The Application of Internet of Things in Greenhouse

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Abstract—*Current commercial monitoring and controlling systems for agriculture are too expensive for most farmers in Taiwan, where population in farming sector is shrinking and aging. Further, data about the environment, plant growth, and production are not systematically stored and analyzed to provide a feedback for future planting. The project has completed a design with Internet of Things (IoT) technology for a local greenhouse. Major production factors are selected for controlling and monitoring. Hardware and software is implemented with open sources. The preliminary testing has shown positive results, which promise to bring changes to the experimented site. Moreover, the created model can be easily applied or scaled up in different farming environments with little change and affordable expense.*

Keywords—*smart greenhouse, Internet of Things, cloud database*

I. Introduction

Agricultural industry in Taiwan is facing enormous challenges as a result of aging and shrinking population engaged in agriculture, and typically small farming land owned by individual farmers. One innovative way to break through this barrier is to employ emerging technology to enhance its competitiveness.

Currently, commercial systems available for monitoring and controlling planting environment are too expensive for small farmers. Besides, most of them are closed systems that farmers, especially the elders, have difficulty making adjustment to different environment changes or farming needs. Lastly, current systems generally do not collect or store data about environment from sensors or the growth and production of plants. Therefore, no data analysis can be provided as clues to adjust the planting environment, and no statistical lessons can be drawn to feedback future planting.

As one of the fastest growing technologies, IoT refers to those physical devices that are connected to the internet, can collect and exchange data, and may be controlled from internet [1] [2] [3]. As applied in many areas, this technology fits well to our requirements for monitoring and controlling planting environment. Yet, not much of past results related to IoT application in green house control from literature satisfies the needs in such categories as low costs, open source, high adaptability, and capability of collecting environment data [4] [5] [6].

In response to Taiwan Council of Agriculture's call for "Agriculture Excellency," this sponsored project proposes a greenhouse management system using the IoT and cloud database technology to meet the above requirements [7] [8]. This project aims to design a system for use in practice, not just a research in labs, with certain features:

1. Relatively lower implementation costs and easy adoption with open sources and available devices for development.
2. Easy data collection and traceability for the whole planting process to improve farm product quality [9].
3. Openness for further feedback and improvement with open strategy and implementation.
4. High adaptability and scalability: Different plants have different environment requirements (sunlight exposure, soil moisture, etc.) at different growth stages. The system features easy control for adapting to this need.

II. Design, Implementation, and Deployment

Our proposed system focuses on controlling and monitoring some major production factors, such as air temperature, humidity, soil moisture, and light exposure. The design consists of four layers as shown in Table 1.

Table 1. System Architecture

application layer	data analysis, mobile application (Android)
data layer	cloud database (ThingSpeak)
network layer	WiFi/ 4G router
sensor/control layer	Arduino board (WeMos D1); Sensors: Air Temperature/humidity, Soil moisture, Light; Other devices: growing plant LED, relay, electromagnetic switch, sprinklers, exhaust fan, LCD display

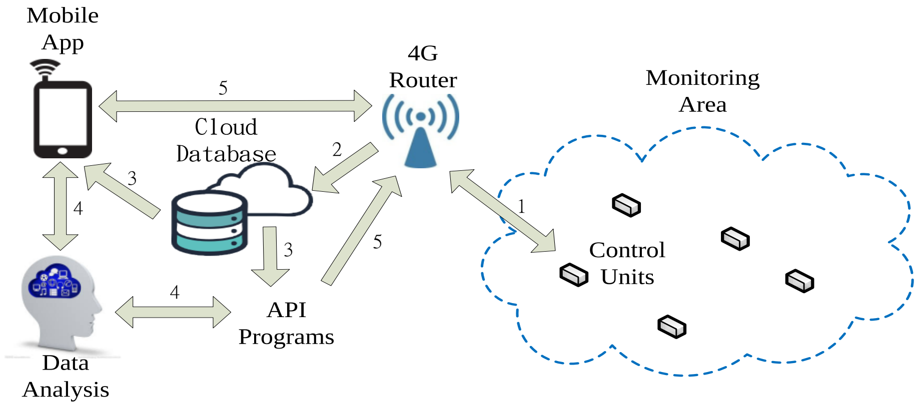

Fig 1: The system operation flow of the smart greenhouse

Figure 1 illustrates how the system operates. At the sensor/control layer, an Arduino board is used to connect sensors to detect environment changes in the greenhouse. The system will start the fan to increase air flow in an over-tempt condition, turn on the water pump if the soil is too dry, and switch on the growth lamps to supplement sunlight in case of lack of luminosity. The sensing data are also transmitted to a cloud database at a pre-set time interval. The network layer is responsible for receiving and transmitting sensing data through WiFi to a designated cloud database through a 4G router. The data layer stores the transmitted data, where ThingSpeak cloud database (https://thingspeak.com/) is chosen because it is free and easy to use and also provides APIs for data retrieval. At the application layer, the stored data can be further combined with external information, such as farming knowledge or whether forecast, for system control decision-making. Users can use a mobile phone or browser to monitor the environment conditions. Threshold values for each control device can also be set through these two means to Arduino board for further regulation.

The system was implemented at a local greenhouse, as shown in Figure 2, where 27 control units equipped with devices of the sensor/control layer as Table 1, are deployed. Threshold values were tested and set for each sensor according to the requested environment conditions before operation. As the sensing data reach the designated values, the system will initiate the relays connected to controlled devices, such as the equipped ventilation fans or water valves/pumps. The sensing data are transmitted to the cloud database, and then organized, analyzed and presented through web pages or applications. Table 2 shows an example of measurements from three different sensors. These data can also be presented with certain visualization effects so that farmers can easily depict the clues or trends, as shown in Figure 3.

TABLE II. AN EXAMPLE OF SENSOR MEASUREMENTS OF THE GREENHOUSE

Control unit ID	Temperature (°C)	Air humidity (%)	Soil moisture (%)
1	38	56	59
2	38	55	62
3	37	55	59
4	37	56	62
5	38	57	63
6	38	58	59

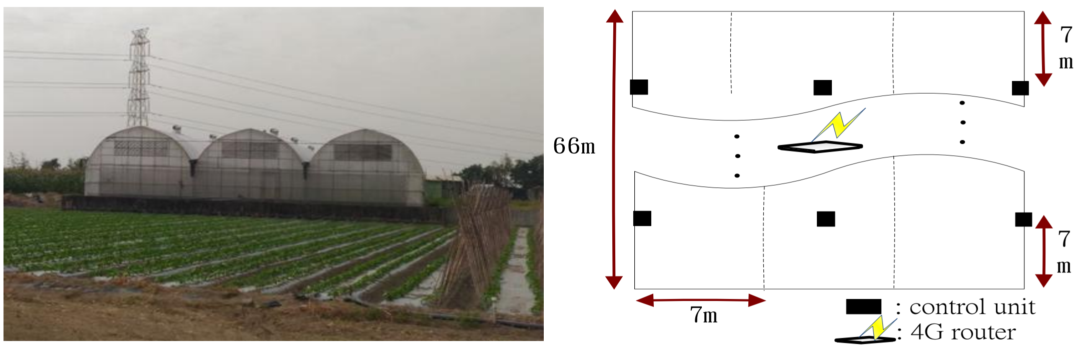

Fig 2: The greenhouse and system deployment

Fig 3: The visualization of the sensing data of a control unit through web pages

III. RESULTS AND DISCUSSION

The project is still undergoing and the preliminary implementation and testing have shown some positive results with some lessons learned.

Different plants require different sunlight exposure, and a plant requires different amount of water at different growing stages. The system records data such as the luminosity time and soil moisture, and controls devices such as lamps or sprinklers to meet the needs of different plants at different stages. This adaptability with remote monitoring and controlling through mobile apps or web pages makes diverse planting more possible and convenient in one single green house.

Agricultural goods take longer time and processes to harvest than other manufactured products. Each farming process contributes to the final results. Establishing environment data record of each growing process provides traceability and adds value to final products. Yet, processing the data manually is cumbersome and infeasible. The proposed system offers an easy model for fulfilling the change and further provides learnability for continuous improvement.

IV. CONCLUSIONS

Smart farming is a key to enhance competitiveness in the agriculture industry. Our project has completed a system and tested it on a local greenhouse with certain features and advantages: such as low implementation costs, easy data collection and traceability, and high adaptability and scalability to support different plants with different environment requirements at different growth stages. Further, the system programs are open to download from Google Drive (https://goo.gl/kAvnkb) for further feedback and improvement.

Among all, soil moisture sensors require special care in practice because they are so highly sensitive that different values may be read in different locations or even at different depths on one same location. This would make setting the threshold

In the future, the proposed system is expected to be applied to different agricultural areas and plants. It is also possible to further integrate solar power or extend to irrigation control, nutrient supply, or alarm systems.

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