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Environmental monitoring and intelligent irrigation system research[1]

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Abstract. A remote irrigation system based on GPRS and LabVIEW is designed, aimed at the requirements of modern precision agriculture and water-saving society. We use K60 as the lower monitor recording the temperature, humidity and other environmental parameters which sends the data by the transmission medium of GPRS. Through the internet network, the remote data are transmitted to the host computer. At the same time, an intelligent water-saving irrigation is realized by introducing the fuzzy control system. It plays an important role in studying wheat growth in further depth. The simulation experiment results show that the system is simple, stable and reliable. The interface is friendly. It meets the purpose and requirement of expected design.

Key words. GPRS, LabVIEW, data acquisition, water saving irrigation, wireless sensor, networks, fuzzy control.

1. Introduction

The shortage of water resource is the basic national condition in China. Although the total amount of water resource is rich, our country has access to less water per capita. As a large agricultural country, agricultural water accounts for a high proportion of the total water consumption. According to statistics, in 2007, agricultural water accounted for more than 60 % of total water consumption. But nearly 6.7 million hectares of farmland do not have water enough for irrigation. Our

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country is short of 40 billion cubic meters of water every year.

Thus, water-saving irrigation is the strategic measure to realize precision agriculture construction, which has a great significance to safeguard the economic, ecological and social sustainable development of China. Form the 1980s, Israel, United States and other developed countries have been successful in use of remote sensing technology and data communication technology in the forecast of soil moisture and environment monitoring for crop growth [1–2]. In our country, the precise irrigation technology started late and generally uses the method of timing for irrigation. If the soil needs water, it is irrigated in time, but utilization of water resources is very low and waste is serious. Although the extensive irrigation phenomenon has been basically controlled, application of control-irrigation devices is very rare, so that agricultural water-saving technology also needs to be further improved [3–4]. In order to achieve the data remote transmission, real-time acquisition, display and storage, the project introduces environment monitoring and irrigation control using wireless networks by combined application of sensor technology, computer technology and virtual instrument technology [5–6]. Based on the change of soil moisture and crop demand in different periods, the system adopts the manual control solenoid valve and automatic control of two modes of switching to achieve intelligent monitoring irrigation. Data curve satisfy the need of accurate control of a wide range of drip irrigation, which can easily evaluate the change of parameters and collect an amount of information [7–8]. To reduce waste effectively, enhance adaptability of the control system and realize a certain amount of intelligence level, fuzzy control was added to the system.

2. Analysis of the problem

As shown in Fig. 1, the structure of the system is divided into lower monitor data acquisition, wireless data transmission module, host computer monitoring software module and several other parts. Sensor is set up at the monitory point, measuring current traffic data in the field. Transmitting data to the monitoring center using GPRS DTU allows the remote host computer a better real time monitoring and storage managing in the form of database.

3. System principle

3.1. Hardware structure

The system hardware mainly includes the main controller in the field, environmental sensors, solenoid valve, power supply system, wireless transmission module and interior control center. A part of signal is converted to digital signal by the single chip microcomputer (SCM) through the modular conversion circuit and then it is treated and transmitted to the remote monitoring host computer. It associates database and carries out remote control of electromagnetic valve switch to realize intelligent irrigation.

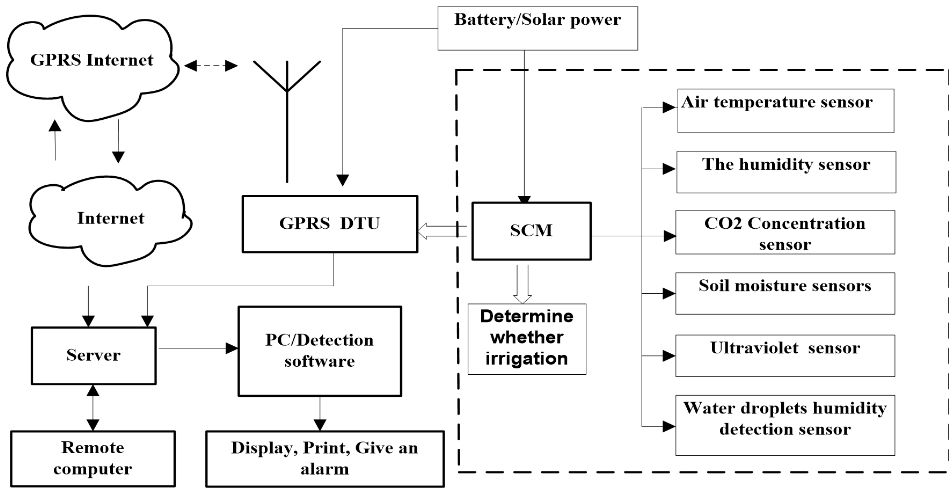

Fig. 1. Overall structure of the system

3.2. Sensor nodes

All of the environmental parameters, after being measured by the environmental sensors distributed in the field, are transmitted to the field main controller which transmit them to the control computing center through GPRS module [9–10]. Field data acquisition is a sensor network, which is made up of thousands of sensor nodes [11]. Each of the sensor nodes consists of various environmental elements of the sensor, node controller, STC15 SCM, and CC1100 wireless RF module. The data collected by CO_2 concentration sensor and soil moisture sensor is transmitted to the AD conversion circuit, then after passing through regulating circuit, filter circuit and amplifying circuit are transformed to the digital signal and transmitted to microprocessor. Other data (collected by the air temperature and humidity sensors and UV sensor) are transformed to digital signals directly, then the signal is stored in microprocessor internal storage and transmitted to gathering node through the CC1100 wireless transmission module.

The gathering node master controller of the system is the K60 SCM of Freescale-TM Semiconductor based on ARM Cortex-M4. It has a low power consumption and contains the mixed signal microcontroller. It is rich in serial interface and CAN bus interface and can collect 16 bit AD collection. The main controller deals with the data transmitted from nodes that is then stored. The processed data is sent to the GPRS module through the TTL turn RS232 module. The main controller judges whether it should open the solenoid valve according to the data that is sent by the GPRS module.

Its wireless transmission module uses the GTM900C wireless module Huawei (a three-frequency band GSM/GPRS wireless module, supporting the standard AT commands and enhancing them), and the highest rate of the GPRS data service can reach 85.6 Kbit. Both data acquisition module and GPRS DTU need the battery to supply electricity. When battery power is less than 10 %, in order to charge up it in time, an intelligent control system send instructions to control monocrystalline silicon solar panels, and fully charged battery charge can supply the device for 3 months.

To increase the reliability of the system, μC/OS-II operating system is implemented in the SCM. Compared with the traditional SCM, it can also avoid the program run errors in the development work or falling into an infinite loop, makes the debugger easy and uses for the system extremely safe condition [12].

4. Software design

The server uses Windows 7 system to write static IP address and port into the initialization of the GTM900C. The host computer monitoring adopts TCP/IP network protocol in writing the program and performs on the server based on LabView2012.

4.1. System login

The login interface of the system is shown in Fig. 2, containing only input of the correct user name and password. The remote monitoring system mainly includes three parts: monitoring, data curve display and data processing.

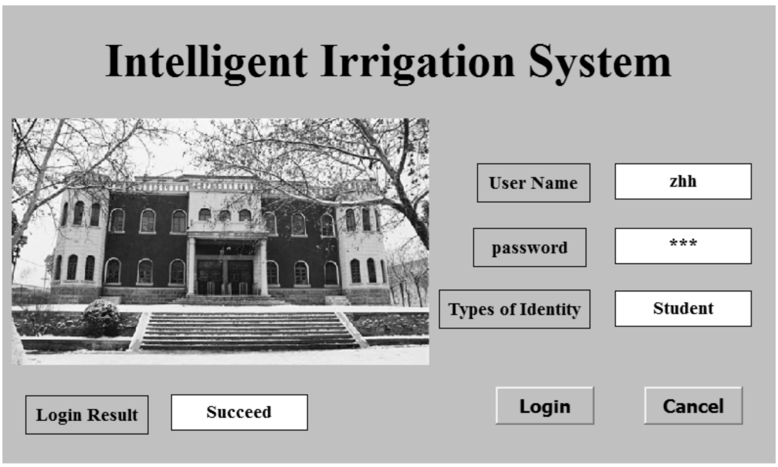

Fig. 2. Login screen

4.2. Design of the monitoring interface

Monitoring interface main sets TCP listening port, the server-side runs to monitor first of all, and then enters the same port with the DTU's configuration. Since DTU is within mobile intranet and has no fixed IP, DTU is assigned randomly to the remote address and remote port, then the address is connected to the IP but port assigning is not the same every time. The section of the alarm setting processes the information collected and triggers alarm if the value is out of range. The part of solenoid valve control sets two control methods (hand control and self control) and it can be controlled manually or automatically, according to soil moisture changing. Intelligent control device automatically closes the solenoid valve when the ambient humidity is higher than the maximum humidity value that is set. Vice versa, when the humidity is below the minimum humidity value, the solenoid valve is opened automatically to achieve intelligent irrigation.

4.3. Choosing graph curves

Host computer improves the function of selecting curve, which allows viewing selectively a variety of data changes. Dynamic invoking sub VI in main VI can be loaded into the sub VI. The curve to be seen is selected on the left side of the check box in Fig. 3, displayed on the right side of this interface, and then printed or otherwise processed.

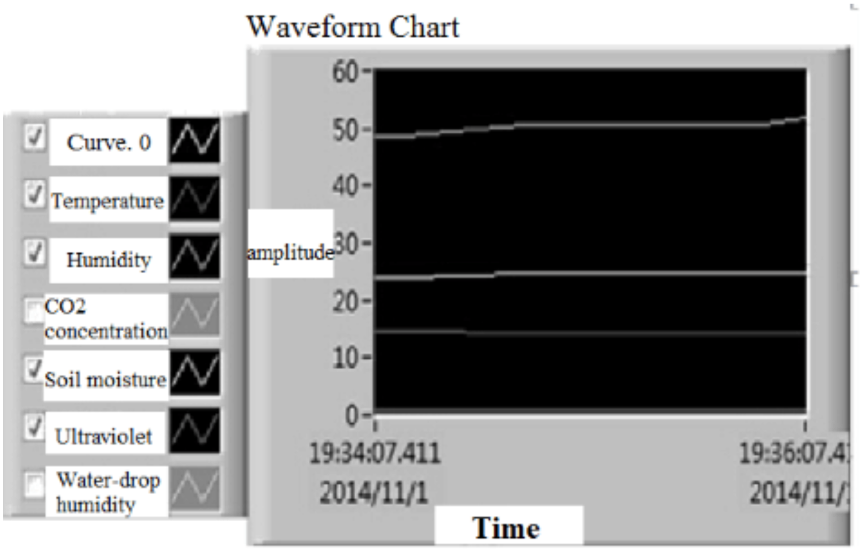

Fig. 3. Data processing interface

For example, checking four options in the check box of Fig. 3 (the curve 0 carried by the system is axis x), the curve can be shown on the side of the screen from top to bottom taking turns air humidity, soil moisture, temperature and ultraviolet (UV) curve (close to axis x), realizing the function curve of choice.

4.4. Remote monitoring realization

The research is carried out with the Widows 7 system as a server connected to VI panel through web browser [13]. VI is open remotely by inputting URL address at the time of configuration in the address bar. If the remote-client wants to operate the host computer, the permission by server must be obtained to gain the control, in order to avoid operation without permission. Therefore, the system can realize local or remote client computer controlling the system environment.

5. System control strategy

5.1. Strategy selection

It is difficult to describe the automatic control process of irrigation system with precise mathematical expressions due to its time delaying and nonlinear process. To solve the complex and difficult problem accurately, the intelligence control irrigation system joins the fuzzy control and emulates the control system by MATLAB. Using the look-up table method, the system adopts two-dimensional fuzzy control structure of double input (soil moisture deviation E, EC deviation rate) and single output (irrigation time U). The variety of the choice of parameters of input and output variables is shown in Table 1 (NB: Negative Big; NM: Negative Medium; NS: Negative Small; ZO: Zero; PS: Positive Small; PM: Positive Medium; PB: Positive Big). The basic structure of fuzzy controller is shown in Fig. 4.

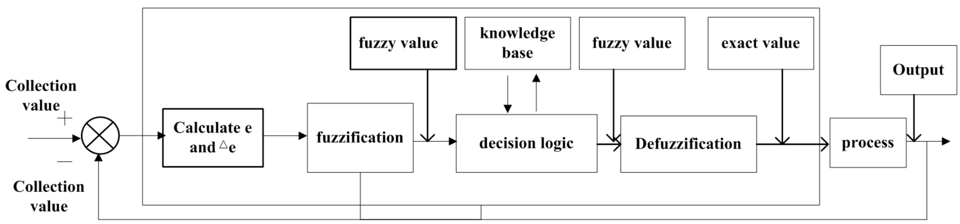

Fig. 4. Fuzzy control chart

5.2. Fuzzy rules

The fuzzy decision adopts Mamdani decision-making model and then uses maximum membership degree method to solve the fuzzy. Both EC and E choose 7 language values, so that there are 49 fuzzy inference rules in the system. According to the summary of agricultural practice in the long term for water-saving irrigation and experimental result of the research about drip irrigation, we can get the fuzzy control rule which is showed in Table 2.

5.3. Simulation experiment and analysis

In order to verify rationality and validity of the fuzzy control scheme, this design uses the simulation software Simulink (which belongs to the MATLAB) for the greenhouse water-saving irrigation system to make a simulated test. As shown in

Fig. 5, the system simulation model is composed of the step input signal, proportion, theory of domain range, fuzzy controller, zero step, function, delay module and display module.

Table 1. Various parameters of input and output variables

Input and output variables	The basic theory of domain	Language input and output variables	Fuzzy set theory domain	Membership function
E	–10 %–10 %	NB, NM, NS, ZO, PS, PM, PB	–3–3	Triangle Gaussian
EC	–2 %–2 %	NB, NM, NS, ZO, PS, PM, PB	–3–3	Gaussian
U	0–80 min	ZO, PS, PM, PB	0–3	Triangle

Table 2. Fuzzy control rule

U EC E	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PB	PM	PM	PS	ZO
NM	PB	PB	PM	PM	PS	ZO	ZO
NS	PM	PM	PS	PS	ZO	ZO	ZO
Z	PM	PM	PS	ZO	ZO	ZO	ZO
PS	PS	PS	ZO	ZO	ZO	ZO	ZO
PM	ZO	ZO	ZO	ZO	ZO	ZO	ZO
PB	ZO	ZO	ZO	ZO	ZO	ZO	ZO

According to agricultural experts' experience and actual system, the relation function of soil water variation and irrigation time are showed in the following formula

$$\Delta y = 100 \sin\left(\frac{\pi \cdot t}{900}\right) . \tag{1}$$

Analyzing the output of fuzzy controller, we can set different values of E and EC to prove the validity of the system. When E = 3, EC = 3, and U = 2.68, the soil is very dry and dries quickly, so the irrigation time should be long, and this is consistent with output results of rules. As shown in Fig. 8, bottom part, when E = 3, EC = 3 and U = 2, the soil is a little dry, dries quickly, and the irrigation time is shorter than above, which also agrees to the output of rules.

The simulation experiment results analysis: when setting goal soil humidity at 25 %, the phase signal inputted to simulation model should be 25. It is the curve

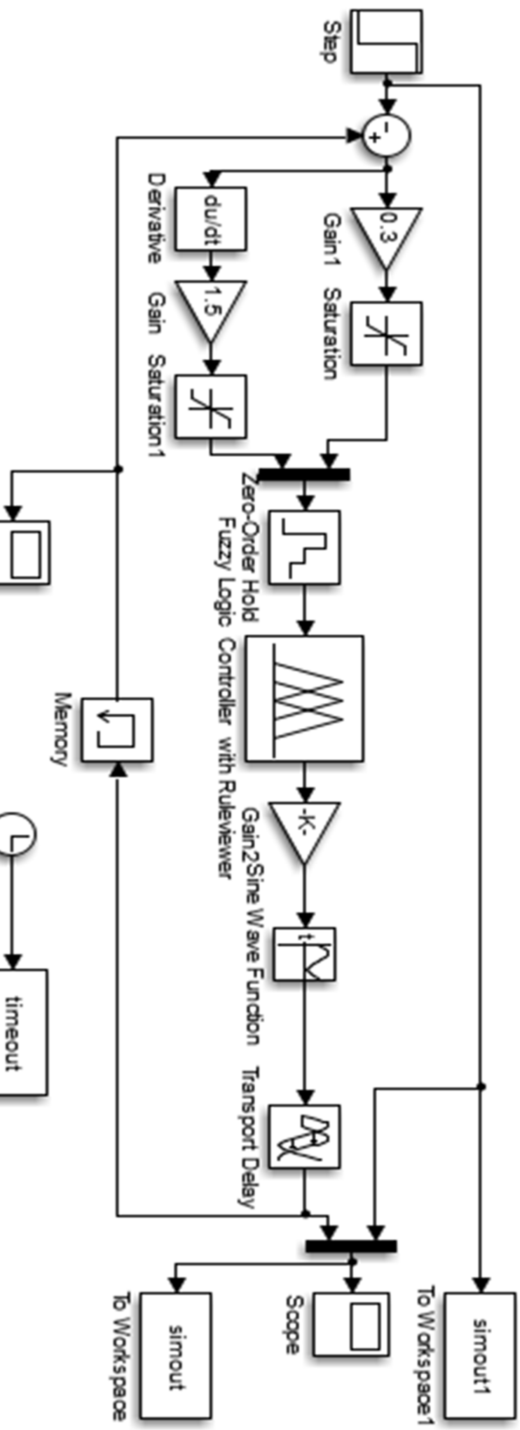

Fig. 5. Simulink model of the irrigation system

obtained by simulation. Figure 6 shows soil humidity simulation graph, where axis x is time in s and axis y is soil humidity in %. From the simulation graph, we can see the error range of simulated soil humidity is stabilized between the 2 % up and down.

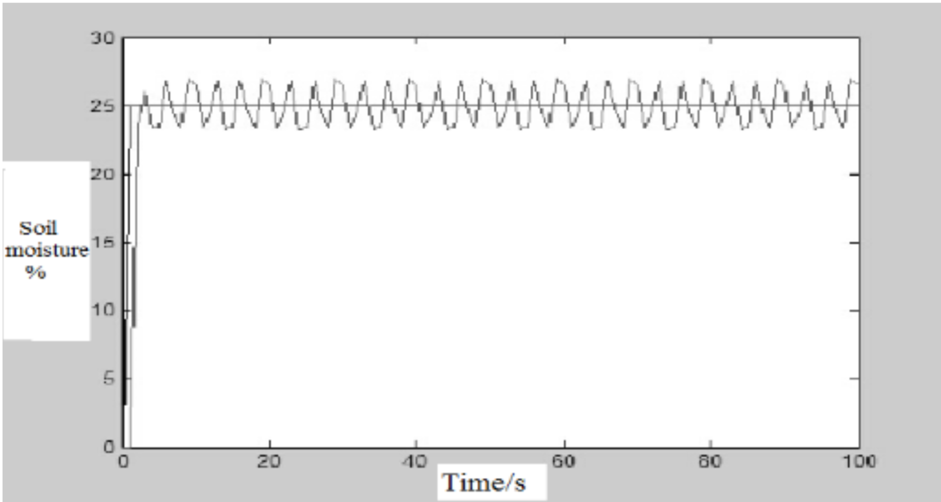

Fig. 6. Output of the rules

By comparing the actual soil humidity and simulation results, we can see that the error is almost the same. The simulated humidity is less than 2 %, and that can achieve the requirement of irrigation system. Obviously, the systematic accuracy can completely satisfy the need of field crops irrigation, and the stability of the system control is good.

6. Conclusion

The research was aimed at designing data management and remote intelligent control irrigation system based on GPRS, LabVIEW and fuzzy control. The system has the advantages of low cost, long transmission distance, fast speed and strong reliability. It is going to play a promoting role for the construction of modern precision agriculture and water-saving society. The results of simulation experiments show that the system can control electromagnetic opening and closing valves automatically, according to preset humidity range, meets the demand of field irrigation, and achieves goals and requirements of the desired design.

1. Completes the data acquisition and processing, and increases two option modes of manual and automatic control, that can intelligently irrigate according to actual humidity,

2. Increases the data curve comprehensive print function; adds the fuzzy control and is verified by simulation of MATLAB, and

3. Can realize monitoring for remote environments in the network, as well as intelligent control for remote water-saving.

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