Design of Intelligent Watering System of Flower Based on ZigBee and WiFi

Wuyang Huang¹ and Fan Yang²,*

¹College of Electronic and Information Engineering, Wuhan Institute of Technology, Wuhan, China
²College of Electronic and Information Engineering, Wuhan Institute of Technology, Wuhan, China

*Corresponding author e-mail: 1804747213@qq.com

Abstract. Aiming at the problem that the traditional artificial watering method in flowers is time-consuming and laborious, and cannot reasonably water the growth of each flower, an intelligent watering system of flower cultivation based on ZigBee and WiFi technology is designed. The CC2530 chip is used as the main control chip for ZigBee communication. Multiple terminal nodes and the coordinator node are wirelessly communicated through the ZigBee network. The RTL8710 is used as the WiFi communication chip to upload data to the host computer. The data and image curves are displayed on the host computer in real time. A composite switching control algorithm based on fuzzy control and PID control is designed. Based on the collected temperature and humidity and light intensity, the irrigation demand is calculated to achieve a better water-saving irrigation effect. Through the test, the entire system with excellent control performance and practical application value.

1. Introduction

In recent years, with the development of social ecological civilization, the government has continuously attached importance to the planning and layout of urban gardening, and has successively introduced standards such as "National Garden City" and "National Ecological Garden City" [1, 2]. The green coverage rate of urban construction areas has also increased, investment of the government in garden greening has also increased, which shows that the flower gardening market is vast [3]. However, the traditional flower garden industry is mostly manual maintenance, and the current flower irrigation methods include drip irrigation, micro irrigation, sprinkler irrigation and so on [4, 5]. With the high labor cost and the low efficiency, the output cannot be directly matched with the input.

But with the development of communication technology, the watering of flowers can be controlled by wireless method. Some systems use GSM digital communication technology to achieve the integration of monitoring and decision-making [6, 7]. However, the cost is high and the technology has not been fully promoted. There are also some systems that add optimization algorithms such as KcET0 can be beneficial to better water-saving irrigation, but the growing environment of flowers is different, the feasibility of operation is lower [8]. ZigBee technology is not compatible with the TCP/IP protocol, it cannot be directly connected to the Internet, it is hard to communicate with the host computer, and it has difficulty to monitor and manage the greenhouse [9, 10]. Therefore, the intelligent flower watering system based on ZigBee and WiFi technology was designed, and a
composite switching algorithm combining fuzzy control and PID control was used to optimize the system's communication connection and control method.

2. Whole Scheme Design

The system mainly includes four parts: terminal node, coordinator node, WiFi module and host computer. The structure diagram of the system is shown in Figure 1. ①The terminal node joins the ZigBee network, monitors the flower environment data in real time, and sends it to the coordinator node; ②The coordinator performs ZigBee networking, receives the data from each terminal node and sends it through the serial port to the WiFi module; ③The WiFi module connects to the WiFi network, connects with the remote TCP server, and sends the received data to the remote server; ④The host computer establishes a TCP server, sends the IP address and port number to the WiFi module, and confirms the connection is established, the received data is displayed in real time, and the terminal device is remotely controlled according to the set value.

3. System Hardware Design

3.1. Terminal Node Hardware Design

The terminal node uses CC2530 as the main control chip, which is composed of power module, serial port module, power amplifier module, antenna module, display module, sensor module and control module. Its hardware structure is shown in Figure 2.

The power module uses the AMS1117 chip and converts 3.3V output voltage to achieve power supply. The serial module uses the CH341 chip to achieve USB transfer. The power amplifier module selects CC2591 chip and adds balun circuit to improve the output power and receiving sensitivity of
the node. The antenna module adopts the dual antenna mode of PCB antenna and SMA passive omnidirectional antenna to enhance data transmission.

The sensor module consists of air temperature and humidity sensor, soil humidity sensor, and light sensor. The control module adopts the relay to control the opening and closing of the solenoid valve. The SRD-24VDC-SL-C relay is used. A TLP521-2 optocoupler is added between the CC2530 and the relay, which can effectively extend the service life of the relay.

3.2. Coordinator Node Hardware Design

The hardware structure of the coordinator node is basically the same as the terminal node. A jumper is set in the serial port module and the coordinator is set by a toggle switch. The schematic diagram is shown in Figure 3. The switch connects the CH341 to the WiFi module in the upper part to realize the setting of the WiFi module by the host computer; the switch connects the CC2530 to the WiFi module in the middle to realize communication and data reception between the CC2530 and the WiFi module; the switch in the lower part connects the CC2530 Connect with CH341 to realize the setting of CC2530 by the host computer. Normally place the switch in the middle for the system to work properly.

![Figure 3. Serial jumper schematic](image)

3.3. WiFi Module Hardware Design

The WiFi module uses RTL8710 chip, it built-in TCP/IP protocol stack, supports 802.11 b/g/n 2.4GHz protocol, and is composed of power module, serial port module, antenna module and display module.

4. System Software Design

4.1. Terminal Node Software Design

The terminal node first initializes the serial port, checks the settings of the network parameters, then it listens for the existence of the ZigBee network. If the network is found to exist, it sends a request to join the ZigBee network. When the terminal node joins the network successfully, the start timer is set to 5s, and data collection starts after the time is reached, the node ID number and data are packaged, which is sent to the coordinator node by calling a function.

4.2. Coordinator Node Software Design

At first, the coordinator node initializes the serial port, sets up a ZigBee network after the settings are completed, and assigns the address of nodes. When the terminal node successfully joins the network, the timer in the network status that change event feedback is triggered, the coordinator receives the host computer command from the serial port, sends the command to make the sensor collect data regularly, and sends the data to the coordinator node. After the coordinator node receives the data successfully, it determines whether the frame header is correct. By verifying the accuracy of the data, it extracts the ID number and data of the terminal node, transmits it to the WiFi module through the serial port.
4.3. WiFi Module Software Design

After the WiFi module is started, it creates UDP and listens to port 9000. The host computer starts to send Hello messages to the port through UDP at regular intervals. After receiving the message, the WiFi module returns a Probe message to the server, which carries the service number. After receiving the Probe message, the host computer judges the service number, and returns the PM message to the WiFi module, carrying the IP address and port number. The WiFi module successfully establishes a service connection with the TCP server after receiving the PM message.

Because the working frequency bands of ZigBee and WiFi protocols are both 2.4GHz, ZigBee protocol divides 16 channels with a channel bandwidth of 2MHz, The channel distribution diagram is shown in Figure 4. WiFi protocol divides 14 channels with a channel bandwidth of 22MHz. The channels between them overlap, which cause interference. The design adopts non-cooperative working mode, and interferes with the respective random dynamic channel allocation methods to avoid the phenomenon that different communication methods occupy the same frequency channel. When the system is running, set WiFi to run only on channels 1, 6, and 11, then set ZigBee to communicate only through 4 channels that do not overlap with WiFi, thereby solving the problem of signal interference.

4.4. Design of compound switching controller

For flowers in different growth states in the garden, from the perspective of soil moisture, closed-loop design by setting a threshold range cannot be effectively controlled. Therefore, a fuzzy-PID composite switching controller is designed, which is controlled based on the fuzzy switching algorithm of the trapezoid membership function. When the deviation is small, PID control is used to eliminate the static difference; when the deviation is large, the control is switched to fuzzy control to speed up the response speed. The control block diagram is shown in Figure 5.

In the fuzzy controller, the dual input variables are the soil moisture deviation e and the deviation change rate ec, and the single output variable is the irrigation amount u. Let the actual measured value and set value of the soil moisture named H and Hd. The relationship is:

\[ e(t) = H_d(t) - H(t) \]  \hspace{1cm} (1)
\[ ec(t) = e(t) - e(t-1) \]  \hspace{1cm} (2)

According to the theoretical results, when the soil moisture deviation is less than 2% RH, PID is better for control. When the humidity deviation is more than 6% RH, fuzzy control can be used to achieve better control results. Therefore, the intermediate trapezoid membership function switching algorithm is adopted, which switch these two control methods smoothly. It is required that UF_P is the
output of the composite controller, $U_{PID}$ is the output of the PID controller, $U_{Fuzzy}$ is the output of the fuzzy controller, and the switching rules are If $e$ is $y$ then $U_{F-P}$ is $UPID$, else $U_{F-P}$ is $U_{Fuzzy}$.

The $U_{PID}$ control weight is $\lambda$, and its corresponding $U_{Fuzzy}$ control weight is $(1-\lambda)$. It is calculated using the weighted average method, and the output $U_{F-P}$ is:

$$U_{F-P} = \lambda U_{PID} + (1-\lambda) U_{Fuzzy}$$ (3)

According to the mathematical model, the transfer function of the controlled object is set as:

$$G(s) = \frac{K}{Ts + 1} e^{-n}$$ (4)

Given the relationship between the irrigation amount and various environmental parameters:

$$Q = 2.83606*exp(0.007458t_1 - 0.00539h_1 + 0.030862l_1)$$ (5)

Where $Q$ is the amount of irrigation, $t_1$ is the temperature, $h_1$ is the humidity, and $l_1$ is the light intensity. The inverse Laplace transform of equation (6) gives, so as to realize the conversion between the calculated irrigation amount and the soil humidity.

$$y(t) = (-74) * \text{heaviside}(t - 45) * (\exp(45/19 - t/19) - 1)$$ (6)

5. System Testing and Analysis

5.1. Packet loss test

We place 3 nodes within a range of 60m from the coordinator node, set the node to send data packets every 10s, and perform 4 tests with a duration of 1, 6, 12, 24h, count the coordinator nodes and the host computer to receive the number of data packets, calculate the packet loss rate of ZigBee and WiFi networks, the test data is shown in Table 1.

| Time/h | Nodes send packets | Coordinator receive packets | Host computer receive packets | ZigBee packet loss rate/% | WiFi packet loss rate % |
|--------|--------------------|-----------------------------|------------------------------|---------------------------|------------------------|
| 1      | 1080               | 1076                        | 1076                         | 0.37                      | 0                      |
| 6      | 6480               | 6458                        | 6458                         | 0.34                      | 0                      |
| 12     | 12960              | 12926                       | 12926                        | 0.26                      | 0                      |
| 24     | 25920              | 25864                       | 25864                        | 0.22                      | 0                      |

According to the test results in the table, in the range of 60m around, the overall packet loss rate of ZigBee is small, the connection of the WiFi network is relatively stable, and the packet loss rate is 0. Therefore, the effect of the system on communication is very stable.

5.2. Function test

We place 3 terminal nodes in the garden pot for functional test, select node 1 and click to start data collection. The environmental parameters and change curves collected by the sensors of this node, which are displayed in real time. Based on the collected air temperature, humidity, and light intensity, the watering amount required for the flowers in this node is calculated according to formula (5), and the watering function is automatically enabled. The system can work normally and stably throughout the entire process.

5.3. Simulation analysis

According to the collected data of node 1, it is found that the required irrigation amount is 52ml. Because of the formula (6), the most appropriate to obtain the corresponding soil humidity of about 36% RH. Simulation is performed using three control methods to achieve the soil moisture. The optimum value is shown in Figure 6. According to the comparison of the results, it can be concluded that the PID control method will have an overshoot amount and a longer adjustment time, the fuzzy control method will have a steady-state error. The effect of the composite control is better than other control methods, which has better steady-state performance and higher accuracy.
6. Conclusion
The designed intelligent flower watering system combines ZigBee wireless acquisition with WiFi communication technology, improves the communication effect between nodes through the optimized design of the hardware, adopts a non-cooperative working method to solve the conflict between the two communication methods. A composite switching controller is designed to achieve better water-saving irrigation effects for flowers with different growth conditions. Through the test results and analysis, the entire system works well, the cost is low, which has great worthy in the future.

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