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DEVELOPMENT OF AUGMENTED REALITY APPLICATIONS FOR REFRIGERATED WAREHOUSE

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Abstract. *Recently, refrigerated warehouses have been highly utilized for storage of fresh foods. Due to the globalization of the food market, changes in demand for marine products, and foreign trade open for marine products, refrigerated warehouses should be operated more efficiently and effectively. However, refrigerated warehouses in Korea are simply only performing storage functions; hence it is necessary to switch them into distribution center typed ones by developing and equipping with relevant solutions. Recently, the distribution logistics industry is required to introduce a real-time management system based on technologies such as Internet of Things (IoT), big data, and augmented reality (AR). Therefore, the purpose of this paper is to develop AR applications for cold chain management to be able to efficiently manage the refrigerated. The proposed application supports effective operation of the frozen warehouse. It is also expected to be used for building a cold chain network and a management system.*
Keywords: Cold chain management, Refrigerated warehouse, Augmented reality

1. **Introduction.** Recently, the fresh food market has been rapidly developed due to changes in consumers' perceptions and industry trends. Consumers are demanding low-priced and high-quality food, and it is necessary to provide a variety of services to meet the needs of such consumers while securing the competitiveness of fresh foods. There is a need to improve the logistics system of fresh foods to meet the customers' demands for products of higher quality. In order to adapt to an unexpected market environment, it is necessary to convert the existing logistics and control system of the refrigerated warehouse into a more integrated logistics system, which also requires a competitive management system. Until now, various researches have been conducted on general warehouses that store dry cargo using the latest technologies including IoT (Internet of Things), big data [1]. However, the interest in refrigerated warehouses is very weak. Refrigerated warehouses require different researches because they have various important characteristics compared to ordinary room warehouses, such as poor working environment, frequent breakage of stored products, freshness issues, and long-term storage of products due to difficulty in first-in and first-out selection. It is necessary to analyze the effect of applying the AR to

the logistic system as a part of the technology innovation that can improve the logistics system.

This research provides an AR-based methodology to increase responsiveness to uncertain events such as equipment failures and temperature changes in a refrigerated warehouse and to support real-time information. The ability to gather all information together and easily provide such information to the workers is one of intrinsic advantages of AR. The proposed methodology in this paper is to support the decision-making process and to overcome unexpected events, such as machines failure and abnormal temperature. The developed system can be operated on various operating systems such as iOS and Android using Unity [2]. In this study, we chose the Android-based application because of its wide usage in portable devices. Since the result of this study will be an open-sourced, the scalability of the developed technology is also considered. This research is expected to be the basis for the introduction of AR throughout the entire cold chain system. In addition, the proposed methodology is expected to be applicable not only to the cold chain but also to various industries such as manufacturing and service industries. The paper is structured as follows: Section 2 presents the literature analysis of the cold chain and AR; Section 3 deals with the use of AR in a refrigerated warehouse; Section 4 explains the methodology and applications; finally, Section 5 includes some concluding remarks.

2. **Literature Review.**

2.1. **Cold chain.**

Frozen and refrigerated warehouses are warehouses with refrigeration and refrigeration facilities for keeping seafood and meat products fresh [3]. Because of the role of storage, which is a major part of the distribution of fresh food, there is a growing interest in the management of refrigerated warehouses [4]. Cold chain refers to a system for distributing logistics objects while maintaining a low temperature. Unlike general products, agricultural products, aquatic products, meat products, and medicines, which are applied to cold chain logistics, require continuous management of temperature and humidity [5]. Due to the characteristics of cold chain, various researches have been conducted on the operation status and improvement plan of the refrigerated warehouse [6,7]. In addition, a study on operational planning to improve the efficiency of the refrigerated warehouse system by separating the picking and storage areas has been conducted [3].

2.2. **Augmented reality (AR).**

AR is a technology derived from a field of virtual reality (VR), and refers to a computer graphics technology that superimposes virtual contents created in 3D in the real world of the user's eyes [8]. Techniques for providing enhanced visualization information and interacting with various types of users using augmented reality technology using mobile devices or wearable devices have been studied [9-12].

The existing refrigerated warehouses, which have only the function of simple storage, have a standardized distribution system to improve the efficiency and competitiveness of the entire logistics supply chain management. Table 1 shows the comparison of identification technologies. Previously, barcodes were widely used for logistics management. However, bar code technology has many drawbacks. For example, the recognition distance is limited and cannot contain a lot of information. Due to such problem, researches on radio frequency identification (RFID) technology have been conducted recently. RFID is a technology that recognizes information of a tag attached to an object through radio waves in a non-contact manner, and stores and processes the collected information [13]. Through this technology, the entire logistics information can be grasped. However, RFID also has some problems such as expensive tag prices, usage of different radio frequencies in each country, differently in recognition of RFID tag because of disturbance from material such as metal and liquids.

Table 1. Comparison of identification technologies

Division	Barcode	RFID	AR
Data type	Only number	Any type	Any type
Access online	Cannot	Cannot	Can Access directly
Cost	Negligible	$\$0.1 \sim \$50$	Negligible
Read/Write	Read only	Read/Write	Read/Write
Reading	1 item	Multiple items	Multiple items
Standardization	Yes	No	Not necessary
Interference	Obstructed barcodes cannot be read (Dirt covering, torn, etc.)	Influenced by metal and liquids	Detects even when dark lighting or part of the target is covered
Decoder device	Barcode reader	RFID reader	Any PC, Mobile which has decoder software

2.3. **Controllability reinforced manufacturing.** Prior to this study, we studied the controllability reinforced manufacturing (CRM) in a manufacturing area. Because of disconnection with actual manufacturing facility data, such data cannot flow in the manufacturing system. Because of these problems, we suggested CRM in the previous study [14], which can be considered as a kind of cyber-physical production system (CPPS) that enhances the function of equipment control in the concept of existing AR-based manufacturing. Controllability refers to the ability to control from a particular equipment to the overall system by adjusting the input parameters of the system. When a specific parameter can be controlled, the state variable is controllable. The system is said to be controllable when all state variables of the system are controllable. In CRM environment, it is possible to verify and predict such state variables through process simulation from the product design stage to the actual process. In addition, the AR-based system enables real-time on-site monitoring, comparison of performance against plans, functional visualization through manufacturing execution system (MES) linkage, and facility control and management.

3. The Use of AR in Refrigerated Warehouse.

3.1. **AR in cold chain system.** Cold chain refers to a distribution system that maintains the proper temperature from production to consumption as the object to be preserved at low temperature as shown in Figure 1. Although AR is in relatively initial stages of adoption in logistics, it could offer significant benefits. For example, AR can give logistics providers quick access to anticipatory information anytime and anywhere. Managers and workers can access the real-time logistics information through AR devices. This is crucial to achieving load optimization and accurate planning and operation. This study aims to develop a new management system in a refrigerated warehouse as shown in Figure 1. Especially, in the case of refrigerated warehouses, it is necessary to provide value-added services as a distribution center that integrates various functions such as packaging, assembly, processing, sales, exhibition, and marketing as well as storage only. This means systems must be redesigned to accommodate these new services.

The AR can be used to visualize the proposed information in the current real warehouse environment. Also, it can be used to display information in real time in the worker's field of vision. AR systems can provide the worker with critical information displays on their cargo such as confirmation of cargo temperature. AR devices also could help by replacing the need for printed cargo lists and load instructions. AR supported cargo lists would also allow for real-time information generated quite often during the loading process.

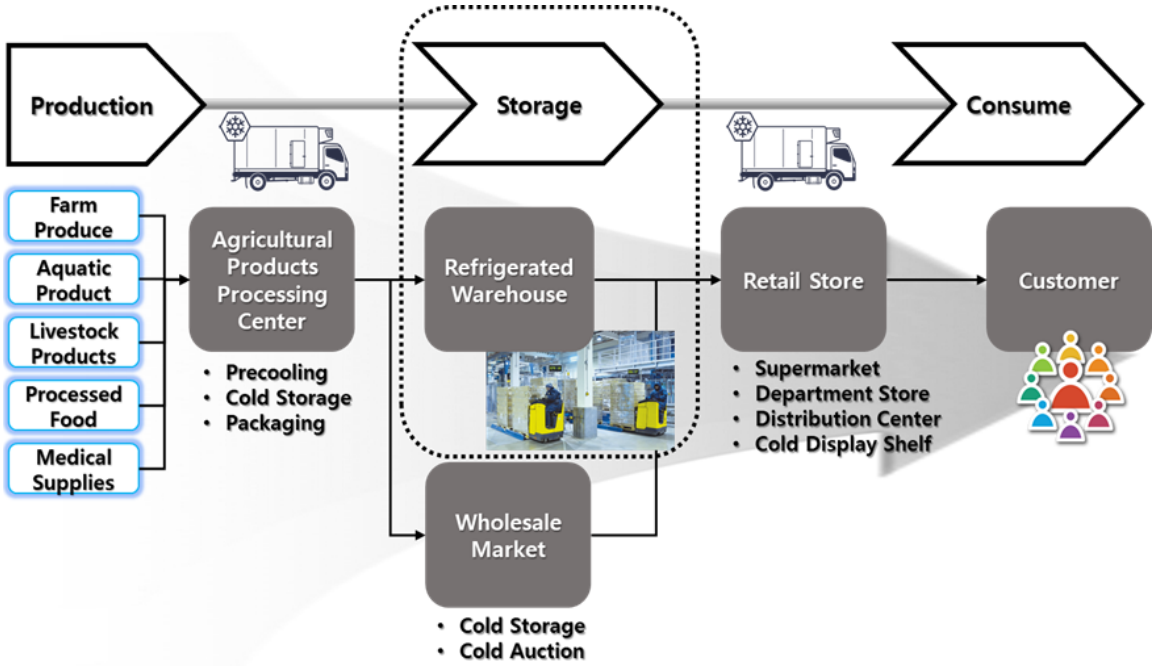

FIGURE 1. Cold chain system structure

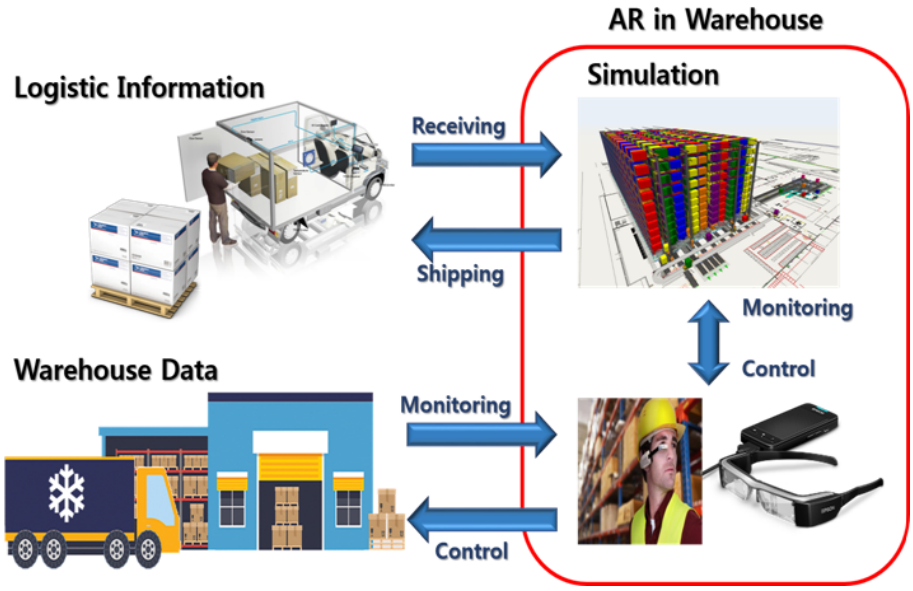

FIGURE 2. The structure of AR used in refrigerated warehouse environment

3.2. **AR in refrigerated warehouse.** As shown in Figure 2, the integrated management system using the AR proposed in this study means a real-time control and management system for the refrigerated warehouse. The proposed system is able to compare the logistics status, simulation result, and input/output plan of the cold chain in real time. Also, it can reduce the loss of time and resources by providing the information that the operator and the manager want in real time through the AR. Furthermore, through the control of the storage facility and the transportation equipment, it is possible to expect the performance such as the improvement of the operational efficiency and the establishment of the optimal operation plan based on the simulation result, and the prediction result can be immediately reviewed in the field by applying the changed facility control to the simulation. It is also possible to control simple facilities in the field if necessary. The proposed AR technology-based facility recognition function extracts the features of

various facilities. This allows the facility to match the unique information it has. In other words, the management data according to the characteristics of the facility can be defined differently, and the manager can automatically pop up the data that he or she intends to check. This application can recognize various images or texts and recognize multiple image targets. In addition, powerful tracking of the target prevents data loss when moving equipment, and provides a reliable recognition rate for target detection even in dark lighting or in areas where a part of the target is hidden. To recognize the equipment through AR technology, we can use various mobile equipment including camera (e.g., mobile phone, tablet PC and smart glasses).

4. Development of AR Applications for Refrigerated Warehouse.

4.1. **System definitions.** The methodology of AR-based facility identification and data linkage (ABIL) is composed of facility monitoring technology and interactive interface technology. Facility monitoring technology allows facilities to be identified through AR and to pop-up related data for monitoring. This technology identifies the facility as a unique object through AR identification technology and imports predefined data from database. Interactive interface technology makes it possible for a worker to identify immediately visualized defects in the field, the abnormal condition of equipment, the information of the logistic plan, and the working instruction. The system proposed in this study can be applied to inventory identification for inventory management and product location in a warehouse, as well as identification of shipping and receiving status.

Figure 3 shows a conceptual diagram of ABIL. Through the proposed interaction system, as shown in Figure 3(a), data can be acquired from the facility and facility data can be provided to the simulator. Input data are transmitted to the system server through the wireless Internet, which is converted into query statements in the server and input to the DB. In this research, an AR environment has been implemented in which the operator can monitor equipment data by linking the AR equipment and DB. As a result, real-time synchronization between legacy systems including the simulator and the data management system is performed as shown in Figure 3(b). Therefore, we can acquire the basic technology to implement the bidirectional interaction system over the entire process from the AR module to the AR device.

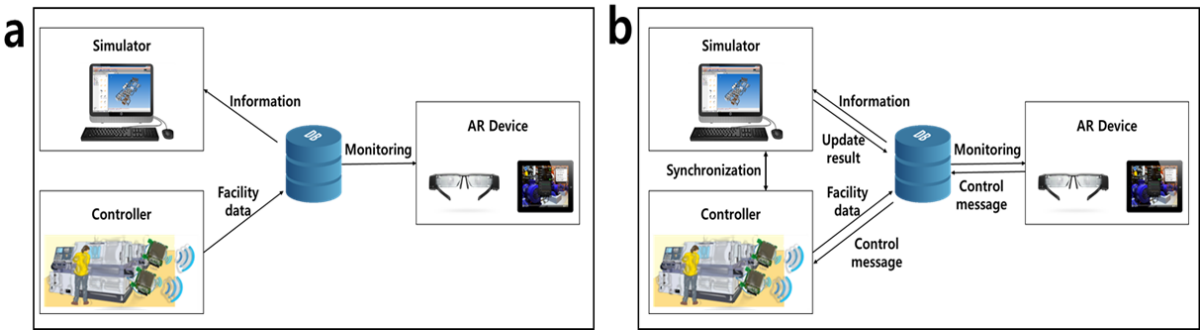

FIGURE 3. (a) One-way interaction system; (b) two-way interaction system

4.2. **System development environment.** In this study, an application development environment has been developed by using an image target and a virtual button that are linked to a tracker by camera rendering by using Vuforia [15] and Unity based on Android. Vuforia is an AR software platform that uses AR capabilities to create powerful programs. Various images or texts can be identified and multiple image targets can be identified. Unity is an integrated development environment (IDE) which is used for the development of the application, in order to enhance the representation of 3D objects. By using Unity,

developers can develop 3D-optimized programs in an easy and intuitive work environment. In addition, Unity also supports multi-platform applications and can be applied to various platforms as well as Android and iOS. The reason to choose Android-based approach is that it is widely used in portable devices. Applications can be executed not only on Android but iOS, and various other environments as well. This is effective in the logistic field where various AR equipment are combined. The developed application visualizes actual logistics data and simulation results to the manager in real time through the AR device. Managers can make decisions and verify logistic plans based on the simulation results.

4.3. **Data linkage function.** When the facility identification is completed, data that are matched with equipment should be extracted. To extract the data, the DB is connected using the primary key defined for each facility. In this study, we use MySQL DB which is one of commonly used databases for storing and processing data. In order to receive the values stored in MySQL, which is a relational DB, from the Android application, it is necessary to connect DB to the Android-based devices. However, according to Android's security policy, it is impossible to access a relational DB directly. In this study, therefore, we implemented the interworking using the method of connecting the DB through the web such as hypertext preprocessor (PHP) or Java server pages (JSP). When information in DB is loaded into Android, such information can be used after changing the data exchange format by parsing in the form of JavaScript object notation (JSON), which is an open standard format. Once these tasks are completed, an environment in which equipment identified key facilities can be retrieved from DB is established.

4.4. **User interface.** To build an AR interface, Qualcomm Vuforia module is used by employing Unity engine. Figure 4 shows some of screenshots of the implemented ABIL system. Figure 4(a) shows the basic screen of the application. The user can monitor desired information such as facility number, storage level, storage period, and shipment information of the identified equipment. The aforementioned information is predefined and can be freely set according to the characteristics of the administrator and the facility.

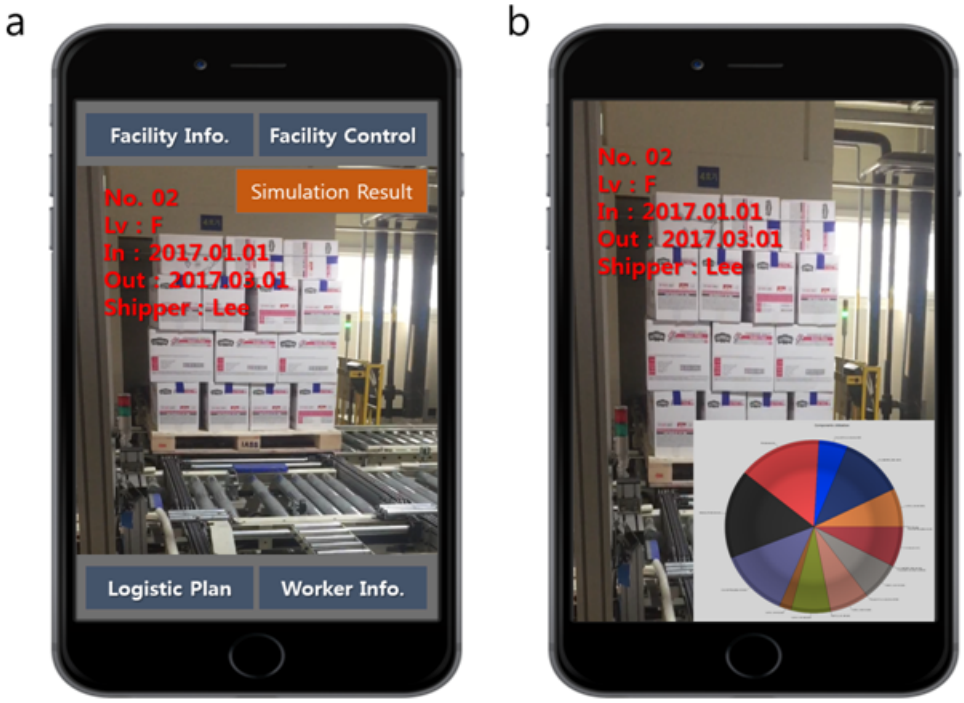

FIGURE 4. (a) Basic screen; (b) simulation result screen

In addition, a user interface was created to show a virtual button on the basic screen of the application to access the detailed items. For example, when the simulation result button in Figure 4(a) is clicked, the screen showing the simulation results as in Figure 4(b) appears. Also, the detailed facility information that is not displayed on the basic screen can be retrieved through virtual buttons in the screen, and it is possible to expand to the function of information input and facility control information transmission/reception which are currently being implemented. This allows the operator to implement a user environment that can be controlled in the event of an emergency.

5. **Conclusions.** In order to improve the competitiveness and operation efficiency of the refrigerated warehouse, a management and monitoring system is crucial. This study proposed the AR-based methodology to improve the controllability of equipment by linking the AR equipment with equipment data and finally implemented the demonstrative system. The developed system is a monitoring system that can verify equipment and process data at the site through wireless connection of AR equipment and DB. It consists of a user interface that enhances facility controllability through virtual buttons and enables the operator to control facilities and transmit data in an actual environment through an interoperable interactive environment. This study is meaningful in that the proposed system can monitor the facilities and check the possibility of control by incorporating AR technology into the refrigerated warehouse. Other relevant issues, such as supporting environmental information and decision-making environment in the field through interworking with various logistics management systems will be included in future works. Expansion of this research will be expected to support the environment that can deal with various facility information and decision results on the field through interworking with various logistics systems.

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