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Design of Intelligent Water-Saving Irrigation System Based on Internet of Things

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Abstract

This paper studies the design of water-saving irrigation system based on Internet of things. The structural model of the water-saving irrigation system was established, and the hardware and software of the control system were designed, with emphasis on the design and coverage calculation of the sensor nodes in the wireless sensor network. The wireless network and control system are tested, including network coverage, network connection, optimal communication distance and accuracy of data transmission. The experimental results show that the data transmitted by the wireless sensor is accurate and reliable, and the software and hardware of the automatic control system can work normally. The system can carry out intelligent irrigation timely and accurately.

Keywords

System Structure, Network Design, Coverage Calculation, Control System

1. Introduction

Internet of things technology has not only been widely recognized and developed in the world, but also greatly promoted the development of environment and traditional agriculture, gradually leading the development direction of "precise monitoring" and "precision agriculture".

Mare designed a practical and low-cost green-house monitoring system based on wireless sensor network technology according to the analysis of the features of greenhouse environment [1]. Kaewmard studied sensor data collection and irrigation control on vegetable crop using smart phone and wireless sensor networks [2]. In China, the agricultural Internet is developing rapidly. The new generation of network technology has been widely and deeply popularized in rural areas, and farmers have also widely applied various modern technologies in the modern agricultural science and technology production and operation environment, affecting and changing the traditional farming environment and agricultural production methods. Li designed a rice intelligent water-saving irrigation system based on agricultural internet of things [3].

The agricultural Internet of Things project mainly monitors agricultural products dynamically to obtain information. There are many online sensor nodes distributed in the monitoring agricultural network infrastructure [4]. By installing these wireless sensors, people can obtain soil quality and soil climate information at any time. Farmers can obtain inspection results timely and accurately, and find and solve relevant production problems in a timely manner through relevant agricultural technology production reference information. The combination of the Internet of Things and agricultural production mode will make agriculture gradually shift from a production mode that is manpower centric and relies on isolated machinery to a production mode that is information and software centric, so that a large number of automatic and intelligent production equipment will be used.

The water-saving irrigation system based on the Internet of Things can automatically detect and control irrigation water wirelessly, monitor the temperature and humidity information at the irrigation site in real time, and effectively transmit it to the monitoring management center through the Internet of Things access. Agricultural management personnel can master the specific situation of each irrigation area according to the data received by the monitoring center. Therefore, the establishment of intelligent water-saving irrigation system based on Internet of things is of practical significance and application value to prevent farmland from over-drought or over-waterlogging and to minimize agricultural water use. This paper studies the design of water-saving irrigation system based on Internet of things.

2. Intelligent Water Saving Irrigation System Design

The framework of intelligent agricultural water-saving irrigation system is mainly composed of agricultural meteorological sensors, soil water classification sensors, acquisition control modules, wireless communication modules, solenoid valve control boxes, Internet of things management and control systems [5].

1) The sensing network module: it includes a sensing unit (soil moisture sensor, air temperature and humidity sensor), an embedded processing unit, and a communication protocol unit. The sensor is responsible for the collection of internal parameters of the backwater tank, reservoir, and paddy field. The solenoid valve is an automatic execution device in this system, and can be connected to water pumps and nutrient supplement equipment.

2) Control module: It refers to the data acquisition control module that controls the work of the data acquisition equipment and the execution of the equipment. Its main role is to control the operation status of the data acquisition

equipment through the setting of the crop decision irrigation software, and also according to the instructions issued by the decision software. Control the opening/closing of the solenoid valve [6].

3) Data transmission module: The system uses wireless transmission to connect internal and external information transmission channels. The outside passes through a 5G communication network. The internal network uses short-range low-power ZigBee wireless communication technology and combines temperature and humidity sensors to transmit soil moisture data.

4) Internet of things management and control platform: mainly composed of computer and crop irrigation decision software. Crop decision-making irrigation software is the receiver of data and the issuer of instructions, and is the soul of the entire system. It mainly implements parameters setting, data storage, and sending instructions.

5) Video monitoring module: use cameras and wireless network equipment to remotely check farmland conditions and pool conditions in real time. The control platform can implement joint alarm methods such as voice, graphic information, etc., to ensure that relevant alarm information is received at the first time, and to control water flow and irrigation at the fastest speed.

3. Network Structure of the Irrigation System

3.1. Network Structure

The intelligent irrigation system network consists of two parts: the self-organizing network between the internal sensor nodes and the external transmission network. The former mainly realizes the collection of sensor data and the data interaction between the sensor and the execution controller, while the latter realizes the transmission and communication of internal network environment information. The network design needs to be composed of: wireless sensor nodes, wireless routing nodes, wireless gateways and information transmission. The internal sensing nodes are self-organized through ZigBee, and then the monitoring center and wireless gateway transmit humidity and control information through 5G. Each sensor node automatically collects soil moisture information through temperature and humidity sensors, and analyzes and judges whether irrigation is required and when to stop irrigation, as well as preset upper and lower temperature limits. Among them, the wireless gateway connects the ZigBee wireless network and the 5G network, which is the core part of an intelligent water-saving irrigation control system based on the Internet of Things. Proper network planning and topology will directly affect system performance. It is necessary to focus on network deployment and network capacity calculation.

3.2. Network Node Deployment and Coverage Calculation

The sensor area network is built by ZigBee. The deployment of network nodes will affect the quality and information collection of the network, and then affect the information transmission effect. In the process of node deployment and coverage capability calculation, first, the number of nodes is calculated according to the plane idealization model in the network layer. Secondly, the deployment effect is analyzed based on the energy consumption model of the wireless sensor network. According to wireless communication theory, energy attenuation models can be divided into free space models and multi-channel attenuation models with distance. When the distance is less than or equal to the threshold constant, power consumption is proportional to the square of the distance when sending data. When the distance is greater than the threshold constant, the power consumption is proportional to the fourth power of the distance. In coverage-first deployments, hexagonal cells are often used. Equations (1-1) and (1-2) can be used to calculate the total number of nodes n and the coverage radius R [7].

$$\sum_{i=1}^{N}\left(\pi\left(ir_c\right)^2-\pi\left(\left(i-1\right)r_c\right)^2\right)\frac{R^2-\left(ir_c-r_c/2\right)-r_c^2/4}{ir_c-r_c/2}c=n \tag{1-1}$$

$$\frac{R^2-\left(R-r_c/2\right)^2-r_c^2/4}{R-r_c/2}\cdot\frac{3n}{\left(4R^2+r_c^2\right)R\pi}=\frac{1}{3\sqrt{3}r_s^2/2} \tag{1-2}$$

In this process, Matlab can be used to solve the modeling and simulation, and the maximum area of coverage can be estimated. As shown in Figure 1, the relationship between the number of network sensor nodes n and the coverage radius R is simulated. From the simulation Figure 1, it can be seen that too large a single point's capacity will lead to a smaller coverage, resulting in too large response time, which will affect the user's business.

3.3. Network Test

Network test items include whether the network connection is normal, whether the applicability of network protocol and the selection of optimal communication distance are reasonable. Check the data transmission and reception of each distance interval, as shown in Table 1.

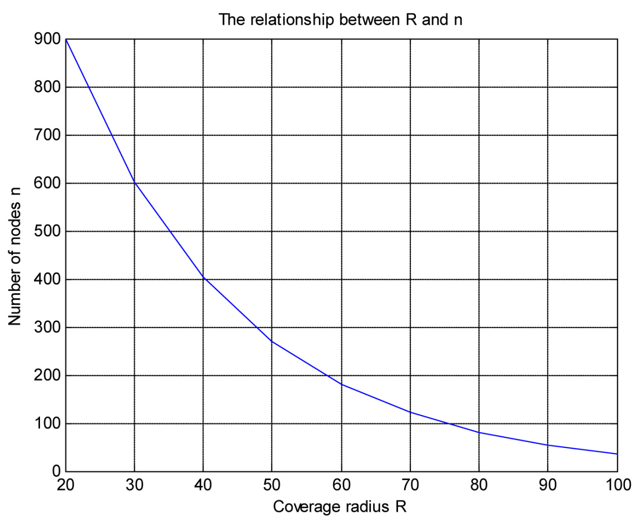

Figure 1. Relationship between coverage radius R and number of nodes n.

Table 1. Communication distance of water saving system.

Communication distance/m	Number of successful signal transmission	Number of successful signal reception	Success rate/%
100	100	100	100
200	100	100	100
300	100	100	100
400	100	100	100
500	100	100	100
600	100	98	98
700	100	63	63
800	100	35	35

The communication distance test results show that the RF chip can realize signal transmission and reception with 100% success rate within the effective communication distance. Therefore, the maximum communication distance of the system test is designed to be 500 m.

4. Irrigation Control System

4.1. The Hardware Design of the Control System

The hardware part of intelligent irrigation control includes measurement and control module, solenoid valve, power distribution control cabinet and installation accessories. According to the parameters such as soil temperature and humidity, light intensity and CO_2 concentration, it controls environmental adjustment equipment, including fans, wet curtain pumps, irrigation solenoid valves, CO_2 gas fertilizer machines and other equipment.

The collected data is regularly stored in the computer server, which has high real-time property, which can ensure that the corresponding soil moisture control measures are taken in the shortest time, which is beneficial to the accuracy of intelligent control. When real-time performance is higher, security and stability are also higher.

Through application software, basic data of various sensing devices can be stored, processed and excavated, such as soil information sensing devices, air environment monitoring sensing devices, external weather sensing devices and information sensing devices. Through intelligent decision-making by the central control software, effective instructions can be formed to guide management personnel, or the actuators can be directly controlled by sound and photoelectric alarms to adjust the irrigation valve. When you click the application software, you can visually view the data information collected in real time, such as air temperature, air humidity, light, carbon dioxide, soil temperature, soil humidity, etc. At this time, it can be judged whether various data are within the normal range. If it is outside the normal range, an alarm will be issued. According to the actual situation, control the opening and closing of fans, wet curtains and pumps to decide whether to irrigate the farmland. An intelligent water-saving system that can automatically control irrigation water is implemented.

4.2. System Software Design

In the automatic irrigation control system designed based on Internet of things technology, all system operation subroutines are completed based on the main program design, and all subroutines are completed within the framework of the system main program. The system main program design is shown in Figure 2.

When the main program starts running, first initialize the system and adjust the command parameters of the single chip microcomputer and the control module, adjust the threshold range of the basic parameters of the control system according to the growth stage of crops and local soil moisture, temperature and humidity, and adjust and select the manual mode and automatic mode according to the irrigation demand and actual situation. Observe the water level of the reservoir. When it is lower than the warning water level, the system will automatically give an early warning and open the electric valve to store water. The water quantity detection sensor, temperature sensor and humidity sensor arranged in the irrigation monitoring area will transmit the real-time environmental conditions and soil moisture to the control module through the Internet of things, and finally form accurate irrigation control decision-making instructions such as sprinkler irrigation water quantity and sprinkler time. When the irrigation is completed, the system will automatically stop running.

4.3. The Control System Test

Test the control system. The same soil was selected to test soil moisture with two different methods. One group of data was collected by the automatic detection system, and the other group of data was measured by the drying weighing method. The experimental data are shown in Table 2. Comparing the two groups of data, the error of soil moisture collected by the automatic control system does

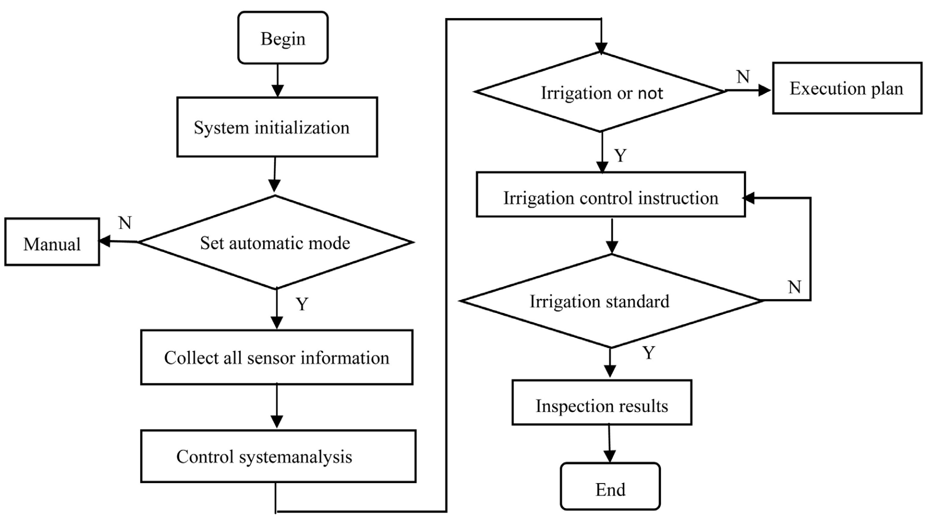

Figure 2. The main program flow.

Table 2. Experimental data of soil moisture.

group	1	2	3	4	5	6	7	8	9	10
Monitoring value	45.1	45.3	42.3	44.5	45.2	43.6	41.5	40.8	45.7	47.2
Drying measurement	46.3	42.8	43.8	47.1	43.5	46.2	39.6	42.1	47.8	45.8
value Absolute error	1.2%	2.5%	1.5%	2.6%	1.7%	2.6%	1.9%	1.3%	2.1%	1.4%

not exceed 3%. The collected soil moisture information is transmitted to the monitoring center, and the wireless sensor transmission data is accurate and reliable. The software and hardware of the system can operate normally, and the system can conduct intelligent irrigation timely and accurately.

5. Conclusion

It takes intelligent water-saving irrigation as the research goal, and designs a water-saving irrigation system based on the Internet of Things in this paper. But irrigation of agricultural fields is a very complicated job. In the future research, we need to further improve the system design that can be better applied to agricultural irrigation. There are many factors influencing irrigation decision-making in agricultural crop growth, such as climate, plant growth environment and soil ph etc. Different irrigation strategies should be adopted according to different growth needs of plants.

Fund

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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