2005 e 2011, respectively. He did sandwich doctoral stage, PDEE-CAPES, in the IST-Institute Superior Tecnico, Lisbon, Portugal in 2009. He is currently post-doctoral and professor of automation and control engineering in the IFSP – Federal Institute of Education, SP, Brazil. His research interests include Fuzzy controller, Artificial Neural Network, machine monitoring, diagnostic, electrical machines, FPGA and Industry 4.0.