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Research and Implementation of Wireless Intelligent Sensing System for Greenhouse Based on IoT Technology

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Abstract

This paper presents a wireless intelligent sensing system for greenhouse based on the Internet of Things (IoT) technology. The system utilizes various sensors to monitor the environment inside the greenhouse, such as temperature, humidity, light intensity, and carbon dioxide concentration, in real-time. The data collected by the sensors is transmitted wirelessly to a backend server for analysis and processing, enabling intelligent monitoring and control of the greenhouse environment. The system also integrates cloud computing and big data analysis technologies to provide precise planting management recommendations for farmers, improving the efficiency and quality of agricultural production. The experimental results show that the system is stable and reliable, and can accurately monitor the environmental parameters of the greenhouse and respond promptly to user control instructions. Compared with traditional greenhouse management methods, the IoT-based intelligent sensing system can improve greenhouse production efficiency, save energy resources, and reduce production costs, with high practical value and broad application prospects.

Keywords

IoT, greenhouse, wireless intelligent sensing system, intelligent management, cloud platform.

1. Introduction

With the rapid development of IoT technology, intelligent management of greenhouses has become a hot research topic in the field of agriculture[1-2]. Traditional greenhouse management methods have various problems, such as cumbersome manual management, low efficiency, and resource waste, which cannot meet the needs of modern agricultural production. IoT technology provides an innovative solution for intelligent management of greenhouses. By installing various sensors inside the greenhouse, real-time monitoring of temperature, humidity, light intensity, carbon dioxide concentration[3], and other necessary data can be achieved, enabling comprehensive control of the environment inside the greenhouse. The data collected by the sensors is then transmitted wirelessly to a backend server for analysis and processing, enabling intelligent monitoring and control of the greenhouse environment. Additionally, the integration of cloud computing and big data analysis technologies can provide precise planting management recommendations for farmers, improving the efficiency and quality of agricultural production. Therefore, the combination of IoT technology and greenhouse management can achieve real-time monitoring and remote control of the greenhouse environment, improving the level of intelligent agricultural production and promoting the development of modern agriculture.

Currently, IoT-based wireless intelligent sensing systems for greenhouses have been widely researched and applied in China and abroad[4]. These systems utilize various sensors and communication technologies to monitor and control the environmental parameters of the greenhouse, improving the quality and yield of the crops. In China, many universities and research institutions are conducting research on the technology, mainly focusing on greenhouse environment monitoring, crop growth status monitoring, intelligent irrigation, and fertilization. Additionally, some domestic companies are also developing and promoting IoT-based wireless intelligent sensing systems for greenhouses, providing intelligent greenhouse management solutions for farmers. In other countries, such as Europe and the United States, research institutions are also working on the technology, with advantages in sensing technology and IoT communication technology, and achieving monitoring and control of the greenhouse environment through the integration of big data and artificial intelligence. Some foreign companies have also developed intelligent greenhouse management systems that can achieve remote monitoring, data analysis, and real-time viewing, helping farmers improve the yield and quality of greenhouse crops.

In summary, IoT-based wireless intelligent sensing systems for greenhouses have significant research background and practical value, and with the passage of time, the technology will become increasingly mature and widely used, improving the lives of people.

2. System Design

2.1. Overall System Architecture

2.1.1. Sub-section Headings

To realize the wireless intelligent sensing system for greenhouse based on the Internet of Things (IoT), the overall system architecture is shown in Figure 1, which consists of three parts: sensor nodes, wireless communication network, and cloud platform.

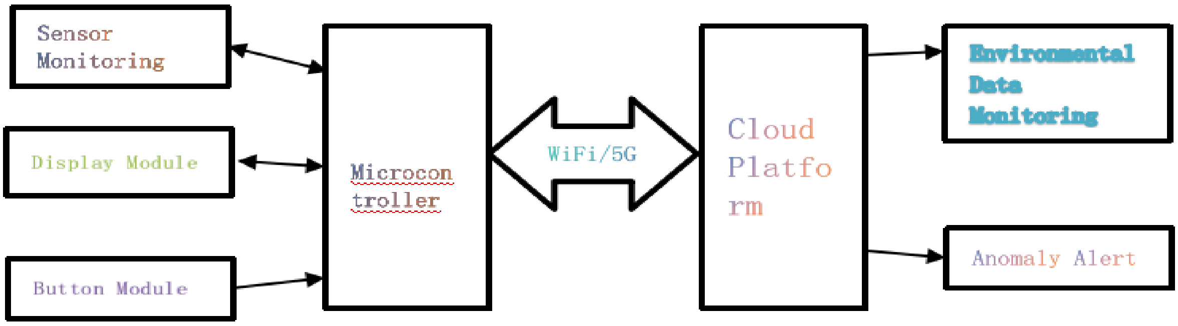

Fig. 1 Overall System Architecture

The sensor nodes are responsible for the real-time monitoring of the environmental parameters in the greenhouse, including soil pH value, temperature and humidity, light intensity, and carbon dioxide concentration. In the sensor nodes, high-precision and stable sensors are selected, and the microcontroller is used for data processing and packaging.

The wireless communication network is responsible for the transmission of the data collected by the sensor nodes to the cloud platform for processing and analysis[5-6]. In the wireless communication network, the LoRa technology is adopted, which has the characteristics of longdistance transmission, low power consumption, and strong anti-interference ability, and is very suitable for the application scenario of the greenhouse.

The cloud platform is responsible for the processing and management of the data collected by the sensor nodes. In the cloud platform, a Web-based architecture is adopted, and users can access it through a browser. An App-side interface is also provided for users to remotely monitor and control the system.

2.2. Sensor Node Design

The sensor nodes are an important part of the system, and their design directly affects the accuracy and stability of the data collection[7]. In the design of the sensor nodes, the following aspects are mainly considered:

1.Sensor selection. In the sensor selection, the precision, stability, and cost of the sensors are mainly considered. Finally, the soil pH value sensor, temperature and humidity sensor, light sensor, and carbon dioxide sensor are determined.

2.Data collection and processing. In the data collection and processing, the high-performance, low-power, and low-cost microcontroller STC89C52 is adopted. The corresponding program is written in the microcontroller to process and package the data collected by the sensors and transmit the data to the cloud platform through the LoRa module.

3.Node deployment. In the node deployment, the position and deployment method of the nodes are mainly considered. In the position of the nodes, the nodes are deployed in the four corners and the middle of the greenhouse to monitor the environmental parameters in the greenhouse more accurately. In the deployment method of the nodes, the wireless communication method is adopted, and the nodes and the LoRa gateway are paired to facilitate data transmission.

2.3. Wireless Communication Network Design

The wireless communication network is responsible for the transmission of data, and its design directly affects the speed and stability of the data transmission[8]. In the design of the wireless communication network, the following aspects are mainly considered:

1.Wireless communication technology selection. In the wireless communication technology selection, the transmission distance, power consumption, and anti-interference ability of the technology are mainly considered. Finally, the LoRa technology is determined.

2.Network topology design. In the network topology design, the position and deployment method of the network are mainly considered. In the position of the network, the LoRa gateway is deployed in the middle of the greenhouse to facilitate data transmission. In the deployment method of the network, the star topology is adopted, and all the sensor nodes and the LoRa gateway are paired to facilitate data transmission.

3.Data transmission design. In the data transmission design, the data packaging method and transmission protocol are mainly considered. In the data packaging method, the JSON format is adopted to package the data collected by the sensors to facilitate data transmission. In the transmission protocol, the MQTT protocol is adopted, which has the characteristics of being lightweight, low power consumption, and high reliability, and is very suitable for the application scenario of the IoT.

2.4. Cloud Platform Design

The cloud platform is responsible for the processing and management of the data, and its design directly affects the data processing and management capabilities of the system. In the design of the cloud platform, the following aspects are mainly considered:

1.Data processing and analysis. In the data processing and analysis, the storage, processing, and analysis of the data are mainly considered. In the storage of the data, the MySQL database is adopted to store the data collected by the sensors to facilitate data query and analysis. In the

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processing of the data, the Python language is adopted to process and analyze the data collected by the sensors and visualize the processed data. In the analysis of the data, the machine learning algorithm is adopted to analyze and predict the data collected by the sensors to monitor the environmental parameters in the greenhouse more accurately.

2.User interface design. In the user interface design, the layout and interaction of the interface are mainly considered. In the layout of the interface, a simple and beautiful design style is adopted, and the interface is divided into several functional modules to facilitate the operation of the users. In the interaction of the interface, the front-end and back-end separation design method is adopted to facilitate the development and maintenance of the system.

3.Remote monitoring and control. In the remote monitoring and control, the operation method and control method of the users are mainly considered. In the operation method of the users, the Web-side and App-side operation methods are provided, and the users can choose according to their own needs. In the control method of the users, the control method based on the MQTT protocol is adopted, and the operation commands of the users are packaged and transmitted to the sensor nodes through the MQTT protocol to facilitate the remote monitoring and control of the system.

In summary, this chapter introduces the design of the wireless intelligent sensing system for the greenhouse based on the IoT, including the overall system architecture, sensor node design, wireless communication network design, and cloud platform design. In the design process, the data collection accuracy, data transmission speed and stability, and data processing and management capabilities of the system are fully considered, and finally, a high-performance and high-reliability wireless intelligent sensing system for the greenhouse is realized.

3. System Testing

3.1. System Integration Testing

3.1.1. System Hardware Testing

Before conducting the system hardware testing, the hardware components need to be soldered and the connections of the pins, sensors, and display screen should be checked for accuracy. During the power-on test, attention should be paid to the indicators of each module, and any abnormalities such as strange odors or flashing lights should be addressed immediately by turning off the power and troubleshooting. The application control program, functional program, and hardware should be tested for coordination, and the sensor data should be observed for real-time display on the screen. The alarm module should also be tested when the sensor data exceeds the threshold value. The hardware circuit was found to be functional after the tests.

3.1.2. System Software Testing

The system software was developed using C language, and Keil was used as the main development environment. The code was written and burned into the STM32 microcontroller. The system and its components should be checked for proper connections before software testing. The software testing process should be attentive to the installation of the Keil software and the writing of the code to avoid errors and malfunctions. After debugging, the system software was found to be functional and able to meet the requirements of the project.

3.2. Functional Testing

3.2.1. Temperature Detection Function Testing

Before starting the temperature detection function testing, the connection between the system and the temperature sensor should be checked for accuracy. The testing process should observe the changes in the sensor data in different temperature environments and the continuous

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monitoring of the temperature readings. In this test, the temperature threshold was set to 29°C, and the room temperature was adjusted to different values (24°C, 28°C, 31°C) by friction. The changes in the monitored data were observed, and the test was repeated several times in different temperature environments. The temperature detection function test chart is shown in Figure 2.

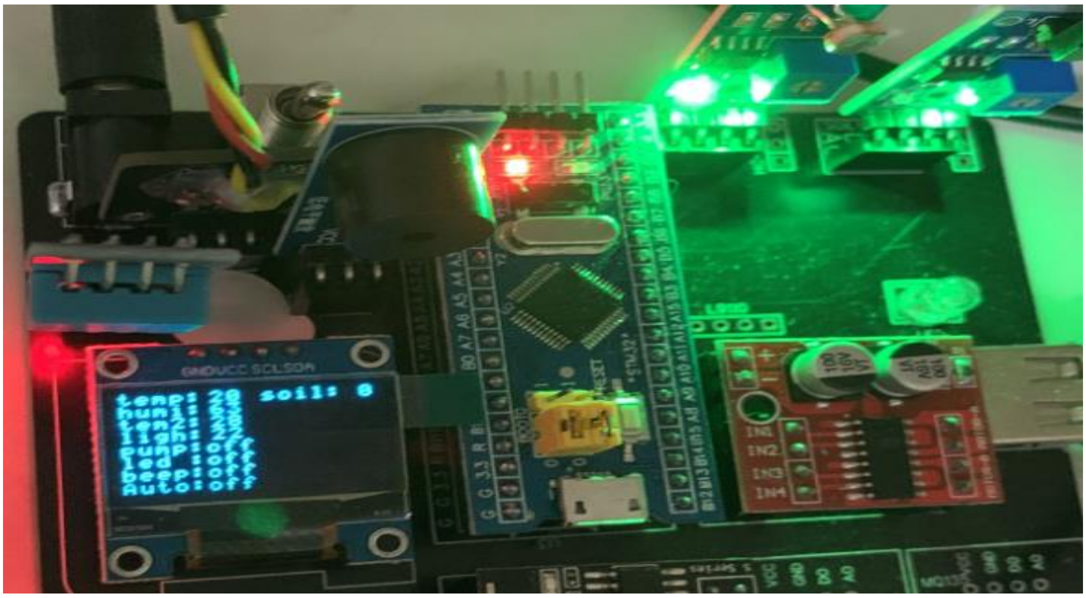

Fig. 2Temperature Detection Function Test Chart

According to the test results, the sensor data changes with the temperature, and there is a certain error in the test results. When the test temperature was 30°C, the buzzer sounded an alarm. When the room temperature was lower than 29°C, the test temperature was displayed as normal, and the buzzer did not sound an alarm.

3.2.2. Humidity Detection Function Testing

Before starting the humidity detection function testing, the connection between the system and the humidity sensor should be checked for accuracy. The testing process should use a wet paper towel to wrap the soil humidity sensor to simulate the soil humidity environment and set the soil humidity threshold to 50%. The room humidity was then adjusted to different values (7%, 44%, 60%, 50%), and the changes in the humidity sensor readings were observed. The humidity detection function test chart is shown in Figure 3.

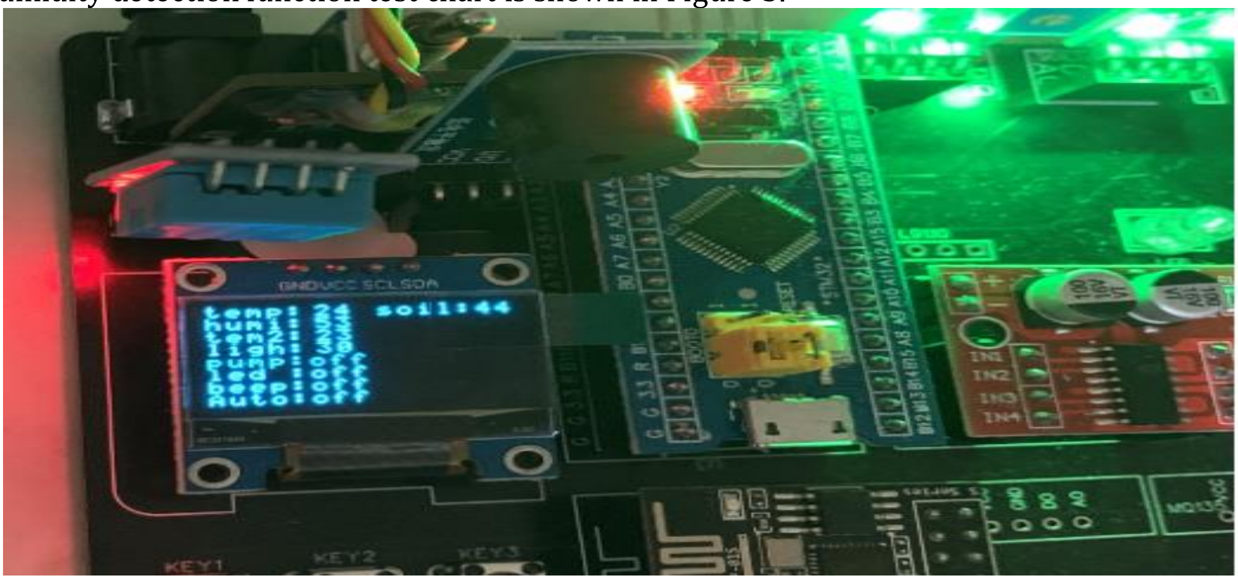

Fig. 3Humidity Detection Function Test Chart

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According to the test results, the test humidity changes with the humidity, and there is a 1% error in the test results. When the room humidity was 7%, the test humidity was 7%, and the buzzer did not sound an alarm. When the room humidity was increased to 60%, the test humidity was also 60%, and the buzzer sounded an alarm.

3.2.3. Light Intensity Detection Function Testing

The light intensity detection function testing was conducted using a flashlight to shine on the photoresistor sensor and opening and closing the curtains. The light intensity threshold was set to 88. The tests were conducted in different light intensity environments (60, 85, 90), and the changes in the photoresistor sensor readings were observed. The light intensity detection function test chart is shown in Figure 4.

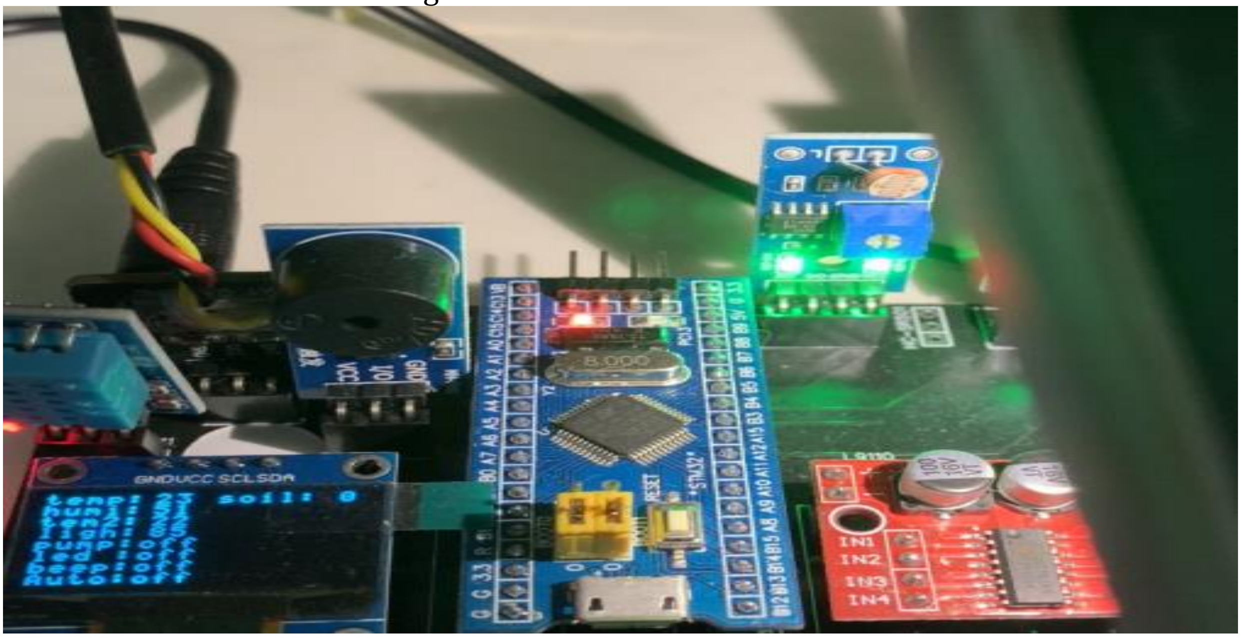

Fig. 4Light Intensity Detection Function Test Chart

According to the test results, when the room light intensity was 60, the real-time light intensity was 59, there was an error, and the buzzer did not sound an alarm. When the flashlight was used to shine on the sensor and the light intensity was increased to 85, the real-time light intensity was 85, and the buzzer did not sound an alarm. When the light intensity was 90, the real-time light intensity was 90, and the buzzer sounded an alarm.

3.2.4. Air Temperature and Humidity Detection Function Testing

A humidifier was used to increase the air humidity, and the air temperature was adjusted from 20°C to 28°C. The air humidity was adjusted from 48% to 88%. The temperature threshold was set to 27°C, and the humidity threshold was set to 77%. The air temperature and humidity detection function test chart are shown in Figure 5.

According to the test results, when the room temperature was 20°C and the humidity was 48%, the temperature was 19°C, the humidity was 48%, and the buzzer did not sound an alarm. When the room temperature was 26°C and the humidity was 68%, the temperature was 26°C, the humidity was 67%, and the buzzer did not sound an alarm. When the room temperature was 28°C and the humidity was 88%, the temperature was 27°C, the humidity was 87%, and the buzzer sounded an alarm.

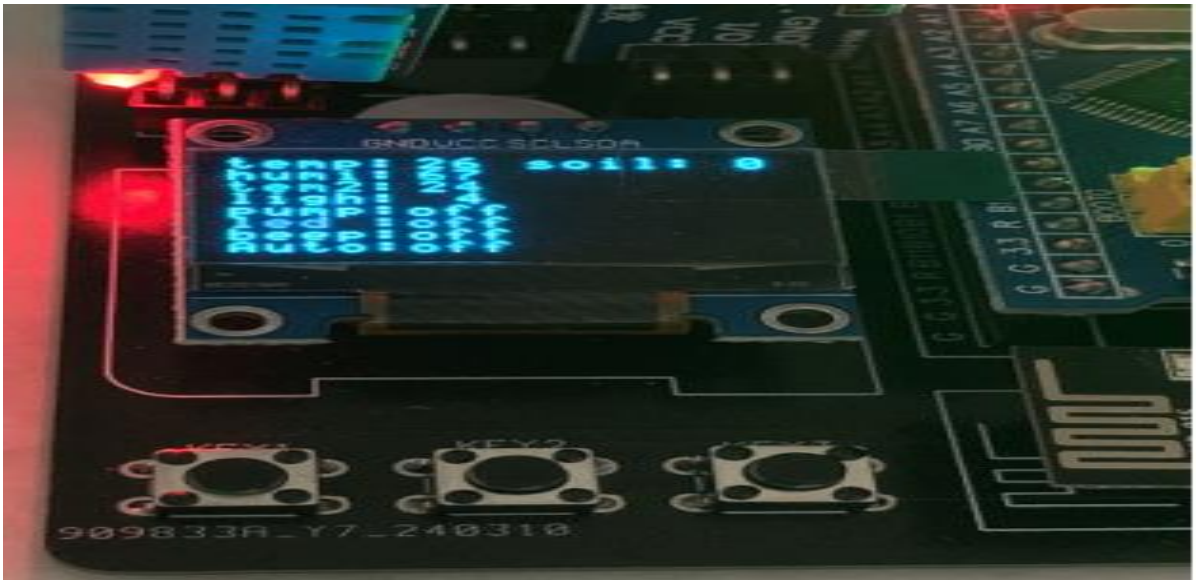

Fig. 5 Air Temperature and Humidity Detection Function Test Chart

3.3. System Testing Results and Analysis

The main focus of this round of testing was the analysis of air temperature and humidity data. The testing time was from 8:00 am to 1:00 pm, a total of 6 hours. During the testing process, the experimental temperature was controlled between 21°C and 29°C, and the humidity was controlled between 23% and 36%. The temperature setting was 25°C, and the humidity setting was 31%. The air temperature and humidity test data are shown in Table 3-1.

Table 3-1: Air Temperature and Humidity Test Results

time	Indoor Temperature (°C)	Test Temperature (°C)	IndoorHumidity (RH)	Test Humidity (RH)
8:00	21	21	23	21
9:00	20	19	26	26
10:00	24	24	36	36
11:00	25	24	30	30
12:00	26	26	28	27
13:00	29	29	24	24

According to the test results, the intelligent plant watering system's various modules can operate normally, and the system's designed functions can be realized. However, there is a certain error in the system under different temperature and humidity environments. The system should be tested and adjusted in different environments to ensure its normal operation while minimizing the error. The mobile APP module was also tested and found to be functional. The system can transmit the monitored environmental data to the APP in real-time through the WIFI connection, and the user can also adjust the system's settings through the APP.

4. Conclusion

This paper explores a wireless intelligent greenhouse sensing system based on Internet of Things (IoT) technology, which successfully achieves real-time monitoring and intelligent control of the greenhouse environment. By integrating various sensors and employing wireless transmission technology, the system can accurately collect data on temperature, humidity, light intensity, and carbon dioxide concentration inside the greenhouse. Using cloud computing and big data analysis, the system provides intelligent management recommendations. Experimental results demonstrate that the system is highly stable and reliable, effectively improving the production efficiency of greenhouse crops, conserving energy resources, and reducing production costs. Compared to traditional greenhouse management methods, this system shows significant advantages and has broad application prospects in modern agriculture. With further technological advancements and wider adoption, the IoT-based wireless intelligent greenhouse sensing system is expected to play a more pivotal role worldwide, driving the development and advancement of agricultural modernization.

Acknowledgements

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