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Research Article

Multi-Sensor Greenhouse Automation and Remote Control with a Cloud

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Abstract

Greenhouse effect to the earth causing the world food crisis is more and more serious. How to increase the crop production becomes the most important issue at present. Traditional greenhouse is applied in assuring a steady growing environment using a giant hood to reduce the fluctuation of temperature and humidity emitted from outside climate impact. However, to increase plant growth, the control of appreciate air temperature, air humidity, soil humidity, soil ph value, and illumination in greenhouse is obligatory. In addition, low labor in the farm will make more crop production. Therefore, an automation system of greenhouse equipped with multiple sensors is presented. To assure a stable environment in the greenhouse, a remote monitoring and controlling system for greenhouse is essential. To reach a fast and easy communication between the greenhouse and the user, an IoT base communication using a private cloud is adopted. To promise the safety of greenhouse, a reed switch along with alarm system is established. In the study, multiple sensors, including air's temperature sensor, air's humidity sensor, a sunshine illumination sensor, a soil humidity sensor, and a reed switch, are installed to detect environmental condition. To reach a good growing environment for the plants, multiple actuators (sunshine-proofing net, fan, heating bulb, water sprayer, LED, and mist sprayer) are recommended to be within the agriculture system. To facilitate online monitoring and controlling, a cell phone interface is planned as a remote user. Consequently, the IoT base greenhouse demonstrated in this paper can efficiently increase crop production, save manpower, and reduce the production cost.

Keyword: Automation; Cloud; Greenhouse; IoT; Monitoring

Short Communication

Because of greenhouse effect, hydrology and water resources have been seriously influenced [1,2]. Akinniran et al. indicated that the rainfall has direct relationship relating to the crops production [3]. An example in Africa revealed that global warming leads to the change in temperature, precipitation, and sea level rising. All of these are come from the increment of atmospheric carbon dioxide which may considerably affect agricultural production [3]. According to Mahato's research [4], the climatic change will affect crops' quantity, quality, growth rates, photosynthesis, transpiration rates, and moisture availability. In order to promise satisfactory crop productivity, a plastic greenhouse used to isolate the hard climate is proposed [5-7]. During the last two decades, there has been a revolution in greenhouse production technology in greenhouse design, quality of plastic cover, fertigation, and insulation [8]. In 2010, Chiu suggested an automatic greenhouse system which can alter environmental parameters to an appropriate condition [9].

In order to online monitor and control the inner environmental parameters within the greenhouse, a PC-based server system is adopted [9]. The greenhouse's plant information detected by the sensors will be sent back to the server PC. The server PC within the greenhouse will forward the raw data to remote PC by wiring the internet from the remote PC to the greenhouse. However, it is a

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hard work for farm to have an internet wiring system on site. In order to conquer the drawback, an IoT based automatic monitoring/controlling greenhouse system is presented. Here, a micro-controller system connecting to the sensors will be wirelessly connected to the cloud via the Wi-Fi module. A cell phone installed near the greenhouse can served as a movable AP network. The agriculture information detected by the sensor will be wirelessly sent to the cloud via the movable AP network. The remote user can freely login to the cloud to check the agriculture data and manipulate greenhouse's actuators by using an interface on the cell phone. In this system, four agriculture sensors, including an air temperature sensor, an air humidity sensor, an illumination sensor, and a soil humidity sensor, are used. And five kinds of actuators (a fan, a heating bulb, a water sprayer, a mist sprayer, and a sunshine-proofing net) are using to adjust the agriculture parameters. Moreover, to reassure the greenhouse security, a reed-switch in conjunction with an alarm system is also equipped within the greenhouse.

System Structure

An IoT-based greenhouse system is depicted in Figure 1. As indicated in Figure 1, the environmental parameters of sunshine illumination, air temperature, air humidity, and soil humidity will be online detected by the related sensors installed within the greenhouse. To adjust agriculture parameters, several actuators equipped within the greenhouse are adopted. Here, the heating bulb and electrical fan is used to manage environmental temperature. Water sprayer is used to control soil humidity. Mist-sprayer is applied to adjust air's humidity. And sunshine-proofing device is used to adjust greenhouse's inner illumination transmitted from the sunshine. Moreover, to keep greenhouse in a safe condition, a security system with reed-switch in conjunction with an alarm device is installed. An Arduino board is adopted as a micro-controller. The wiring diagram of the system is illustrated in Figure 2. As indicated in Figure 2, all the sensors will be wired to the micro-controller. For the remote user, there are two-mode selection (one of manual mode and the other of automatic mode) designed within the user's interface (cell phone). The user can remotely initiate the automatic control process by clicking the auto-mode button on the cell phone. The control logic for greenhouse's automatic system under an auto-mode situation is shown in Figure 3. As indicated in Figure 3, an appropriate range (10~20oC) of air temperature is preset. In addition, a soil humidity threshold with 50% is specified. Moreover, the criteria of greenhouse's inner illumination with 200 (lux) is fixed. The actuators will be triggered upon the mentioned logic. Considering a safety of the greenhouse, a control logic of greenhouse's security system (auto mode) is adopted and shown in Figure 4. As illustrated in Figure 4, the alarm will be activated when an intruding signal detected by the reed-switch is received by the Arduino.

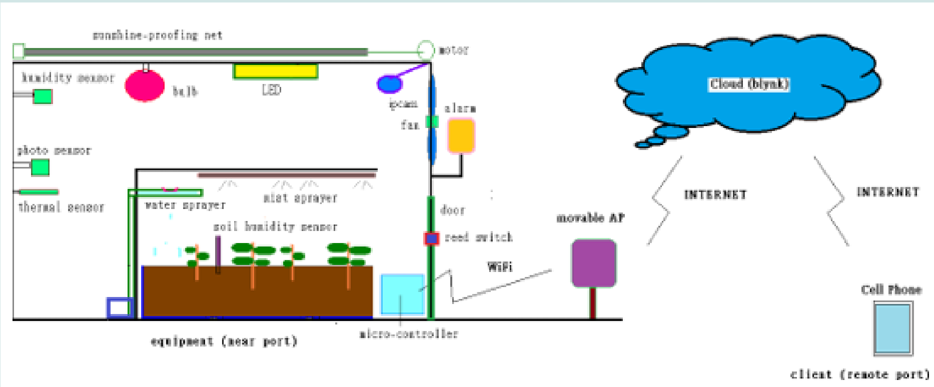

Figure 1: An IoT-based greenhouse system.

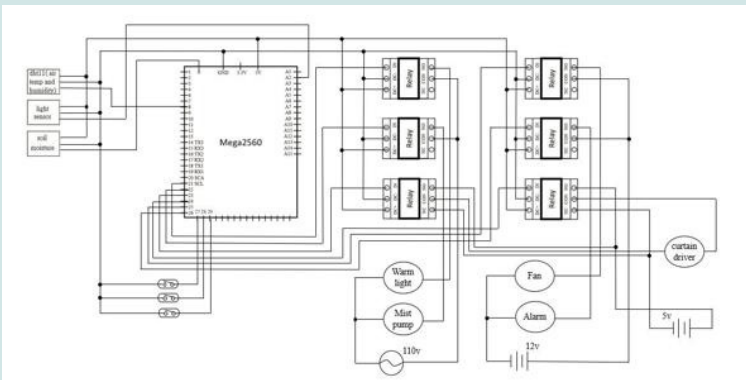

Figure 2: The wiring plan of the greenhouse's micro-controller.

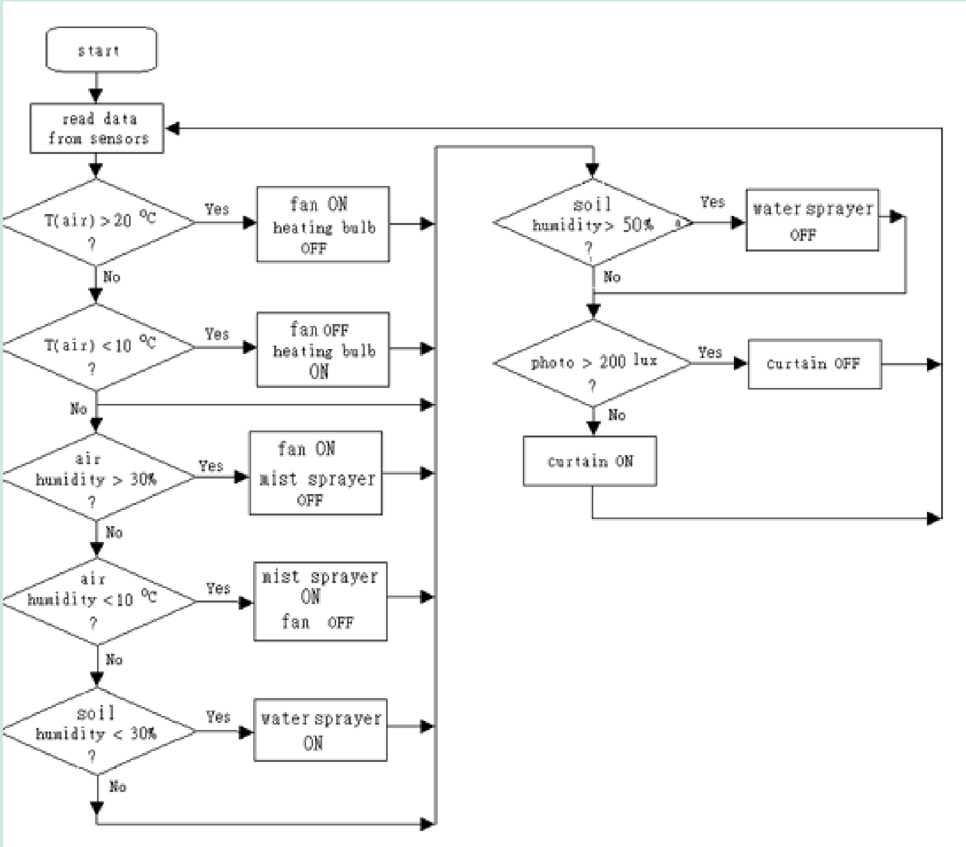

Figure 3: The control logic for the greenhouse's planting system (auto mode).

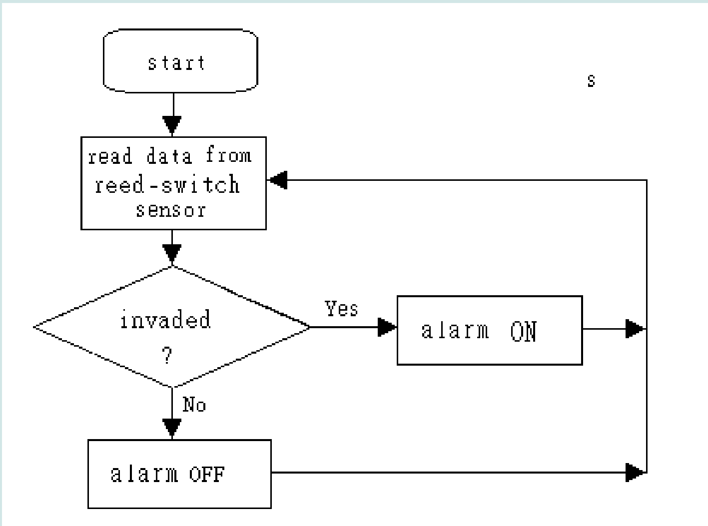

Figure 4: The control logic for the greenhouse's security system (auto mode).

Data Communication System

As illustrated in Figure 1, a cloud named blink is adopted in the IoT system. A Wi-Fi module with ESP-8266 chip is connected to the micro-controller. The micro-controller can connect to a movable AP and then login to the cloud via the Wi-Fi modulus. For the remote user, a cloud App is established within user's cell phone. The user can freely online monitor agriculture information such as the air temperature, the air humidity, the soil humidity, and the greenhouse illumination. Moreover, a manual mode is designed in the cloud App. The user can click the manual button first and then manipulate each actuator in individual when the agriculture environmental parameters are not in an appropriate status. Furthermore, to facilitate management and control of the greenhouse's agriculture, the user can click the auto-mode and remotely start up greenhouse's automatic control process.

Results and Discussion

There are five sensors (an air temperature sensor, an air humidity sensor, a sunshine illumination sensor, a soil's ph. sensor, and a reed-switch sensor) and seven actuators (a sunshine-proofing net set along with one DC motor, a heating bulb, a fan, a mist sprayer, a water sprayer, and an alarm) in the IoT-based greenhouse. Two modes of greenhouse can be selected in the remote user's interface (cell phone). In the auto mode condition, sunshine-proofing net (shown in Figure 5) is forwarded by a DC motor when the sunshine illumination detected by the illumination sensor is beyond the maximum criteria. As indicated in Figure 6, fan is triggered when the temperature within the greenhouse is higher than the upper bound of temperature threshold. Similarly, as illustrated in Figure 7, mist sprayer is activated when the air humidity is lower than the specified humidity. In addition, Figure 8 points out that the heating bulb is started if the temperature within the greenhouse is lower than the specified temperature. Moreover, as depicted in Figure 9, water sprayer is turned on if the soil humidity detected by the humidity sensor is lower than the specified value. Furthermore, as demonstrated in Figure 10, alarm system is triggered when the intruder approaches to the greenhouse. The detailed logic for planting and security within the greenhouse is written in the Arduino. An abstract of the Arduino program is depicted in Figure 11. The interface of the remote user is established and shown in Figure 12. As can be seen in Figure 12, four kinds of environmental parameters are online monitored. A mode's option button in conjunction with four actuators' buttons is set up within the cell phone's interface. Consequently, the prototype of the IoT-base greenhouse system is established and shown in Figure 13.

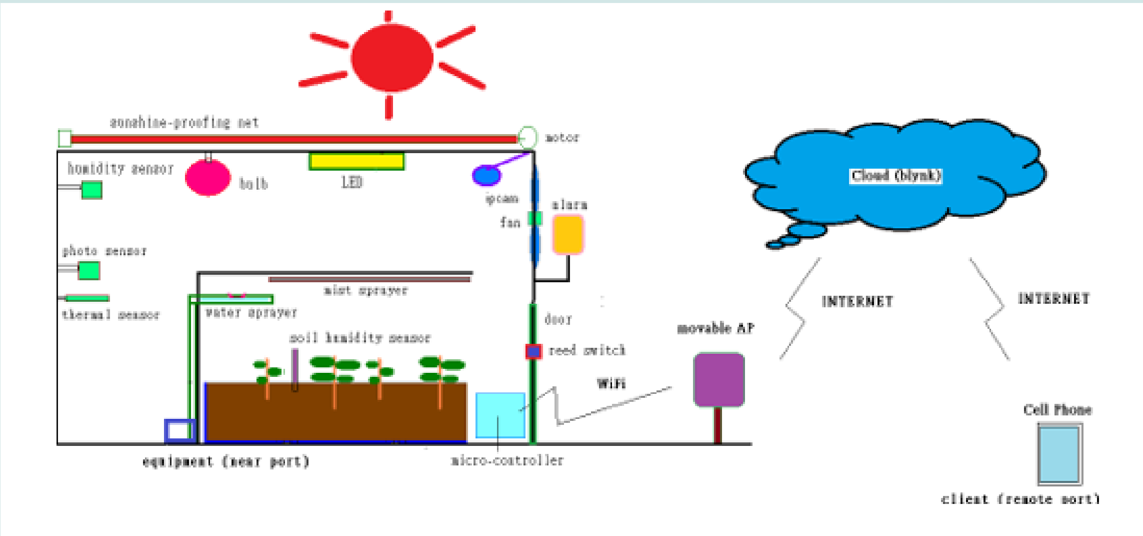

Figure 5: The sunshine-proofing net is forwarded by a DC motor when the sunshine illumination is beyond the maximum criteria.

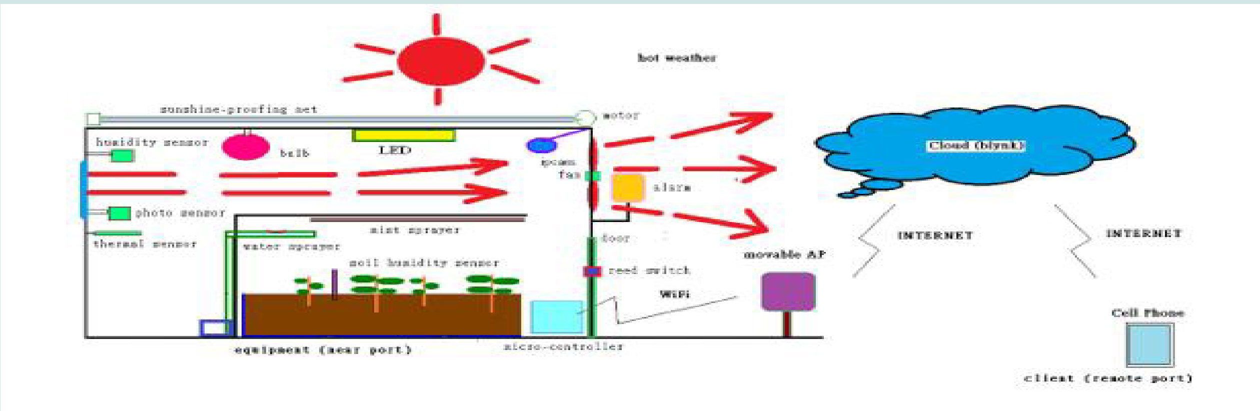

Figure 6: The fan is actuated when the temperature in greenhouse is higher than the specified temperature.

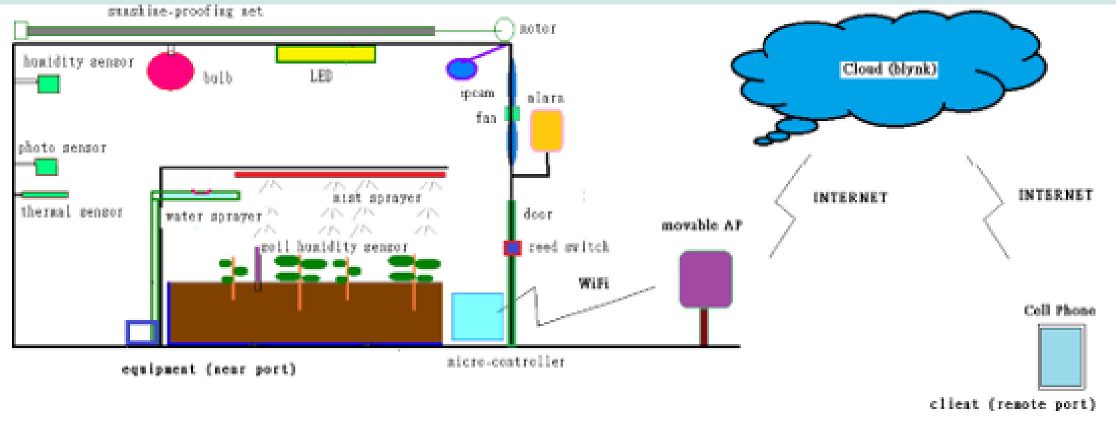

Figure 7: The mist sprayer is activated when the air humidity is lower than the humidity threshold.

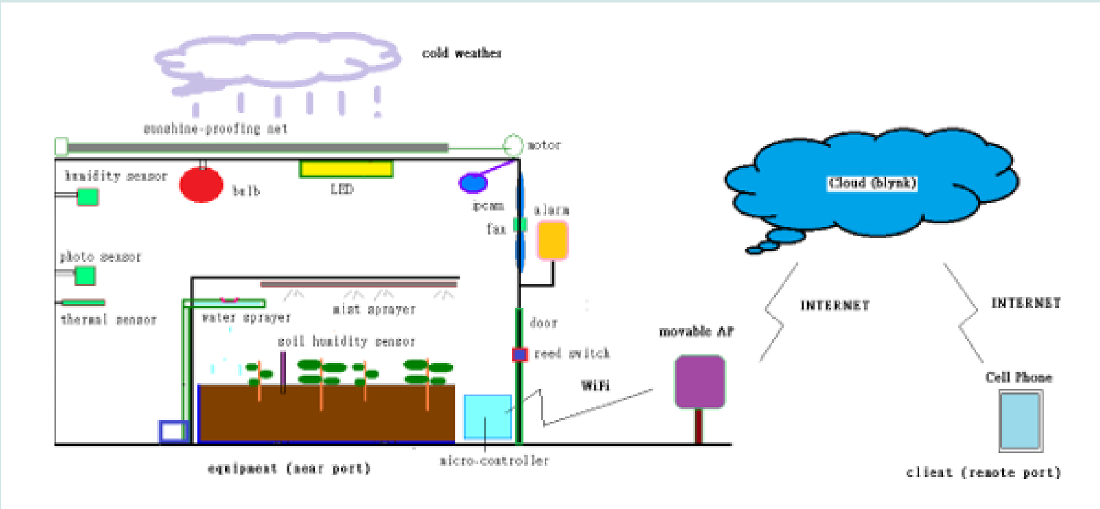

Figure 8: The heating bulb is started when the temperature within the greenhouse is lower than the specified temperature minimum.

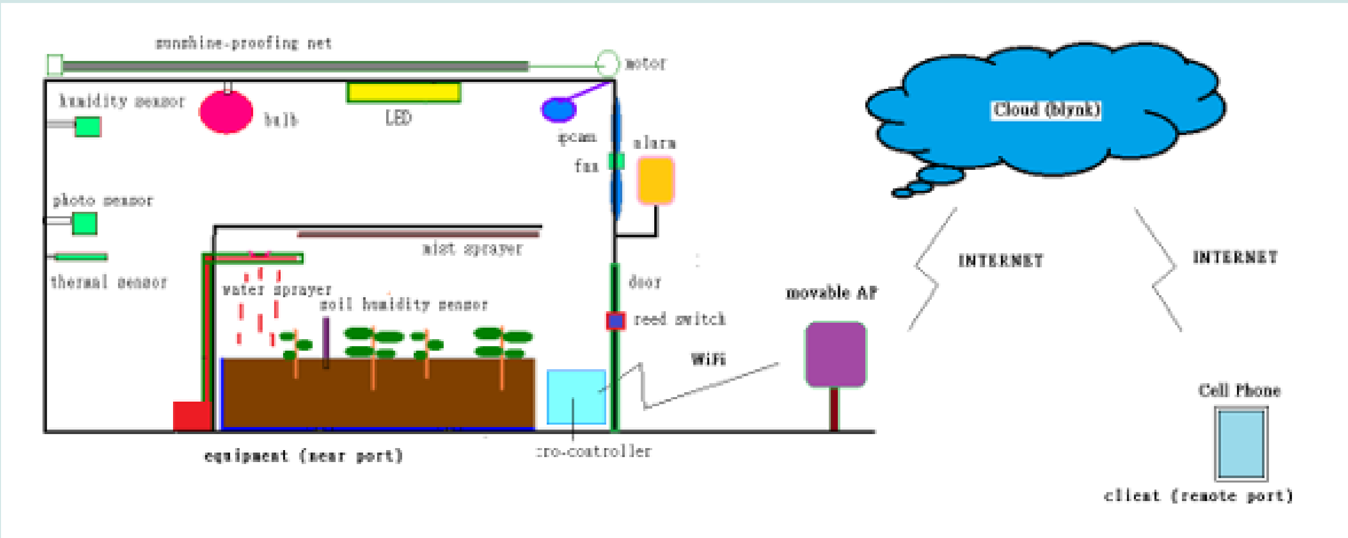

Figure 9: The water sprayer is activated when the soil humidity is too low.

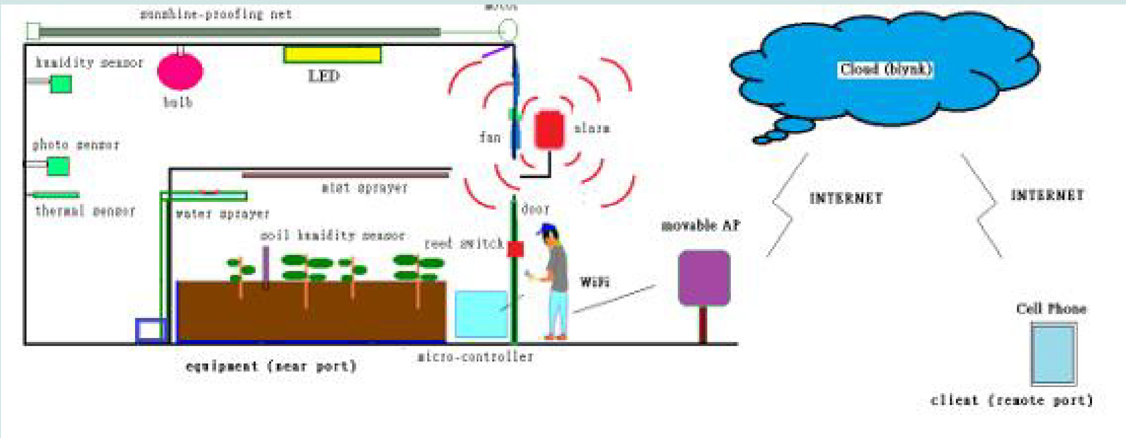

Figure10: The alarm system is activated when the greenhouse is invaded.

```
#define dhtPin 8
#define dhtType DHT11
DHT dht(dhtPin, dhtType);
//int bml=49 ;
float h=0;
float t=0;
int moister=0;

int value=0;
int light=21 ;
int pump=22;
int motorF=23 ;
int motorB=24 ;
int fan=25;
int alarm=26 ;
int safety=27 ;
int limit0=28 ;
int limit1=29 ;
int a;

int hL=30;
int hH=60;
int tL=25;
int tH=28;
int valueT=100;
int moisterT=800;
int safetyv=0;
int limit0v=0;
int limit1v=0;
```

Figure 11: Abstract of the Arduino program.

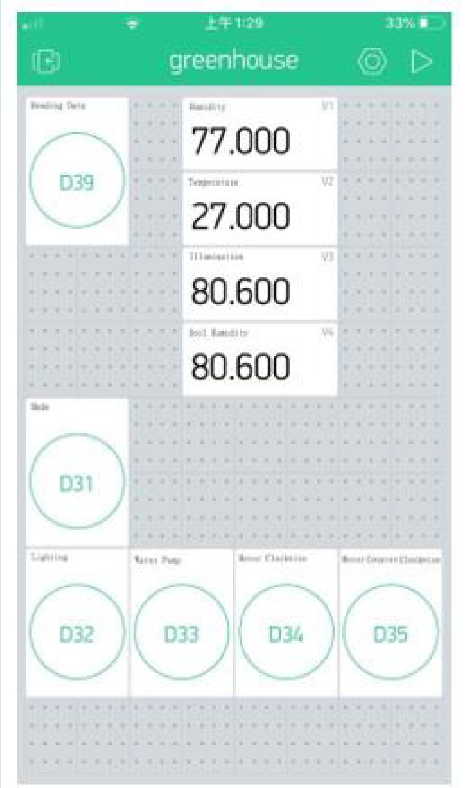

Figure 12: The environmental parameters shown on the cell phone.

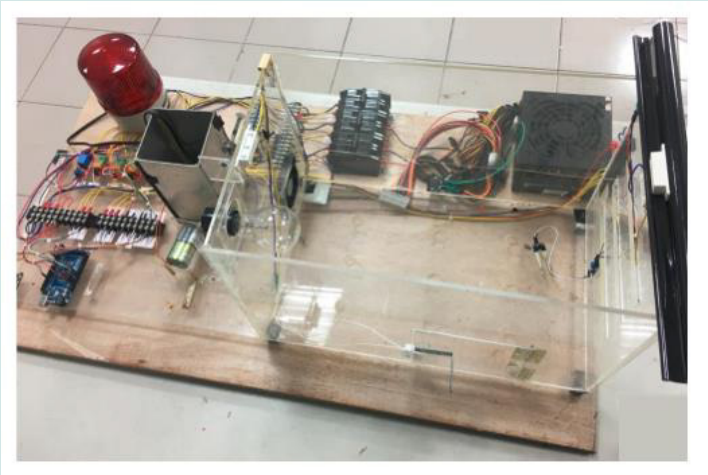

Figure 13: A prototype of an IoT-based greenhouse system.

Conclusion

It has been shown that an IoT-based greenhouse is online monitored and controlled by five sensors and six actuators. Considering an online plant's monitoring, four kinds of environmental data detected by the sensors will be transmitted from the near port (greenhouse) to the cloud via a Wi-Fi module in conjunction with a movable AP network. The remote user can use the cell phone to login to the cloud and to monitor these plant's parameters. In addition, user can remotely set up the system mode (automatic mode and manual mode). The greenhouse will automatically adjust plant's environmental parameters when the auto mode is selected. On the contrary, the actuators within the greenhouse can be remotely controlled if the manual mode is selected. Moreover, a security system with reed-switch in conjunction with an alarm system is also established. Consequently, an IoT-based greenhouse which can provide an easy way to online monitor/control planting information and to assure the greenhouse security without using internet wiring on the farm is demonstrated.

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