IoT-Based Defect Predictive Manufacturing Systems

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Abstract— **Recently, attempts have been made to change the paradigm of existing plants by applying ICT to the manufacturing industry. It can be seen as an extension of factory automation, which used to automate production facilities and unmanned work in the past, but Smart Factory is an advanced model to predict and respond to the future situation. In this paper, we propose a controller that is optimized for a specific task so that manufacturing process data can be acquired from production facilities in real - time by a sensor node based on wireless sensor network and a gateway with wired/wireless interface. And describes the design and implementation of smart factory service model.**

Keywords—Wireless Sensor Network, Industrial IoT, Manufacturing Process

I. INTRODUCTION

By integrating ICT technology with existing supply chain management (SCM) technology to secure corporate productivity and enhance survival competitiveness by upgrading quality control at product production sites, Smart factory technology is emerging that can provide intelligent services such as automatic recognition of production quantity and automatic management of material inventory information online in real time[1]. For this reason, we will strengthen product competitiveness through optimized production, control and quality advancement through interlocking between manufacturing facilities and systems, and the introduction of smart factories that combine IoT is expected to serve as a means to enhance domestic manufacturing efficiency[2]. Therefore, in order to increase production efficiency in factories that already have production facilities, it is necessary to upgrade the plant so that the equipment, materials, and systems can be linked to the wired/wireless network and integrated operation of the manufacturing process[3].

In this paper, the factory to apply the proposed system already has the maximum production quantity per hour based on the time of facility introduction. Therefore, it is stated that the system proposed in this paper can not be improved beyond the maximum production capacity even if applied to existing production line. However, in this paper, we aim at real-time defect detection and tracking of the causes of past failures to report problems in the manufacturing process and to implement a system that predicts future failures due to environmental changes. In this paper describes design and implementation of smart factory service model for analyzing and predicting based on data collected in each process by collecting process data in real time by implement ICT for factory equipped with bottled water production facilities.

II. SYSTEM COMPONENTS

In order to collect the data related to the process and the production status of the manufacturing facility in real time, we divided the system components as follows. The basic structure of the system consists of 'wireless sensor network - gateway - server', and some 'gateway - server' structure is used in which the gateway is directly connected to the facility according to the situation.

A. Wireless Sensor Node

Depending on the structure of the plant, wireless sensor network systems were used to collect process data in areas where wired-based acquisition systems are difficult to apply. The Wireless Sensor Node applied an IEEE 802.15.4 Phy chipset that supports the 2.4 GHz ISM band. Due to the continuous operation of the production line, In order to provide a uniform response to all sensor nodes, TDMA (Time Division Multiple Access) is applied. Therefore, the sensor node receives the time information periodically provided by the master node included in the gateway and designed to transmit the data in the timeslot allocated to the sensor node.

B. Gateway

Typically, a gateway transmits a packet of a sensor node using a wireless sensor network to a server or a control packet received from a server to a sensor node. The gateway includes a Linux-based Embedded System with embedded Ethernet interface and a Master Node for wireless sensor network. The master node is configured with the same H/W as the sensor node, broadcasts the time information of the TDMA in the beacon, and delivers the packet received from the sensor node to the Linux based embedded system. In addition, the master node can be operated as a weighing system using an expansion port and is designed to have an isolated I/O for interworking with a PLC. Therefore, the gateway is designed to transmit process data to the server directly in production facilities in areas where wireless sensor networks are not needed.

C. Actuator

To provide visual or auditory feedback to the user, the system provided an warning light as an actuator. It is designed to be controlled by the server based on the data collected from the sensor node and based on the feedback provided to the user. In addition, by providing a 7Segment Display, the user can configure the system to accurately recognize the state measured in the system.

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D. Server

In this system, the server is divided into two types according to its roles. One is OPC server for interworking with the injection machine and the other is the central server that collects process data from WSN-based sensor node and gateway and provides web application services as described above and plays a pivotal role of the proposed system in this paper.

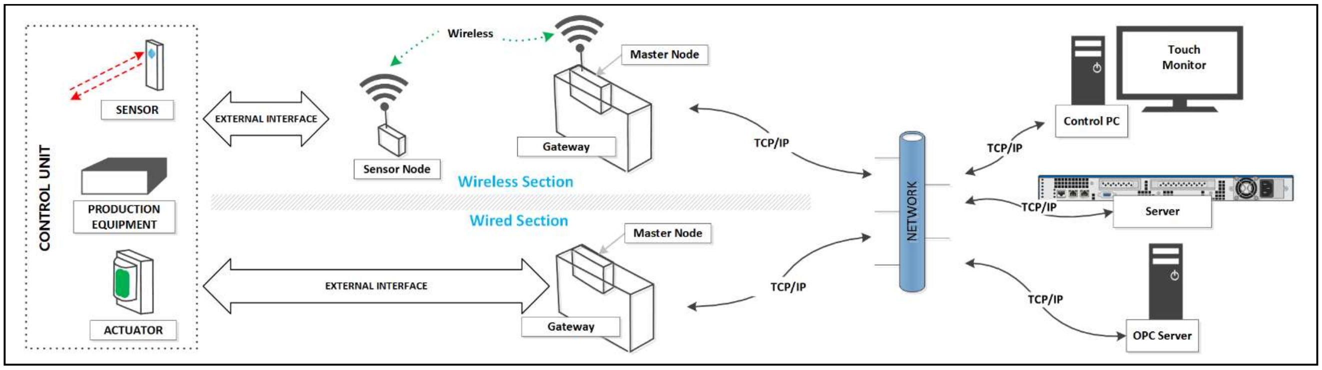

Figure 1. System configuration diagram

The OPC server collects real-time information of the injection machine through the OPC protocol and stores the read data in the DB of the process data analysis server. The packet collected from the gateway consists of the data collection service of the server analyzing the packet to separate the management packet and the data packet, and the data separated into the data packet is stored in the DB. In addition, the collected process data is designed to provide a UI service based on a web application so that the status can be viewed on an authorized user or a public display.[4]

E. PC Based Measurement System

A PC based collector supporting touch input was applied to the defective products weighing system. The worker weighed the defects generated in each process through the weighing system and designed the system to manage the defective history by using the display with the touch interface.

III. SYSTEM IMPLEMENT

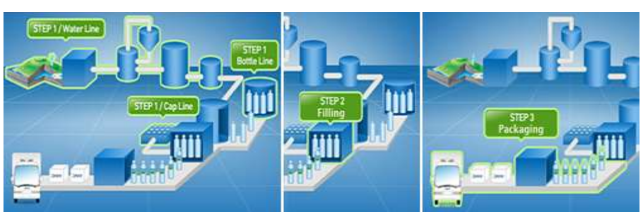

Figure 2. Main process in three stages[5]

The plant to which the aforementioned system is introduced consists of three processes, as shown in Figure 2. PET bottle manufacturing in step 1, filling bottled water in step 2, and packaging the product in the last three steps. The following is a brief introduction to the systematic content that enables the specific functions in each process to be applied to the above-mentioned components.

A. Automatic Measurement system of Raw Metrial's Weight

The factory is operated by introducing facilities for direct manufacturing of PET bottles. However, at the time of arrival of raw materials of PET bottles and use a movable pallet scale to estimate the total input weight by sampling only some samples. In this paper, we propose a real-time measurement system in the raw material input room and design it as follows to trace the total input atomic amount and input material in the main plant as follows.

PET bottles containing bottled water are made of PET chips as raw materials and are put in a ton bag. There is a work section where the field worker operates the hoist and repeats the injection of raw materials into the PET silo input port. The first designed weighing system was designed to wirelessly collect the weight of raw materials using crane scale with a communication function. The weight of the raw material is 1,050 kg, the crane scale which can measure the weight of 2,000 kg is applied considering the stability, and the battery-based wireless sensor node is applied to transmit the weight value suspended in the midair. The crane scale supports the RS-232C interface and the IMU sensor module is embedded in the sensor node to wake up the sensor node when motion occurs. But the crane scale was changed to the fixed platform scale due to the environmental (height) restriction of the material input chamber and the problem of periodical maintenance and stability of the battery.

B. Weighing System of Defective Products

The defective product weighing system is to manage the events of all bad conditions occurring between the time when the product is put into the material silo and the time when the product is shipped to the product. To facilities that can cause defects are preform inspection machine, arrangement, print quality inspection machine and visual inspection and defects occur in the following situations.

- Injection machine - if the machine is shut down due to maintenance and equipment problems
- Preform Inspection System - Problems with preform molding
- Arrangement - Drops that occur when modifying supply rails
- Print Quality Inspector - if there is an error in the seal character

- Visual Inspection - Levels of beverages, leaks, and cap leaks

Injection machine produces preforms firstly after raw material input. If injection problems occur due to maintenance and equipment problems, raw materials that are discarded until restarting and defective products due to the above defects are transferred to PC-based defective weighing system So that it can be managed and recorded.

C. Counting System of Products

The exit gate, which is the end point of the production line, products are packed in pallet units and moved outside the factory. It is designed as an optical sensor of 3 channels to enable the detection of height and direction on the side of the corresponding exit gate. The system works with a nearby gateway based on the wireless sensor network.

D. OPC(OLE for Process Control) Server

In order to collect status information of the machine supporting Euromap63 (Data Exchange Interface), we set up to extract key data using OPC Server. In addition, the data logger is used to record the data collected from the equipment in the OPC Server database (DB) of the Prediction System.

E. Prediction System of Defective

In order to apply the system proposed in this paper to a factory that already has production facilities and products, it is necessary to understand the current production facilities first. Since the production line is selected and installed depending on the target total production amount and system cost at the time of introduction, most of the production equipment manufacturers are mixed with equipment of other companies. In order to collect process data from different manufacturers' equipment, we constructed the system using the proposed wireless sensor nodes and gateways.

In order to predict the defects using the collected information, we designed and implemented the 'Manufacturing Factory Data Analysis Web Application' with the following structure and applied it to the bottled water factory.

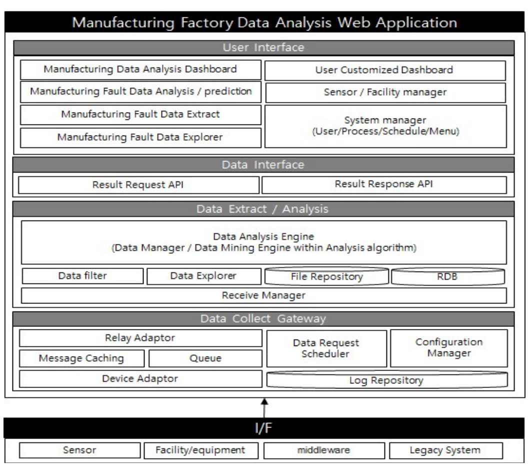

Figure 3. Quality analysis forecast management platform structure

Quality analysis prediction management collecting manufacturing process data transmitted from the gateway in real time within the platform. Based on this, data mining through analytical forecasting algorithm is performed to extract process parameters that can affect the process, and it is used as a rule base to provide poor quality prediction, defect tracking, and service function to optimize operating conditions of facilities. In order to enhance the quality control by providing the service function to optimize the operating conditions of the facility, the system is implemented as in the above block.

IV. Conclusion

So far we have described the system we have configured to apply the real-time production process data acquisition system to the plant. In order to construct this system, it is most important to operate stably without any obstacle as it is applied to a factory where 24-hour production is most important. To do this, the proposed system has been serious consideration about the interface method in the directly or indirectly interlocked part so as not to affect the existing equipment even if the failure occurs. In addition, in the case of unexpected situations such as equipment failure, power outage, and network failure due to unexpected situations occurring in the factory, the reliability of the system can be increased by various methods such as continuous health check, buffering and power redundancy to prevent data loss. The proposed system in this paper has the advantages of applying the IoT - based process data collection system to the factory already equipped with the production facility and verifying the efficiency in the existing process with minimum cost and finding out the problem.

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