Greenhouse Environment Management System Based on Growth Measurement

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***Abstract*— This paper proposes an AI-based system for monitoring crop growth, utilizing Teachable Machine for analyzing stages of radish growth and optimizing greenhouse conditions. The system captures images, analyzes them against learned data, and adjusts the environment in real-time for energy efficiency and enhanced crop development. The results can be monitored by users through an application, providing insights for effective harvesting and prediction of growth patterns, aiming to improve yields, quality, and reduce energy consumption.**

***Keywords*— Plants, Crops, Machine learning, Deep learning, Artificial intelligence**

I. Introduction

At the 26th Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC) held in the United Kingdom in 2021, several countries, including Korea, declared 'carbon neutrality by 2050'[1]. From October 2023, the EU Carbon Border Adjustment Mechanism will require companies with multiple greenhouse gas emissions to report their emissions. The EU Carbon Border Adjustment Mechanism was established to ensure that the EU's climate goals are not undermined by carbon leakage. Carbon leakage is the migration of greenhouse gas emissions to countries with lax climate policies, negating the efforts of countries with strict climate policies. In response, more and more companies are joining the RE100 program, which provides 100% of their electricity from renewable sources[2]. The core of global greenhouse gas emissions is energy consumption, and reducing greenhouse gas emissions in the energy sector is key. In particular, expanding the supply of eco-friendly energy such as renewable energy and reducing the use of fossil fuels are the most effective ways to reduce greenhouse gases[3]. As of 2018, carbon emissions from agriculture accounted for 2.9% of Korea's total carbon emissions, with 28% coming from the facility horticulture sector[4].

A lot of fossil fuels are consumed for heating and cooling

to maintain the temperature in greenhouses. Therefore, we studied how to reduce carbon emissions by increasing energy efficiency in facility horticulture. This research is a system that automatically adjusts the environment by self-diagnosing the growth status of crops. The camera takes pictures of the crops and the Teachable Machine analyzes the growth of the crops. Based on the analyzed results, a driver is operated to maintain the optimal environment in the greenhouse. Different crops require different temperatures, humidity, and carbon dioxide, so adjusting the temperature according to the current crop growth status can reduce wasted energy.

In the following section, we describe the method and results of analyzing the growth level of crops with Teachable Machine, and in the conclusion, we propose the expected effect and utilization plan.

II. Using the Template

A. Automated Greenhouse Systems

Advances in automation systems in greenhouse management have led to significant measurable improvements. Recent technologies, particularly sensor-based monitoring and control systems, have transformed greenhouse operations. Jones, A., et al. (2021). "Automated Climate Control in Greenhouses: Impact on Efficiency and Yield." conducted an extensive study to quantify the impact of implementing automated climate control systems in greenhouses. They reported a significant increase in operational efficiency, quantified as a 20% reduction in energy use compared to traditional greenhouse management practices. This reduction was primarily due to optimized adjustments to heating, cooling, and ventilation systems based on real-time environmental data.

The study also highlighted significant improvements in crop yields: the automated system increased yields of temperature-sensitive crops like tomatoes and cucumbers by 15%. These improvements were associated with precise control of environmental conditions to consistently maintain optimal growing temperatures and humidity levels.

These quantifiable benefits highlight the importance of automation in controlled agricultural environments[5].

III. Using the Template

A. Greenhouse Environmental Management System

Crops require different amounts of light, carbon dioxide, temperature, humidity, and nutrients at different stages of growth. For example, tomatoes have a germination temperature of 25-30℃, a seedling temperature of 20-25℃, a flowering temperature of 20-25℃, a growth temperature of 17-27℃, and a hypertrophy temperature of 25-30℃. Setting these temperatures in advance and having the environment automatically adjust to them will not only reduce unnecessary energy consumption, but will also be very beneficial for crop growth.

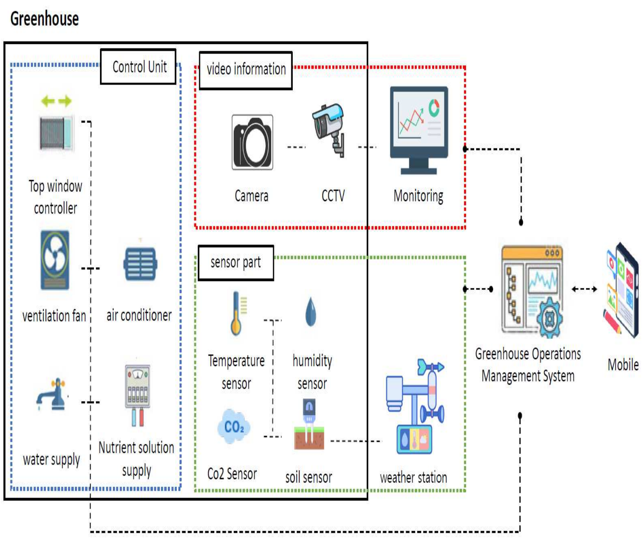

Figure 1. Greenhouse Environmental Management System Schematic

<Figure 1> is a basic block diagram of a greenhouse environmental management system. The greenhouse is managed by the Greenhouse Operations Management System. First, crops are photographed with a depth camera to analyze the growth of the crops. Based on the analyzed growth level, the optimal environmental conditions of the greenhouse are automatically set.

The sensor part collects environmental data inside and outside the greenhouse and stores it in the DB of the Greenhouse Operations Management System. The sensor part includes temperature sensors, humidity sensors, soil sensors, carbon dioxide sensors, and weather station information.

The Greenhouse Operations Management System analyzes the stored environmental data and controls the drivers of the Control Unit. Controlled drivers are Top window controller, ventilation fan, air conditioner, water supply, and Nutrient solution Supply. If the internal and external environmental data measured by the sensor part is out of the set range, the control unit is driven. If the temperature is too high or too low, the air conditioner is operated, and if the carbon dioxide is too low or too high, the ventilation fan is operated. The top window controller is activated when the weather station indicates too much or too little light, and when the temperature difference between the inside and outside of the greenhouse is large. In addition, the amount of Nutrient solution Supply is adjusted through the soil sensor.

The video information of the crops is stored by cameras and CCTV. The camera is a depth imaging tool for analyzing crops. CCTV is a recording tool to analyze the overall situation of the greenhouse. The depth camera is more accurate in identifying objects or targets than RGB cameras. In addition, it can measure depth to distinguish between stems and leaves.

B. Growth Information Measurement System

To analyze crop growth, we used Teachable Machine. Teachable Machine is a web-based tool designed to create machine learning models quickly and easily. To analyze the growth of the crops, we connected Teachable Machine with the Greenhouse Operations Management System.

To make sure that Teachable Machine analyzed the data correctly, we tested it with heatwaves.

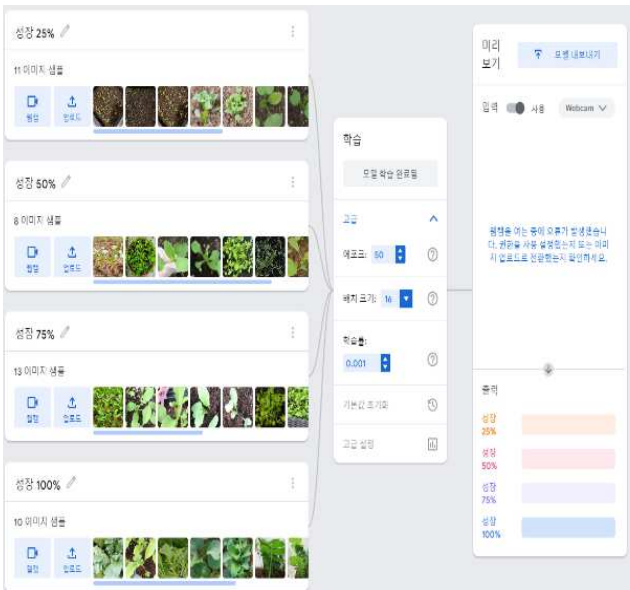

Figure 2. Greenhouse Environmental Management System Schematic

<Figure 2> This is the process of training a Teachable Machine on the growth of a sugar beet. We set 100% as the time when the crop can be harvested, and divided the growth process into 25%, 50%, 75%, and 100%. Since the growing period of a radish is 8 weeks, we set 25% for weeks 1-3, 50% for weeks 4-5, 75% for weeks 6-7, and 100% for weeks 8 and beyond. We trained the Teachable Machine with images corresponding to each process, and the training images were collected, refined, and extracted from data obtained after growing radishes by hand and data obtained using Google Image Search.

When a user requests information about the growth of a crop in the application, the camera observing the crop sends an image of the current crop to the Teachable Machine. The Teachable Machine then analyzes the image based on the data it has already learned.

C. *Analysis results*

Figure 3. Analysis of the degree of growth of the teachable machine

<Figure 3> is a screen that shows the results after analyzing the sent image. Teachable Machine sends the results to an application linked to the Greenhouse Operations Management System. The user can view the results sent to the application to understand the current growth information of the crop and apply the cultivation method that fits the current state to grow the crop.

IV. USING THE TEMPLATE

This system measures the degree of growth and automatically adjusts the optimal environment for the current growth.

The images taken by the depth camera are analyzed by the Teachable Machine of the Greenhouse Operations Management System for the current growth degree. The optimal environment data is set according to the analyzed growth degree.

The environmental data of the sensor part is stored by the Greenhouse Operations Management System, and the control part is operated according to the set data. All environmental information, data, and real-time monitoring information can also be viewed on mobile devices.

The greenhouse environmental management system based on growth measurement can be expected to improve crop yield and quality by maintaining optimal conditions for each growth stage. Furthermore, adjusting the environment to the growth of the crop reduces unnecessary energy consumption. This reduces the use of fossil fuels and thus reduces greenhouse gases. Reducing carbon emissions from facility horticulture can reduce up to 0.6% of total carbon emissions.

The system could determine higher levels of growth if it implemented more sophisticated artificial intelligence rather than Teachable Machine. We will continue to work on improving the AI to increase accuracy.

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