Intelligent Food Distribution Monitoring System

Ganjar Alfian[1(✉)], Hyejung Ahn[2], Yoonmo Shin[1], Jaeho Lee[1], and Jongtae Rhee[2]

[1] u-SCM Research Center, Nano Information Technology Academy, Dongguk University-Seoul, Seoul 100-272, Korea
{ganjar, ymshin, rapidme}@dgu.edu
[2] Department of Industrial and Systems Engineering, Dongguk University-Seoul, 26, 3-ga, Pil-dong, Chung-gu, Seoul, Korea
{macarori, jtrhee}@dgu.edu

Abstract. Food quality and safety has gained main attention, due to increasing health awareness of customer, improved economic standards and lifestyle of modern societies. Thus, it is important for consumers to purchase good quality products in order to keep the customer satisfaction level. In this study, we propose traceability system for food by monitoring the location as well as temperature and humidity. The RFID technology and wireless sensor network are utilized in this study to perform the experiment. The real testbed implementation has been performed in one of the Korean Kimchi Supply Chain. The result showed that our proposed system gave the benefit to the manager as well as customer by providing real time location as well as temperature-humidity history. It will help manager to optimize the food distribution while for the customer it will increase the satisfaction by maintaining the freshness of product.

Keywords: Monitoring system · RFID · Temperature and humidity sensor

1 Introduction

Food quality and safety has gained main attention, due to increasing health awareness of customer, improved economic standards and lifestyle of modern societies. Thus, it is important for consumers to purchase good quality products in order to keep the customer satisfaction. In South Korea, there have been a number of cases reported by Korea Agro-Fisheries & Food Trade Corporation related to illegal agricultural food distribution channels that disguised cheap imported agricultural food products as the quality products into the local food chains [1]. In addition, the economic cost of foodborne illness in the USA alone is 50 billion to 80 billion dollars annually; it includes the health care costs, lost productivity, and diminished quality of life [2]. Therefore, in agriculture food industry, the strict control and monitoring of food freshness and quality is very important.

The RFID (Radio Frequency Identifier) technologies promise to revolutionize future inventory management [3]. The RFID applications hold tremendous promise;

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such as RFID tag monitoring. Tag monitoring is a key component in applications like item tracking and inventory control. By frequently scanning its inventory, a retailer can quickly determine if anything is missing, and act accordingly. In addition, the RFID technology has been implemented successfully in Supply Chain Management to reduce the inventory losses [4], for identification and monitoring of agricultural animals [5, 6], food traceability system [7], and healthcare applications to improve patient care as well as reduce overall costs [8].

Furthermore, Wireless sensor networks (WSN) are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. By utilizing the sensor, the history of room temperature and humidity can be presented in the system as real time [9].

In addition, to monitor the freshness of product, the time temperature indicator (TTI) can be used also to monitor the freshness of product. A TTI is a device or smart label that shows the accumulated time-temperature history of a product. Time temperature indicators are commonly used on food, pharmaceutical, and medical products to indicate exposure to excessive temperature. The application of TTI for food safety management has been successfully demonstrated in previous study [10].

This study proposes *E-Pedigree Food Tracking System* which is integrated with EPCIS (Electronic Product Code Information System). *E-pedigree* or electronic pedigree is an electronic document which provides data on the history of a particular batch of a drug. In this case, we use this pedigree system to protect the quality of food product in order to avoid the illegal agriculture food distribution channels. EPCIS is an EPC global standard for sharing EPC related information between trading partners. EPCIS provides standard for capturing and communicating the business events for tracking and tracing products within an enterprise and across the supply chain. In addition, the *Real-time Temperature-Humidity Sensor* also will be developed, thus the temperature and humidity of product can be monitored. The *TTI QR Code based Scanner* will be developed as addition, to recognize the color of TTI, thus the product freshness can be presented to customer. By integrating these three systems, it is expected to assure the quality and safety of agriculture food products throughout the whole supply chain, so that the customer can check the quality of product whenever he/she buys the agriculture food product.

2 Methodology

In this study, we are considering Kimchi distribution network which consists from Kimchi Producer, Transporter, Distributor, and Customer. The pedigree system for agriculture food products (i.e., kimchi) based on the EPC global network is developed. With the usage of RFID, EPC global architecture and wireless sensor networks (WSN), we can not only track and trace the product across the complete supply chain but also we can monitor the environmental information such as temperature and humidity of agriculture food product.

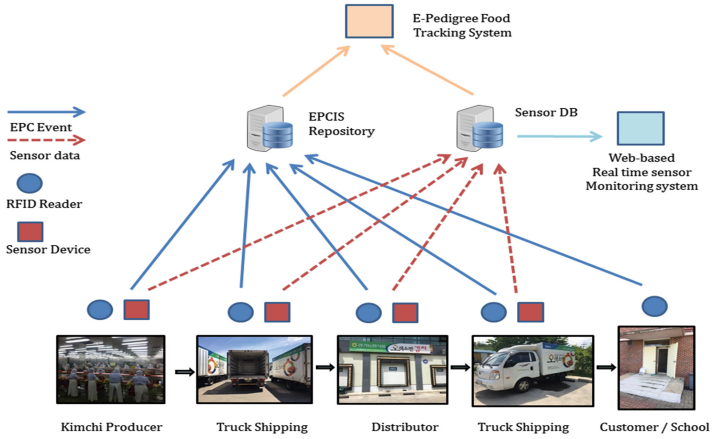


Fig. 1. Pedigree system and sensor architecture

First, for the *E-Pedigree Food Tracking System,* the history of each product is stored in the EPCIS repository. The design of the e-pedigree system can be seen as follow.

As can be seen in Fig. 1, the system architecture shows the *EPC event* and the *sensor data* flow between different supply chain partners. The supply chain partners capture the EPC code (product information) using RFID Reader and store it in EPCIS repository while the temperature-humidity data are captured by sensor device and store it into sensor database. In the end, by combining two databases from EPCIS repository and sensor database, it will create complete pedigree of product (i.e., location, process business, temperature, humidity, etc.).

In order to capture the EPC data, the RFID reader are utilized in this study. The RFID reader, antenna, antenna holder and laptop/computer are needed to gather the Tag information. The *capturing application* will be developed in this study, based on Java Programming Language to receive the data from Reader and sent it to the EPCIS repository.

Second, for *the Real-time Temperature-Humidity Sensor*, the sensor device will be installed in each room of the Kimchi Supply Chain, such as cold storage of producer, cold storage of truck (transporter), and cold storage of distributor. The real time sensor device will be developed based on android application. The sensor device is attached to the android Smartphone, the data (temperature-humidity) are handled by the android app and send it to the sensor database (in server) frequently, such as for every 5 s/1 min. Thus the changing temperature and humidity inside the room will be monitored real time and can be seen in the *web-based sensor monitoring system*.

Third, for *TTI QR Code based Scanner App*, the QR code is printed on the TTI (Time Temperature Indicator) and attached on the product (kimchi package/box), thus the changing color in TTI will reflect the color QR code as well. Traditional QR code only represented as black and white, while in this study, the QR code color can be represented as a variety of *Color Lab Value* (can be seen in Table 1). Thus the functionality of *TTI QR Code based Scanner App* we developed in this study is

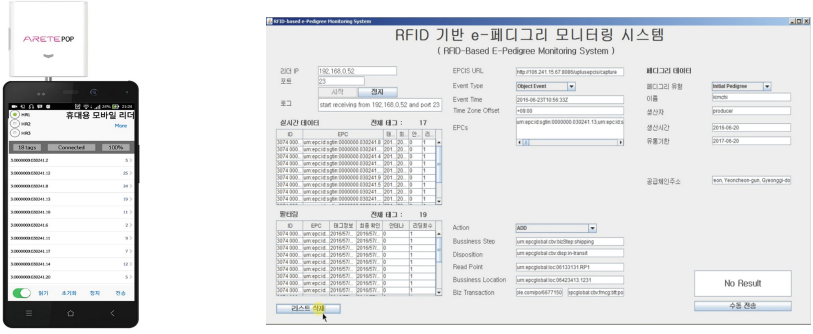
expected not only understanding hidden information of QR code but also understanding its color (color of TTI). Each information of color in QR code represents different quality of product. The detail information can be seen in Table 1. The TTI QR code which is attached on the product (such as kimchi box) will be captured by our *TTI QR Code based Scanner App*, detects the certain color and return the detail information which can reveal the product quality.

Table 1. Each color lab value of QR code represents different food quality.

TTI image	Food status	Detail	TTI description
	Good quality of product	색체계 L a b Color Lab Value 85.36333 -11.2733 -3.40667 색체계 R g b Color Rgb value 210.02 225.63 222.987	Just activated
	Still Fresh for current use	색체계 L a b Color Lab Value 84.58 -15.9433 -6.00333 색체계 R g b Color Rgb value 169.692 220.437 221.767	Still usable for food
	Almost expired	색체계 L a b Color Lab Value 82.39 -20.56 -10.67 색체계 R g b Color Rgb value 145.051 216.96 224.167	Almost expired
	Already expired	색체계 L a b Color Lab Value 79.83333 -23.1633 -14.41 색체계 R g b Color Rgb value 123.697 211.381 223.819	Already expired

3 Result and Discussion

For the implementation of *E-Pedigree Food Tracking system,* the RFID tags are attached on the Kimchi box which are delivered to the whole supply chain. The RFID reader (*ALR-9900* RFID Reader) read the tags, while our *RFID capturing application* receives the data and sends it to the server through HTTP protocol. The *RFID Capturing application* has received the tags data and presented in the left side of the program. The EPC document and additional pedigree data are generated in the center and right side of the program respectively, detail can be seen in Fig. 2(b).



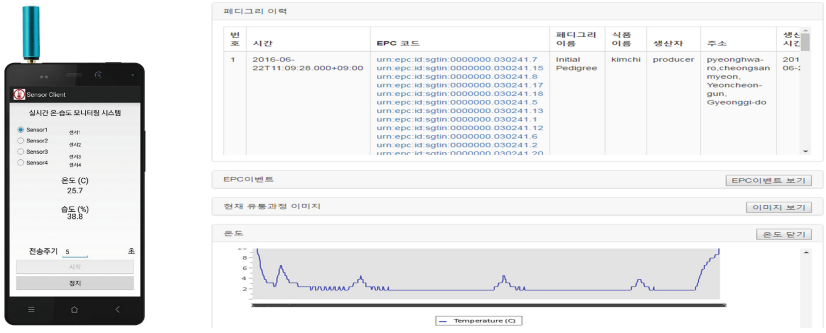
(a) (b)

Fig. 2. (a) The hand held reader and (b) RFID capturing application

In addition, the RFID reader (*ALR-9900* RFID Reader) is not suitable for flexible used, such as for truck driver. Thus in this study, we have developed *hand held RFID reader* based on android application. The RFID dongle reader (AretePop RFID Reader) is utilized to read the data, while the android app is developed to handle the data before sending it to the EPCIS server. The detail can be seen in Fig. 2(a).

For the *Real-time Temperature-Humidity Sensor*, the sensor device is used for the study. The sensor device (FTLab smart sensor) is attached to the Smartphone through the audio jack. The sensor data (temperature and humidity) is then gathered and presented on the Smartphone screen by the app we have developed. The detail can be seen in Fig. 3(a). The app can be used for different sensor functionality, i.e. in this study we utilize four sensors and installed in different location. In addition, the temperature and humidity is sent by the sensor device to the server frequently, thus the real-time temperature-humidity data of each location in Supply chain can be presented.

As can be seen Fig. 3(b), the *e-Pedigree food tracking system* based on the web is developed. The *e-Pedigree Food tracking system* present the history of product, the location and the temperature-humidity regarding the product, thus the manager can optimize the distribution of products as well as monitoring product quality.



(a) (b)

Fig. 3. (a) The handheld reader and (b) e-Pedigree food tracking system

Furthermore the *TTI QR Code based Scanner App* is developed in this study based on the android environment. Once customer open the app and put the camera of Smartphone above the TTI QR code in the correct position and good light condition, the app will automatically detect the information inside the QR code and its color. The app opens the other page which shows the detail quality of product. As explained before, the app analyzes the majority of color which contain in TTI QR code, then show the similar color which represent the quality of product. As can be seen in Fig. 4(a) and (b), the blue color of TTI QR code represents the good quality of product, safe to be consumed by customer.

(a)

(b)

Fig. 4. (a) The app scanned the TTI QR code based and (b) shows the product quality based on its color

4 Conclusion

This study has successfully implemented the *e-pedigree food tracking system*, which helped customers in order to assure the quality and safety of agriculture food products throughout the whole supply chain. By using this *e-pedigree food tracking system*, the customer can see the detail of food history from producer until retailer, thus they can believe that the certain product (or food) does not contains from illegal channels.

In addition, by utilizing wireless sensor networks (WSN), *the real-time temperature-humidity system* was developed to monitor the temperature-humidity of cold storage for whole supply chain. Thus the manager can monitor the temperature and humidity real time, and act accordingly if something happen (i.e., the temperature is not stable). In addition, by presenting the temperature-history in product pedigree, it will help the customer to understand the product quality in detail.

Furthermore, the *TTI QR Code based Scanner App* was developed to understand the color of TTI QR code which is attached on the product. The app was able to detect the information of QR code and its color which represent the quality of product. This app will help customer to analyze the color of TTI QR code and give the information of product quality to the customer easily.

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