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A Study on Greenhouse Management Framework for Intelligent Control Service of Greenhouse

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Abstract

In this paper, an intelligent control of the greenhouse in the Greenhouse Management Framework (GMF) has been designed for the purpose of increasing the farmer's profit and promoting the ease of agricultural production. The GMF is divided into Greenhouse Control Engine and Crop Growth Engine. The Greenhouse Control Engine consists of Data Aggregator, Greenhouse Information Storage, and Greenhouse Control Agent. The Greenhouse Control Agent includes Information Analyzer, Control Device Selector, and Greenhouse Control Model. The Crop Growth Engine consists of Crop Status Information Storage and Crop Growth Agent. The Crop Growth Agent includes Crop Status Predictor, Environment Set-points Decisioner, and Crop Growth Model. In this paper, the aim to reduce the consumption cost of the control device driven for the optimal greenhouse growth environment is one of the major features of the framework that is being proposed. In order to reduce heating cost, which consists of a major part in the cost of cultivation, we have tested the performance of our proposal for the GMF through the simulation. The simulated results confirm the decrease of heating costs from the present GMF.

Keywords*: Greenhouse Cultivation, Intelligent Control, Greenhous Management Framework, Cost of Cultivation, Heating Costs*

1. Introduction

The recent trends in the international markets prove that in spite of the economic recession and world financial crisis, the energy prices (exchange rate, oil prices, etc.) are raising constantly. Due to the increase in oil prices and energy prices, the price of agricultural products is also rising to a very high level [1].

On the other hand, prices of the domestic agricultural products are showing an upward trend overall. With the increase of production cost due to the oil prices, the farmer's profit is rather decreasing lower. In the case of domestic, the main raw materials of the energy supply markets are dependent on imports. Thus, the energy costs consumed in the cultivation process of agricultural products act as important factor that directly impact the farmer's profit.

The main objective of greenhouse cultivation is to increment the economic profits of the grower by means of finding a trade-off between the improvement of the quantity and quality of the horticultural products and the cost of obtaining adequate climatic conditions using automatic control strategies [2]. Research on existing greenhouse control systems focused on the increase of crop yield. However, from the viewpoint of farmer's income, shipment of crops at the proper period is just as important as the increase of crop yields. Especially, in the case of the domestic market, the size of market is limited and the price of crops is decided depending upon the distinctiveness of holidays or seasons. As a matter

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of fact, a key factor of increase in farmer's incomes is not only the increase of crop yields, but also choosing the proper period of production.

We have studied the Greenhouse Management Framework (GMF) focusing on the following parts. GMF is classified into two engines, depending on how to increase the farmer’s profit through intelligent control service of the greenhouse. The Greenhouse Control Engine helps to reduce the cost of the energy consumed for optimal control of the greenhouse environment, and the Crop Growth Engine explains how to increase the margin by adjusting the harvest season and to increase the yield.

The paper is organized as follows. Section 2 describes work related to the topic. Section 3 describes the architecture of the GMF, and the simulated performance of the proposed system is presented in Section 4. Finally, section 5 marks the conclusion.

2. Related Work

Facilities cultivation energy reduction technical development is being executed in various ways. In the aspect of crop cultivation, when the heating load is high in the midwinter, crop cultivation is stopped or crops that do not necessitate much of heating load, which is appropriate to local temperature environment, are chosen. For the aspect of heat conservation of facilities, perfect heating that minimizes the heat loss to the outside or partial heat conservation technical development is being practiced to minimize the heat conservation space in the greenhouse. In the heater usage technique, facility horticulture energy input could be saved by recently developed energy saving techniques, which are based upon the thermal efficiency improvement of heater. For developing an alternative energy, greenhouse heating and cooling heat pump has a function of re-collecting more than three times of injected energy using natural heat in the atmosphere that serves the purpose of heating in winter and cooling in summer, and also centrally supplying flower gardens [3].

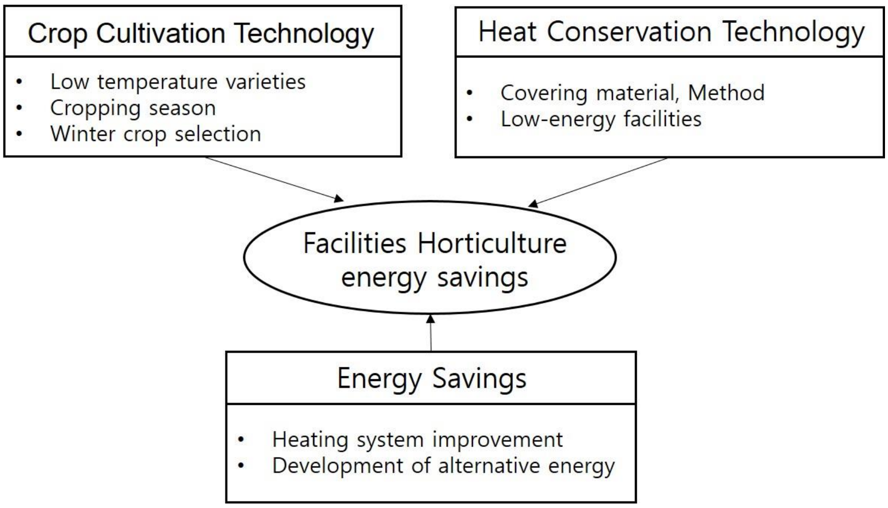

Figure 1. How to Reduce Greenhouse Energy

There are also other various ways, but domestically, energy is saved by efficiently using light and heat energy of designed electric lamps utilizing height adjuster [4]. In the case of Japan, the heat pump's heating and cooling is being used, which reduces the prime cost of fuel and improves the quality of roses at the same time. Also, they are overcoming fuel crisis with a tripled film, which is adding 2 layers of film on the interior of house [5].

Likewise, facilities cultivation energy reduction technique is being developed in many ways. However, ways to conserve energy by implementing new devices are being introduced instead of conserving energy utilizing the already existing devices in the greenhouse. Installation of new devices may be a heavy burden to farmers as it necessitates high initial cost. For this reason, the paper researches on framework of saving energy cost by utilizing control systems that already exist in greenhouses instead of implementing new devices.

3. Greenhouse Management Framework (GMF)

In this paper, the proposed GMF consists of a physical layer, middle layer and application layer, as in Figure 2. The physical layer contains environment sensors to measure the environmental conditions in the greenhouse, control device for controlling the environment of the greenhouse, and crop sensors to measure growth status of crops. The middle layer is divided into the Greenhouse Control Engine and the Crop Growth Engine. The Greenhouse Control Engine consists of Data Aggregator, Greenhouse Information Storage, and Greenhouse Control Agent. The Greenhouse Control Agent includes Information Analyzer, Control Device Selector, and Greenhouse Control Model. The Crop Growth Engine consists of Crop Status Information Storage and Crop Growth Agent. The Crop Growth Agent consists of Crop Condition Predictor, Environment Set-points Decisioner, and Crop Growth Model. The application layer consists of the greenhouse environment monitoring and greenhouse control services that are connected with the sensors or control devices.

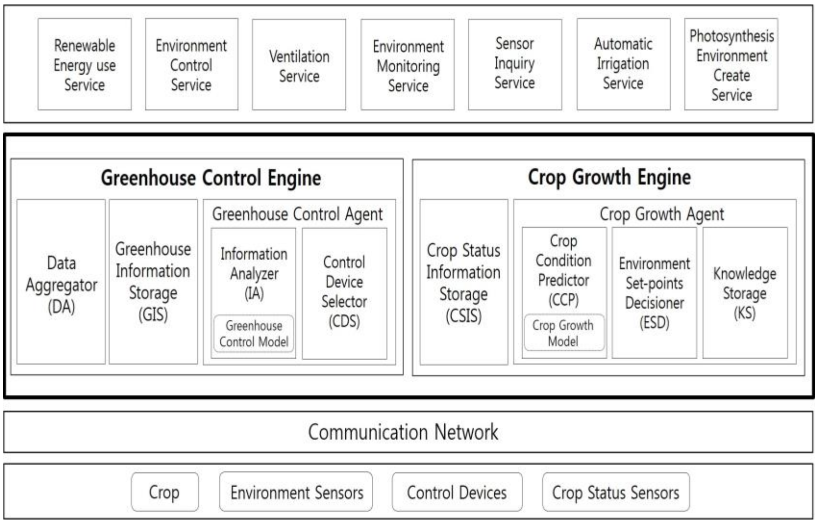

Figure 2. GMF Architecture

3.1. Control Variables of Intelligent Greenhouse

The growth of the crop is affected in the internal environment on the greenhouse. It is important to keep the growth environment in optimal condition to adjust the major environment variables in the greenhouse such as temperature, humidity, CO2, and illumination according to optimal growth environment in the greenhouse. The variables related to greenhouse control are shown in Figure 3.

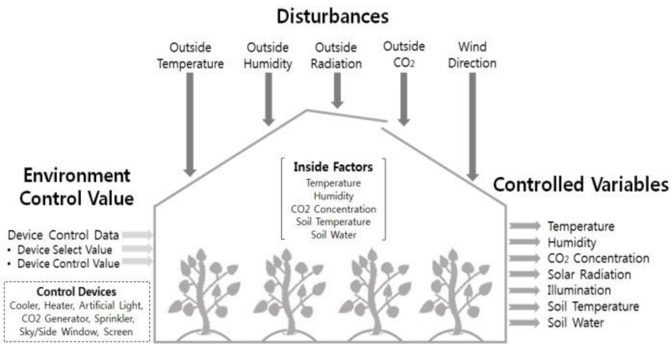

Figure 3. Control Variables of the Intelligent Greenhouse

3.2. Greenhouse Control Engine

The Greenhouse Control Engine collects environmental data from the greenhouse. Considering the energy-efficiency for creating the greenhouse environment of optimal condition is based on the growth environment set-points that are calculated from the Crop Growth Agent of the Crop Growth Engine, and carry out the control device selection and device control function.

3.3. Crop Growth Engine

Crop growth engine stores the growth state of the current crop. Also, it determines the environment set points values by predicting the crop conditions of the future through the status information of the crops, environment create data, and climate data.

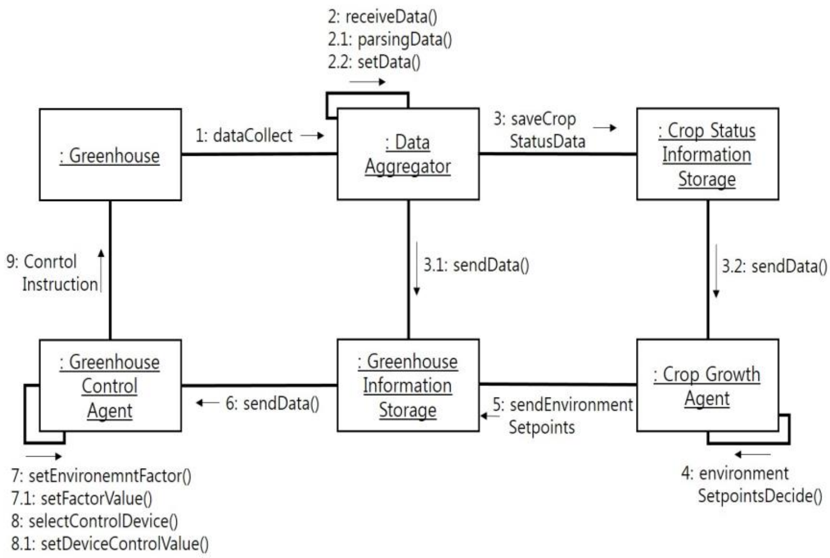

Figure 4. Optimal Control Services of the Intelligent Greenhouse

3.4. Optimal Control Services of the Intelligent Greenhouse

The greenhouse optimal control service is the main service of this framework. In order to optimize the control in the greenhouse environment, the Greenhouse Control Engine and the Crop Growth Engine interacts with each other. The driven process of service is as follows. First, information about the greenhouse environment, crop status information, and control device information is collected through the sensors of the greenhouse. The collected information is then generated into a packet, and stores the crop status information in the Crop Status Information Storage. To determine the environment set-points values through the status information of the crops, environment create data, and climate data in the Crop Growth Agent. Determined set-points are stored in the Greenhouse Information Storage. The greenhouse environment information and environment set-points values are passed to the Greenhouse Control Agent in the Greenhouse Information Storage. The Greenhouse Control Agent determines the factors that control the environment of the greenhouse and analyzes the data received. Then, to select the appropriate control device in accordance with environment factors, status information of the control device is received from the Greenhouse Information Storage, which later transmits the control command to a greenhouse. The motion process of services is shown in Figure 4.

4. Simulation

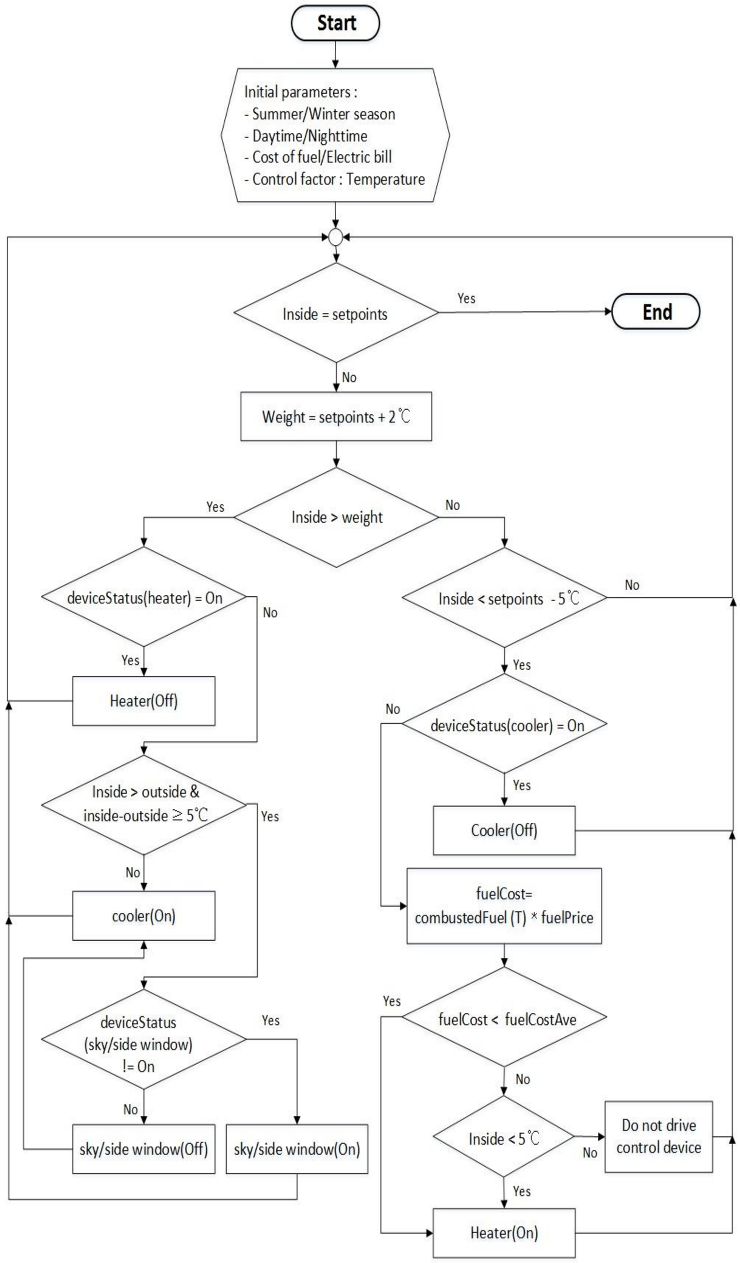

Figure 5. Control Device Selection and Drive Algorithm

4.1. Algorithm for Simulation

We designed the algorithm for simulation as in Figure 5. The algorithm is without using all the devices, and only the minimum device required for heating and cooling were used. Control devices used are heater, cooler, and sky/side window. Also, inputs the initial parameters based on summer/winter season, day time/night time, cost of fuel/electric bill, and control factors as shown in Table 1. It is divided into summer and winter because, depending on the season, the inside and outside temperature of the greenhouse is different. Also, since the day/night growth has different temperatures, the plants are divided into daytime and nighttime. In this paper, prototypic implementation is done to test the reduction of the heating costs; the control element is a temperature. To analyze the heating costs of the greenhouse cultivation through the algorithm by using the temperature of the greenhouse that includes the inside and outside, set-points value, the control device status, fuel prices, the average fuel.

Table 1. The Initial Parameters of the Algorithm

Initial parameters	Contents
summer season	5-10 (month)
winter season	11-4 (month)
day time	8-18 (hour)
night time	21-3 (hour)
cost of fuel	combusted fuel(T)×fuel cost
electric bill	power consumption×energy charge
control element	Temperature, humidity, CO2, illumination

4.2. Analysis of Simulation Results

In order to analyze the reduction of heating costs, we have used the lettuce crop in the prototypic greenhouse. Growth temperature of the lettuce is 10~15℃ at day time, 5~15℃ at night time in winter season. We have also collected at 30min intervals via the sensor and used the temperature data of January to run many heating operations. The set-points values were set arbitrarily according to the growth temperature of the crops of cultivation.

Figure 6 and Figure 7 are divided into day time/night time, and are showing the inside temperature of the greenhouse, temperature after applying the GMF, and arbitrarily the set-points value in January. It can be seen that the set-points values became similar by comparing the temperature before and after applying of the GMF.

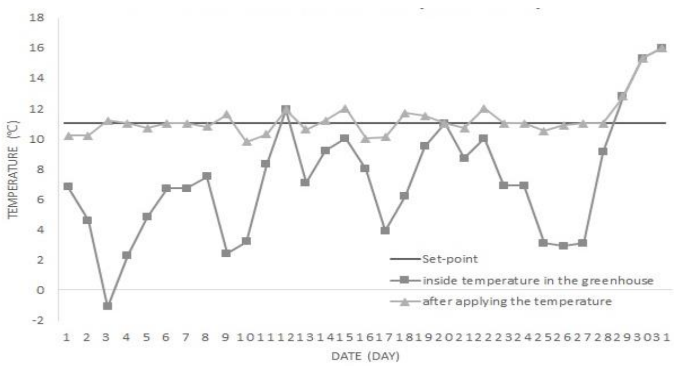

Figure 6. Daytime Temperature (January)

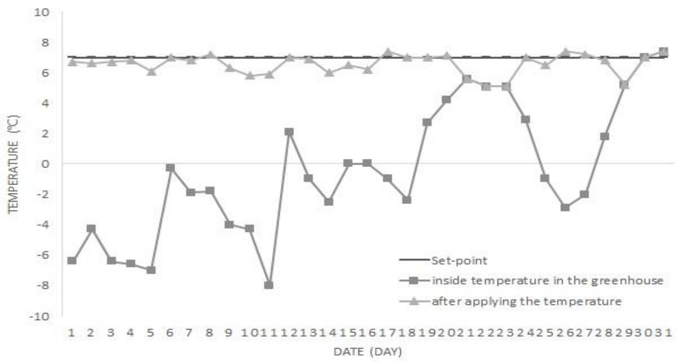

Figure 7. Nighttime Temperature (January)

However, the temperature values in the Figure 6 (29~31 days) and Figure 7 (21~23, 29~31 days) is the same reason as the temperature before applying because the control device has not been driven by the algorithm.

Figure 8 shows daily fuel usage fee of the greenhouse before and after applying the GMF. Looking at the usage fee after applying the GMF as in Fig, except the date of not driving the control device, it is possible to see that usage fee is smaller than the present greenhouse system.

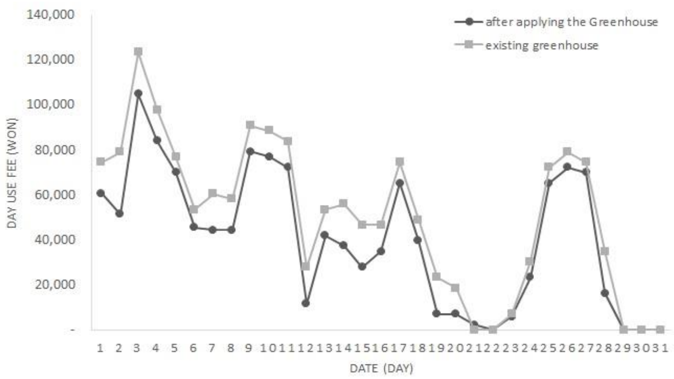

Figure 8. Usage Fee of Fuel (January)

Figure 9 shows the total month fuel usage fee. It has been confirmed that cost of reduction is about 1.2 times more than fuel costs of the existing greenhouse fuel costs after applying the GMF.

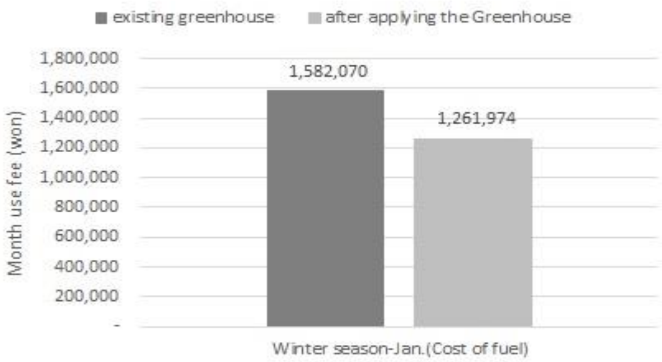

Figure 9. Compare with Month Total Fuel Usage Fee (January)

5. Conclusions

In this paper, the Greenhouse Control Engine and Crop Growth Engine for the intelligent control of greenhouses were discussed under the Greenhouse Management Framework. Also, by designing an algorithm for the simulation in a prototypic environment, we have successfully tested, compared, and verified the reduction of heating costs in agriculture from the present greenhouse environment.

For our future works, we are planning to study the algorithm of the crop growth. Also, to study the interaction between the Greenhouse Control Engine and the Crop Growth Engine, to provide more efficient services must be done.

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