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Research Article

An Automatic System Design for Orchard Irrigation Based on STM32 and Zigbee Technology

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Abstract: This study designs an intelligent system, which can achieve automatic irrigation for orchard by wireless manner. The system mainly includes a soil moisture monitor and control unit made up of a variety of sensors, a central control unit based on STM32F103 and the wireless sensor network based on Zigbee technology. First, the soil moisture monitor and control unit measures the real-time data such as humidity and sends the data to the central control unit by a wireless sensor network based on Zigbee technology. The central control unit sends a control command according to data received to the soil moisture monitor and control unit by the same communication way and sends the data about control command, humidity and *etc*. to the mobile devices over GSM the in the meantime. This is a high efficiency and energy saving system, which has clearly contributes to save labor, conserve more water and increase production of fruit.

Keywords: GSM, monitor, orchard irrigation, STM32, wireless, Zigbee

INTRODUCTION

The irrigation technique is an extremely important for to agricultural production. China is a large agricultural country short of water. Chinese peasants mainly use flooding irrigation and furrow irrigation at present caused by the lack of modern technology, high costs of modern farming techniques and so on. But traditional irrigation not only results in an inefficient in use of water and labor, but also results in fertilizer loss, soil salinization and water logging. According to the survey, currently, 98% of farmland are irrigated with traditional irrigation in China. The effectively utilizing rate of water is only 40%, which remains far below those of developed countries, of around 70-80% (Wang and Lian, 2010; Zhai, 2010).

In view of the above problems, many researchers make relative researches. Wang *et al*. (2013) designed a drip irrigation control system based on fuzzy control algorithm for the greenhouse. Shi *et al*. (2013) designed soil humidity monitoring system based on the wireless sensor networks. Liu *et al*. (2015) discussed the modes of micro-irrigation technique, key parameters for designing micro-irrigation system and optimal matching of micro-irrigation system. Jiang *et al*. (2012) designed a type of Wireless Sensor Network (WSN) node suitable for orchard information acquisition based on a MSP430F149 as the processing core and the nRF905 chip. Yue *et al*. (2014) designed a wireless irrigation solution for small-scale orchard growers to realize automatic time-control irrigation based on MSP430F2132 micro controller, CC1100 and GPRS. However, because of the complicated technology, high construction and maintenance costs and so on, the techniques above are difficult to popularize.

In order to solve the problems mentioned, this study designs an automatic system for orchard irrigation based wireless sensor network, as Fig. 1. The system is mainly composed of the soil moisture monitor and control unit, the monitoring Zigbee system, the central control unit and the mobile devices. The work approach is as follow:

Step 1: The soil moisture monitor and control unit measures the data about the humidity of soil in real time and sends the data to the central control unit by the monitoring Zigbee System.

Step 2: The central control unit sends a control command about irrigation to the soil moisture monitor and control unit, according to data about the humidity of soil and threshold set by the farmer, by the same communication way and sends the data about control command and humidity to the mobile devices over GSM the in the meantime.

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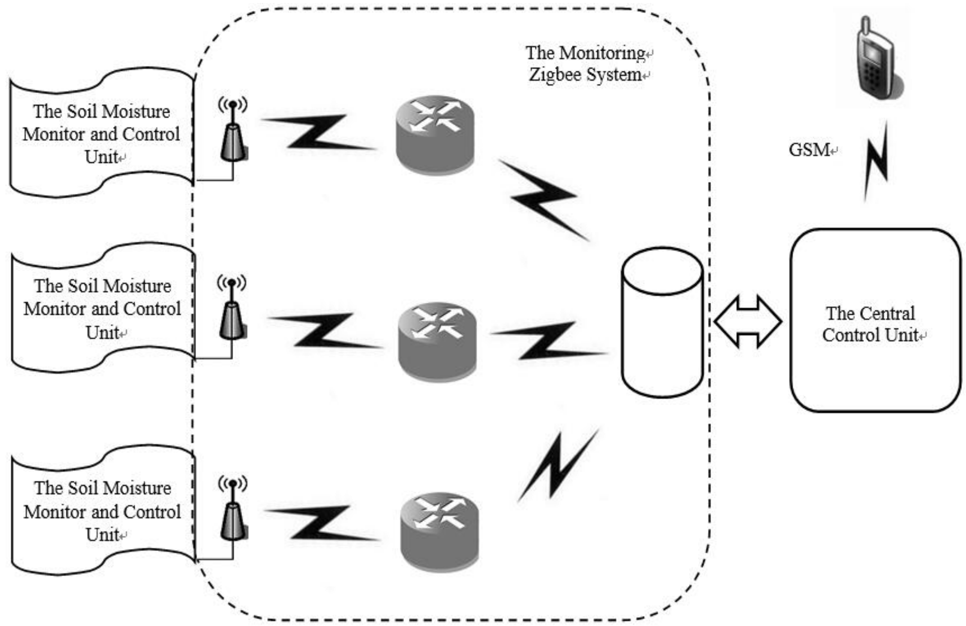

Fig. 1: The main structure of the system

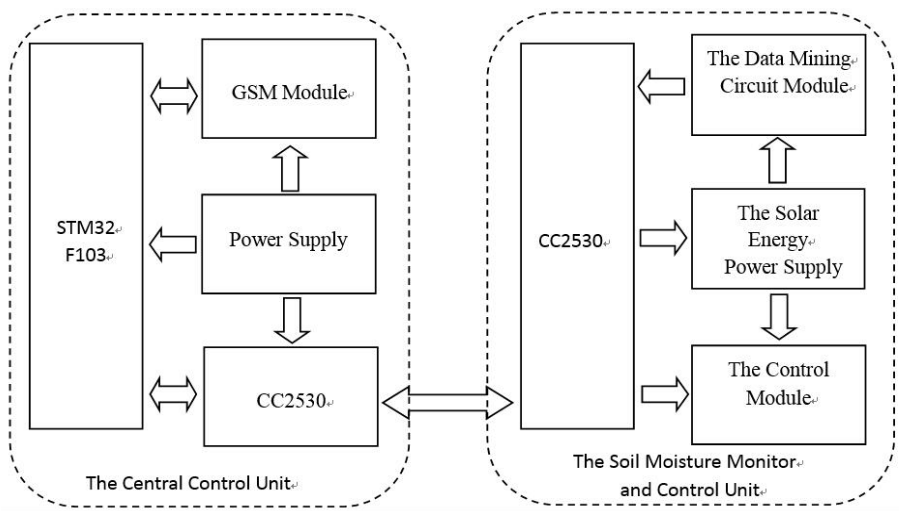

Fig. 2 Design the hardware system

Step 3: The soil moisture monitor and control unit executes the commands form the central control unit.

Finally, the system is applied to The Yunlu Orchard, an orchard of Jieyang City, Guangdong, China, as an experimental and obtains satisfactory results. Besides, the paper especially introduces the soil moisture monitor and control unit and the central control unit.

MATERIALS AND METHODS

As is shown in Fig. 2, the system mainly includes the central control unit and the soil moisture monitor and control unit. The software designs, hardware designs and materials for system are as follow.

The design of the central control unit: The design of the central control unit concludes STM32 processor, GSM module, Zigbee Coordinator and Power Supply Module.

The design of power supply module: Figure 3 shown, when we input 12V to V12, the V5 can out 5V to power the SIM900A and the V3.3 can out 3.3V to power the Zigbee Coordinator and the master control chip. There should be a capacitor like C_{18} at the input port of 7805 because the 7805 is too easy to produce the self-oscillation. At the same time, if there is not a capacitor

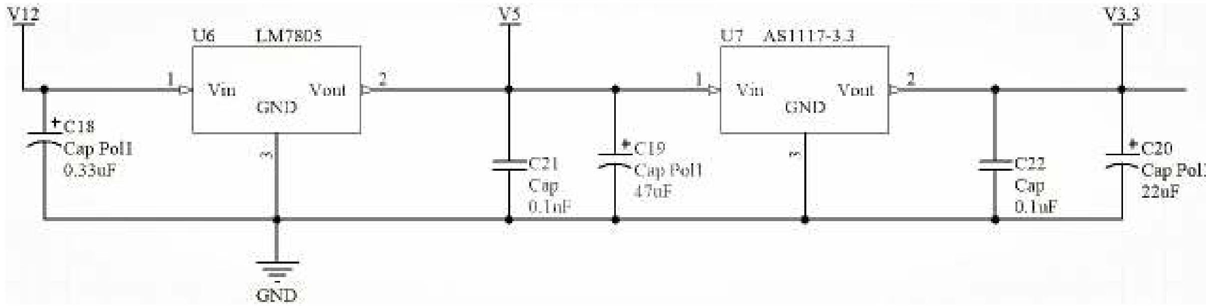

Fig. 3: The design of power supply module

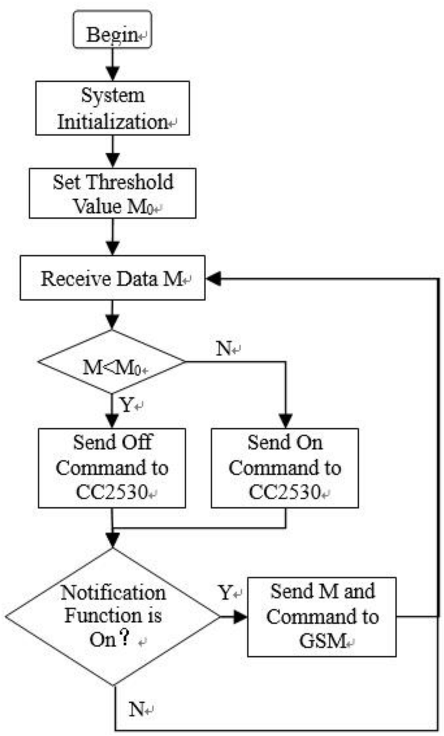

Fig. 4: The main programming flowchart about the master control chip

at the output port of 7805, the electrical energy stored in the output capacitance will damage to the regulator. The methods of preventing AMS1117-3.3 from the self-oscillation and protecting AMS1117-3.3 are similar. What's more, these capacitors can restrain the electromagnetic interference from external environment.

The master control chip: The master control chip uses STM32F103ZET6 manufactured by STMicroelectronics. There are two important reasons to use STM32F103ZET6. First, it is able to hold up to 72 MHz frequency and supports external storage such as SD. The second reason is that I^2C of it is conducive to communicate conveniently between the master control chip and peripherals. The STM32F103 performance line family operates from a 2.0 to 3.6V power supply. A comprehensive set of power-saving mode allows designing low-power applications (Sun *et al*., 2010). Need of special note is that every end of crystal oscillator connects to ground through a capacitor of 10pF, which can keep processor from error reset caused by outside distraction. The study uses UCOS-II as the operating system. The main programming flowchart is shown in Fig. 4. System Initialization includes whether the notification function is open.

The GSM module: The GSM Module uses the ATK-SIM900A manufactured by ALIENTEK Company. The ATK-SIM900A is industrial-strength GSM/GPRS Module embedded with a SIM900A, which can transfer voice, SMS and so on. The ATK-SIM900A supports RS232 and operates from a DC 5-24V power supply (Zhai *et al*., 2012). For connecting SIM900A to STM32F103, the port pin output mode of STM32F103 should be configured as Push-Pull and connects with 5.0V through a resistance of 12k because of the level unmatched matters. And our design connects TXD of STM32F103 to the RXD of SIM900A and RXD of STM32F103 to the TXD of SIM900A. At the same time, for transmitting data between SIMCARD and SIM900A, the I/O of SIMCARD connects with the SIM_DATA of SIM900A through a resistance, which makes impedance matching better. Similarly, the RST of SIMCARD connects with the SIM_RST of SIM900A through a resistance for transmitting reset signal and the CLK of SIMCARD connects with the SIM_CLK of SIM900A through a resistance for transmitting clock signal. The mainly circuit schematic of ATK-SIM900A is shown in Fig. 5. Part of AT commands is shown in Table 1. The major steps to send text messages are shown in Fig. 6. The GSM Module can sent text messages informing users of some information about equipment operating condition and soil moisture.

The design of the soil moisture monitors and control unit: The design of the soil moisture monitor and control unit includes the data mining circuit module, the central processing module, the control module and the solar energy power supply module.

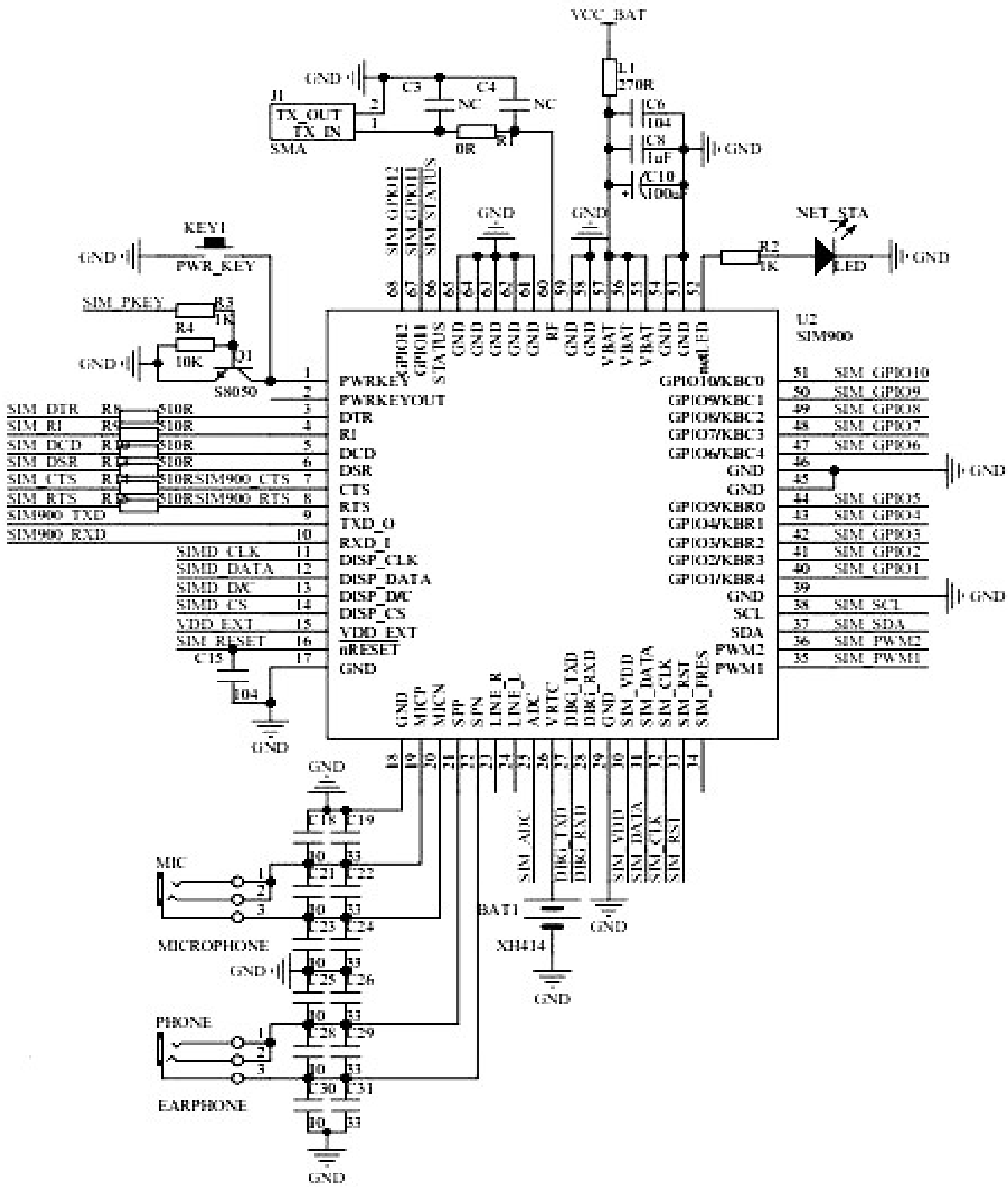

Fig. 5: The mainly circuit schematic of ATK-SIM900A

Table 1: Some important AT commands

Command function	AT command
AT+CNMI	Select message prompt
AT+CMGF	Select SMS message format
AT+CSCS	Select the TE character set
AT+CSMP	Set text parameters
AT+CMGR	Read the message
AT+CMGS	Send SMS message

The central processing module: The central processing module uses the CC2530F256, with 256KB of flash memory, which can store the information about Soil Moisture. The CC2530 is with an industry-standard enhanced 8051 MCU. Short transition times between operating modes further ensure low energy

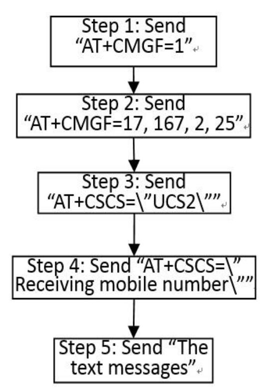

Fig. 6: The major steps to send text messages

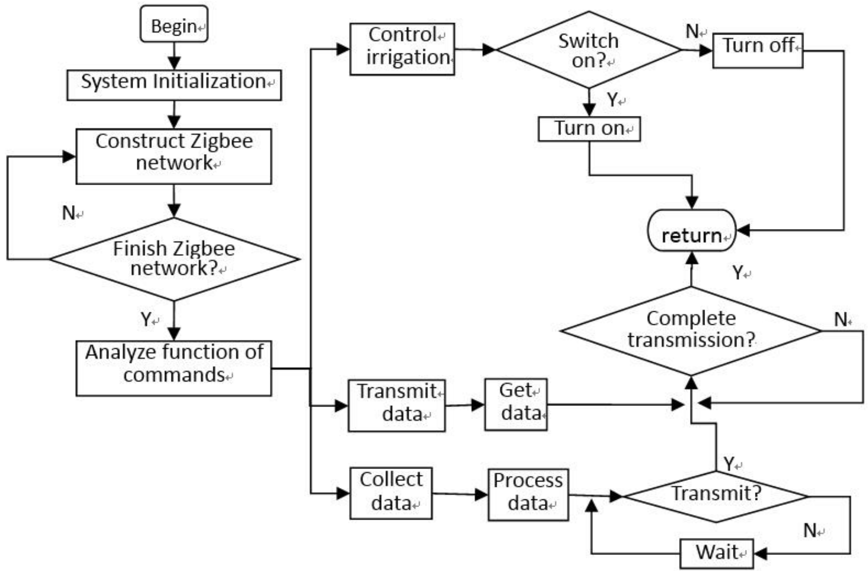

Fig. 7: The main program frame of the central processing module

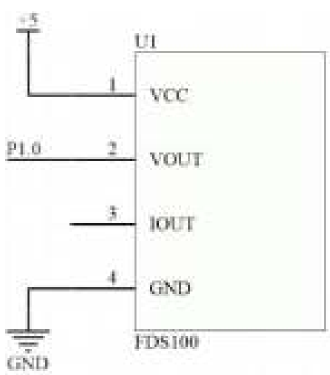

Fig. 8: The circuit of FDS-100

consumption. Combined with the industry-leading and golden-unit-status ZigBee protocol stack (Z-Stack™) from Texas Instruments, the CC2530F256 provides a robust and complete ZigBee solution, which is a convenient for adding sensor nodes more easily (Song and Tan, 2015). There are three kinds of device in Zigbee network: Coordinator, Router and End-device. The transfer process of soil moisture from End-device to Coordinator is follows. End-devices are placed in different monitoring sites on the orchard for collecting information such as soil moisture. They connect with soil moistures sensor by using IO I^2C bus timing simulation and then send the relevant information to Routers. The Routers relay the information of packet to the other nodes. And the Routers have the functions of establishing, searching and fixing the relevant routing paths. So, the Router should be always active. Finally, the Coordinators send the information from Routers to the STM32F103ZET6. The transfer process from Coordinator to End-device is similar. The main program frame of the central processing module is shown in Fig. 7.

The data mining circuit module: The data mining circuit module uses FDS-100 as soil moisture sensor. The FDS-100 has the measurement precision of 3% and its range is 0 to 100%, with working temperature between -60 and 180°C. Its range of operating voltage is 5 to 12V and the range of working current is 21 to 26mA. So, it meets the requirements of the system. It connects to P1_0 of CC2530. The circuit of FDS-100 is shown in Fig. 8 (Song and Tan, 2015).

The solar energy power supply module: The solar energy power supply module is similar to the design of power supply module. The main difference is that we input 12V from solar panel to U12. This power supply mode solves the problem that there is the inconvenience to power the soil moisture monitor and control unit.

The control module: The relay of the central processing module uses SRD-05VDC-SL-C. K1 is the SRD-05VDC-SL-C. U2 is the TLP521-2. D4 is the 1N4148. LED0 is the status indicator light. P1 is the Power Interface. The LED0 is lit, which means the relay stays energized and the orchard is irrigated. The circuit of control module is shown in Fig. 9 (Zhang, 2014).

RESULTS AND DISCUSSION

The study has tested ours system on December 2, 2015, at The Yunlu Orchard. The weather is sunny. We chose tree testing points labelled as A, B and C. The threshold of A is set to 32%, B is set to 30% and C is set to 28%. The moisture sensors of tree points are usually buried 5cm. The results of the experiment can be seen in the Table 2.

Table 2: The results of the experiment at the Yunlu Orchard

The plot	Threshold	Time	Soil moisture (%)	Water pump	Monitor
A	32%	10:00	33.8	Off	Normal
		12:00	31.0	On	Normal
		14:00	34.4	Off	Normal
		16:00	33.6	Off	Normal
		18:00	31.2	On	Normal
B	30%	10:00	33.5	Off	Normal
		12:00	31.4	Off	Normal
		14:00	29.1	On	Normal
		16:00	33.4	Off	Normal
		18:00	32.1	Off	Normal
C	28%	10:00	33.7	Off	Normal
		12:00	31.2	Off	Normal
		14:00	29.6	Off	Normal
		16:00	27.2	On	Normal
		18:00	31.8	Off	Normal

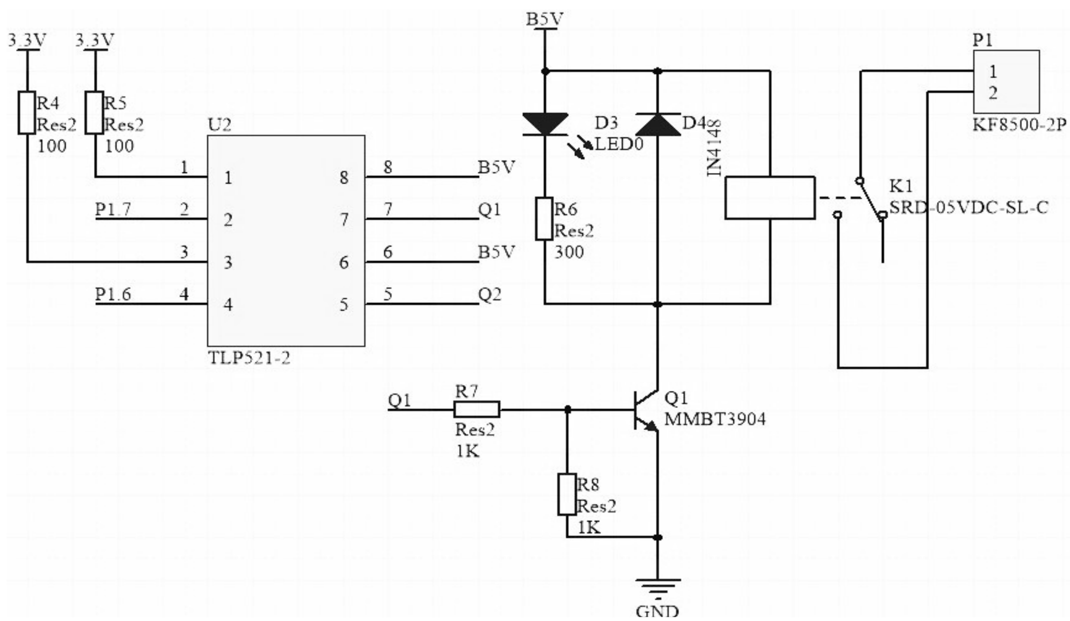

Fig. 9: The circuit of control module

The system works well. When the test values of soil moisture is below the threshold, the water pumps open and when the test values of soil moisture is higher than the threshold, the water pumps off. The test values of soil moisture at noon are lower than in the morning because the water of soil is boiled off by sunlight but increases as the monitor open. Comparing with the system based on nRF, this system based on Zigbee is more reliable and adds sensor nodes more easily because of the Z-stack communication protocol (Li *et al*., 2012). The testing results show that the actual transmitting distance of this system during normal work can reach 69 m, more than 50 m of the system based on nRF24L01 (Ju *et al*., 2012).

CONCLUSION

At present, China is an agricultural country but the agriculture is facing "four high" bring pressure such as water shortages, land degradation, high labour costs, high cost of the scientific agriculture. Our study develops and exploits an automatic technique system design for irrigation which has advantages of the good real time, low costs, high reliability and high precision. It contributes to save water and decrease the production cost.

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Conflict of interest: We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

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