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Greenhouse Monitoring System Using Wireless Sensor Networks (WSN) Based on IoT

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Abstract: The popularization of greenhouse cultivation in agriculture is becoming more and more common, providing sufficient vegetables throughout the year. However, the traditional indoor temperature and humidity monitoring in greenhouses still requires manual measurement on a regular basis, which is inefficient and has poor accuracy. In order to solve the problem of greenhouse temperature and humidity monitoring, a time-sensitive, convenient, and easy-to-use remote monitoring system for greenhouse temperature and humidity is designed. The system collects data with an Arduino Uno control board and uploads and stores data on the ThingSpeak cloud platform with an ESP8266 control board. The DHT22 high-precision sensor is used as the temperature and humidity data acquisition module. And use the browser or smart phone to view remotely at any time. The analysis and test show that the system has high accuracy and low cost. low cost. It is a reliable monitoring system that has a great role in promoting greenhouse vegetable cultivation.
Keywords: Temperature, Humidity, Arduino Uno, Esp8266, ThingSpeak.

I. INTRODUCTION

Greenhouse-planting vegetables is anti-seasonal planting. Changes in the external environment and normal vegetable growth and development in the natural environment cause opposite changes. But the greenhouse has the ability to regulate indoor environmental factors within a suitable range [1]. This means that the greenhouse can provide an ideal environment for vegetables and other plants to grow and bear fruit regardless of season. This is beneficial for farmers because they can plant vegetables at any time of the year.

With the development of China's national economy, people's living standards are improving, and the winter greenhouse vegetable market is expanding rapidly, especially in the northern region in the cold winter, relying only on the long-distance transportation of vegetables to the north. Not only is the cost high, but there is also a delay in the best period of vegetable consumption [2]. Relying on agricultural science and technology and promoting plastic greenhouse planting vegetables is a potential development trend of vegetable cultivation.

Climate change, scarce resources, and population growth are straining the global agricultural economy. Farmers are looking for methods to increase crop productivity and resilience. Now most farmers are still using manual ways to inspect the management of vegetable greenhouses, a waste of a lot of manpower and material resources, and the temperature and humidity control of vegetable greenhouses is not ideal, often due to improper control of temperature and humidity caused by crop yield loss, thus bringing great losses to farmers [3]. Especially small-scale vegetable greenhouses in rural areas still use traditional manual temperature and humidity control methods, but there are shortcomings such as low control accuracy and untimely response. Traditional methods of greenhouse environment monitoring were manual and inconsistent, resulting in limited quantifiable data.

Vegetable greenhouses and other production techniques have significantly increased the efficiency and adaptability of agricultural production, which is currently developing quickly under the direction of science and technology. With the application of modern information technology, wireless communication technology, Wireless Sensor Networks (WSN), Internet of Things (IoT) technology, and low-power embedded technology in the greenhouse control system, the greenhouse environmental control system in general is moving in the direction of wireless, networked, intelligent development. Especially in recent years, the rapid development of mobile Internet and the emergence of wireless communication such as 5G have ensured the reliability of IOT data transmission and provided the necessary conditions for real-time monitoring [4]. Make it possible for people to monitor the information they need anytime and anywhere. The control of temperature, humidity, light, and other parameters in the process of agricultural production is of great significance in promoting crop growth. Internet of Things-enabled greenhouses permit precise regulation of temperature, humidity, and light levels.

With the rapid development of micro-electro-Mechanism System (MEMS), system-on-chip (SOC), wireless communication, and low-power embedded technology, wireless sensor networks (WSNs) have been born. Wireless Sensor Networks (WSN), with their low-power, low-cost, distributed, and self-organizing characteristics, have brought about a change in information perception.

WSN is a new hot research field in the international arena and is an emerging wireless network technology. Wireless sensing systems are developing towards micro-miniaturization and intelligent development. WSN can be regarded as a "sensor module" with "wireless sensor module" and "wireless sensor network", and can be used as a "sensor module" and "wireless sensor network". WSN can be regarded as a network composed of "sensor modules" and "wireless networking modules.", WSN is a wireless network composed of self-organized ways; its network coverage area is wide, the cost is low, and it is more suitable for the application of large-scale monitoring [5]. Wireless sensors not only sense signals but also collaborate to collect and process data from the geographic area they cover and send the information to the control room for management to complete other operations.

A typical WSN architecture includes sensor nodes, gateway nodes, the Internet, a user interface, etc. WSN nodes are usually composed of micro-control units, wireless transmission units, sensor units, and power supply management units, which are able to collaborate to complete the data acquisition, processing, and transmission functions [6]. The nodes in a WSN are usually near the temperature and humidity collection points, and the wireless sensor nodes will construct a self-organizing way through the wireless network so that the communication area can sense, collect, and process the data information that needs to be taken in the network coverage area.

Now that the smart greenhouse management system can effectively improve the temperature, humidity, light, and other vegetable growth factors regulating ability, the application of an intelligent vegetable greenhouse control system can not only improve the degree of automation of vegetable greenhouses but also help to improve the control accuracy of vegetable greenhouses. At present, the intelligent management system has been widely studied and partially applied in the process of modern agricultural production [7]. After practical testing and application, the intelligent vegetable greenhouse management system, relative to the traditional management and monitoring methods of vegetable greenhouses, has obvious advantages.

Intelligent vegetable greenhouse management system: the core of its design is a large number of sensing and monitoring devices for real-time monitoring of the environment in the vegetable greenhouse, which will monitor the data obtained as an important parameter for intelligent control of vegetable greenhouses [8]. The intelligent vegetable greenhouse control process will rely on the automatic analysis of the control system by the relay module for a variety of environmental regulation equipment drive control and ultimately realize the automation and intelligent control of the vegetable greenhouse.

Greenhouse temperature and humidity monitoring and control equipment, including a variety of open windows, forced ventilation, pulling the curtain protection, auxiliary temperature regulation, etc., can effectively improve the greenhouse internal production environment [9]. The commonly used vegetable greenhouse control system generally consists of a microcontroller, temperature and humidity detection and control, light intensity detection, and other modules. Through the microcontroller on the greenhouse internal environment of temperature and humidity, light intensity signal acquisition, after the collection of data by the liquid crystal display in real-time, will be measured value and threshold for comparison. If the parameters exceed the normal adaptation range of crops, the microcontroller drives the temperature and humidity, light intensity, and other control circuits to control the corresponding processing equipment inside the greenhouse. When the production environment parameters to reach the appropriate range of crops are met, processing equipment is shut down.

With the rapid development of the economy and modern technology, modern agriculture has also begun to gradually develop in the direction of intelligence. A variety of agricultural facilities are used to create a favorable environment for the growth of crops, among which smart greenhouses have become an important part of agricultural farming. At present, the degree of automation of traditional crop greenhouses is low, and the technology used to gather environmental data is relatively backward [10]. In order to solve the above problems, a remote monitoring vegetable greenhouse environment monitoring system based on Internet of Things technology is designed.

The remainder of the article is divided into four main sections, with Section II describing the related work. Section III describes in detail the process by which the study was carried out. Section IV presents the experimental results. Section V is the conclusion.

II. RELATED WORK

This section will outline the main solutions proposed and developed for the smart greenhouse. In the literature, the different solutions of intelligent vegetable greenhouse system research for internal environmental monitoring of the greenhouse were summarized. And each solution uses a different approach to embed IoT technology into traditional greenhouse planting.

D. Sandilya *et al*. [11] designed and developed a smart system for the greenhouse to monitor internal greenhouse environment factors: soil moisture, temperature, humidity, and light intensity. Arduino Nano was used as the miccontroller to collect the monitoring values; after that, these data were transferred to ESP01 by wired connection, then transferred to Raspberry Pi 3 through a wireless network.

The results showed that the proposed system could remotely monitor the environmental conditions inside a greenhouse via the MQTT protocol. A. Supriyanto *et al.* [12] proposed an intelligent monitoring system for hydroponics systems. In this system, the DHT11 sensor was used to collect humidity values, and the DS18b20 sensor was utilized to detect water temperature. An Arduino Uno was used as the microcontroller to collect the monitored data. The data could not only be displayed on an LCD screen but would also be uploaded and stored in the database by the ESP8266 microcontroller through a wireless connection. To display the monitored data, a webpage was developed with a friendly user interface. The results showed that this proposed system was deployed in a real hydroponic planting system, operated at high performance, and reached a 95% accuracy rate. A. Abosaq *et al.* [13] proposed a smart greenhouse system for monitoring soil moisture, light intensity, humidity, and temperature inside a greenhouse. The system used an Arduino Uno as the microcontroller to provide power to the whole system. A solar panel was utilized to supply power through an inverter. The proposed system was tested in a small greenhouse and showed that it could monitor and record greenhouse environmental factors automatically. The system was successfully able to measure the changes in environmental factors and provide feedback to the user. The results of the system were promising, and the researchers concluded that it could be used in other greenhouses. Y. Liu [14] Proposed a smart greenhouse to monitor the ambient temperature and humidity of the greenhouse. A DHT22 sensor was used to collect both temperature and humidity, and an ESP8266 microcontroller was utilized to collect the sensor data, which was then transmitted and stored in the cloud database via a wireless network. The live-monitored data could be displayed on an LCD screen.

Apart from that, a smart phone app was designed to access the monitored data remotely too. A heating panel and a fan were integrated to adjust and maintain the internal environment at an idea level based on the automatic response algorithm. This proposed system could alleviate farmers' workload and inspection times. This proposed system would help farmers monitor their crops in real-time and make timely decisions. Furthermore, it could also help to reduce the cost of production and improve the efficiency of the farming process. F. Zhang *et al.* [15] developed a NB-IoT-based intelligent greenhouse management system. The system could monitor the temperature, wind speed and direction, humidity, and light intensity. The STM32F103ZET6 chip was chosen as the main microcontroller based on its accuracy and efficiency. The AM2306 digital sensor was selected to collect temperature and humidity.

A BH1750FVI sensor was used to monitor the light intensity value. SM5384B and SM5385B sensors were used to monitor wind direction and speed. The NB-IoT-IoTwork was responsible for transmitting data between sensors and the cloud server and receiving commands from the remote terminal. Furthermore, a HC-08 Bluetooth microcontroller was designed for data transmission between terminal nodes and smart phones. A phone-based and a web-based user interface were developed to display the monitored data. The system was tested and achieved 99.8% data transmission accuracy.

As we have seen, all the presented prototypes apply sensors to monitor the environment surrounding greenhouse plants. Nevertheless, a number of these systems are not readily adaptable or scalable. The objective of this project is to develop a smart greenhouse that is not only readily adaptable to various crops, but also manages the administrative and economic aspects of the farm without requiring a deep understanding of the technical implementation.

III.METHODOLOGY

The utilization of IoT technology has been implemented across several industries. A temperature and humidity monitoring system for a smart greenhouse is built by employing the Internet of Things (IoT) concept. This section is divided into two subsections: system architecture and experimental setup.

A. System Architecture

In this project, a smart greenhouse temperature and humidity monitoring system is designed for a greenhouse. The DHT22 sensor is selected to collect both ambient temperature and humidity inside the greenhouse. The Arduino Uno microcontroller is utilized to collect and process the sensor data. The data will be encapsulated into a packet and sent to the ESP8266 microcontroller from the Arduino Uno through JavaScript Object Notation (JSON) serial communication. After that, the ESP8266 will transmit the received data to the cloud server for storage. The user could access the monitored temperature and humidity data remotely through the network. The ESP8266 microcontroller also serves as a router, allowing communication between the Arduino Uno and the cloud server. The cloud server can be used to store and analyze the data. The overall block diagram of the proposed system is shown in Fig. 1.

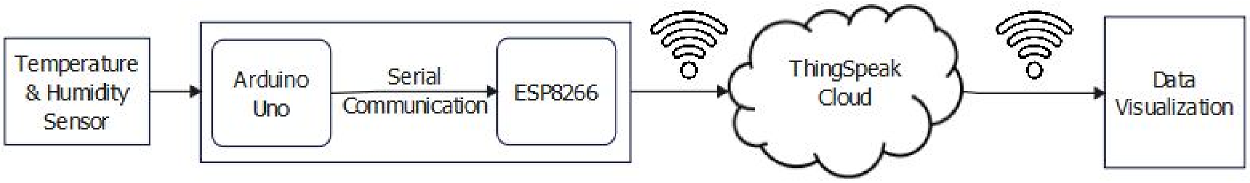

Fig. 1 System block diagram.

B. Experiment Setup

To carry out this research, there are main two parts for this project: data acquisition and data transmission to the cloud platform.

1) *Temperature and Humidity Acquisition Module:* The DHT22 temperature and humidity sensor is used in the design, which is a single-bus sensor that can output digital signals. The DHT22 sensor contains a resistive humidity sensor and an NTC temperature sensor that can be directly connected to a high-performance microcontroller. The DHT22 calls up calibration coefficients in a disposable programmable memory during signal processing, which are calibrated and stored programmatically in a precision calibration chamber. The use of a single-wire serial interface makes the system design process easier and faster. The digital temperature and humidity sensors are highly integrated, combining temperature detection, humidity detection, A/D conversion, and signal conversion in one unit and outputting a digital signal through a digital serial data interface. The DHT22 temperature and humidity sensor belongs to a digital sensor. Its low power consumption, strong anti-interference ability, small size, low price, ability to measure temperature and humidity at the same time, full-range calibration without the need to recalibrate, ability to be used interchangeably, and fast response time Meet the requirements of use. Sensor to resist moisture-sensitive elements and thermistors as the integration of temperature measurement elements, connected to an 8-bit microprocessor. Will have been adjusted to the correct data burned into a disposable programmable read-only memory. Sensor internal detection signal processing will be read directly. The sensor is highly accurate, easy, and fast. The diagram of DHT22 sensor is shown in Fig. 2.

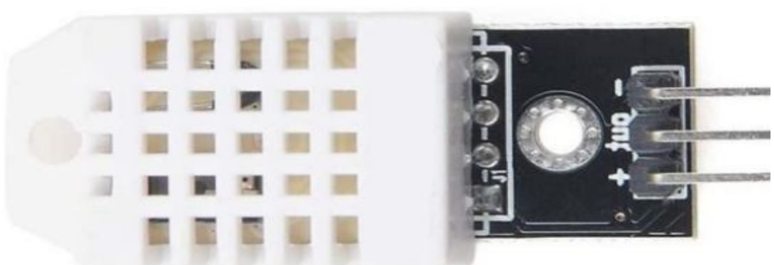

Fig. 2 DHT22 sensor.

Arduino Uno is an open-source hardware project platform. The core device is an ATmegal28 microcontroller. The platform includes a board with simple I/O functions and a set of program development environment software. For other microcontroller development platforms, Arduino's biggest advantage is its ease of use and ability to develop their own projects in a fairly short period of time. Fig. 3 shows the diagram of the Arduino Uno microcontroller.

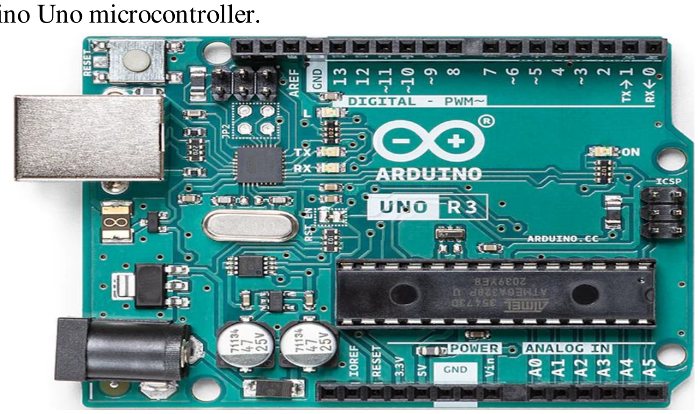

Fig. 3 Arduino Uno R3 module. (Source: https://www.arduino.cc/)

2) *Design of Wireless Communication Systems:* In order to meet the intelligent control needs of vegetable greenhouses, a large number of sensors and environmental control equipment are deployed. And with the planting of crop varieties changing, the deployment of sensors and control equipment in the vegetable greenhouse may also be increased, decreased, or adjusted. If all the sensors and control devices are connected in a wired way, then a large number of signal transmission lines will be deployed in the vegetable greenhouse, which will greatly increase the cost of intelligent vegetable greenhouses, but also the intelligent vegetable greenhouse management and maintenance of the later period brings great difficulties. For this reason, all the sensors and control devices inside the intelligent vegetable greenhouse use wireless control devices for communication. Because of the sensors and control devices in the work, the amount of data generated is not large, so the whole system of communication problems can be solved through wireless serial communication. Wireless serial communication is a low-rate communication method because of its simple implementation, stable operation, and strong anti-interference ability, so it is very suitable for deployment in the intelligent vegetable greenhouse application system. So, based on above considerations, ESP8266 microcontroller is chosen to be as the wireless communication module. ESP8266 microcontroller is a high-performance WiFi serial module. The internal integration of the microcontroller unite (MCU) can realize serial communication between microcontrollers. It is currently one of the most widely used WIFI modules. The ESP8266 supports softAP mode, station mode, and softAP + station coexistence mode. The ESP8266's powerful on-chip processing and storage capabilities allow it to integrate sensors and other application-specific devices through the GPIO port, realizing the lowest up-front development and operation of the least occupied system resources. The built-in cache memory helps to improve system performance and reduce memory requirements. The use of ESP8266 can realize very flexible networking and network topologies. The diagram of ESP8266 microcontroller is shown in Fig. 4.

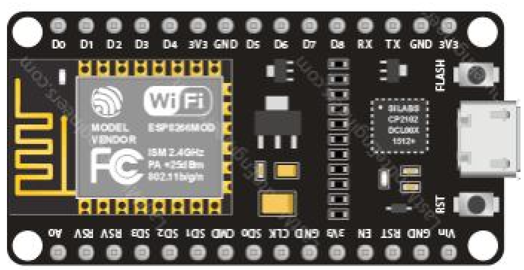

Fig. 4 ESP8266 microcontroller module.

Table I shows the specific pin connections of different hardware modules. The Arduino Uno pins of D5, D6, VCC, and GND are connected to the ESP8266 pins of D5, D6, VCC, and GND, respectively. The out, VCC, and GND pins of DHT22 are connected to the pins of D7, VCC, and GND, respectively. The overall connection diagram of hardware modules is shown in Fig. 5.

TABLE I
Hardware connection specifications

Arduino Uno	ESP8266	DHT22
D5	D5	
D6	D6	
D7		out
3.3V	3V3	
5V		+
GND	GND	-

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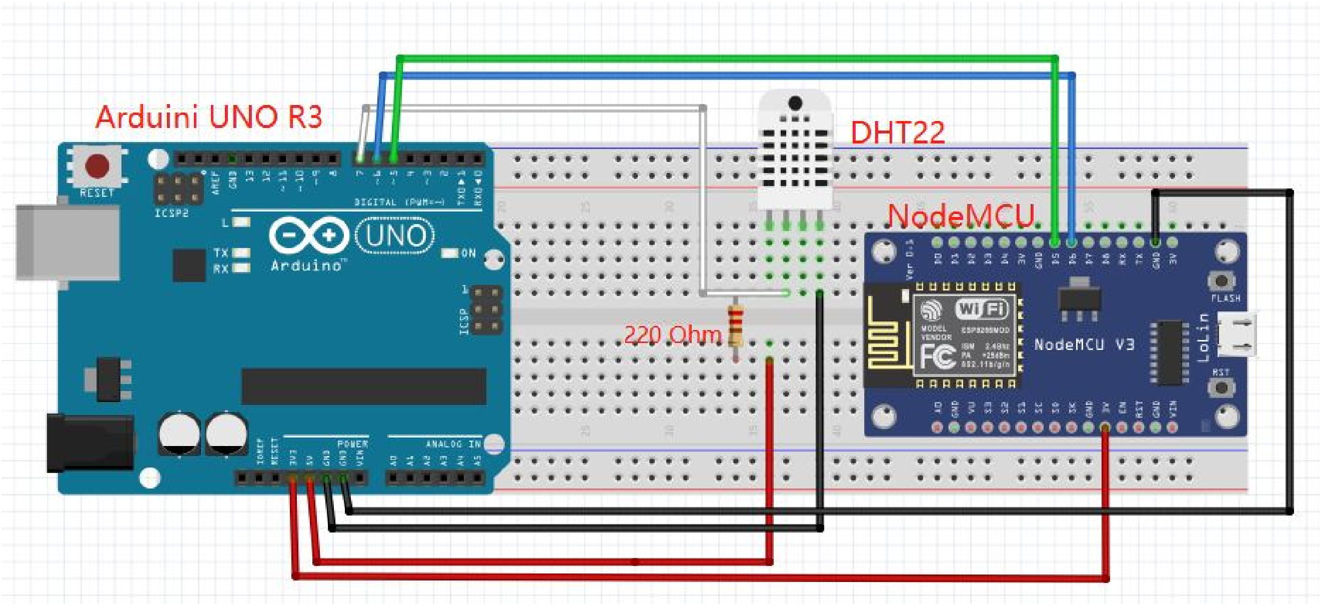


Fig. 5 Overall connection diagram.

IV. RESULTS

Based on the above-proposed methodology, the real hardware prototype was constructed as shown in Fig. 6. The Arduino Uno microcontroller collected temperature and humidity data. The collected data was then passed to the ESP8266 microcontroller via JSON communications. After that, the data would be transferred and uploaded to the ThingSpeak cloud platform. The users could access the monitored data remotely through the network by using a specific channel ID. This system was tested within one week; it ran normally and verified its reliability. The friendly user interface makes it easy for farmers to inspect the current and historical temperature and humidity data of the internal greenhouse as shown in Fig. 7. The stored data could then be used to make decisions regarding watering and irrigation, temperature regulation, and other greenhouse management tasks. By using this system, the farmers could reduce inspection times and costs, thereby improving their working efficiency. The system also kept track of any changes in the temperature and humidity, allowing for quick action if necessary. Additionally, the system could be used to provide insights for increasing yields and optimizing the use of resources.

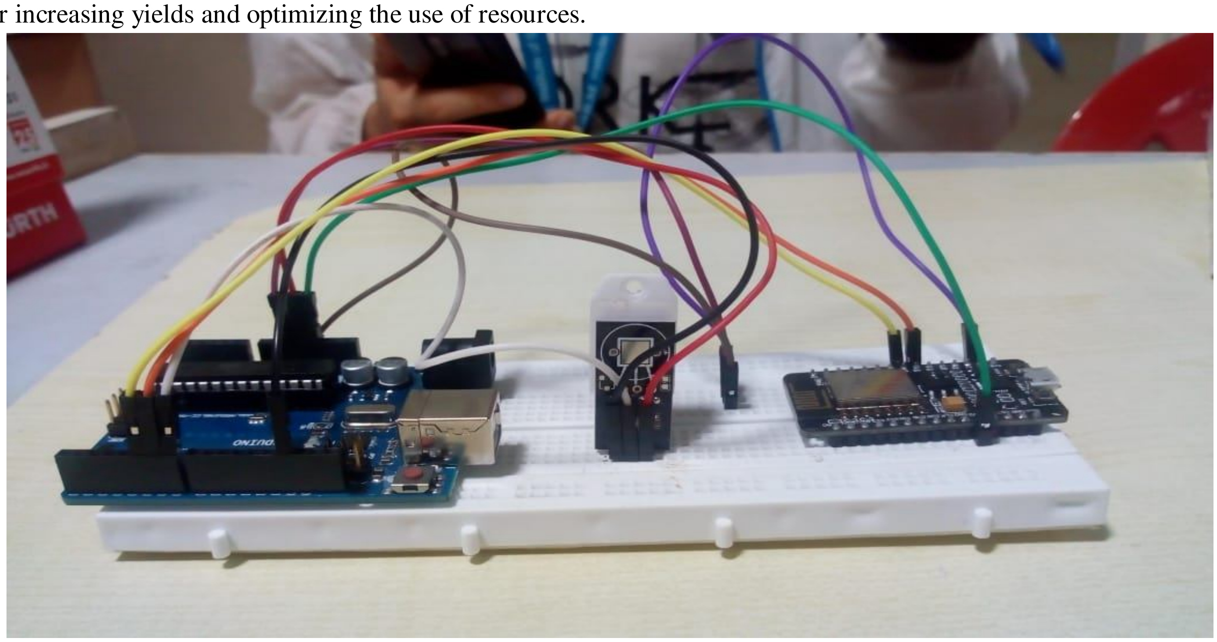
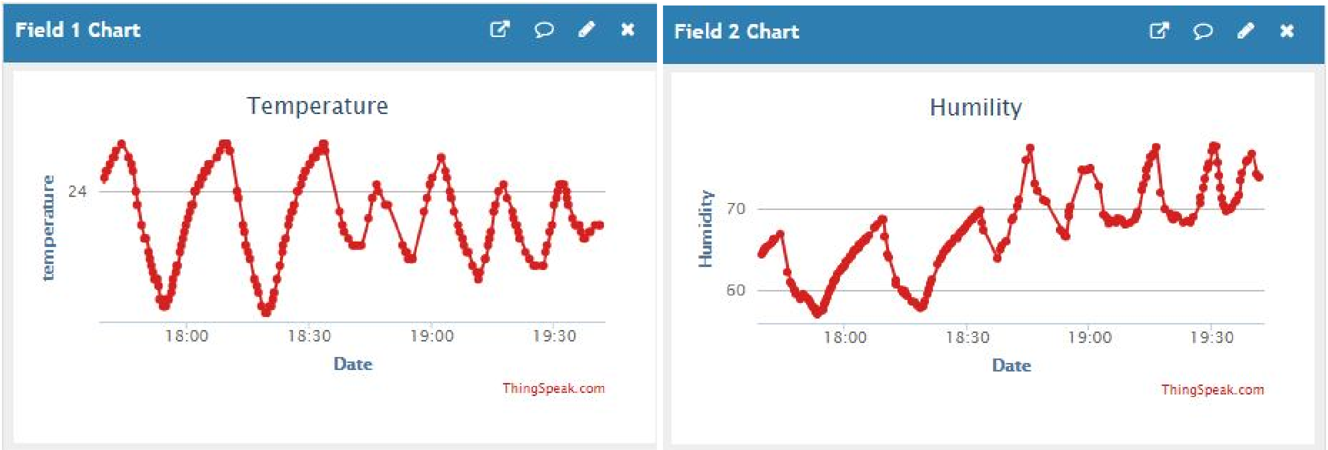


Fig. 6 Constructed hardware prototype.



(a) Temperature (b) Humidity

Fig. 7 Monitored data through the user interface.

The data would be updated in 20 seconds interval. From Fig. 7, the temperature and humidity value dynamically change in a normal range. And there is a negative correlation between the trends in temperature and humidity.

V. CONCLUSIONS

Intelligent vegetable greenhouses are the inevitable trend of modern agricultural development. The research and design of traditional vegetable greenhouses through the utilization of Internet of Things (IoT) technology can quickly realize the upgrading and transformation of traditional vegetable greenhouses into intelligent vegetable greenhouses. This paper creates a low-cost, reliable, real-time monitoring system for greenhouse temperature and humidity. The data acquisition module and the wireless communication module are the main parts of the intelligent vegetable greenhouse monitoring system and provide a detailed plan for how to design and set it up. When combined with some mature sensor units and control units on the market at present, it can quickly realize an intelligent vegetable greenhouse temperature and humidity monitoring system. Due to the use of modular design, the system is inexpensive. Easy to install and maintain. Suitable for promotion in the actual production of agriculture.

VI. ACKNOWLEDGMENT

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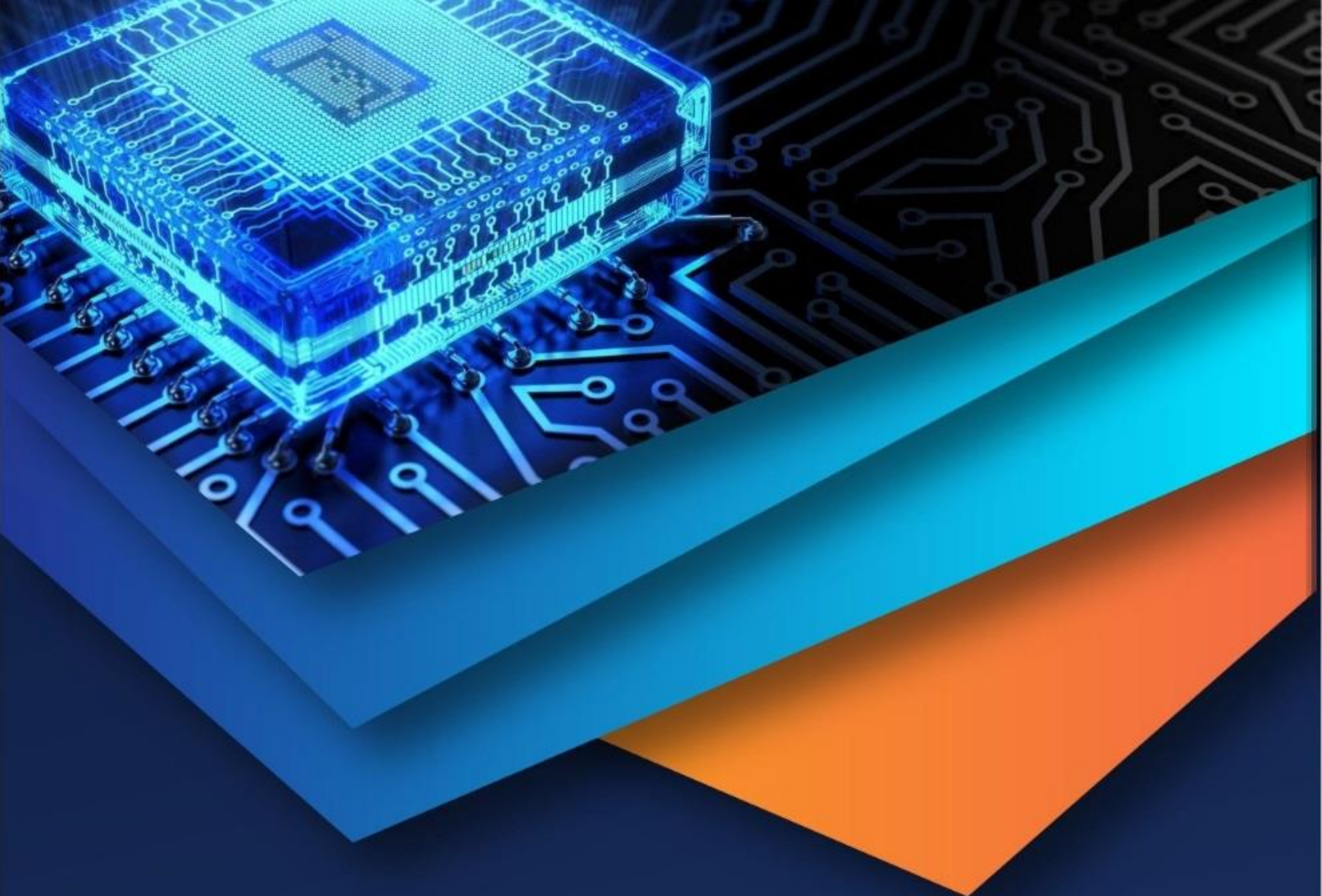

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