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The Research of Interworking System for Closed Plant Factories

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식물공장을 위한 인터워킹 서비스 시스템에 대한 연구

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Abstract The plant factory represents one of the future agricultural systems into which ubiquitous information technology (U-IT) is incorporated, including sensor networking, and helps minimize the influence of external experimental factors that constrain the use of existing greenhouse cultivation techniques. A plant factory's automated cultivation system does not merely provide convenience for crop cultivation, but also expandability as a platform that helps build a knowledge database based on its acquired information and develop education and other application services using the database. For the expansion of plant factory services, this study designed a plant factory interworking service (PFIS) which allows plant factories to share crop growth-related information efficiently among them and performed a test on the service and its implementation.

Key Words : Convergence, Plant Factory, Vertical Farm, Interworking Service

요 약 식물공장은 센서네트워크를 비롯한 U-IT 기술이 접목된 미래 농업기술 중 하나로서 기존 온실재배 기술의 한계인 외부 환경적 요인의 영향을 최소화 할 수 있는 장점을 갖고 있다. 식물공장의 자동화된 재배 시스템은 작물 재배에 대한 편의 제공이라는 단순한 범위를 벗어나 식물공장에서 취득된 정보을 기반으로 하는 지식베이스의 구축과 이를 활용한 교육, 기타 응용 서비스 개발이 가능한 플랫폼으로서의 확장성을 제공한다. 본 논문에서는 식물공장의 서비스 확장을 위하여 식물공장 간 작물생육과 연관된 정보의 효율적 공유를 위한 Plant Factory Interworking Service(PFIS) 를 설계하고 이에 대한 구현 및 서비스 테스트에 대한 연구를 수행하였다.

주제어 : 융합, 식물공장, 수직농장, 인터워킹 서비스

1. Introduction

Recently, there has been increasing concern over the future food due to environmental pollution and abnormal climate changes, with changing consumer preferences (e.g., to seek easy access to cleaner and safer farm products); as a result, this has contributed to highlighting the need for changes in the agricultural production environment. Plant factories are researched in response to those changes and as a technical

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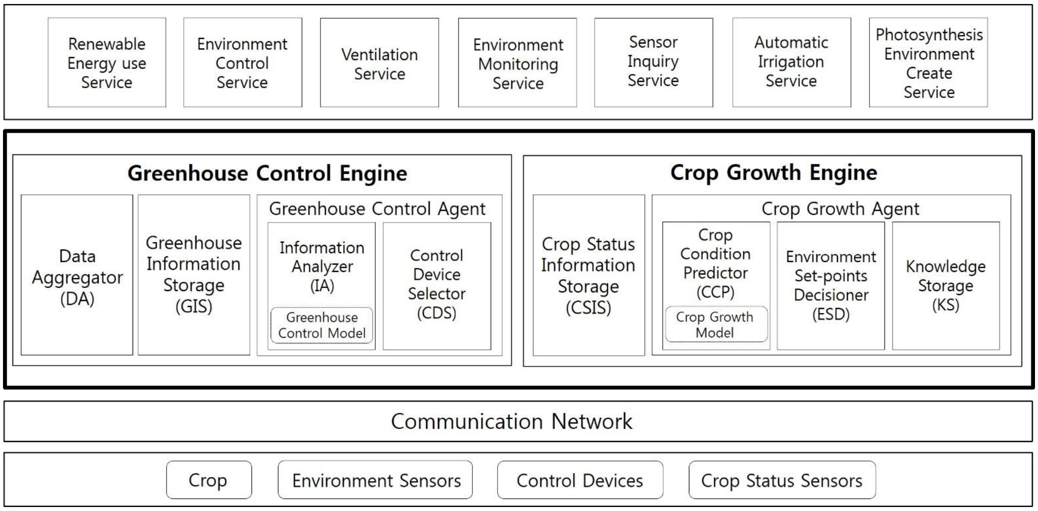


Fig. 1. Greenhouse Management Framework

alternative to future agriculture. A plant factory is a new agrotechnology system developed through a fusion of agriculture and information technology [1-3].

It allows agricultural production to be diversified in a more flexible way by expanding farming into a base platform with minimal dependence on the existing simple production systems for greenhouse or outdoor culture. The automated system technology of plant factories can help improve the accessibility of non-professional farmers to crop cultivation and enables the factories to create a knowledge base through information exchanges and develop service models such as standard growth models for crop cultivation. Derivative applications based on plant factories require services for the inter-factory exchange and sharing of diverse information about crop growth and development. This study designed and constructed an interworking service for information sharing between plant factories so that those services can be made available[4-6].

2. PLANT FACTORY INTERWORKING SERVICE (PFIS)

So far, a wide variety of studies have been conducted on information technology (IT) applications in agricultural environments, and there are an increasing number of cases where their findings are applied to real-world crop-growing conditions. Recent studies are more than just attempts to promote the efficiency of crop cultivation and tend to pay a lot of attention to automated agricultural production systems. With plant factories being a primary focus of such attention, there is a growing need for studies focusing on how information about farming environments accumulated with a wide range of information technologies should be developed into effective services [7-10].

Previously, we investigated a greenhouse management framework (GMF) for ideal greenhouse control and attempted to apply the framework to plant factory systems by modifying and refining it for such purpose [11-16]. Figure 1 shows the GMF.

In the present work, the GMF's automated control strategies and data analysis algorithm exhibited higher reliability when they were applied to plant factories, than to greenhouse environments. This makes sense because our analysis revealed that the influence of changing external environmental conditions during crop cultivation was relatively low in plant factories, compared to greenhouse environments. Success in crop production is influenced by many different environmental factors. If the influence of environmental factors were great under particular growing conditions, the usability of information acquired in the course of crop cultivation would be limited only to such conditions. However, plant factories typically provide similar growing conditions to crops of the same species. This suggests that the data collected and accumulated under a wide variety of growing conditions can be valued as universal information sources for plant factories.

That's why we examined the applicability of the GMF as a plant factory system and investigated plant factory interworking services for effective collection of crop production-related information from different plant factories.

2.1 Service Overview

As shown in Figure 2, the PFIS refers to an automatic service that helps the same or different types of plant factories to exchange and accumulate those data acquired from them. In each plant factory, the sharable data defined by the manager is accumulated in its shared database via the interworking service and made available for a wide range of database-based applications. One reason for service operations at an application level is that it is necessary to take into account the cases where two plant factories have different sub-platforms.

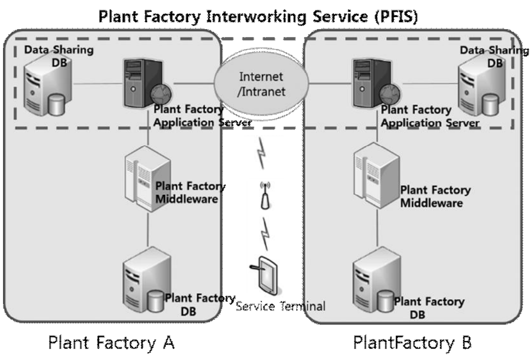


Fig. 2. Plant Factory Interworking Services.

2.2 Service Structure

As shown in Figure 3, the PFIS is divided into two service areas: server and client services. Each service area consists of three different levels: interworking service database (ISDB), interworking service interface (IDI) and interworking service application (ISA).

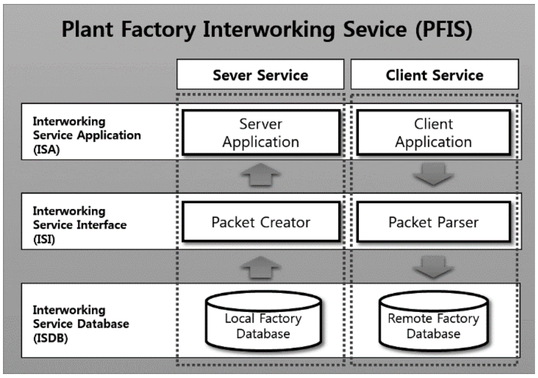


Fig. 3. Plant Factory Interworking Service Structure

2.2.1 Interworking Service Interface (ISI).

The ISI consists of a packet creator and packet parser–which are components for the efficient processing of information intended to be shared between plant factories–and includes a protocol for transmission of packets generated by requests from each server and client. The packet creator defines the data packets the server intends to send, while the packet parser serves to convert the data received from the server into a form storable in the remote factory database. Figure 4 shows the process flow of the ISI. For data transmission and process in the ISI, this study predefined some packets for data intended to be shared between plant factories. Information directly related to crop cultivation was classified into three categories: crop growth information, factory environment information and, environment devices status information. Basically, each packet was composed of a fixed-head field and unfixed-head field: The fixed-head field was created to contain information applying in common to all messages, and the unfixed-head field was individually defined according

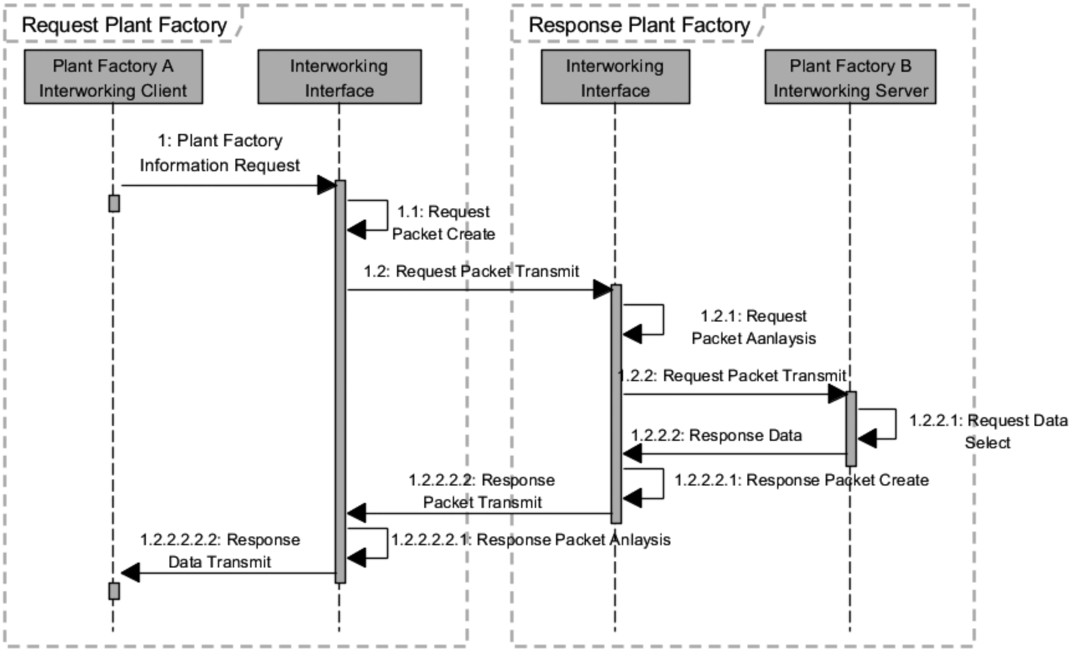


Fig. 4. Interworking Services Squence Diagram

to the type of requested information.

Data packets are divided into three types: environment information, control information and growth information. Table 1 is an example showing the composition of a predefined environment information packet.

Table 1. Packet Example (Environment Information)

Field Type	NO	Field Name	Code	Type	index	Length
Fixed	1	Trans Date	001X	STR	8	8
	2	Trans Time	002X	STR	14	6
	3	Msg Type	003X	STR	18	4
	4	Tran-ID	004X	STR	22	4
	5	Message NO	005X	STR	28	6
	6	Plant Factory ID	006X	STR	36	8
UnFixed	7	Measurement Date	007X	STR	44	8
	8	Temperature	008X	STR	48	4
	9	Humidity	009X	STR	52	4
	10	Illumination	010X	STR	56	4
	11	CO2	011X	STR	60	4

2.2.2 Interworking Service Database (ISDB).

The ISDB is divided into two different sub-databases: a local factory database for a local plant factory's data to be shared with other plant factories and a remote factory database for storage of data collected from remote plant factories. Each sub-database consists of four tables, namely Plant Factory Info, Environment Info, Device Info and Crops Info. Each data is transmitted after conversion into server and client data packets via the interworking

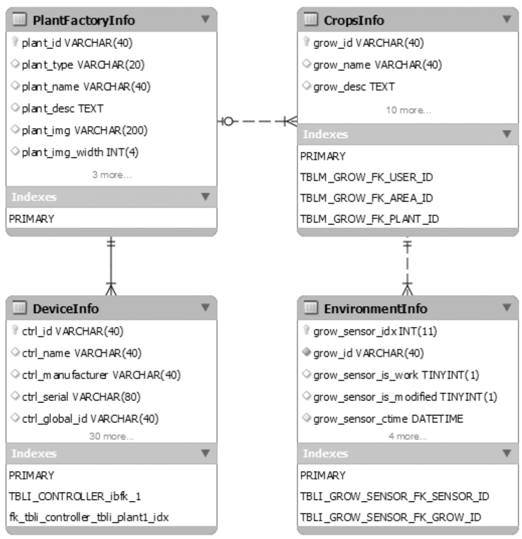


Fig. 5. ISDB Schema

service interface and stored in each table after reconversion via the client's interface. Figure 5 shows the schematic structure of the ISDB.

2.2.3 Interworking Service Application (ISA).

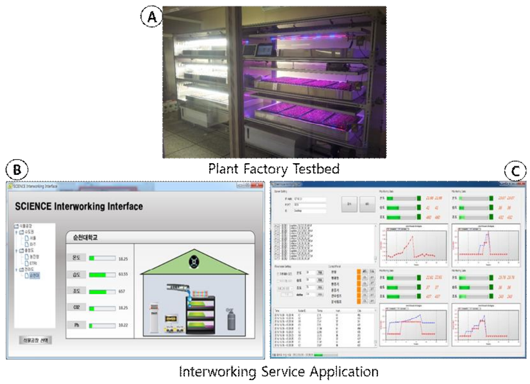
The ISA for testing has been developed as an application that performs server and client functions. The ISA runs always on both the server and client PCs driving the service, acquires sharable information for the interworking service on a regular basis from the main database of each plant factory, and sends the collected information to the client side.

The ISA's key features are as follows:

- Service registration
  - In common: Making a server-client connection and setting the cycle of sending and receiving information.
  - For the server: Registering information on remote plant factories that want the interworking service. Required information includes the remote interworking service server's IP address and user information.
  - For the client: Defining information to be shared and matching the field names between a plant factory's database and the interworking service's local factory database.
- Information transmission and reception
  - Sending and receiving in a timely manner the information shared between the server and client. Such information is converted into a defined packet format for transmission.
  - For the server: Importing a local plant factory's shared information from the local factory database and, upon request from the client, transmitting the shared information after conversion into the packet format of the interworking service.
  - For the client: Requesting shared information from the server and converting and storing the packets received from the server in the remote factory database.

3. SERVICE IMPLEMENTATION AND TESTING

The Java Development Kit (JDK SE 7) was used as an SDK for construction of the proposed service, and MySql 5.x was employed to build a database for storage of shared data. In this study, the information used for testing (i.e., environment, crop growth and device status) was collected while leaf lettuce was grown in a self-created testbed environment, and data from the previous cropping season was used as data for the remote plant factory.



The application was configured to run at all times on two PCs and gather updated data between plant factories on a regular basis (or at intervals of ten minutes). Further, the application for testing included an additional feature for the comparison of data between two plant factories. Figure 6 shows a plant factory testbed environment created for testing purposes and the operating status of the service application.

'Ⓐ' is a 6-chamber plant factory test bed. Temperature, humidity, illuminance CO2, PH sensor are installed.

'Ⓑ' is the service monitoring screen of the interworking interface. Displays recent environmental information of selected plant factories.

'Ⓒ' is an additional service screen for graphically showing the environmental change of the selected plant plant.

4. LIMITATIONS AND FUTURE PLANS

In this study, the tests found that the regular collection of shared information took place in a stable manner. In the future, with the application of technology for creation of dynamic databases, the interworking service will be further improved in terms of service expandability and adaptability.

Future studies need to focus on determining the effective scope of data sharable between plant factories, with the attempts to reduce the unnecessary amount of collected data. Since plant factories do not involve rapid changes in the internal environment unlike greenhouses or outdoors, the data on crop growth in them is likely to form a relatively gentle curve. This can be settled by finding an appropriate value for the cycle of data collection between plant factories.

5. CONCLUSION

The present study implemented and tested an interworking service designed to define packets for information sharing between plant factories and include databases of shared information. This study is an attempt to develop a service that helps collect and accumulate valid data related to crop growth among plant factories growing crops of the same species. Data from this work could be used in future studies regarding the development and optimal control of ideal engines for plant-factory-based crop growth and in a wide range of other plant-factory-based applications. Further, the service is expected to be extendable to many different types of food production systems combined with sensor networks.

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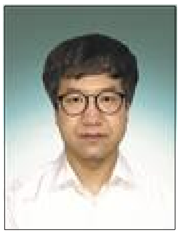

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