A Study of an Agricultural Ontology Model for an Intelligent Service in a Vertical Farm

Taehyung Kim, NamJin Bae, MyeongBae Lee, Changsun Shin,
Jangwoo Park and Yongyun Cho*

*Dept. Information and Communication Engineering, Sunchon National University,
413 Jungangno, Suncheon, Jeonnam 540-742, Korea
{taehyung, bakkepo, csshin, jwpark, yycho}@sunchon.ac.kr*

Abstract

The development of agriculture has led to the development of civilization. In other words, the development of agriculture is one of the most important factors to the development of human life. So, many studies for the recent agricultural environments focus on the IT-agricultural convergence to aim for smart and ubiquitous agricultural services. However, most of existing IT-agricultural technologies for smart services in agricultural environments are less flexible or less real time because they tend to be dependent on particular systems and use a few of fixed environmental data. And also they always need a human intervention about a variety of exceptional situations. To resolve the limitations and disadvantages, this paper designs the vertical farm ontology that is defined as the environmental, control factors and relationship between each factor for the crop growth using OWL based on RDF. The defined factors in the vertical farm ontology can be extended continuously, and its knowledge can be shared and reused in a various domains of agricultural environment.

Keywords: *Ubiquitous Agriculture, Context Modeling, Ontology, Smart Service*

1. Introduction

Understandably, humans and agriculture are inseparable. However, the cultivation area has gradually decreased, because of the continued population growth and the urbanization and the anomaly climate such as lack of sunlight, frequent precipitation, unusually high or low temperatures and global warming. In addition, the continuous decline and aging of the agricultural workforce have caused the risk such as the unstable supply and price hikes of agricultural products. Therefore, to solve these problems, the vertical farm as an alternative has emerged.

The vertical farm is a continuous production system that cultivates crops without the human intervention through the automatic control in a suitable space for the crops growth environments such as light, temperature, humidity, carbon dioxide levels, and nutrients [1]. Therefore, with the introduction of the vertical farm, agriculture stands on the systemized and automated steps of the new agricultural revolution through the convergence of various latest technologies. For the new agricultural revolution, many researches and developments are under way to provide smart services, and their goal is the same that they want to create ubiquitous environments in the vertical farm. However, existing smart services have the limitation and disadvantages as follows.

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* Corresponding Author

1. Most existing smart service systems are dependent on the particular system. So, in order to extend, fix or delete a service, it should be handled by the original developer.

2. And they have a less reliability because of few fixed environmental factors or control factors for the crops growth.

3. And also they always need a human intervention about a variety of exceptional situations during the services.

To solve this limitation and disadvantages, this paper designs an ontology-based context modeling for an intelligent service in the vertical farm. The vertical farm ontology is defined as the environmental factors and control factors and relationship between each factor for the crop growth using OWL based on RDF. The defined factors in ontology can be extended continuously. And knowledge of the vertical farm ontology can be shared and reused in a various domains of agricultural environment. And it is provided by web-based platform so it is independent in the particular system. Using this vertical farm ontology, the situation from the real world can be represented by the context-information that human, as well as a computer can understand. Therefore, a computer is able to recognize a situation themselves without a human intervention. Through this paper, intelligent services for the optimal growth of crops can be provided without a human's interference in a vertical farm.

2. Related Work

The purpose of ubiquitous computing is to provide the necessary services to users at anytime and anywhere through the convergence of a various science and technology [2].

One of many studies using ubiquitous computing is u-agriculture. U-agriculture combines IT skills in each steps such as production, quarantine, distribution, consumption. U-agriculture is fusing with IT skills in each step such as production, quarantine, distribution, consumption in the narrower sense. it's goal is not increasing productivity but verifing safety. The system is to improving productivity and quality by providing crops with an optimal growth environment through monitoring and control in manufacturing step.

Likewise, many studies about u-agriculture are underway to develop a service platform. However, most of the existing service system or platform just focuses on monitoring and automatic process controlling [3-4].

For more intelligent services in greenhouse or vertical farm, it is essential that computer can understand a situation from the real world. In order to do that, context modelling is needed for agriculture. The ways of a context modeling are Key-Value Models, Markup Scheme Models, Graphical Models, Object Oriented Models, Logic Based Models Ontology Based Models, and so on. Through this survey, as shown in Table 1 [5], the Ontology based Models is the best way to design a vertical farm environment. The component of ontology consists of class, instance, relation, property. The ontology language is used RDF, OWL, SWRL, and so on.

Ontology is a description (like a formal specification of a program) of the concepts and relationships that can formally exist for an agent or a community of agents. This definition is consistent with the usage of ontology as set of concept definitions, but more general. And it is a different sense of the word than its use in philosophy [6].

Table 1. Appropriateness Indication [5]

Approach - Requirem.	dc	pv	qua	inc	for	app
Key-Value Models	-	-	–	–	–	+
Markup Scheme Mod.	+	++	-	-	+	++
Graphical Models	–	-	+	-	+	+
Object Oriented Mod.	++	+	+	+	+	+
Logic Based Models	++	-	-	-	++	–
Ontology Based Mod.	++	++	+	+	++	+

Many studies are underway for intelligent service in a smart farm [7-8]. However, more research and implementation are needed because the u-agriculture is in the beginning step.

3. A Vertical Farm Ontology

In this chapter, we propose and design an ontology-based context modeling for an intelligent service in a vertical farm. As the first step, the situation factors that could be considered in a vertical farm is classified and defined. Then, ontology for a vertical farm is designed by using OWL based on RDF. Finally, this paper validates ontology for a vertical farm through an ontology reasoner and a research engine for the applicability in intelligent services. The ontology development tool is a Protégé 4.2.

3.1. Situations Categorization for a Vertical Farm

For the higher level intelligent services, situations that are considered to cultivate crops in a vertical farm are categorized and defined as shown in Table 2. This categorization is based on the standardization process of a vertical farm in Korea.

Table 2. The Category of a Vertical Farm

Main Category	Sub Category	Sub Category
Crop Growth Knowledge	Crop	Species, Name, ...
	Growth Environment	Temperature, Humidity, Light, Sunshine hour, …
	Growth Status	Leaf, Root, Stem, …
	Disease and Pest	Disease, Pest, …
Vertical Farm Environment	Location	Building, Floor, Room, Sector, …
	Facility	Control Devices, Monitoring Devices, …
	Environment	Atmosphere, Nutrient Solution, Soil, Season, …
	System	Access, Network, …
	Person	Administrator, Staff, Public, …

The 2 main categories compose the situation of a vertical farm. Crop Growth Knowledge has sub categories related to information of a crop growth. Crop is defined for the categorizing all species of crops. Growth Environment consists of the factors that crops are needed to grow up. In Growth Status, it helps to confirm a current crops growth status through a rate of growth from leaves, stems and roots of the crops. Disease and Pest define all of the information associated with the diseases and pests that can occur during the cultivation.

Vertical Farm Environment has sub categories related to every situation inside of a vertical farm for a crop growth. Location consists of any location information that can be defined. Facility consists of the definition of control devices and sensor devices in a vertical farm. Environment is divided into the internal and the external climatic environment. System defines a system, network property and an access method. In order to grand access permissions, Person separates insiders and outsiders.

3.2. Design of a Vertical Farm Ontology

The first step in design of ontology for a vertical farm is to design a class model. The second step is to design individuals. The final step is to design properties between each class and individual.

The class model is designed based on categorization in Table 2. In this paper, ontology for a vertical farm focuses on crops growth. Therefore, the individuals are defined according to the scenario that cultivates cabbages in a vertical farm. The Figure 1 shows a class representation of ontology for a vertical farm.

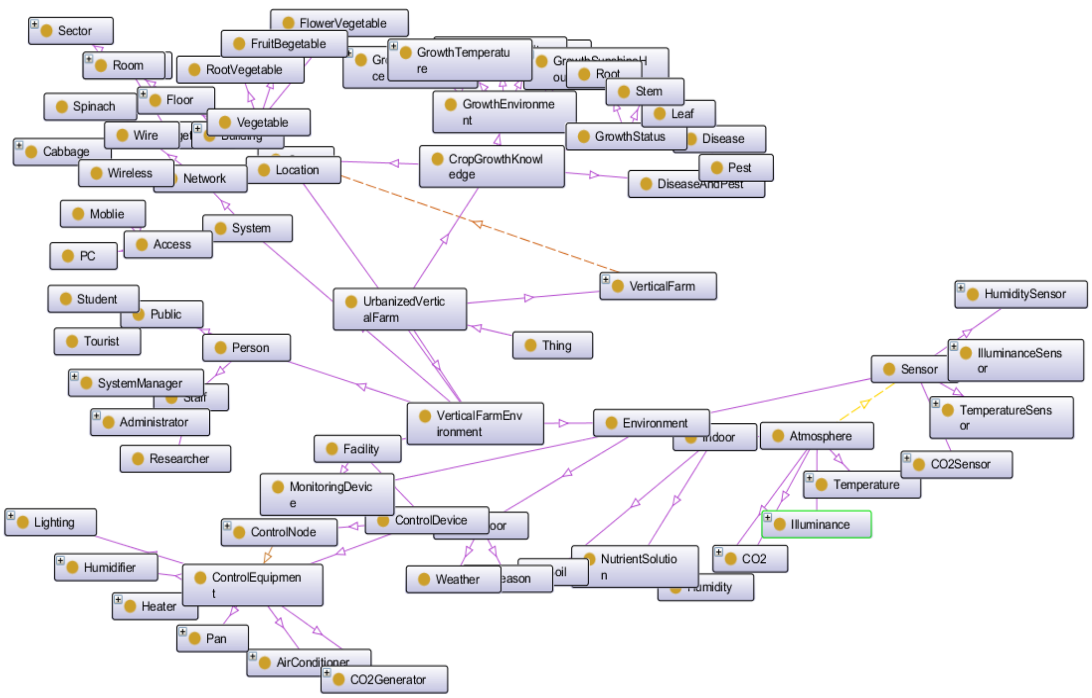

Figure 1. The Class Representation of Ontology for a Vertical Farm

The Properties are divided into the Object Property and the Data Type Property. The Object Property defines relations of each class and individual. The Data Type Property defines relations between individual and real data. Naturally, the more relations are defined, the more situations can be expressed in a vertical farm environment.

3.3. The Class Model Design of a Vertical Farm

As Figure 2, the class of composing Vertical farm ontology consists of 'VerticalFarm', 'VerticalFarmEnvironment', 'CropGrowthKnowledge'.

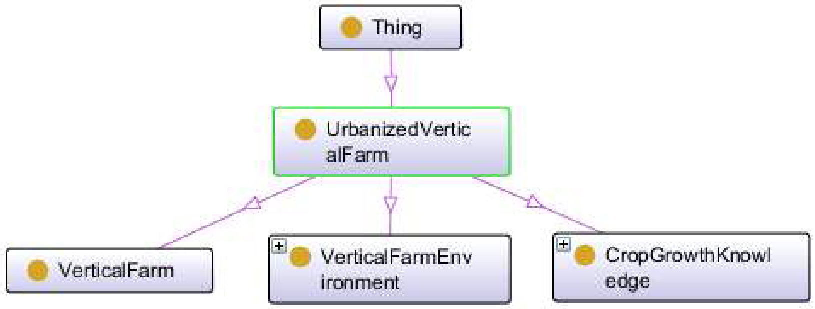

Figure 2. VerticalFarm Class Diagram

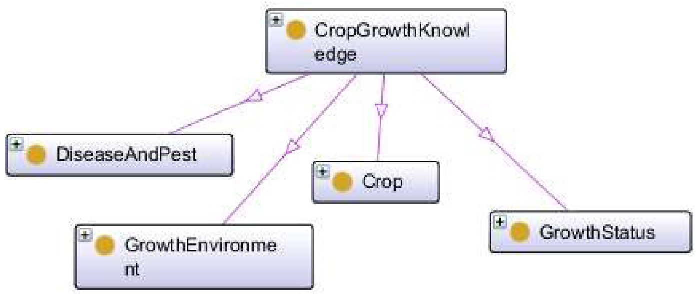

Figure 3. CropGrowthKnowledge Class Diagram

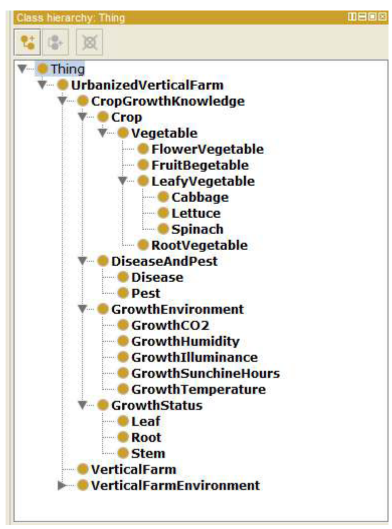

Figure 4. The Hierarchy Structure of 'CropGrowthKnowledge' Class

'VerticalFarm class' is a class for the actual vertical farm and 'VerticalFarmEnvironment class' consists of internal/external environmental factors required in vertical farm. 'CropGrowthKnowledge class' consists of factors class related growth of crops and crop. As Figure 3, 'CropGrowthKnowledge class' has crop class, DiseaseAndPest class, GrowthEnvironment class and GrowthStatus class.

Each defined sub-classes have a hierarchy, such as Figure 4. The crop class divided best advantageous vegetables in vertical farm. And the vegetables re-divided 'FlowerVegetable', 'FruitVegetable', 'LeafyVegetable' and 'Root vegetable'. It is always possible to expand the redefinition.

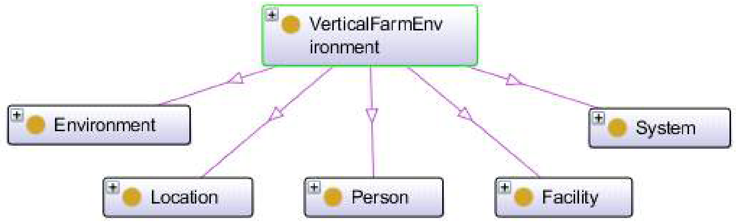

Figure 5. 'VerticalFarmEnvironment' Class Diagram

The Figure 5 shows a diagram of the 'VerticalFarmEnvironment' class. The 'VerticalFarmEnvironment' class consists of environment, location, person, facility and system.

The 'Environmet' class defined environmental factors of inside and outside in vertical farm. The 'Facility' class defined component and device for installed device on the inside of vertical farm. The 'System' class defined factors for connection status and network status on the inside of vertical farm. And the 'Person' class defined by separating the manager of a vertical farm and external person. Finally, 'Location' class defined by separating each area of vertical farm for recognizing location of user and devices. Figure 6 is the hierarchy structure of 'VerticalFarmEnvironment' class.

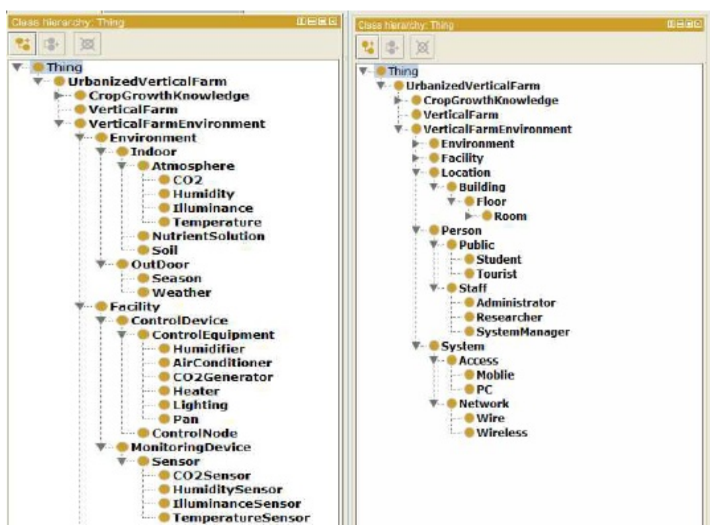

Figure 6. The Hierarchy Structure of 'VerticalFarmEnvironment' Class

3.4. Validation of a Vertical Farm Ontology

Using the Protégé, an ontology can be verified and be able to retrieve the desired information through the search engine. As shown in Figure 7, the computer can understand that the growth temperature of cabbage is 19 degrees Celsius. And also the computer can know that the heater (HEAT01) is operating in location LS01, and it controlled by CNODE03

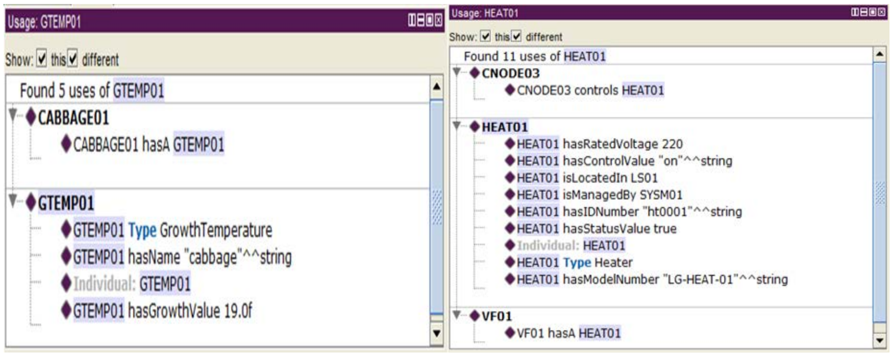

Figure 7. The Properties of a Vertical Farm Individuals

The Figure 8 shows the search results of an ontology using the DL Query that is included in the Protégé. The results of a search can be a class, super class, sub class or individual. The result of a search about cabbage cultivation is a VF01 that is an individual of a vertical farm. And, the result of a search about sensed value 80 is a SHUM01 that is an individual of a humidity sensor. In addition, it is possible to search according to various scenarios.

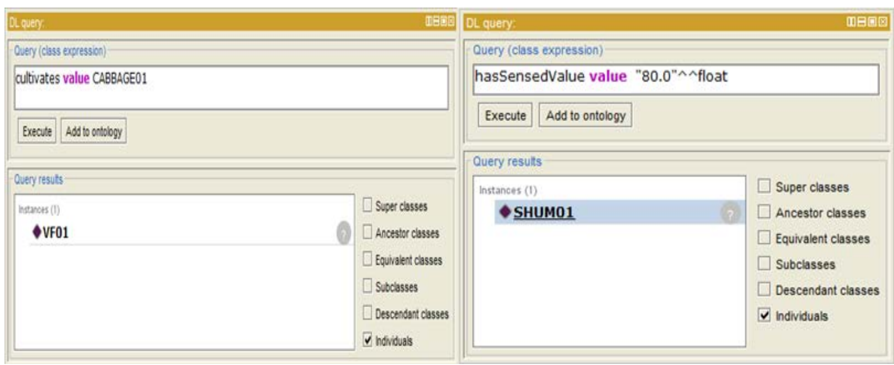

Figure 8. The Properties of a Vertical Farm Individuals

4. Conclusion and Future Works

In order to build the ubiquitous agriculture environments, an agricultural ontology should be reasonably designed. However, continuous research efforts are needed to build a complete agriculture ontology that requires significant time, effort and knowledge. Therefore, an aim in this paper is to build the ontology for a vertical farm environment rather than for all areas of the agriculture in this paper. The next works will focus on design and implementation of an intelligent service based on the designed vertical farm ontology in a test bed.

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Authors

Taehyung Kim received his Master degree in engineering at Sunchon University. He is also a researcher of Go-Lab at Sunchon National University too. His main research interests include Embedded Software and Ubiquitous Computing.

NamJin Bae is a Master Course of Sunchon National University. He is also a researcher of Go-Lab at Sunchon National University too. His main research interests include Syste Software, Embedded Software and Sensor Network.

MyeongBae Lee is a PhD student of Sunchon National University. He is also a researcher of Go-Lab at Sunchon National University too. His main research interests include Ubiquitous Computing and Middleware.

Changsun Shin received his PhD degree in computer engineering at Wonkwang University. Currently, he is an associate professor of the Department of information & communication engineering in Sunchon National University. His main research interests include Distributed Real-Time Computing, Distributed Object Modeling, Ubiquitous Agriculture and Ubiquitous Sensor Network (USN).

Jangwoo Park received his BS, MS and PhD degrees in Electronic engineering from Hanyang University, Seoul, Korea in 1987, 1989 and 1993, respectively. In 1995, he joined the faculty member of the Sunchon National University, where he is currently a professor in the Department of Information & Communication engineering. His research focuses on Localization and SoC and system designs and RFID/USN technologies

Yongyun Cho received the PhD degree in computer engineering at Soongsil University. Currently, he is an assistant professor of the Department of information & communication engineering in Sunchon National University. His main research interests include System Software, Embedded Software and Ubiquitous Computing.