A Smart Fan System for Temperature Control in Plant Factory

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ABSTRACT

Decreasing the variation of environmental parameters is a very important task for an automated plant factory. An uneven temperature distribution may hinder the growth of plants. Fans are usually added to reduce temperature variation. In traditional, devices in a plant factory are manually activated after sensors detect unusual readings. This method is time consuming and labor intensive. In recent years, wireless sensor networks (WSNs) have been applied to environmental monitoring. In this paper, we propose an automated fan system controlled by sensor nodes in a WSN. Sensor nodes can not only be used to measure the actual condition of a plant growing area, but also be connected with other devices in the plant factory. Compared to using a number of fans, the use of a servo motor is more effective, because it can push air flow into larger areas. The system proposed in this paper includes two parts: a fan and a servo motor. A sensor node is also employed in this proposed system to turn on the fan by using its microcontroller unit (MCU) chip to generate pulse-width modulation (PWM). When unusual readings are detected by the sensor node in the proposed system, this sensor node will generate proper PWM to make the servo motor turn to a right direction and then activate the fan. By using this proposed automated fan system, the variation of temperature is significantly reduced. The experimental results also indicate that plants can grow up much better in this well controlled environment.

Keywords: Wireless Sensor Network, Plant factory, automated system

1. INTRODUCTION

Plant factory is a type of automatic cultivation systems which cultivate plants in an indoor environment with shelves, air-conditioning systems and LED lights. In such systems, all of the environment parameter such as temperature, humidity and illumination are artificially controlled. To avoid the damage brought by microorganism, soil-transmitted diseases and heavy mental pollution, plant factory uses artificial media and hydroponic systems instead of soil and streams in the cultivation process. Employing the concept of the plant factory not only reduces the diseases associated with

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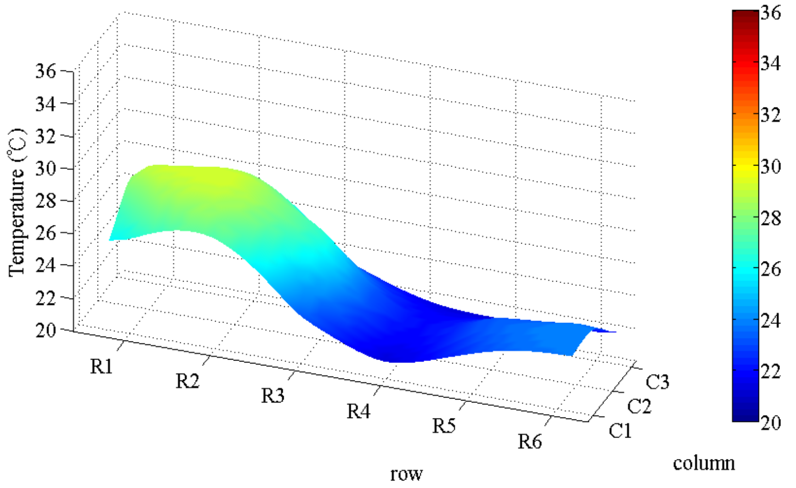
plants but also prevent overusing pesticides. Thus, in such an environment the plant production output is highly stable.

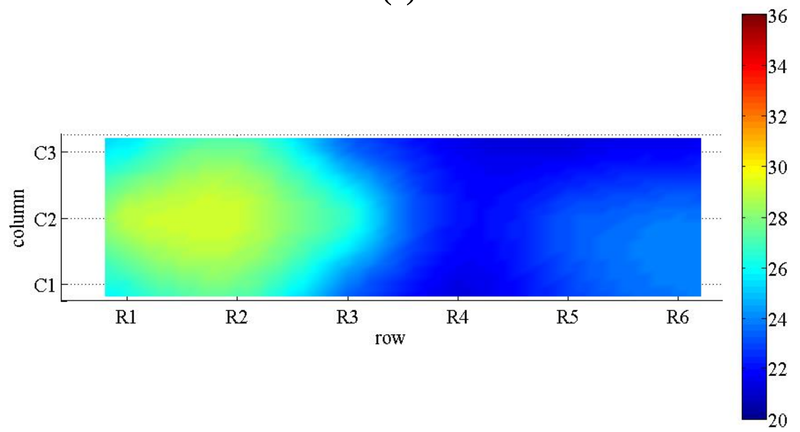
Furthermore, a number of factors may influence plant growth, such as the temperature of plant surface, illumination, air flow, relative humidity and carbon dioxide density (M.P.N. Gent and Y-Z.Ma, 1998). In an artificially controlled plant factory, the cultivation is isolated from the natural environment, since all of the environmental parameters are managed by electronic equipment. Temperature influences all enzymes related to plant growth such as water potential, transpiration, photosynthesis, metabolism, so it is important to provide a proper environment for plants in their growing process. Plant factory uses artificial lights as the major source of illumination which seems to provide an ideal environment, but a large amount of accumulation of light may cause leaf scorch. Generally, an air-conditioning system is used to maintain a constant temperature in a plant factory, but the air conditioner is often placed too high to control the air-flow between cultivation layers. In this study, a wireless sensor network (WSN) was used to monitor environmental parameters and sensor nodes in the network. The sensor nodes were placed in different layers of a shelf to collect data, and the data was sent back to a central control center through wireless transmission. Moreover, a fan system combined with an automatic control module was added to control the temperature in the factory. The fan system produced air-flow to cool down the air temperature (Moureh and Flick, 2004), and the automatic control module received the command from the monitoring system to change the direction of fans. Through analyzing the temperature data of the whole shelf done by the control center and controlling the direction of fans in a real-time manner, it was expected that uneven temperature over the cultivation area could be reduced. In addition, this study measured the flash and dry weight of the Boston lettuce that grew in a cultivation shelf located in a plant factory to examine the relationship between lettuce growth and change in temperature.

2. Related Works

In our previous work, we showed that plant factories with WSN-based environment monitoring and control system could reduce labor power required to operate the plant factories; it could preserve unnecessary energy consumptions, as well (Wu et al., 2008). According to the measurement results, we found that the temperature distribution in different level of the plant tray is inconsistent. The reason is that the distance between plant trays is too close and air exchange cannot take place. Therefore, the conditioned air cannot be evenly distributed, and it causes temperature differences in every cultivating areas of a single plant tray. This phenomenon also causes the lettuces in the same plant factory to grow at different rates (Chang et al., 2011).



(a)



(b)

Figure 1 Temperature distribution in the cultivation layer
(a) contour surface and (b) contour map (Yen-Wei Chang et al., 2011).

3. MATERIALS AND METHODS

Some studies have indicated that the growth of plants requires specific environmental parameters, such as the requirements on temperature, humidity, and illumination (Samara et al. 2009). Samara and Koutsoumanis, for example, argued that the proper growth temperature and carbon dioxide (CO_2) concentration for Boston lettuce was around 20 ℃ and 1,200 ppm, respectively. In this paper, the experimental location was a vertical cultivation plant factory. The vertical cultivation plant factory included three cultivation shelves, as shown in figure 2, an air conditioner, a monitoring system that consisted of several sensor nodes and a gateway, and a smart fan system proposed by this study. The proposed smart fan system consisted of a control node, a fan, and a servo motor. The Octopus II was used in the proposed smart fan system as the control node (Sheu et al., 2008), which could produce the *pulse-width modulation* (*PWM*) signal. The PWM signal could let the servo motor to choose the determined angle. After the gateway collected sensing data from the sensor nodes, including temperature, humidity, and illumination, the data was transmitted to an end-server database through the Ethernet communication protocol. The next step for the monitoring system was to detect the heat points at the cultivation shelve.

The environmental data was collected every 10 minutes. At the end of every round of data collection, the gateway would calculate the heat points at the cultivation shelf and transmit a packet that contained the locations of these heat points to the node in each smart fan. After receive the packets, the node would determine whether the locations were covered by them and then produce a correct PWM signal to make the servo motor turn to the right direction and turn on the fan in the servo system. The major purpose of the smart fan system was to decrease the standard deviation of the temperature distribution in the cultivation shelve. With the proposed fan system, a detected heat point would not last more than 10 minutes.

The whole experiment lasted about 35 days. After 14 days of seeding, the seedlings of the lettuce were move to the cultivation shelve, as shown in figure 3. Seedlings with very similar appearances and sizes were selected in the experiment.

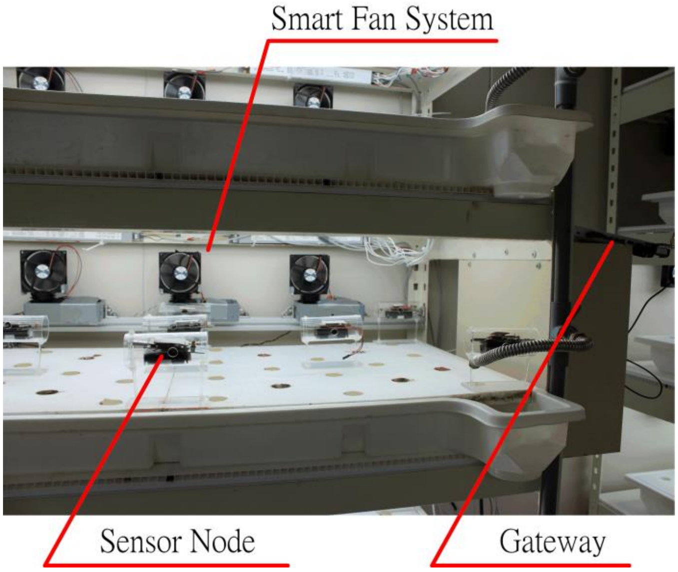


Figure 2 The proposed fan system and the experimental location

Figure 3 The lettuce and the proposed fan system

4. RESEARCH RESULTS

In figure 4, the results show that the temperature in the cultivation shelf cooled down and the flash weight of lettuce increased because of employing the proposed fan system. The measured temperature was between 30 ℃ and 35 ℃, and the average flash weight was about 47.2g when the fan system was not activated. The situation was greatly improved when the fan system was used. The temperature dropped to the range of 20 ℃ and 30 ℃, and the flash weight of the lettuce increased by 52.5%. But the increase in the dry weight was not significant, as shown in figure 5. This is because the growth of the lettuce in terms of the flash weight may correlate with the water ratio in the lettuce, not with the dry weight of the lettuce. From the viewpoint of agricultural economy, an increase in the flash weight of the lettuce may also suggest an increase in the benefit brought by selling the lettuce.

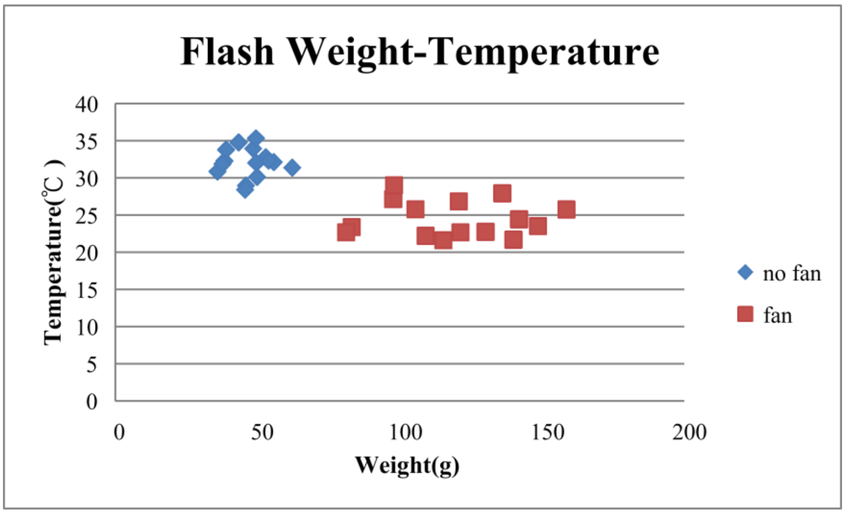


Figure 4 The relationship between the flash weight of the lettuce and temperature

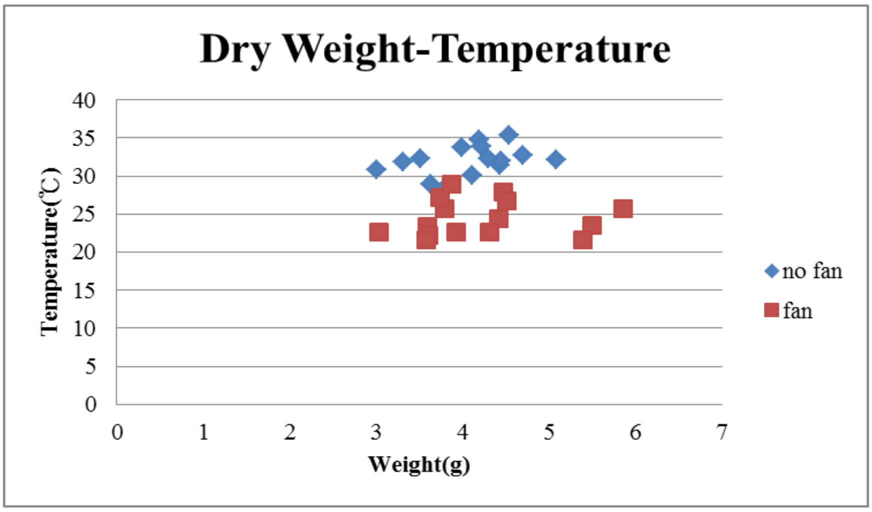


Figure 5 The relationship between the dry weight of the lettuce and temperature

5. CONCLUSIONS AND FUTURE WORKS

By using this proposed automated fan system, the variation of temperature was significantly reduced because the air flow rate increased, and the system eventually helped cool off the air. The experimental results also indicated that plants could grow up much better in this well controlled environment.

In our future studies, this smart fan system will be applied to large-scale cultivation systems, since plant factories require very precise control and a stable environment.

6. ACKNOWLEDGEMENTS

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