Monitoring of Macadamia Nut Planting Environment Based on Smart Sensor Technology

Jinyun Zhang¹, Xiujuan Zhao¹, Liang Tao¹, Shijun Wu¹, Qianqian Chen¹

¹Guangdong Eco-engineering Polytechnic Department of Horticulture, Guang Zhou, Guang Dong, China 510520

*Corresponding author email: jzzt223@gxstzy.edu.cn

Abstract: Smart sensor network technology integrates sensors, embedded computing, modern networks, wireless communication and distributed information processing technologies, and is currently a frontier hot research field in the world. The application of wireless sensor network to the greenhouse environment monitoring system to realize self-organizing network, wireless data transmission and intelligent control is also of great significance to the realization of agricultural modernization. The purpose of this paper is to study the monitoring of macadamia nut planting environment based on smart sensor technology. Since the greenhouse environment monitoring system has very high requirements for power consumption, cost and stability, this article selects ZigBee wireless sensor network technology with low power consumption, low cost, high stability, etc. to build a set of monitoring temperature and humidity greenhouse wireless smart sensor network model. According to the actual requirements of greenhouse environment monitoring, this article proposes a new type of ZigBee technology-based greenhouse macadamia nut planting environment monitoring system solution, and gives the overall structure of the system. Considering many aspects such as cost and power consumption, this article stores, displays, analyzes and processes the acquired data. The functions of the system meet the design requirements. The system realizes the collection of greenhouse parameters and the data display and processing functions, and realizes the video monitoring of the greenhouse. Experimental studies have shown that in the actual greenhouse environment, due to a large number of crops blocking, it is bound to produce certain obstacles to signal transmission, but because of the large number of nodes, the distance between the node and its parent node will not exceed 25m, which also ensures The data collected by sensor nodes can be safely and error-freely transmitted to the coordinator node in a multi-hop manner.

Key words: Smart Sensor Technology, Macadamia Nut Cultivation, Environmental Monitoring, Wireless Sensor Network
1. Introduction

With wireless sensor network technology, it can provide users or farmers with ground information, soil information, nutrition information, harmful substance monitoring and warning, growth information, etc. in real time. Based on this information, users can develop relevant strategies to help farmers discover production in time. Problem, and accurately determine the location of the problem, so that agriculture will shift from a production model that is human-centered and rely on agricultural machinery to a production model centered on information and software, using various types of automation, intelligence, and networking. Production equipment, truly realize ubiquitous digital agriculture.

My country has conducted a lot of research on the use of network communication technology for the dissemination and promotion of agricultural science and technology, as well as for remote consulting services. To manage a group of greenhouses, Zhang W developed an approximately distributed wireless data acquisition and control system. In each greenhouse, a wireless network based on 433.92MHz technology is used to connect the sensor network and the local controller, the actuator network and the local controller are connected through the controller area network, and the local controller is connected through another 458MHz radio frequency It is wirelessly connected to a central PC, and the upper data communication is connected to the central PC and the remote network via Ethernet [1]. The wireless network communication system established by Chen Yufeng connects the agricultural machinery in the farm, such as cotton pickers, sprinkler irrigation machines, variable fertilizer applicators, and personal communication equipment to the base station, and provides these machinery with more professional farmland information and Operation guide [2]. Yin Xiaoman established a wireless local area network for farmland and greenhouse. This network is used to monitor the growth of crops and remotely control the production system. The research results show that this remote control strategy model can greatly improve and increase productivity and reduce manpower requirements. [3].

According to the requirements of greenhouse environment testing, in different experimental conditions and locations, the designed ZigBee greenhouse monitoring system is tested for wireless communication and networking, temperature and humidity acquisition testing, packet loss rate testing and power consumption calculation. According to the results of the experiment, the feasibility of applying ZigBee wireless sensor network to the greenhouse environment is verified.

2. Monitoring of Macadamia Planting Environment Based on Smart Sensor Technology

2.1 Overall Scheme Design of the Environmental Monitoring System for Macadamia Planting Based on Zigbee

The main task of this paper is to study a ZigBee wireless sensor network suitable for greenhouse environment monitoring. According to the characteristics of greenhouse production, when building a wireless sensor network application system, the main design requirements of the system are as follows:

1) Requirements for temperature and humidity measurement

The macadamia planting greenhouse monitoring system designed in this paper requires timely and accurate acquisition of temperature, room temperature and humidity information, so that users can understand the crop growth environment in the greenhouse in real time [4-5];

2) Requirements for miniaturization

ZigBee network nodes are required to be small enough to be easily distributed in large quantities on the greenhouse site to obtain more comprehensive information. At the same time, it is convenient to move and reorganize the network.

3) Scalability requirements

The node must have a complete and unified external interface. When a new hardware device needs to be connected, it can be added directly to the original node without the need to redesign a new node.
3

(4) Stability requirements
The environment of the greenhouse is more complicated, which puts high demands on the stability of the nodes. The node designed in this paper requires all hardware components to work normally in the complex environment of the greenhouse [6-7].

(5) Low cost requirements
Because the wireless sensor network designed in this paper is applied in agricultural production, and the sensor nodes need a lot of dispersal, this puts forward requirements on the production cost of each node, and each component of the node requires a higher cost performance.

(6) Low power consumption requirements
The sensor node is powered by two dry batteries, which requires low power consumption in the process of information collection and network transmission, so that the node has a long enough working life.

2.2 Hardware Design of Zigbee Macadamia Nut Planting Environment Monitoring System
Based on the design requirements of the greenhouse environment monitoring system, combined with ZigBee technology, a new type of greenhouse environment monitoring system solution is proposed. It is composed of sensor nodes, router nodes, coordinators and upper PCs, and adopts a tree-shaped network topology [8-9].

(1) The coordinator is the center of the entire wireless sensor network. It is responsible for establishing a new network, processing sub-nodes' network access applications, and managing network connections. The coordinator node is powered by the USB bus, and at the same time is connected to the upper PC through the USB interface to send data to the monitoring center.

(2) The router node should not only act as a coordinator in its own subnet, manage network connections, but also act as a relay node, responsible for finding an optimal transmission path for each data frame passing through it, and then Send it to the destination address. Since the ZigBee protocol is a short-distance communication technology, the transmission distance is within 80 meters, and the existence of the relay node also greatly expands the data transmission distance. The router node is a full-function device, powered by a dedicated power source, and does not sleep.

(3) The sensor node belongs to the front-end equipment of the network and is mainly used to collect temperature and humidity information. When the node is not working, it can enter the dormant state and wake up by the timer. The sensor node is a streamlined functional device, powered by two dry batteries, and the ability to process information and communication is weak [10].

(4) The host PC is located in the monitoring center, and the serial port debugging tool (USB bus interface has been virtualized as a serial port to display the information uploaded by the coordinator, and real-time display of the working status of the node, including the node’s 64-bit MAC address, 16-bit Network address, connection status, communication port number and temperature and humidity information.

2.3 Data Fusion Technology
Data fusion makes full use of multiple sensor resources, and through the reasonable control and use of these sensors and their observation information, the redundant or complementary information of multiple sensors in space or time is combined according to certain criteria to obtain more A subset of the various components of the system constitutes a more superior performance.

Suppose there is an estimation of the length of a certain object, and n people give the estimated value $x_1, x_2, ..., x_n$, the accuracy of each person's estimation is different, so the weight of each person is also different, and the weights are $w_1, w_2, ..., w_n$, $y$ are weighted averages. The variance is $s^2$, the calculation formula of the weighted average is as follows:

$$y = \frac{\sum_{i=1}^{n} (x_i \times w_i)}{\sum_{i=1}^{n} w_i}$$ (1)

\[ S^2 = \frac{(y-x_1)+(y-x_2)+\cdots+(y-x_n)}{n} \]  

In practical applications, \( w_i \) is usually selected as \( 1/n \). Although this method is simple, it is often used in practical applications. The data fusion method based on two methods of arithmetic mean and estimation can obtain reliable initial measurement values in real time, eliminate uncertainty in measurement, improve the accuracy and repeatability of measurement results, and obtain more reliable real-time measurement results. This method is suitable for the slow variable detection system. Therefore, it is suitable for data fusion of soil moisture in the greenhouse.

Assuming that the humidity in the soil has been measured \( n \) times, the obtained measurement column first obtains consistent measurement data according to the distribution diagram method, and then divides it into two groups according to the principle of symmetry. The first group of measurement data is \( T_{1m}, m \leq (n+1)/2 \). The second set of data is \( T_{2k}, k \leq (n+1)/2 \), then the arithmetic averages of the two sets of data are:

\[ \bar{T}_1 = \frac{1}{m} \sum_{i=1}^{m} T_{1i} \]  
\[ \bar{T}_2 = \frac{1}{k} \sum_{i=1}^{m} T_{2i} \]

The corresponding standard errors are:

\[ \tilde{\sigma}_2 = \sqrt{\frac{1}{m-1} \sum_{i=1}^{m} (T_{1i} - \bar{T}_1)^2} \]

3. Experimental Research on Macadamia Planting Environment Monitoring Based on Smart Sensor Technology

3.1 System Monitors the Temperature and Humidity Accuracy Test of the Greenhouse

Among the factors that affect the growth of macadamia nuts, temperature and humidity have the greatest impact on the yield and quality of macadamia nuts. Therefore, the greenhouse environment temperature and humidity monitoring of the greenhouse environment is the most important and basic for the greenhouse monitoring system. When doing this experiment, we use the data collected by the temperature and humidity sensor as a benchmark for numerical comparison.

3.2 Wireless Communication and Networking Test

Due to limited conditions, this article designed to use three ZigBee modules (one is used as a coordinator to connect to a laptop, and the other two are terminal devices), using a star network topology to form a simple ZigBee network. Before the start of the experiment, first program the coordinator program and the terminal device program into these modules through the emulator. The coordinator node is connected to the computer through a USB interface. The USB interface here has been virtualized as a serial interface, so the uploaded data can be displayed through the serial port debugging tool.

3.3 Temperature and Humidity Collection Test

In order to simulate the real environment of the greenhouse, this experiment is carried out in the flower cultivation glass house of our school. On the one hand, it verifies the data collection and data transmission capabilities of the network, and on the other hand, it can also verify whether the node designed in this paper can work normally in the complex environment of the greenhouse. The experiment time was in the afternoon of September 12, 2018. The weather was fine, the outdoor temperature was around 35°C, and the humidity was around 42%RH.

The network established in this experiment is a simple star network composed of a coordinator
node and two terminal equipment nodes. Among them, the terminal equipment must be connected to sensors to form a sensor node, which collects environmental data on the greenhouse scene.

4. Experimental Research and Analysis of Macadamia Nut Planting Environment Monitoring Based on Smart Sensor Technology

4.1 System Monitors the Accuracy Test of the Temperature and Humidity of the Greenhouse

Among the factors that affect the growth of macadamia nuts, temperature and humidity have the greatest impact on the yield and quality of macadamia nuts. Therefore, the greenhouse environment temperature and humidity monitoring of the greenhouse environment is the most important and basic for the greenhouse monitoring system. The accuracy of temperature and humidity monitoring in the greenhouse directly affects the growth status of macadamia nuts. The accuracy of the monitoring system is very important. The accuracy test of the temperature and humidity monitoring of the greenhouse by the system is shown in Table 1.

| Sensor | Temp  | Humidity | Date   | Time |
|--------|-------|----------|--------|------|
| 1      | 19.47 | 36.58    | 20181115 | 1034 |
| 2      | 22.48 | 35.26    | 20181115 | 1538 |
| 3      | 18.34 | 34.18    | 20181115 | 1638 |
| 4      | 17.97 | 31.85    | 20181115 | 1738 |

Figure 1 shows the specific data of the 4 wireless sensor nodes collected by the system. Because of the different locations of wireless sensor nodes, the data they collect are also different. Place the TSI handheld temperature and humidity sensor near the sensor node 3 for measurement. Because this experiment was conducted in a spring greenhouse, the humidity data collected was low. At this time, the average value of the greenhouse collected by the sensor is 19.53 °C. The temperature difference is -0.83%. The relative humidity is 28.3%, and the relative humidity difference is 2.273%. The system measurement data meets the requirements of agricultural production control accuracy.

4.2 Barrier-Free Data Transmission Packet Loss Rate Test

The experiment was chosen to be carried out on the open field of our school. The distances between nodes were 20m, 40m, 60m, 80m and 100m, and the number of data packets sent was 100. After many repeated tests, the experimental results are shown in Figure 1.
Figure 1. Test results of packet loss rate of barrier-free data transmission

From the experimental results, it can be seen that within the range of 90m, the data transmission packet loss rate has been decreasing, and packet loss began to appear until 90m. This also shows that in an open and unobstructed place, the reliable communication distance of the ZigBee node designed in this paper is 70m.

4.3 Test of Packet Loss Rate of Obstructed Data Transmission

The experiment is chosen to be carried out in the laboratory of our school, the receiving node is placed indoors, the sending node is placed outdoors, and data transmission is carried out across the wall. The distance between nodes is set to 5m, 15m, 25m, 35m, and 45m, and the number of sent data packets is 100. After repeated tests for many times, the results of the experiment are shown in Figure 2.

Figure 2. Obstacle data transmission packet loss rate test results

It can be seen from the experimental results that within a range of 25m, there is no packet loss in data transmission. At 30m, the packet loss is already serious. At 45m, almost no signal is received. In the actual greenhouse environment, due to a large number of crops blocking, it is bound to cause certain obstacles to signal transmission, but because of the large number of nodes, the distance between the node and its parent node will not exceed 25m, which also ensures that the sensor node collects Data can be safely and error-free transmitted to the coordinator node in a multi-hop manner.

5. Conclusions

This article carried out the experimental test of the greenhouse wireless sensor network, mainly including: wireless communication and networking test, temperature and humidity acquisition test, packet loss rate test and power consumption calculation. The experimental results show that the ZigBee greenhouse environment monitoring system solution designed in this paper is completely feasible. The ZigBee warm macadamia nut planting environment monitoring system designed in this paper can accurately measure and collect temperature and humidity information, and can safely and accurately transmit this information to the coordinator node through multi-hop; the node battery meets the performance of the ZigBee greenhouse environment monitoring system Consumption requirements.

Acknowledgements

Forestry reform and development fund of central finance in 2020 (subsidy for forestry science and technology promotion and demonstration) "Demonstration of high yield cultivation of new
Macadamia strains

References

[1] Zhang W, Yang H, Feng W, et al. Application Study of Greenhouse Environment Monitoring System Based on ZigBee Technology[J]. Asian Agricultural Research, 2017(02):43-47+75.

[2] Chen Yufeng. Research on the agricultural greenhouse environment monitoring system design based on Internet of Things technology[J]. Jiangsu Science and Technology Information, 2018, 035(027):49-52.

[3] Yin Xiaoman, Ma Jun, Chen Boxing, et al. Design and implementation of smart home environment monitoring system based on ZigBee technology[J]. Automation and Instrumentation, 2019, 000(003):96-99.

[4] Yoo H S, Suh E K, Kim T H. A Study on Technology Acceptance of Elderly living Alone in Smart City Environment: Based on AI Speaker[J]. Journal of Industrial Distribution & Business, 2020, 11(2):41-48.

[5] Li Chuanyao. Study on monitoring and evaluation of ecological environment quality in Jinan based on GIS and RS[J]. Jiangsu Science and Technology Information, 2017, 000(026):73-74.

[6] Chen M, Wang J, Li P, et al. Development of intelligent gateway for heterogeneous networks environment monitoring in greenhouse based on Android system[J]. Transactions of the Chinese Society of Agricultural Engineering, 2015, 31(5):218-225.

[7] Lombardo L, Corbellini S, Parvis M, et al. Wireless Sensor Network for Distributed Environmental Monitoring[J]. IEEE Transactions on Instrumentation and Measurement, 2017, 67(99):1214-1222.

[8] Xue-Fen W, Yi Y, Tao Z, et al. Design of Distributed Agricultural Service Node with Smartphone In-field Access Supporting for Smart Farming in Beijing-Tianjin-Hebei Region[J]. Sensors & Materials, 2018, 30(10(1)):2281-2293.

[9] Beak M S, Kwon S Y, Lim J H. Improvement of uniformity in cultivation environment and crop growth rate by hybrid control of air flow devices[J]. Journal of Central South University, 2015, 22(012):4702-4708.

[10] Seo J H, Park H B. Forest Environment Monitoring Application of Intelligence Embedded based on Wireless Sensor Networks[J]. KSII Transactions on Internet and Information Systems, 2016, 10(4):1555-1570.