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The Internet of Things, Factory of Things and Industry 4.0 in Manufacturing: Current and Future Implementations

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Abstract. In the currently rapidly changing industrialized world, globalization, product customization and automation are playing an imposing role in the development of the manufacturing sector. Nowadays, the innovative concepts of The Internet of Things, Factory of Things and Industry 4.0 are aimed to revolutionize the way technology can help improve production around the world. While in some international corporations these concepts are being deeply studied and are starting to be implemented, also in middle-size and large manufacturers it is clear they could contribute with many advantages; however, skepticism and uncertainty are still present among managers and stakeholders. In this paper, the current and coming state-of-the-art technology and implementation of the Factory of Things paradigm are presented and examples of the current implementation in global manufacturing companies are analyzed. Additionally, this article will discuss the potential implementation of this Industry 4.0 in a large manufacturer, and how it can help increase the control and efficiency of production, material flows, internal logistics and production planning.

Keywords. The Internet of Things; Factory of Things, Smart Factory; Industry 4.0; manufacturing; internal logistics; production.

1. Introduction

In the past decades, technology has been playing an imposing role in the development of the manufacturing sector. In many European countries, an stimulus to industry is required to be able to compete with the powerful emerging industrial sectors of countries such as China, India and Brazil [1]. There have been different so-called “revolutions” that had a huge impact on the outcome and necessities in manufacturing while also motivated by the shift in the habits of the average consumer in the modern society [2]. The so-called first revolution in manufacturing has been considered to be the mechanization of industrial processes around the beginning of the 19th century; the second revolution followed with assembly lines and mass production, starting at the end of the 19th century [2]. During the second half of the 20th century, the development of computers and automation lead to the third revolution, also called Industry 3.0 or the Digital Revolution [2, 3]. Finally, up to the present days, the fourth revolution or so-
called Industry 4.0, seems to be the next step in manufacturing around the world [1]. This fourth revolution, as defined by many authors, has been categorized as being based on the flashing technologies of Internet of Things (IoT), Factory of Things (FoT), or as the revolution of Cyber Physical Systems (CPS) [4-8]. IoT is also known in the United States as the Industrial Internet Consortium (IIC) [9]. The integration of IoT and CPS with manufacturing is defining this term of the fourth industrial revolution [10]. Following the trend of these revolutions, the concept of Industry 4.0 was first introduced by the German government during the Hannover Fair in 2011 [1, 9]. This revolution is step-by-step starting to be a necessity to survive in the manufacturing sector. Nowadays, demand in manufacturing tends to be for a higher mix of products with shortened cycle times, requiring more agile and flexible production structures where just the existing automation is not enough [10].

In this paper, an introduction to IoT, and FoT and Industry 4.0 is presented in Sections 2 and 3 respectively followed by the current implementation of this technology in some major manufacturing companies in Europe in Section 4. Section 5 presents an analysis of the implementation of IoT and FoT in middle-size and large manufacturers through a potential application example. To sum this up, conclusions and future work on this study are presented in Section 6.

2. Internet of Things

IoT is the concept or paradigm of connecting different kinds of physical devices enriched with embedded electronics (Radio Frequency Identification (RFID), sensors, actuators, etc.) to a network or internet so they can communicate with each other for controlling and monitoring purposes, to access internet and data clouds and to adapt to their own environment [3]. Kevin Ashton, in 1999, first introduced this as support for supply-chain management; nowadays it is also fueling other technological revolutions, such as Space 2.0, Health 2.0 or Medicine 2.0 [11-13]. The connection of IoT devices is usually done wirelessly by different technologies such as Bluetooth, RFID, Wi-Fi or telephone data [14].

With this wireless technology, one of the main goals is to have a shared and distributed system compound by different kinds of connected “smart” devices that communicate and cooperate to perform aggregated as well as individual tasks. The main advantages are the potential to decentralize the control of complex systems, the information transfer, to self-adapt to changes in the system and its environment, and to establish extended standards that will make complex systems easier to understand, more flexible and feasible to manage in an efficient way [10].

3. Factory of Things and Industry 4.0

The concept of FoT is the application of IoT and information systems to develop and implement this innovative technology in manufacturing systems where integrated physical objects communicate, store, analyze, and visualize information about their status, surrounding environment and tasks [3, 14]. FoT is the extension of IoT to develop and implement this technology in the shop floor of production systems. It is also known or directly related to the terms Industry 4.0, Smart Factories, Smart Manufacturing, Mass Customization, Thinking Factory, SmartFactory or the Factory of
the Future, having the goal of improving and making more efficient production systems [3, 8, 9]. From the beginning of the design process until the final planning of the production and distribution, all the information can be shared and analyzed together with the implementation instructions and improvements along the life cycle of the product. It enhances the whole product process in a distributed manner making it more efficient, adaptable and aiming for more sustainable manufacturing [3, 4]. One of the main goals is to allow production cells, machines and robots the possibility of achieving the concept of “plug and work” [10, 14]. Most of the components of a production floor will be flexible and can be readapted almost in real time to processes and material flows or be relocated in the production chain [3]. Due to this and the extensive monitoring work required, one of the keystones of Industry 4.0 is digitalization.

Digitalization can be partially defined as bringing together a computer processing force and operations in a process [15]. It can be crucial for data processing, storage and transmission when either the amount or the desired speed, or both, of managing information are demanding. An idealization of combining digitalization and the IoT is that most of the devices on the shop floor will have an IP address that could be accessed by everyone with permission. This will allow those individuals to send or receive data that can help to monitor, control, design, program, maintain, and coordinate those devices in cooperation with the system.

Principally due to that manufacturing systems around the world represent a significantly growing share of the global trade and due to the increasing demand of individualized products and natural resources, manufacturing is nowadays becoming more challenging than ever [16]. The IoT and FoT are intended to help filling the existing gap between the physical world of industrial systems and its representation in information systems [17]. The manufacturing will be highly flexible in the volume and customization level of the production, highly integrated among customers, companies and suppliers and above all sustainable [3]. This FoT paradigm has the common goals of increasing the quality and efficiency of manufacturing systems, reducing the time of new products reaching the market, enhancing flexibility, trying to respond to a growing demand of customized high-quality products, and surviving in a market of global competitors [8]. However, as stated by Jian Qin et al., even though many manufacturing organizations and companies are working on this topic of Industry 4.0, the evaluation of the level of achievement is still uncertain [1].

4. Internet of Things and Factory of Things, Current Implementation

As part of this study, several visits to some international manufacturing companies were organized in order to learn more about the state-of-the-art technology in Industry 4.0. Germany started the race towards this 4th industrial revolution in a leading position, and some of the pioneer companies in this field were analyzed. Two of the main German companies that claim to be particularly advanced in this field are Siemens and BMW.

According to Siemens, a great deal of effort is being placed on linking together the virtual and real developments and production processes: “Fundamental change in manufacturing industry leads to increasing digitization and networking to leverage productivity” and “With 7,500 software engineers, the Industry Sector is trendsetter for linking product development and production through the use of IT” [18]. There is much
focus on this effort put into digitalization and integration of the different processes involved in production. In their plant in Bad Neunstadt, Siemens mainly produces electric motors, around 600,000 per year with 30,000 variants, and this is the forefront plant within the Siemens corporation regarding digitalization and Industry 4.0. The centerpiece of their development is a showroom or stand located on the shop floor with several monitors acting as an information panel where extensive work of data collection and real-time monitoring is collected, analyzed, summarized and visualized. It is possible to access the performance and downtime of individual machines, working stations or working areas, as well as the expected and real production data, the tool-change operations performed and required, the processing times, their failures, the waiting and blocking times etc. With this real-time information available on the shop floor directly, and remotely to everyone with permission, it is really easy to identify problems, predict tasks and resources and to analyze work load and performance. However, the production planning of the machining area is manually optimized, as well as the operations to reduce machine set-up time; this information board is merely used as a complete monitoring system for the different machines and work centers on the shop floor. This information can be extremely useful for planning, improvement and management tasks but it was not considered to determine the production planning in real-time and to adapt the pace of the different production areas and entities involved. There were no machines, robots or production cells communicating with each other to cooperate and coordinate to meet an optimized flow of products depending on the demand and capacity. Other characteristics of Industry 4.0 that Siemens is starting to take advantage of are the integration of the processes of product design, production planning, production engineering, production execution, and production services. Most of these here mentioned processes are digitalized but are still far away from being integrated and coordinated under the umbrella of a decentralized management platform.

Another German pioneer concerning Industry 4.0, the car manufacturer BMW, has developed an impressive work of product design integration, customization, and assembly. With a lead time of 40 hours and a cycle time of 58 seconds, the assembly lines are perfectly coordinated with the production planning in order to have full control of the different variants being produced at all times. The customers who purchased a vehicle can track in real-time its manufacturing processes from the beginning to the delivery, being able to remotely change some of its characteristics and equipment until the last minute. However, besides this impressive customization and product-design integration, few examples of Industry 4.0 were appreciated and most importantly, BMW was conscious that Industry 4.0 is being used as a marketing strategy to sell related products to help achieving this technology in the future.

According to the study by Jian Qin et al. [1], generally the current manufacturing sector has not yet achieved the Industry 4.0 level; although many companies together with researchers are irrefutably working on it, there is still a huge gap between the current and expected level of achievement of Industry 4.0.

5. Factory of Things in Middle-Size and Large Manufacturers, a More Tangible Implementation

Due to the general difficulties of becoming highly skilled in applications and technologies of Industry 4.0 in manufacturing, regions which traditionally has this kind of industry need the support and knowledge to develop those skills in an effective
manner [19]. Usually they mainly use simple autonomous PLC automated systems without using the interaction potential that this technology presents [19]. More specifically, with an application example of an industrial partner involved in this project, a feasible Industry 4.0 can be considered in order to increase the general efficiency of the production and logistics systems, as well as the coordination and cooperation of the different agents involved on the shop floor. With the industrial partner—a water pumps manufacturer with a production of around 140,000 pumps a year and 1,200 employees—the efficiency and quality of the production can be increased with closer communication and collaboration between the different entities involved (processors, PLCs (Programmable Logic Controllers), automated warehouses, transports, conveyors, barcode/RFID readers, suppliers etc.) resulting in a smoother and more efficient production and reducing bottlenecks and quality failures [4]. Some of the key data that should be shared and accessed in real-time by the different items and systems are the forecasted production, received parts, delivered parts, set-up and process times, failures, shortages, downtime, buffer levels and level of storages. Furthermore, by the IT integration of the production and logistics levels with the planning level and considering both customers and suppliers, a greater flexibility for complex and customized production can be achieved [19]. Coordination and communication with an ERP (Enterprise Resource Planning) or an equivalent system should be a key aspect to increasing efficiency and flexibility. The aspect of managing the internal logistics according to the pull system and just-in-time production can also lead to increased flexibility for customization and adaptation of the production to the demand. It can also contribute to a better planning of the peak times of traffic and production at specific periods of the day/week/month to minimize the risk of accidents (for example “smart” transports such as AGVs (Automated Guided Vehicles) could analyze the information of transit times of the operators to avoid using specific paths during shift change, lunch or break times). Another clear benefit is the data management; digitalization and real-time monitoring can be key aspects for system understanding, analysis and improvement of the materials and production flow.

A great deal of effort is necessary with the standardization of the different devices involved in production, such as PLCs, computers, mobile phones, robots, machines, and transports, to allow the integration and wireless communication with the required security and privacy aspects considered. Much of this technology is already present in middle-size and large manufacturers, however, the key concepts of communication, compatibility, and integration are still ballasting the implementation of Industry 4.0 in the overall production system.

6. Conclusions and Future Work

In this paper, we have demonstrated that there is a still a huge gap between the potential implementation of the paradigms of IoT and FoT and their current state in manufacturing. There is a significant improvement potential by connecting and coordinating many of the nowadays existing technologies to the information networks. The main benefits of this revolution besides improved monitoring, control and design in an integrated manner are: increasing quality and efficiency, reducing the time to reach the market for new products, and enhancing flexibility and capacity of mass production of customized high-quality products. Specially in large manufacturers, the bases are starting to emerge; however, the standardization of the communication,
flexibility of the machines and devices, and compatibility of the different components still have to be achieved in most of the commercial industrial equipment. In addition, the security, skepticism and privacy issues still have to be addressed and improved to fully appreciate the potential of this fourth industrial revolution.

As part of this research, further analysis together with industrial partners and several application studies are being carried out to analyze the possibilities of overcoming these barriers and to materialize the potential benefits this technology presents.

References