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Crop Information Multi-Source Sensor Integrated Detection Device

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Abstract

The rapid acquisition of crop growth information and environmental information is of great significance for scientific and effective management of water, fertilizer and environment, and for ensuring crop yield and quality. This research uses TOF imaging, thermal infrared imaging and multi-spectral imaging modules, combined with environmental temperature, humidity and light sensors to construct an integrated detection device for crop growth and environmental information. The three-dimensional phenotypic parameters of crops were obtained by using the Intel real-sense radar camera L515. The canopy temperature used to detect the moisture state of crops was obtained by using the Gaode infrared thermal imaging sensor. MS3100 multispectral imaging was used to obtain two-dimensional image information of crops, and SHT11 wireless temperature and humidity sensor and BH1750FVI light intensity sensor were used to obtain temperature, humidity and canopy illumination and other crop growth environment information. On this basis, the data acquisition program and human-computer interaction interface were developed based on the Windows platform, which realized the acquisition of multi-source sensing information of crop growth and environmental information.

Keywords: Crop information; Environmental information; Three-dimensional imaging; Infrared thermal imaging; Multi-source sensing.

1. Introduction

Obtaining the environmental information of crop growth is of great significance for realizing the independent variable operation of agricultural machinery and improving crop yield and quality. Traditional methods rely on artificial experience to obtain crop information, while nutrient information is usually obtained by chemical analysis methods. Both of them expose many shortcomings, such as high cost, long time, and complicated operation.

Scholars at home and abroad have a wide range of research fields for crop growth information detection systems. A. Elvanidi et al. [1] utilized a hyperspectral machine vision system as a non-contact technique to detect nitrogen deficiency in soilless tomato. Karla Saldana Ochoa et al. [2] used machine vision and remote sensing satellite images to monitor and obtain real-time growth status of field crops. David L. Ehret et al. [3] analyzed the yield, growth status and water use of greenhouse tomato through neural network. The model predicted the yield and growth demand well, indicating that automatic prediction of relevant information could facilitate the automatic management of greenhouse. Devin L. Mangus et al. [4] developed a crop water stress monitoring system with high temporal and spatial resolution. The CWSI method derived from thermal infrared imaging technology and TIRIS remote measurement of canopy temperature could be used as an alternative irrigation scheduling method to inform decision-making in greenhouse irrigation and management. Liu Maocheng et al. [5] designed a hand-held leaf nitrogen diagnosis system with photoelectric sensors, however, it has not yet verified plants with different varieties, different growth periods, and different nitrogen treatments. The chlorophyll content detection system designed by Cheng Kun et al. [6] realized the real-time detection of chlorophyll content and the temperature and humidity of the environment where the leaves are located without damaging the leaves. Liu Qing et al. [7] combined wireless sensor technology and acoustic emission technology to realize the greenhouse soil temperature and humidity, air temperature and humidity, carbon dioxide concentration and light intensity, and collected acoustic emission signals reflecting the disease status. The system improves the automation and intelligence level of the greenhouse and has good portability. Meihuiliang et al.[8] proposed a WIFI-based dynamic detection system for greenhouse environment, aiming at the problem of complex wiring and easy aging of greenhouse detection system, which could realize remote detection and provide valuable experience for automatic detection in greenhouse.

Most of the existing detection technologies are distributed, and the detection information is not comprehensive, hence, it is difficult to comprehensively monitor the environmental information such as crop nutrition growth, temperature, humidity and illumination. Meanwhile, in view of the lack of practical rapid detection instruments and agricultural machinery supporting devices, it is hard to perform variable operations according to the growth state of crops and difficult to optimize the control of water and fertilizer according to the real needs of crop growth. This device studies the acquisition method of directional information of crop comprehensive growth based on TOF optical field phenotype, thermal infrared imaging and other new optical sensing technologies, and research on multi-source information correction method based on structured light and dynamic sensing of detection environment. On this basis, based on the extracted optimal growth directivity characteristics, a simplified optical detection model is established, and TOF depth camera imaging, infrared thermal imaging and other sensors are selected to develop an integrated and portable crop comprehensive growth detection sensor system. To form a multi-source sensing integrated detection device that could not only independently complete the field detection of crop growth information, but also support the use of agricultural machinery and equipment to achieve accurate detection of crop growth information, providing scientific basis for water, fertilizer and gas management and accurate variable operation.

2. Design of multi-source sensing device

The device is based on sensor technology, intelligent control technology, intelligent algorithm, etc. to solve the real-time detection of crop growth, and provide scientific basis for water, fertilizer and gas management and accurate variable operation. The overall scheme of multi-source sensor integrated detection device for crop information is shown below in Fig. 1. The multi-source integrated detection device consists of a handheld multi-sensing probe and detection platform, as shown below in Fig. 2.

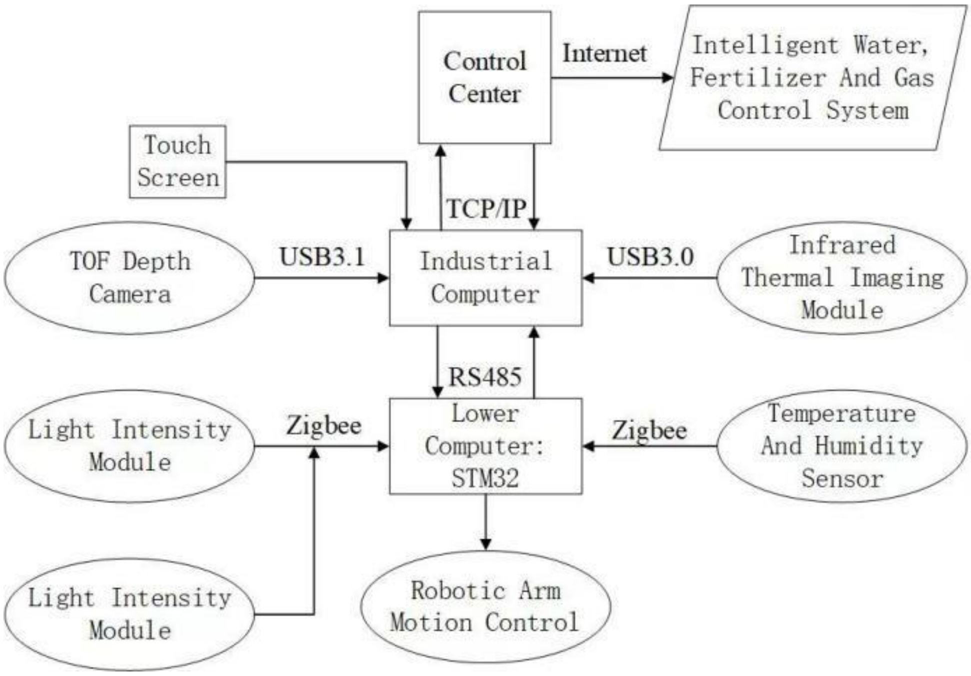

Fig. 1. Overall Scheme of Multi-source Sensor Integrated Detection Device

Fig. 2. Multi-source sensing integrated detection device

The device mainly consists of an industrial computer as the upper computer. Due to the large amount of data from Intel L515 TOF depth camera, USB3.1 type-c interface is required. After comparison, the industrial computer is selected to receive the data from L515, and then a software system is designed to analyze the three-dimensional point cloud information, obtain the results, and display crop growth related information through the interface on the touch screen. The information of the infrared thermal imaging module also needs to be analyzed and calculated using the SmartView 4.3 software of the industrial computer to obtain crop water state parameters such as canopy air temperature difference and water stress index. Crop nutrition and growth status information are transmitted through the MODBUS protocol equipped with the RS485 physical interface, and output on the human-computer interaction interface independently developed based on LabVIEW.

In addition, information such as air temperature and humiditylight, intensity, carbon dioxide concentration, etc., as the environmental status information of crop growth, has low real-time requirements, and does not affect the synchronous acquisition of depth imaging and infrared thermal imaging information. Therefore, the device uses wireless modules to connect environmental factor detection sensors. In order to reduce wiring and improve transmission performance, it is required to use zigbee protocol to fuse sensor information, upload environmental information to the upper industrial computer, and display it in different areas on the interface of the touch screen.

3. Hardware module design of detection device

3.1. Radar camera module for comprehensive growth characteristics of crops

The device uses Intel real-sense optical radar camera L515, including a 1024 x 768 @ 30Hz TOF depth sensor and a 1920 x 1080 @ 30Hz RGB image sensor. Therefore, the L515 could be used for TOF 3D scanning modeling, hence, the three-dimensional point cloud could be generated by using the official SDK, combined with the open source PCL library function to analyze the crops, including plant stem, fruit, leaf structure, 3D morphology feature extraction, further to analyze the growth state of crops. Moreover, RGB sensors could extract the color characteristics of crop leaves, and establish RGB models to analyze leaf nutrition.

Based on the extraction, analysis and fusion of the comprehensive information of the two sensors, a multi-source perception model for the comprehensive growth characteristics of crops is established. The crop multi-information multi-source integrated sensor probe used is shown in Fig. 3 and the three-dimensional image obtained by L515 is shown in Fig. 4.

Fig. 3. Crop multi-information multi-source integrated sensor probe

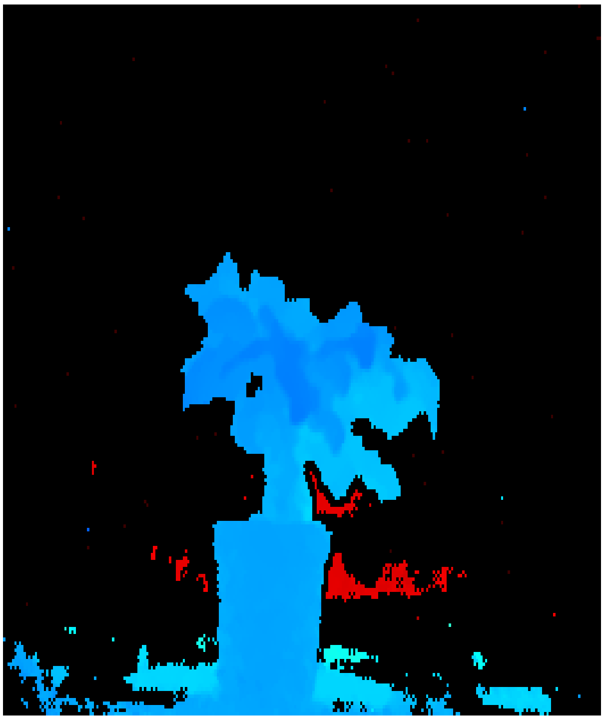

Fig. 4. Three-dimensional image obtained by L515

The L515 radar camera could maintain high precision in the range of 0.25m~9m, accurately provide 23 million depth pixels per second and reach 1024px×768px depth resolution at 30frame/s speed. Meanwhile, the L515 has a built-in visual processor to reduce motion blur artifacts and photon depth delay. It is small in size, low in power consumption (less than 3.5W), easy to install on handheld devices with a long battery life, providing scientific basis for water, fertilizer and gas management and accurate variable operation in real time. The visible light images were acquired by MS-3100 multispectral progressive scanning digital camera. The MS-3100 camera adopts a 3CCD image sensor, the imaging spectral range is 400-1100 nm, and the highest resolution is 1392(H)×1040(V) pixels, which could simultaneously acquire R, G, B and NIR independent channel images to achieve high-quality crop image acquisition.

3.2. Infrared thermal imaging module

Infrared thermal imaging detection technology mainly converts light energy into heat energy through laser excitation, acts on the surface of plants to generate temperature difference, and is recognized by infrared thermal imaging cameras. It has the advantages of good controllability, great collimation and high detection accuracy. The infrared image of leaves captured by infrared thermal imaging sensor is shown in Fig. 5.

At the same time, infrared thermal imaging could also detect plant diseases. When plants suffer from infectious diseases, the permeability of cell membrane will change, and the water content in mesophyll cells will be more easily lost, which will lead to changes in the water potential of guard cells controlling stomatal movement, leading to heterogeneous opening and closing of stomata. In addition, some fungi will destroy epidermal cells and cause abnormal stomatal opening, while some fungi will secrete H2O2 and cause abnormal stomatal closing. Plants that are attacked by pathogens also have a series of defense reactions, such as the accumulation of salicylic acid (SA) and abscisic acid (ABA) and other substances will also cause heterogeneous stomatal opening and closing. In general, whether plants are stressed by non-infectious diseases or invasive diseases, leaf stomata will open and close abnormally. Infrared thermal imaging could better estimate stomatal conductance. Through this mechanism, the infrared thermal imaging module could be well applied to detect temperature differences and diseases on the surface of crops. This technology could monitor crop moisture information in real time and detect invasive diseases before symptoms appear. Therefore, doing research on the above two aspects is of great significance for promoting the development of precision agriculture technology.

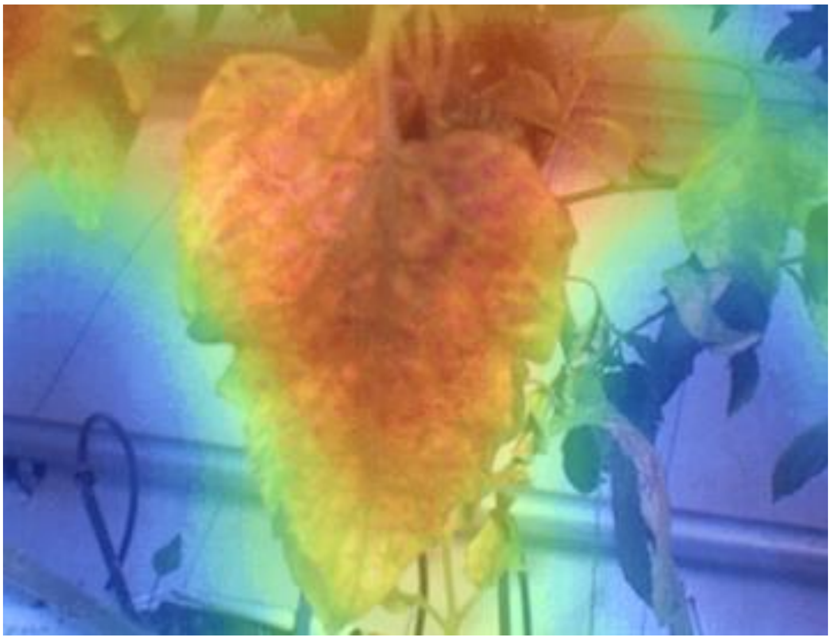

Fig. 5. Infrared image of leaves

3.3. Development of multi-source sensing detection platform

The environment detection sensors in the wireless network are used to monitor the growth environment of crops in real time (such as temperature and humidity monitors, carbon dioxide sensors, optical sensors, etc.), and the monitored data is transmitted to the ZigBee gateway in a wireless form through the ZigBee node. The gateway sends the monitoring results to the data center through Modbus protocol, and intelligently interacts on the display. Through real-time dynamic intelligent monitoring of changes in environmental factors, and combining with plant growth and development rules to judge the growth status of crop.The platform provides a basis for agricultural machinery and equipment operations to judge agricultural hours, determine operation opportunities and parameters, and provides environmental reference for crop growth detection and water stress judgment based on canopy air temperature difference. The wireless temperature and humidity sensing system consists of the upper computer monitoring terminal and the lower computer Zigbee network. The lower computer Zigbee network is responsible for obtaining temperature and humidity data. The upper computer is responsible for displaying the temperature and humidity data in a graphical form, so that the personnel could monitor the temperature and humidity information in real time. The temperature and humidity sensor SHT11 is a high-precision temperature and humidity sensor with ultra-low power consumption. Its temperature acquisition accuracy could reach 0.5 ℃ and humidity acquisition accuracy could reach 3% RH.

BH1750FVI light intensity sensor is used to detect light intensity around plants. It is a light sensor with two-wire serial bus interface that could detect the ambient light intensity in a wide range. The sensor has the characteristics of small size and high reliability, and could monitor the change of light intensity around plants in real time. The circuit diagram is shown in Fig. 6.

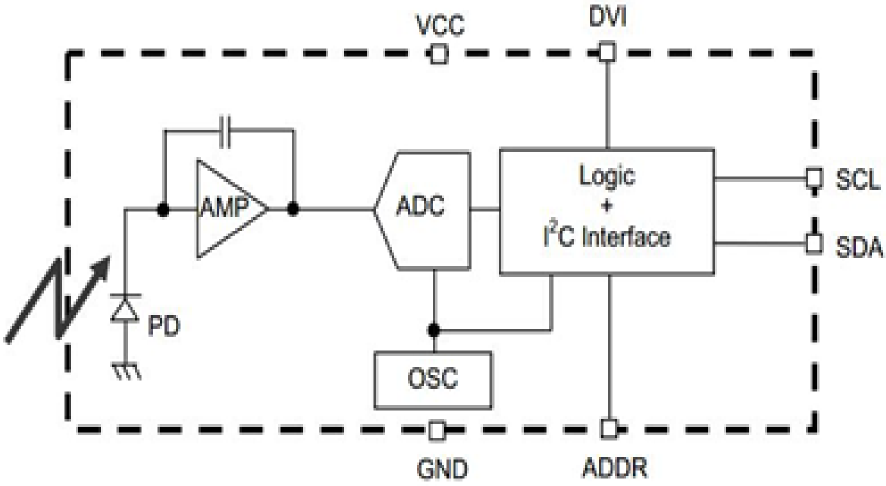

Fig. 6. BH1750FVI circuit diagram

The internal structure of the detection platform is shown in Fig. 7, which contains a display module, a keyboard input module, a power module and a central control module, realizing the acquisition and display of collected data and controlling the input of external signals.

Fig. 7. Internal structure of the detection platform

4. Software design of detection device

The entire detection system is controlled by an industrial computer, which uses an i5 processor, 8 GB of memory, and a 128 GB hard disk. The industrial computer connects the control motherboard, information output device and multi-sensor through cables and communicates with the upper computer through routers. The human-computer interaction control interface of greenhouse growth information and environment multi-sensor detection system is designed through software Labview. After layout management, the interaction interface of growth information and environment information is placed on the left side of the view, and the human-computer interaction interface is placed on the right side of the view. The interface of growth information and environmental information includes display controls for image information and waveform display controls. The human-computer interaction interface mainly includes mode selection, parameter setting and interface switching, etc., and also includes an input module for executing script files for automatic operation of the entire detection system under fixed conditions.

4.1. Multi-sensor data acquisition and processing system

The multisensor acquisition and processing system uses the LabVIEW interface editing function and has the ability to call the Windows32 dynamic link library. In view of the characteristics of LabVIEW calling DLL and the complexity of sensor control, determining the functions that could be called by the visible light camera, infrared thermal imaging, L515 and temperature-humidity-pressure trinity sensors. Each function that could be called corresponds to a specific functional task. It includes initialization function, operation condition initialization function, operation state function, pulse sending function, shaft extension calculation function, stop operation function, zero return function and end operation function, etc. The structure of the block diagram program of the entire LabVIEW sensor part is formed by stacking the loop structure and the sequence structure. Each sequence box corresponds to a certain fixed task and is included in the entire fixed frequency loop structure. Fig. 8 is a flow chart of reading information of temperature, humidity and image, including initialization event and running process event.

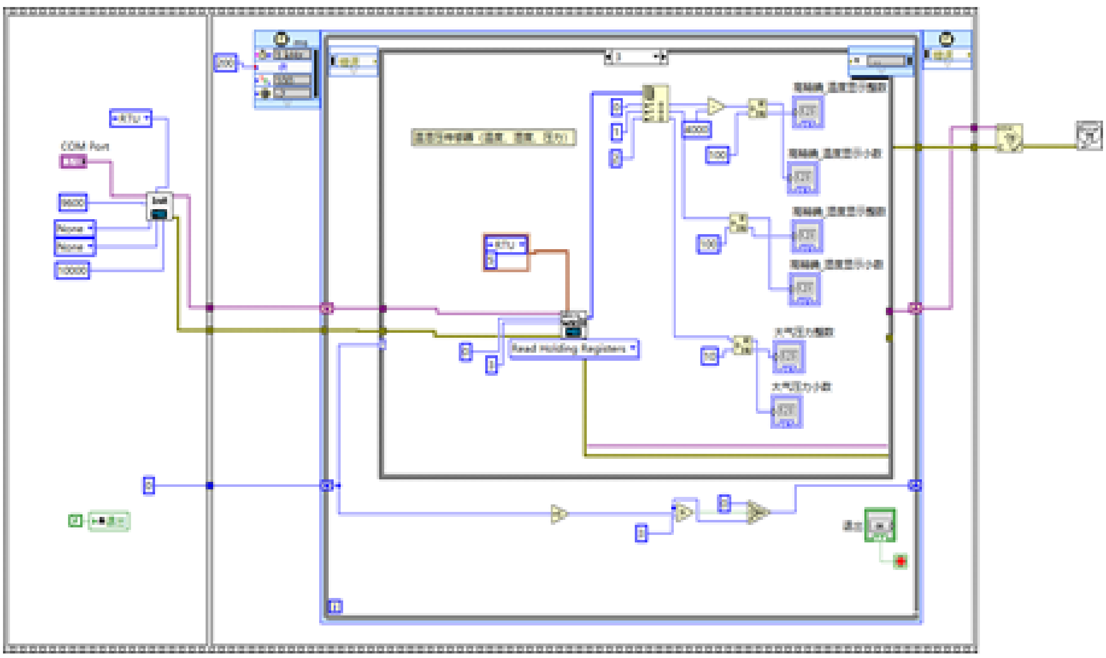

Fig. 8. Program design of data acquisition

4.2. Software design of human-computer interface

The purpose of the design is to realize an interactive system with a user interface based on the industrial computer, which includes the display of collected information and the input of user operations. The interactive interface is shown in Fig. 9.

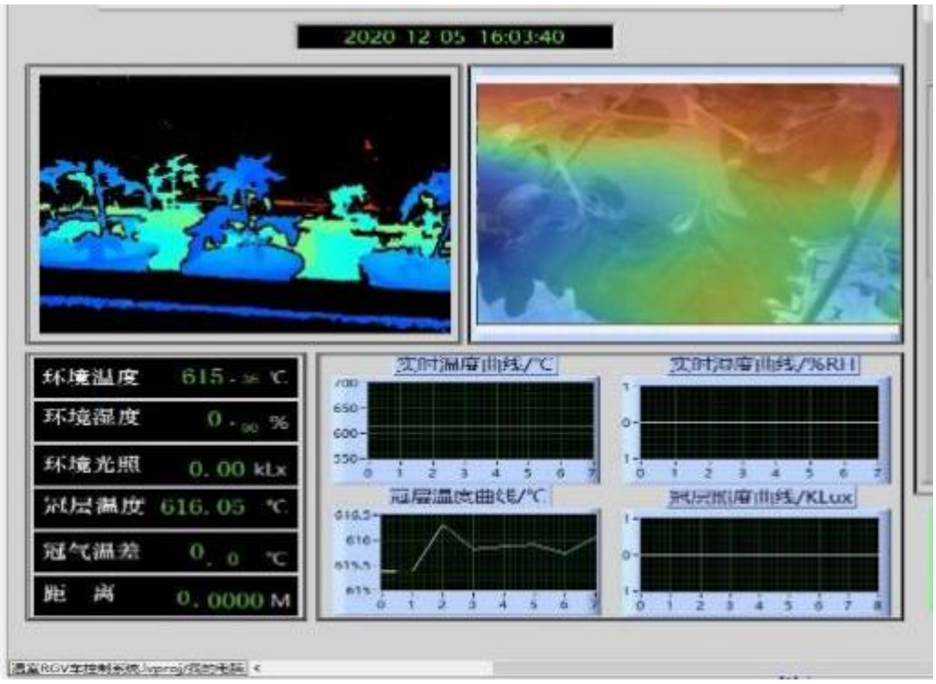

Fig. 9. Human-computer interaction interface

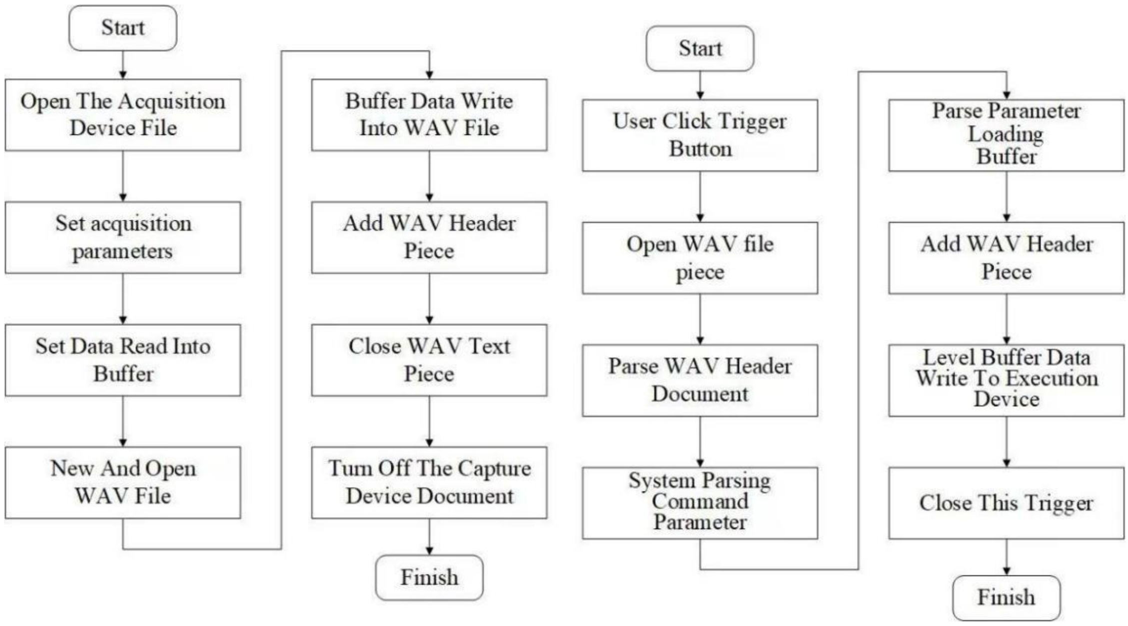

Fig. 10. Flowchart of software design of human-computer interaction interface

The interactive system is designed on the windows system using Qt. The user operates the buttons on the interactive interface through the touch screen or the mouse, and issues commands to call the relevant program modules. When designing with Qt, the signal/slot mechanism is used, which replaces the corresponding operation in the callback function and shields the messy and unsafe function pointers generated during interaction. When we click a button on the interactive interface, it will send out a clicked signal, indicating that it has been clicked. At this time, the corresponding slot function receives the signal and the corresponding qiut function is called. The flow chart of the overall human-computer interaction interface design is shown in Fig. 10.

5. Conclusions

In this paper, a multi-sensor acquisition method for crop growth and environmental information is proposed. By integrating 3D imaging, 2D imaging and infrared thermal imaging detection modules, multi-dimensional phenotypic information of crops is acquired. Based on Windows platform, LabVIEW software is used to compile data acquisition program and human-computer interaction interface, realizing synchronous acquisition of crop environment and multi-source sensing information. The comprehensive habitat information obtained by this device could provide scientific basis for crop water, fertilizer, environmental management and precise variable operation.

Acknowledgments

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