ICIC Express Letters
Part B: Applications
Volume **8**, Number **1**, January **2017**
 ISSN 2185-2766
pp. **221–226**

SMART FACTORY USE CASE IMPLEMENTED FOR QUALITY ISSUES

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Received June 2016; accepted September 2016

Abstract. *The technology adopted in a smart factory was a bleeding edge technology with its uncertainty and unreliable state in the past, but recently it became a leading edge technology with the advancement of sensor network, communication, control, information technology and IoT. The application areas of smart factory extend more in various kinds of industry. They are machining, assembly, fabrication, manufacturing, logistics, wholesale and process oriented industry such as chemical and petrochemical companies. The purpose of this paper is to implement the use case of smart factory in the quality control aspect. A tie rod which is used in the steering system of an automobile is adopted for checking the horizontal flatness. A proximity sensor VCNL4000 is adopted for checking the distance of each part. The feasibility of applying a sensor in the part inspection is tested in this use case.*
Keywords: Smart factory, Quality implementation, Use case, Sensor network, IoT

1. **Introduction.** Is a smart factory just big hype? A smart factory is also referred as smart manufacturing, intelligent factory of the Future, and Industry 4.0. All these terms describe a vision of what industrial production will look like in the near future. Industry 4.0 has been proposed in Germany in 2012. It is not just about more efficient and intelligent workflows in the factory technology, supply chain, production and logistics. The heart of Industry 4.0 is a smart factory, which is intelligent, interconnected and self-adaptive for the changing environment. It is a huge paradigm shift from mass production based on efficiency, stability and control to mass customization supported by variety and customization through flexibility and quick responsiveness. In the smart factory, digitization and automation touch every area to transform the value chain in the company to be maximized.

Key components of a smart factory include smart machines, sensors control systems and networking. In the smart factory, huge amounts of data are generated which have to be transmitted and processed through the communication networks. For the wide area networking, a cloud computing is essential which is stable, fail-safe and real-time communication capability.

Manufacturing processes will be organized differently, with entire production chains – from suppliers to logistics to the life cycle management of a product – closely connected across corporate boundaries. Individual production processes will be seamlessly connected. The relevant areas will include:

- factory and production planning
- product design and development
- supply chain system (SCS)
- enterprise resource planning (ERP)
- manufacturing execution systems (MES)

- wireless sensor networks
- control technologies

Manufacturing paradigms have also evolved across the last century. Initiating from a manual production, American system of manufacturing (ASM) was developed in early 20th century. Then, it evolved into mass production (MP) with high efficiency and low cost. The MP paradigm was climax in 1955 in automobile industry. It was the first year in which 7 million cars were sold in U.S. Ford, and GM and Chrysler have 95% of all sales. Six models accounted for 80% of all cars sold [1]. Until this time, the product variety has been decreased for cost reduction. In order to continue this MP paradigm continuously, input stability, market homogeneity, demand stability and demand growth are required. However, as this condition has not been supported any more, the manufacturing paradigm has shifted from MP to mass customization (MC). The new paradigm of MC is variety and customization through flexibility and quick responsiveness.

Following the "Industry 4.0" by Germany, other countries also proclaimed factories of the future with similar terms. They are "advanced manufacturing" in US, "e-Factory" in Japan, "Intelligent manufacturing" in China and "smart factory" in Korea.

Considering the trend and much interests, it is highly required to propose a reference model and use case of smart factory in the real factory environment. In the industrial field, quality management is always crucial for maintaining competitiveness. Thus, we propose a use case of smart factory implemented for quality control issue. Section 2 investigates the state of the art of a smart factory and proposes a reference model of a smart factory. Section 3 proposes a use case, and implements for a real quality problem. Section 4 summarizes conclusions and future research directions.

2. Smart Factory Model.

2.1. Factory of the future.

In order to be competitive, a production system should be an ecosystem where efficient and lean production can be implemented upon the network of interconnected sensors and devices. For this purpose, an Internet of Things (IoT) should be embedded in the manufacturing and production facility [3].

The essential features of factory of the future are people as key players, distributed intelligence, fast integration and flexible configuration, open standards, virtual real-time representation, digital life-cycle management and secure value-creation networks.

A professional team in the IEC market strategy board has suggested the concept of factory of the future as open value chain, flexible production, human-centered manufacturing, business models and gave a few cases for local initiatives. The details are as the following [2].

- Open value chain: As product life cycles are becoming shorter, value chain system needs to become more adaptable, agile and resilient.
- Flexible production: In order to adapt to changing market environments, manufacturing system should have flexibility in product volume, product variant, design speed, quick delivery, process and automation.
- Human-centered manufacturing: Individual knowledge merges into company knowledge, and sharing knowledge across platforms will be enhanced.
- Business models: Examples of innovative business models are crowdsourcing, anything-as-a-service (XaaS) and symbiotic ecosystem. A crowdsourcing is a blend of 'crowd, and 'outsourcing and describes the process of obtaining ideas, services or content from a large, collaborative group of participants. In the XaaS, services are able to be consumed on demand for faster reaction to change market needs. A symbiotic ecosystem implies global platforms which integrate diverse ecosystems to exploit synergies in the infrastructures.

• Local initiatives: Several associations and initiatives around the world focus on applied digitalization for smart factory. Among the most relevant we can mention as [4]: • Industrie 4.0 – Germany • China manufacturing 2025 – China • Industrial Internet Consortium (IIC) – US • Smart Manufacturing Leadership Coalition – US • Robot Revolution Initiative (RRI) – Japan • Industrial Value Chain Initiative (IVI) – Japan.

2.2. **Industry 4.0.** A German manufacturer refers the next wave of manufacturing with IoT-enabled systems as Industry 4.0. Industry 1.0 depended on mechanical system powered by water and steam. Industry 2.0 was the period of mass production based on division of labor powered by electrical energy. Electronics and control systems contributed to the emergence of the Industry 3.0. Industry 4.0 is peer-to-peer communication between products, systems and machines based on CPS [5]. Industry 4.0 includes smart production with high precision and superior quality, green production with clean and sustainable, and urban production with smart factories close to the consumer and employee [6].

2.3. **Smart factory model.** A reference model of smart factory is composed of IoT, CPS and IoS (Internet of Service). There are sensors, actuators, controllers, mobile devices and computing in the IoT. In the CPS, there are product, material, facility, logistics and various sensors [7]. IoS is composed of ERP, SCM, CRM (Customer Relational Management), MES and PLM (Product Lifecycle Management). In the smart factory reference model, resource material is given as input, and smart product is generated as system output. A reference model of a smart factory utilizing the above concept is shown in Figure 1.

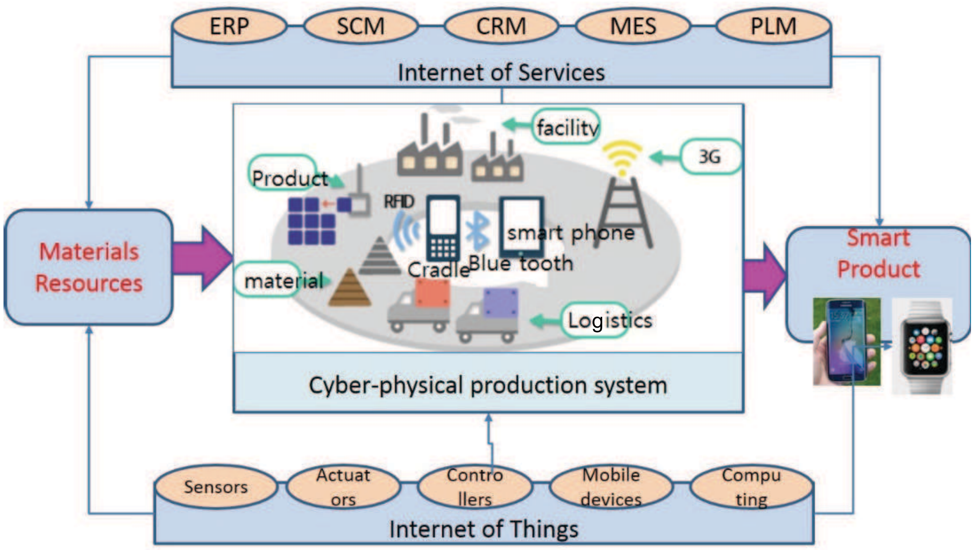

Figure 1. Smart factory reference model

3. Use Case Model and Implementation.

3.1. **Use case model.** The use case of a smart factory for quality issues is tested in this paper. The system architecture of sensor-based inspection system is shown in Figure 2.

The inspection system starts with the identification of quality problem in the domain. Then, the manufacturing process is analyzed (AS-IS process) to solve the quality issues. A sensor based inspection system is proposed and implemented in the laboratory level. Through the test, a feasibility model is developed and tested. Based on the result, the manufacturing process is re-arranged (TO-BE process). A new use case of sensor network based smart factory is developed and proposed.

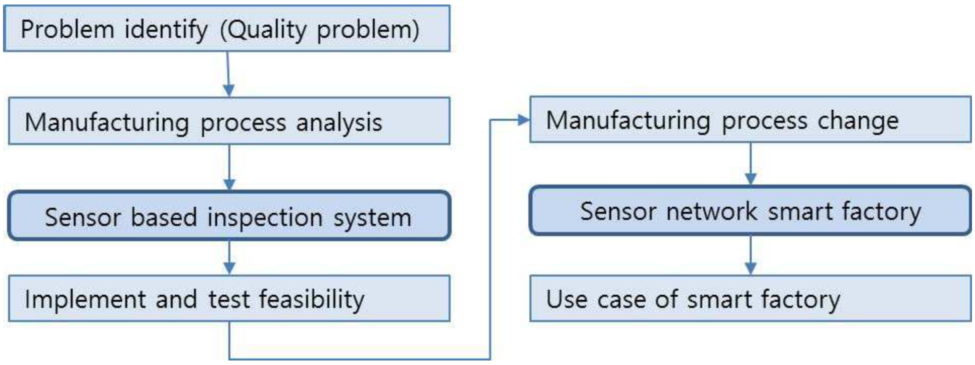

FIGURE 2. Process of smart factory use case using sensor network

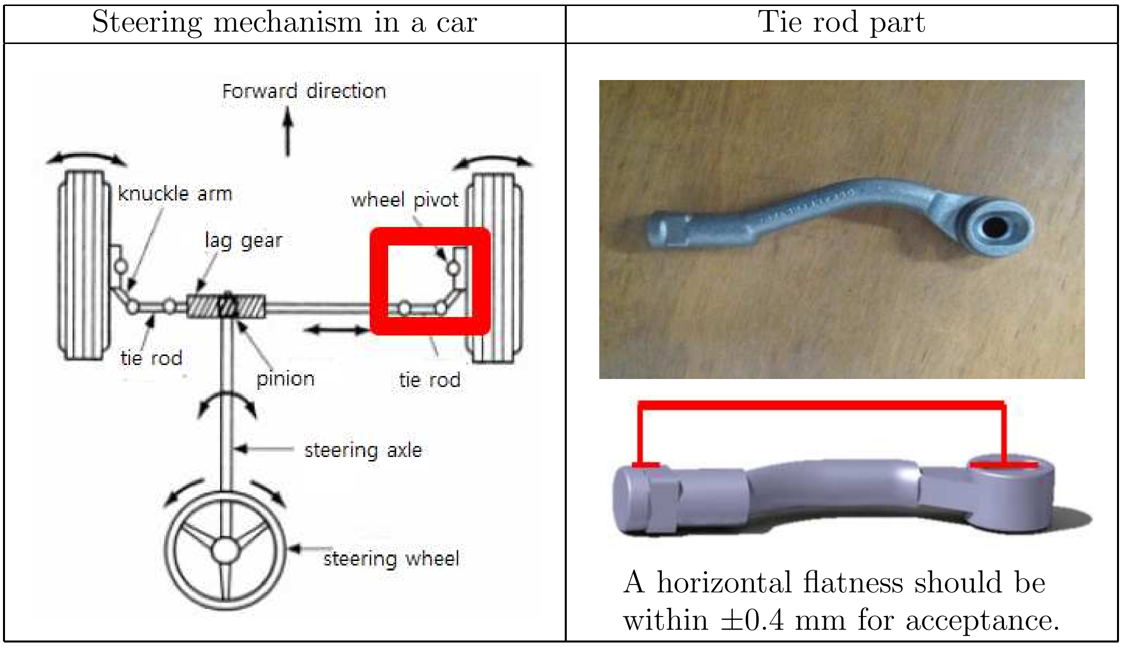

FIGURE 3. Problem domain of steering system, tie rod part and its quality requirement

3.2. **Problem domain.** The problem domain to implement smart factory use case is a tie rod used in steering system of an automobile. The required quality specification of the part is a horizontal flatness within ±0.40 mm.

The steering system, the part of tie rod and its quality requirement are shown in Figure 3.

3.3. **Implementation.** In order to measure the horizontal flatness of a tie rod, a few instruments are used. A Vernier calipers is used to measure an accurate distance as a reference. Distance and proximity sensor are adopted to measure the accurate distance. In this study, we used VL6180 as a distance sensor and VCNL4000 as a proximity sensor. As the VL6180 sensor does not provide the required precision, and VCNL4000 sensor does not return the proximity value, this is why we have used two sensors at the same time. In order to tackle this problem, we measure the proximity value by VCNL4000 sensor for the distance measured by the VL6180 sensor. A system is constructed composed of two types of sensors and regression equation to figure out the required precision using the distance and proximity measure.

Experimental setup for checking horizontal flatness is given in Figure 4. Using the system in the figure, the distance and proximity are acquired, and then a regression model is applied for checking the flatness of the tie rod. Data analysis program was

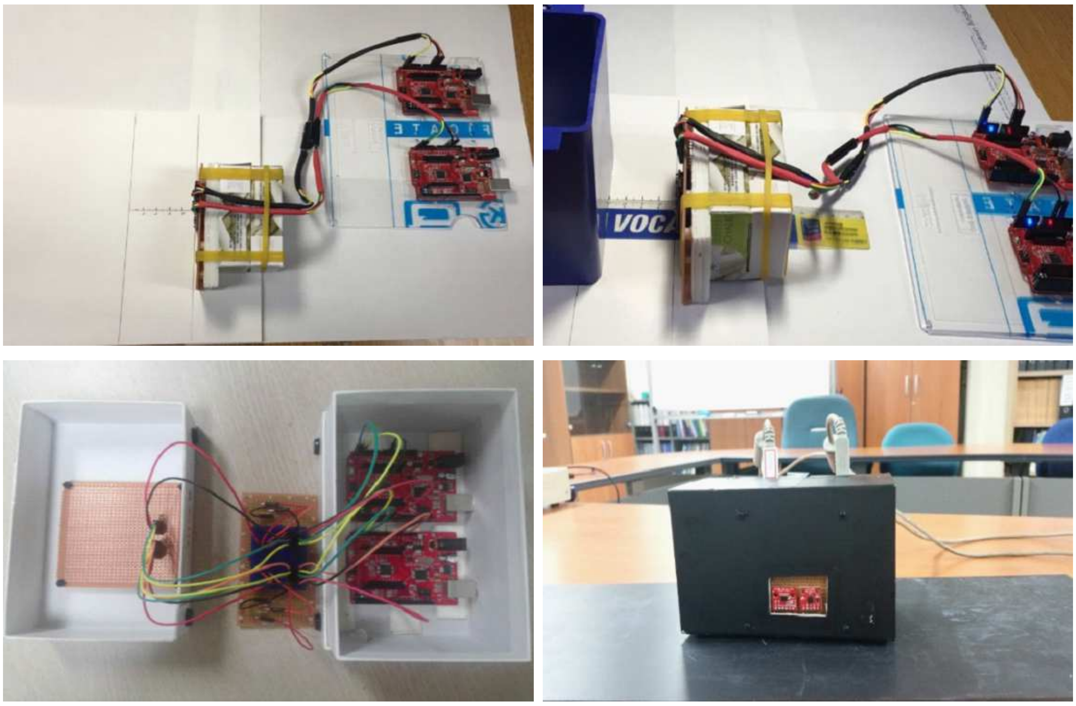

Figure 4. Experimental setup for checking horizontal flatness

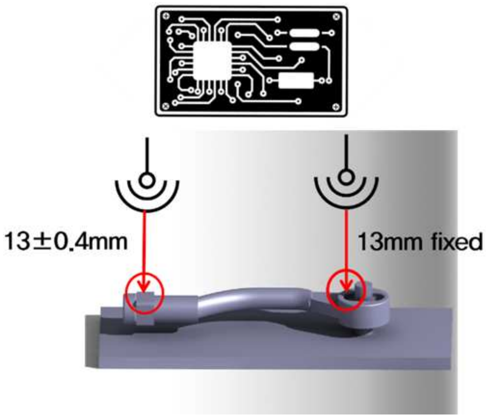

Figure 5. Result of inspection scheme of tie rod horizontal flatness

developed using a single board computer Raspberry pi2 with version lazarus0.9.8, which is a cheap processor.

3.4. **Result.** For an implementation, a real tie rod is tested for measuring the horizontal flatness. Using the system with two sensors and data analytics, the proximity was checked and configured. In order to check the horizontal flatness, both sides of tie rod are measured from horizontal reference line. The returned value from proximity sensor does not give a distance value, and a regression analysis has been applied to finding a reference distance with a minimum error. A value of 13 mm has been acquired in the regression analysis. Using this result, inspection scheme is devised as Figure 5. One side of tie rod is fixed as 13 mm and the other is measured and evaluated whether it is 13±0.4 mm. The accuracy of horizontal flatness within ±0.4 mm has been checked using this framework. The quality improvement through this inspection scheme has been proposed and acquired.

4. **Conclusions.** Smart factory is a buzz word not only in the technology but also in business model. Wireless sensor-based smart factory is proposed and implemented for

the quality issue in the laboratory level. The result showed the feasibility of sensor-based smart factory for quality issue.

The following could be suggested for a further research. First, a wireless sensor network model should be enhanced for the realization of more robust smart factory. Second, in order to add value to the smart factory, semantic knowledge is needed in the IoT data. Third, interface with smart robot and IoT can enhance the practical usage of a smart factory.

Acknowledgement. This research was supported by Kyungsung University Research Grants in 2017.

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