The manufacturing industry has been facing several challenges, including sustainability and performance of production. These challenges are sourced from numerous factors such as an aging workforce, changes in the landscape of global manufacturing and slow adaption of smart manufacturing by implementing IT in manufacturing process.

In recent years, German and US governments have established separate initiatives to accelerate the use of the Internet of Things (IoT) and smart analytics technologies in the manufacturing industries and, consequently, to improve the overall performance, quality, and controllability of manufacturing process. The smart factory is the integration of all recent IoT technological advances in computer networks, data integration, and analytics to bring transparency to all manufacturing factories. In this article, we review the most recent logistic decisions for taking smart factories from idea to reality and then describe the possible technologies for smart factories.

From Traditional Factories to Smart Factories

The manufacturing sector showed a tremendous amount of interest in the new conception introduced in 2013 at the Hannover Fair in Germany. A futuristic plan developed under the auspices of the German Federal Government’s High-Tech Strategy is outlined to be the framework of the fourth industrial revolution. The first industrial revolution occurred by the end of the 18th century with the mechanization of manufacturing processes. Then towards the start of the next century, electricity was utilized to power mass production of goods based on the division of labor (station-oriented). In the 1970s, the third industrial revolution was recognized with the use of electronics and information technology (IT) to achieve more automation of manufacturing operations. Based on the initiative, the fourth industrial revolution is the integration of interconnected systems and IoT in manufacturing, which is called Industry 4.0.

On the other hand, the US government as another global pioneer in the manufacturing industry defined the term cyber-physical systems (CPS). CPS is a complex engineering system that integrates physical, computation and networking, and communication processes. CPS can be illustrated as a physical device, object, equipment that is translated into cyberspace as a virtual model. With networking capabilities, the virtual model can monitor and control its physical aspect, while the physical aspect sends data to update its virtual model. Considering the importance of this topic, cyber-physical...
systems have been called a national research priority of the United States [1] and the European research council [2]. The US government recently established four manufacturing hubs, including additional manufacturing in Ohio, low-power semiconductor manufacturing in North Carolina, digital manufacturing and design innovation (DMDI), and light weight materials in Michigan. In addition, the White House initiated Smart America Challenges based on advanced cyber-physical systems in 2012.

The successful integration of Industry 4.0 and cyber-physical systems provides significant benefits for the entire manufacturing industry. These benefits can be summarized in one term as the so-called: smart factory [3]. The adoption of the smart factory can be a game-changing event that can transform the interaction of engineered systems just as the internet transformed the way people interact with information. To some extent, we are not only living in the physical world, but also in internet (cyber) space. For example, Facebook is our cyber-life that coexists with our real life. Similar concepts and effects also apply to the manufacturing system in a smart factory. Each physical component and machine will have a twin model in the cyberspace composed of data generated from sensor networks and manual inputs. Intelligent algorithms process the data in cyberspace, so that information about the physical components’ health conditions, performance, and risks are calculated and synchronized in real time.

As smart factories leverage the web of information from interconnected systems to perform highly efficiently, agilely, and flexibly, the overall framework can be divided into three major sections as defined by Lee et al. [4]. These sections are components, machines, and production systems, where each of these items brings different levels of understating and transparency to the factory. Smart machines need to use real-time data from their own components and other machines to gain self-awareness and self-comparison. Self-awareness enables machines to assess their own performance and diagnose possible malfunctioning components. Consequently, it can predict and prevent potential failure and risk contributions to the final product. Smart machines can further share their information over the cyberspace to compare their performance and productivity with other similar machines. This self-comparison attribute enables machines to adjust their settings and performance properly through the knowledge they gained from their working history. In this environment, the manufacturing system is also able to schedule customized manufacturing criteria for individual machines based on their performance. Consequently, the production system can configure itself to customize production of every single product based on the current status of all machines involved in the manufacturing line to guarantee high quality production with the optimum operation costs. In such a smart factory, the manufacturer is able to meet customer specifications at any production rate with supporting last minute changes in the production and other flexibilities that are far from achievable in traditional factories.

Necessary Technologies for the Smart Factory

The smart factory defines a new approach in multi-scale manufacturing by using the most recent IoT and industrial internet technologies, which consist of smart sensors and sensing, computing and predictive analytics, and resilient control technologies. These technologies must be bonded together to acquire, transfer, interpret, and analyze the information, and to control the manufacturing process as intended. As mentioned in the previous section, it is possible to fulfill the requirements of the smart factory through cyber-physical systems. Both Industry 4.0 and CPS are in their infancy stages and require more in-depth research for their practical usage to be established in different sectors. The smart factory as the symbol for using CPS in the manufacturing sector is not exempted from the criteria. At the current stage, it is required that applicable frameworks for establishing CPS in the manufacturing industry be defined.

Recently, the author developed and proposed the 5C architecture as the general framework for implementing CPS in manufacturing [5]. The proposed 5-level CPS structure shown in Fig. 1 provides a step-by-step guideline for developing and deploying a cyber-physical system for the smart factory.

5C-level functions (Fig. 2) can be defined as follows:

Level 1: Connection requires acquiring accurate and reliable data from machines and their components. Data source can be from IoT-based machine controllers, add-on sensors, quality inspections, maintenance logs, and enterprise management systems such as ERP, MES, and CMM. A seamless and tether-free method for data management and com-