Design of rice intelligent water-saving irrigation system based on agricultural internet of things

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Abstract. In order to realize the real-time remote monitoring and accurate management of the paddy field environment, the intelligent water-saving irrigation system based on the agricultural Internet of things was designed. The data packet consists of water level, soil moisture, soil fertilizer, crop height, real scene photos and so on, which are collected by the terminal monitoring equipment group, and is forwarded to the gateway through the main controller. The gateway transmits the processed data packets to the cloud server through GPRS, and then sends to the user app or the Internet web page. App and the internet can set the upper and lower threshold of the terminal node water level. According to the comparison results between the water level and the threshold set by the water level sensor, the node solenoid valve is controlled to open or close the gate of the rice field intake, and the automatic irrigation is realized. The system can set a fixed number for each monitoring node to find fault units quickly and enhance system reliability. The system gets the advantages of simple implementation, low power consumption, perfect function, and high reliability.

1. Introduction
China has been a big rice planting country since ancient times. With the acceleration of urbanization in China, the pattern of rice planting is changing the pattern of large-scale planting and the area of rice planting continues to grow. At present, most areas of our country still use the flood irrigation, which wastes a lot of water resources and human resources [1–3]. The promotion and application of intelligent irrigation system will be the main research direction of rice planting in China.

Agricultural Internet of things (IoT) is a network technology that requires a large number of sensor nodes to form a monitoring network. It can help farmers collect all kinds of information they want, need to figure out the problem and find the location of the problem in time. Agricultural IoT is leading the traditional agricultural production model to a new agricultural production model centered on information and software [4–6].

Reference [7] completed the construction of web-based irrigation control system, realized the mechanism of real-time data to push, and tested real-time performance of systematic data collection and control instruction transmission, but the convenience of the app is neglected. Reference [8] although the system cost was reduced and the water utilization rate of crops was improved, the relay station was invoked as the relay station in the star network. Once the relay station is paralyzed, all information uploaded by the relay station will be incorrect, and the system will get to make a wrong judgment.
Aiming at the deficiencies of the above system, the paper designs an intelligent water-saving irrigation system for rice based on the agricultural IoT. The system focuses on the construction of a wireless sensor network and the design of hardware and software. The sensors and control units directly report the monitoring data to the cloud server through GPRS network, to avoid the risk that the system cannot correctly detect the rice information due to the paralysis of a relay station or coordinator. The cloud server is in charge of data analysis, collation, integration, and disaster prediction. Furthermore, the remote real-time monitoring of paddy field environment is realized, and the farmers are kept informed of the monitoring information in the form of app or web page. Push relevant information on irrigation, pest control and fertilizer, and guide farmers to manage rice fields scientifically.

2. Brief introduction of the system frame and each module
The demonstration site of the system is placed in Wuchang City, Heilongjiang Province, China, where the pillar industry and brand production are the rice industry. The development level of the rice industry plays a major role in the development of other related industries in this area. However, due to the lack of scientific knowledge of farming, the development of rice production management technology and management mode of Wuchang is relatively backward, the basic information of the agricultural situation is lacking, and the efficiency of crop water use is not high. It is urgent to develop intelligent water-saving irrigation for rice. The demonstration field is composed of 7 experimental fields, a reservoir, injection channels, and drainage channels. Each field contains a water quality and environmental information collection equipment, a remote control unit for the water inlet and outlet of the paddy field. The layout of the demonstration field is given in figure 1.

![Figure 1. The layout of the demonstration field.](image)

2.1. Overall system architecture
Rice intelligent water-saving irrigation system based on agricultural IoT is composed of information interaction system, terminal monitoring equipment group and reservoir control system. The overall system architecture is shown in figure 2.

2.2. Information interaction system
The information interaction system is composed of the gateway module, cloud server, and the web page, which mainly complete information exchange and processing. The gateway module communicates with the cloud server through GPRS and adopts TCP/IP protocol. Users can use the mobile app or the Internet to understand the water quality and environmental information of rice fields, the current status of control valves and sluices, and the working state of the reservoir pump. Through the cloud server, users can also send control commands to set the upper and lower thresholds of the irrigation water level. The main controller collects the water depth data of the rice field at intervals and pushes the collected data to the specific server address through the TCP protocol. The sensor and server communicate over a long TCP connection, sending a heartbeat every few seconds (Ensure that the smart sensor is in normal working condition). Uplink and downlink data transmission can be achieved. Uplink: intelligent sensor sends liquid level information and the auxiliary picture information collected to the server; Downlink: users can use an app or web pages to send commands...
to smart sensors. The smart sensor adopts the mobile IoT card to communicate with the server. The card has a strong network signal, even in the mountains can send and receive data correctly. Each device is equipped with a unique number using a communication protocol to enhance the security of the system. The number can also be manually configured, and other configurable items include data acquisition interval, reporting data interval time, server IP address, etc.

2.2.1. **The gateway module.** The gateway module is the protocol conversion equipment of the entire monitoring system. The main controller analyzes, compresses and merges the collected data, then submits the data to the cloud server by using the TCP/IP protocol through the GPRS network. After data acquisition, the information acquisition module goes into dormancy state and reduces the power consumption of the system. When the cloud server sends information to the gateway, it also uses the TCP/IP protocol to communicate, receives and parses the data packet from the cloud server through the GPRS network, obtains the user command, and controls the valve. After completing the above operation, the system enters low power sleep mode again. The intelligent sensor has the function of remote software version upgrade, that is, the server sends the upgrade version command and the device downloads the version from the specified address.

2.2.2. **Cloud server module.** The cloud server adopts the TCP concurrent server model, which allows multiple gateways to connect simultaneously. The server always waits for the gateway's connection, and when the gateway has a connection request, a new thread is set up to handle the gateway's business. The server analyzes the data packet of the gateway and stores it in the database for the user to ask the app or web page. At the same time, the cloud server pushes the scientific farm data parameters in each thread to provide scientific reference for the user.

2.2.3. **Application programming.** The app is developed based on BeX5 platform and installs on Android phones to receive GPRS data from cloud servers. In the design, MVC is adopted to separate the presentation of business logic and data, which is beneficial to the expansion of the function. Regarding system functions, remote monitoring, recording, alarm and decisive control of water pump valve are realized, and there are two control modes (automatic control and manual control). The software can draw and display the data curve of different environmental information, facilitate the query of historical record. The open source database (MySQL) is used to store the data of environment and soil in the entire growing period of crops in the database. The data can be read and written quickly by using JDBC database driver and SQL language.

2.3. **Terminal monitoring equipment group**
The terminal monitoring equipment group is the basic unit of the whole system, which includes the water quality and environmental information collection equipment, the remote control unit of paddy water inlet and outlet.
2.3.1. Water quality and environmental information collection equipment. This part is the information collection terminal of the system. To save the system cost, the main controller connects several sensors and forms a sensor network. Each acquisition device is equipped with a liquid level sensor, a soil moisture sensor, a soil fertilizer detection sensor, video monitoring, and ultrasonic measurement. The equipment is powered by solar and wind energy, which ensures an ultra-long supply of power to the system. Equipped with Photovoltaic module, PV controller, fan, fan controller, battery set and a voltage conversion module. PV modules and fans are used to convert light and wind energy into electricity. The function of the PV controller and the fan controller is to control the working state of the power system and to protect the battery from overcharge and over-discharge. The battery has good linearity and load regulation. Its function is to store the electric energy. When the system needs electricity, the battery can provide DC 12V stable voltage. The function of the voltage conversion module is to convert the 12V power supply to other voltage levels and supply power to the GPRS wireless communication mode and the main controller.

Wireless transmission and TCP/IP communication are utilized to connect the cloud server, and then send the collected rice field information to the user. This connection mode can reduce the influence of irregular field partition distribution and imperfect canal construction on the irrigation system and improve the flexibility of the system implementation. The schematic diagram of water quality and environmental information collection equipment is illustrated in figure 3.

![Figure 3. Water quality and environmental information acquisition equipment.](image)

2.3.2. Remote control unit of paddy water inlet and outlet. The remote control unit includes inlet device and outlet device. The structure of the inlet and outlet device is similar, which is composed of the main controller, the control circuit of the GPRS node, relay, motor, high gain wire and actuator. The inlet and outlet actuators are control valve and outlet sluice, respectively. Control valves and sluice gates can be operated remotely and manually. The intake water flows from the injection channel; the outlet water runs away from the drainage channel and through the pipe again into the reservoir to avoid wasting water. The appearance diagram of inlet and outlet device is illustrated in figure 4.

![Figure 4. Appearance of inlet and outlet device.](image)
The user or system decisions can be sent to the cloud server through mobile APP and the Internet, and then directly transmitted to the IoT card of rice field intake unit. The main controller analyzes the command, controls whether the relay is electrified or not, and controls the motor. The motor drives the actuator to open or close the water gate of the inlet and outlet, and completes the automatic water diversion irrigation work of the rice field. The main controller monitors the working status of the actuator in real time and can give feedback to the user in time. Each field's equipment has its own unique number. The faulty device can be found for the first time through the device error message. The remote control unit adopts STM32F103VC series processor as the core controller and integrates communication chip SIM800A to realize remote control of rice field inlet and outlet. This combination has the advantages of high performance, low power consumption and high cost-performance ratio, which is beneficial to future product upgrading.

2.4. Reservoir water pump remote control unit

The remote control unit of the reservoir pump serves as a source of the water injection channel. The liquid level sensor is mounted in the reservoir to realize automatic control.

2.4.1. Power module design.

In the design of the power supply module, the power transformer is utilized to reduce the voltage from 380V to 12V, and then rectifies to obtain DC voltage. Power supply for SIM800A after SPX29302T5 voltage stabilization. In order to ensure the control core STM32 of the unit to work normally (working voltage 2-3.6V). The switch voltage regulator LM2596 is introduced, which is used to convert the DC 12V input into the 3.3V voltage available. The LM2596 switching voltage regulator is a single chip integrated circuit, and it has excellent linearity and load regulation characteristics at the same time. As a communication chip of the remote control unit of the water pump, SIM900a cannot work stably when the working voltage is lower than 3.1V. In order to improve the stability of the system, SIM900a is equipped with a lithium-ion battery. Lithium-ion battery work in shallow discharge state to prolong the battery life to the maximum extent.

2.4.2. Reliability design of the control unit.

The reservoir pump works outdoors all year round, the working environment is relatively complex, and numerous external factors need to be considered. In order to ensure the safe and reliable operation of the system, it is necessary to install a waterproof shell on the periphery of the control unit. Waterproof shell should have a certain air convection design to avoid adverse heat dissipation on the system. Several working status indicator light are set above the panel to represent the current running state of the system, so that the farmers can see clearly.

The field environment of the pump control unit of the reservoir is usually accompanied by strong electromagnetic interference (EMI). The shielding effect can be enhanced by attaching aluminum foil to the control box and grounding to reduce the EMI. Opening the watchdog hardware circuit is an effective measure to guarantee the reliability of the control unit. When the software system fails, the watchdog resets the system. Once the power supply fails, the power will be automatically transferred to the standby lithium battery, which will send the power warning to the user and automatically shut down. After the power is reconnected, the power will be automatically turned on and restored.

![Peripheral interface diagram of control unit.](image)

Figure 5. Peripheral interface diagram of control unit.

The control unit is powered by 380V. The relay interface connects the contactor and controls the start/stop of the pump motor. The 232/485 interface is employed to communicate with computers and
sensor modules. The IoT card is placed in the SIM card holder. External antennas should be positioned in an open space to achieve optimal signal quality. Each interface adopts surge protection to prevent damage to equipment caused by human static electricity. Figure 5 shows the peripheral interface diagram.

3. Software design scheme

In this paper, control chips of the whole control system are stm32 series. The software system platform can support TCP/IP protocol stack. After the main program of the system is powered on, the GPRS network completes initialization, starts the irrigation system and feedback sensor data information. At the same time, each remote control unit sends the information of the control valve, sluice gate and reservoir pump to the user. The system enters standby mode to wait here for the user's command. The user directly manages the execution equipment through the GPRS communication network, and it is easy to set the upper and lower threshold of irrigation water level or soil fertilizer by using the app, web page. For example, when the water level sensor node detects that the water level of the paddy field is below the lower limit set by the user, the intake equipment solenoid valve opens, the outlet equipment solenoid valve ends, the inlet valve opens, and the outlet valve closes. When the water level of the paddy field is higher than the upper limit of the set water level, the opposite operation is performed to achieve automatic irrigation of the farmland; otherwise, the current value of the water level of the paddy field is sent to the user. The main program flow is shown in figure 6.

3.1. Basic information entry

The main purpose of this module is to let users input or update the basic information of paddy fields, such as meteorological data, soil characteristics, etc., to provide data support for other modules. Distinct from other expert systems, users can import the upper and lower threshold of irrigation water level or soil fertilizer to the system, intelligently extract the relevant information and store it in the corresponding database. The flow chart of user input data is shown in figure 7.

3.2. Software design of the actuator

The actuator is the direct control unit for executing system commands. It plays a vital role. Whether in manual or automatic mode, actuators are required to judge the operator's legitimacy. Distinguishing user rights, different permissions to the system has different degrees of operational qualifications.

![Figure 6. The main program flow.](image-url)
Both the administrator and the general user can give control commands to actuator. More specifically, administrator users can add new operator users to the system. The software design flow chart of the actuator is shown in figure 8.

Figure 7. The flow chart of user input data.  
Figure 8. The flow chart of the actuator.

4. Conclusion
In this paper, the data transmission is performed by GPRS. The independent GPRS terminal node is designed. The control node is embedded into the inlet device, which improves the network flexibility of the system and the stability and real-time performance of data transmission between hardware and software systems. The solution of GPRS wireless network technology is provided, which simplifies the design of all kinds of nodes in the system. The information exchange system, terminal monitoring equipment group and reservoir control system are designed in detail. The system collects environmental information such as water level height, soil humidity, soil fertilizer, crop height, field photo and so on in real-time, and adjusts the growing environment of rice in real-time controlling the corresponding equipment according to the need. Make rice grow in the best environment; promote the healthy growth of rice. The gathered information can be used for specialized organization analysis, collation and data fusion, and can also provide the basis for scientific farming. With the introduction of the app and webpage remote control scheme, the function of rice automatic irrigation system has been previously improved, and the practicability of the system has been enhanced.

References
[1] Lei Gang, Wang Weixing, Sun Baoxia, Experiment on wireless sensors network based on double cluster head clustering routing algorithm of energy heterogeneous in paddy field, Transactions of the Chinese Society of Agricultural Engineering, 29 (2013) 24, pp. 139-146.
[2] Mare Srbinovska, Cvetan Gavrovski, Vladimir Dimcev, Environmental parameters monitoring in precision agriculture using wireless sensor networks, Journal of Cleaner Production, 88 (2015) 297-307.
[3] Nikhil Jorapur, Vinay S Palaparthy, Shahbaz Sarik, A low-power, low-cost soil-moisture sensor using dual-probe heat-pulse technique, Sensors and Actuators A: Physical, 233 (2015) 108-117.
[4] Ge Wenjie, Zhao Chunjiang, State-of-the-art and developing strategies of agricultural Internet of Things, Transactions of the Chinese Society for Agricultural Machinery, 7 (2014) 222-230.
[5] Li Jin, GuoMeirong, Gao Liangliang, Application and innovation strategy of agricultural Internet of Things, Transactions of the Chinese Society of Agricultural Engineering, 31(2015) 200-209.
[6] Han Huafeng, Du Keming, Sun Zhongfu, Design and application of zigbee based telemonitoring system for greenhouse environment data acquisition, Transactions of the Chinese Society of Agricultural Engineering, 25 (2009) 7, pp. 158-163.
[7] Li Shuhua, Hao Xingyao, Zhou Qingbo, Pan Yuchun, Design and development of real time data push in web-based automatic irrigation control system, Transactions of the Chinese Society of Agricultural Engineering, 31 (2015) 15, pp. 133-139.
[8] Wu Qiuming, Jiao Xiyun, Pan Yu, He Shengrong, Intelligent micro-irrigation system based on internet of things in arid area, Transactions of the CSAE, 28 (2012) 1, pp. 118-122.