Intelligent Internet of Things Technology in Agricultural Environment Monitoring

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Abstract. The application of the Internet of Things to precision agriculture is conducive to the intelligent and controllable aspects of agricultural production and management, is conducive to the implementation of green agricultural production methods, is conducive to the sustainable development of agriculture, and promotes the structural reform of the agricultural supply side. An intelligent greenhouse environment monitoring system is designed based on the Internet of Things technology, and a wireless network is established using the JenNet protocol to realize real-time monitoring of environmental factors such as air temperature and humidity, soil temperature and humidity, light intensity, and CO\textsubscript{2} concentration in the greenhouse. Finally, the paper uses the time automata modelling tool UPPAAL to verify the system logic correctness and system execution timing verification on the established formal model. The results verify that the agricultural temperature control environment system network based on the intelligent Internet of Things operates stably, with high acquisition accuracy, low node power consumption, accurate feedback control, and meets the intelligent demand for greenhouse data acquisition and control.

Keywords: Intelligent Internet of Things, agricultural environment, CO\textsubscript{2} concentration, environmental monitoring, environmental modelling.

1. Introduction
With the continuous maturity and popularization of the agricultural Internet of Things technology, it is expected that the contribution rate of the Internet of Things technology to the added value of agriculture will increase from 17\% in 2010 to about 33\% in 2021. Looking at the current application of Internet of Things technology in smart greenhouses, most of them focus on information monitoring, transmission and some simple automatic control. In fact, they only realize the replacement of human labour by machinery and equipment [1]. There are still major deficiencies in the application of big data integration, data in-depth mining, growth model establishment, and artificial intelligence. Due to the characteristics and advantages of the Internet of Things, the Internet of Things technology can be applied in fields such as facility agriculture environmental information collection and monitoring, production accident warning, facility environment intelligent control, and crop growth diagnosis.
At present, the low level and high cost of existing greenhouse crop growth environment monitoring and automatic control technologies have led to the slow development of modern greenhouses. The development of a low-cost intelligent greenhouse monitoring system is an important indicator of the development level of agricultural modernization in the future to meet the needs of agricultural modernization and informatization development in accordance with my country's national conditions. The intelligent greenhouse control system collects greenhouse environmental parameters and soil environmental parameters in real time, such as temperature, humidity, light, carbon dioxide concentration, soil pH, etc. in the greenhouse, and compares with the control target, automatically or manually turn on or turn off the environmental control equipment, so that The crops are kept in the best growth environment to provide decision-making basis for automatic monitoring, automatic control, informationization, and scientific management of agricultural production, and promote the development of agricultural production in the direction of intelligent, intensive, and precise.

Based on this research background, the author builds an intelligent agricultural greenhouse based on the Internet of Things technology according to the land climate resource status and the utilization of the greenhouse [2]. The intelligent greenhouse uses the main technology of the Internet of Things to collect and control the environmental information such as light, temperature, humidity, and land fertility in the greenhouse in real time. It can change the previous extensive agricultural greenhouse management methods and provide scientific, efficient and reasonable agriculture. It can provide support and basis for information development.

2. System Architecture

2.1. Overall architecture

The platform adopts a plug-in and modular design, which facilitates the access of many different front-end devices. The platform is divided into four modules: front-end facility site, cloud computing centre, network communication, and user terminal, with flexible communication interfaces between the modules [3]. In the hierarchical structure, it consists of an information perception layer, a feedback control layer, a network communication layer, a cloud computing centre layer, a convergence layer, and an application service layer. The system structure is shown in Figure 1.

![Figure 1. The structure diagram of the intelligent agricultural temperature control system of the Internet of Things](image-url)
2.2. Network communication
The greenhouse site is composed of information perception and feedback control. The information perception part is composed of various sensors, Zigbee communication nodes, and video image equipment. The environmental data sensed by the sensors is gathered at the Zigbee central node. Then it is transmitted to the field gateway device. The video image device data is directly transmitted to the field gateway device. The feedback control part is composed of motor controller, motor equipment and actuator [4]. The motor controller receives the control instructions from the field gateway to the cloud computing centre. After decoding and conversion, it controls the relays, contactors, solenoid valves, etc. of the corresponding motor equipment. Through the control of window opening, shading, heating, cooling, oxygen supplement, light supplement, CO$_2$ supply and other equipment, the purpose of automatic environmental adjustment is achieved.

2.3. Design of monitoring nodes
The hardware structure of the node is shown as in Fig. 2. The sensor communicates with the microprocessor JN5148 through a variety of interfaces, which can realize the comprehensive collection of the environmental parameters of the greenhouse. The air temperature and humidity sensor adopt SHT-11, its temperature measurement range is between -40-123.8°C, and the response time is less than 3s. SHT-11 has extremely high reliability and excellent stability. The light intensity sensor uses the BH1750 module, I2C bus timing, and the measured value is output linearly with the change of illuminance. The range of illuminance that can be measured is 1-535lx, and it is less affected by infrared rays. It is suitable for use in the greenhouse. For the measurement of soil moisture and temperature, the DSW-T2 soil moisture temperature sensor is selected with a 4-20mA analogy signal output. It can measure soil moisture content and temperature at the same time, saving the circuit overhead in the module design.

![Figure 2. Block diagram of node hardware structure](image-url)

2.4. Software design
2.4.1. The main program design of the sensor node. The sensor node is equivalent to the child node of the gateway node. Self-organizing networking is the basic link in the sensing layer of the Internet of Things. It is directly related to the target measurement of the Internet of Things, and converts agricultural information into effective switching values for transmission. The main tasks include: waiting for the gateway node to wake up, collecting agricultural information, sending data, entering sleep, etc. The specific workflow is shown in Figure 3.
The sensor node is usually in sleep mode. When it receives a command from the superior node and is awakened, it immediately sends a request to join the network, and waits for the response of the gateway node. After successfully joining the network, it starts to carry out agricultural information such as soil temperature and humidity, light intensity, PH value, etc. are collected and transmitted to the command sending end node, and the superior node sends a response bit. After confirming that the reception is successful, the sensor node goes into a dormant state again, and so on.

2.4.2. The main program design of the gateway node. The gateway node is mainly responsible for establishing and managing the network, allowing or denying any sensor node to access the network, and sending the data collection of each sensor node to the Internet, and the monitoring terminal reads and records the data through the Internet [5]. The gateway node is always working and will not sleep. Its working process is generally divided into: waiting for monitoring commands, establishing a network, joining nodes, waiting for data information, and sending data.

3. Greenhouse environment monitoring algorithm modelling

3.1. Time automata
Time automata is a natural extension based on automata theory proposed by ALUR and DILL to build real-time system models. The time automata is a six-tuple $A = < L, L_0, \Sigma, X, I, E >$, where $L$ is the set of finite states; $L_0$ is the set of initial states; $\Sigma$ is the set of finite symbols; $X$ is the set of finite clocks; $I$ is the clock limit mapping on the state node, namely Specify a clock constraint $E$ in $\Phi(X)$ for each state node in $L$; $L \rightarrow \Phi(X)$ is a conversion relationship, and there is $E \subseteq L \times \Phi(X) \times \Sigma \times 2^X \times L$. The $\Phi(X)$ in the definition of time automata is a set of clock constraints, and the clock constraint $\varphi \in \Phi(X)$ has a definition for the element $x(x \in X)$ in the clock variable set $X$:

$$\varphi = x \leq c | c \leq x | x < c | c < x | \varphi_1 \land \varphi_2$$  \hspace{1cm} (1)
Where \( c \) is a constant in the set of rational numbers \( \mathbb{Q} \). The network of time automata composed of multiple time automata is called product automata.

### 3.2. Sensory layer modelling

When the sensor system for environmental information collection is running, the environmental information is collected at a certain time interval (sampling period). If the relevant information is not collected within the specified time, the sensor device is in an abnormal state. The sensor model used in this article only has the function of collecting information. Whether the sensor is faulty is determined by the IoT service control module. Therefore, the sensor time automata model is defined as

\[
\text{Sensor}_{-}\text{TA}= \{\text{Idle, Work, Error}, \{\text{Idle}\}, \{\text{Val}_{-}\text{Sensor}\}, \{y\}, \text{SSTAI}, \text{SSTAE}\} \tag{2}
\]

Among them, the sensor has 3 working states, Idle, Work, and Error respectively represent standby, working and error states, which are initialized to the Idle state; \( y \) is the sensor system clock. SSTAI and SSTAE are the node clock constraint relationship and state transition relationship of the sensor time automata, and the specific description is shown in Figure 4.

Because different equipment has different disposal methods, some equipment may be manually operated equipment, so the execution of the equipment model here only executes control instructions, so only the most common equipment operating status is listed, so it is defined

\[
_{\text{Device}_{-}\text{TA}=\langle\{\text{Idle},\text{Work}\}, \{\text{Idle}\}, \{\text{con}\}, \emptyset, \text{DTAI}, \text{DTAE}\rangle} \tag{3}
\]

In the greenhouse, equipment such as lighting and ventilation only needs one switch signal to work. Most of the environmental adjustment equipment in the greenhouse is similar to this working process. The two working states are used as the modelling model in the modelling, which is complicated the equipment needs to be modelled separately. Generally, the equipment usually works in the standby state. In this model, Idle is the initial state [6]. As a passively working environmental control device, there is no influence of time information, it only works according to control signals, and there is no time constraint. The device is only affected by the control signal, and can use the Sync Control variable as the control, and the con variable as the only input signal of the system, and use this to identify the control information when the control signal is synchronized. When the field control device sends an execution control instruction to the execution device, the IoT gateway processes the control
information after receiving it, and then sends it to the execution device through the corresponding port to complete a control job. The IoT gateway time automata model is

$$Net_{TA} = \langle \{Idle, Up, Down, overtime\}, \{Idle\}, \{t\}, \{y\}, NT_{AI}, NT_{AE} \rangle$$  \hspace{1cm} (4)

4. Application case analysis

The operating performance of the entire system was tested. In the selected agricultural demonstration base, a total of 15 devices were arranged, including a coordinator gateway, 12 monitoring nodes and 2 control nodes. The greenhouse in the demonstration base is a column-free arched film-type plastic greenhouse, using a ground-fixed drip irrigation system, and a support arm roller shutter machine to control the up and down rolling of the quilt. The measured soil moisture value here is the moisture value of the soil. After an ordinary moisture sensor is inserted into the ground, the displayed moisture value is always 100%. It is more scientific to use soil moisture here. During the test, no network interruption occurred, the system was stable, and the environmental values collected by the nodes were all within the actual error range. Send a command to the control node, and the water pump and roller shutter will automatically turn on or off to meet the design requirements of the greenhouse environment monitoring system.

5. Conclusion

Precision agriculture is the trend of agricultural development in the world today. Environmental monitoring is the key to supporting precision agriculture technology. Compared with the limitations of traditional farmland environmental monitoring methods, environmental monitoring based on Internet of Things technology meets the requirements of rapid, precise and continuous precision agriculture. Measurement requirements. Aiming at the problems of resource waste and low accuracy in traditional agricultural greenhouses, this research proposes a solution to apply the Internet of Things technology to greenhouses and build smart greenhouse systems.

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