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Innovative Design of Intelligent Detection Equipment for Growth Information of Facility Horticultural Crops

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Abstract

Intelligent equipment technology for facility horticulture is an urgent need for the development of modern facility agriculture. The intelligent monitoring equipment for greenhouse crop growth information can comprehensively monitor the nutrition, growth and environmental information of crops, and provide a scientific basis for the optimal regulation and control of water, fertilizer and environment in the greenhouse. It is a key equipment for the intelligentization of facility horticulture.

This research aims at different growth stages. In accordance with the testing needs of different plant-shaped crops and the operational needs of the unstructured environment in the greenhouse, we developed wheeled and tracked crop growth and environmental information monitoring systems that can autonomously cruise in the greenhouse; at the same time, in order to meet the detection needs of large-plant crops, a cantilever type crop information monitoring system has also been developed. This system suspends the multi-sensor detection system through the gimbal and installs it on the orbit track laid on the greenhouse truss.

Because the detection position is high, it is realized the cruise monitor of greenhouse plants such as cucumber and tomato. In order to achieve comprehensive detection of crop growth information, a multi-sensor detection system for horticultural crop information has been developed. It uses visible-near-infrared binocular multi-spectral cameras, infrared detection sensors, laser ranging sensors, ambient temperature and humidity and light sensors. Through the multiple sensor information fusion, implements the facilities horticulture crops nutrition, growth and the comprehensive monitoring of environmental information. Good application effect has been achieved.

Key words: Facility Horticulture, Crop Growth Information, Intelligent Detection Equipment, Multi-Sensor Detection System, Information Fusion

Preface

China's facility planting area has reached 4.1 million hectares, the largest in the world, but the output and benefits are far from the developed countries such as the Netherlands, the United States, and Japan. Take tomato as an example, its output per unit area is only one quarter to one third of the Netherlands. Most of the greenhouses in China still use manual management, the irrigation method using large water and large fertilizer and the traditional setpoint control method result in a mechanization rate of only 17%, and the



degree of intelligence is almost zero (Jia et al., 2004). The degree of mechanization of the facility industry in developed countries such as the Netherlands has reached nearly 80%, and the application of intelligent equipment such as factory nursery, comprehensive information monitoring, water and fertilizer regulation and automatic harvesting is more common (Ariana et al., 2006). The current low level of facility management, mechanization and intelligence in China has become a bottleneck restricting the development of China's facilities industry.

At present, most of our facility horticulture still uses extensive management mode. Only a few modern greenhouses with automatic management equipment, because of the lack of advanced and suitable crop information monitoring equipment, most of them follow the traditional method of setting value regulation, that is, only considering the collection of greenhouse environmental factors, such as temperature, humidity, illumination and CO₂ in environment, without considering or difficult to comprehensively and accurately detect the real-time growth information of facility crops [3].

In view of the fact that the current greenhouse environment is not accurately controlled according to the plant growth status and the actual needs of plant growth, resulting in low crop yields and high operating energy consumption, the use of dual-position multispectral vision, characteristic spectrum, polarization, infrared temperature detection is proposed. Multi-source information fusion technology for rapid monitoring of nitrogen, phosphorus and potassium nutrition levels of facility vegetables, and the use of binocular visual images, laser ranging and displacement sensors for plant crown width, stem thickness, plant height, and plants and fruits. On-line detection technology for growth information such as growth rate has achieved accurate acquisition of greenhouse crop information.

On this basis, based on mobile and cantilever detection platforms, we have developed a system that can adapt to the detection needs of different facilities and perform comprehensive, accurate and real-time plant sensing. Multi-platform testing equipment for growth information such as growth and nutrition provides a scientific basis for the optimal regulation of greenhouse water, fertilizer and environment (Qin et al., 2009).

Self-propelled crop information detection equipment

At present, most of the comprehensive information collection of facility crops and the environment still uses distributed detection systems. Due to its relatively fixed layout and the fixed-point installation method, it is possible to achieve the detection target when monitoring environmental information, but the distributed detection system. When it is necessary to detect crop nutrition and growth, it is difficult to effectively obtain the comprehensive growth information of crop individuals / groups (Pagola et al., 2008). To this end, the research team has developed wheeled and tracked detection platforms for different greenhouse operating road conditions and environments, and developed two-section and three-section robotic arm systems to meet the needs of different plant types and growing crops.

Platform structure of self-propelled crop information detection system

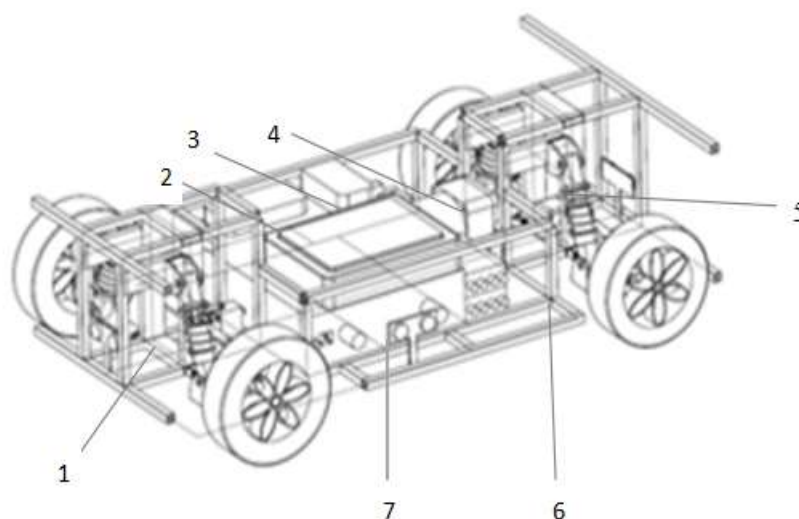
Wheeled mobile platform is shown in Fig.1, is mainly composed of the mobile platform, mechanical arm, and information collection of sensors, control the mobile platform by means of electromagnetic navigation of autonomous cruise, realize the continuous acquisition of crop growth and the environment, three different height of the mechanical arm, can adapt to different type, growth period of different tree height of crop

information acquisition needs, combined with by installing in the end of the mechanical arm and side more spectrum sensing information acquisition device, can realize on crop growth and nutrition integrated information retrieval.



Figure 1. Wheeled crop information monitoring system

Greenhouse road bumps, in order to ensure the stability of the mobile platform, and to overcome the possibility of the overall overturning of the mobile detection platform caused by the shift of the center of gravity of the system during the deployment process of the mechanical arm. In the design of the trolley structure, the independent suspension structure design shown in Fig. 2 is used. The independent suspension structure can reduce the overall center of gravity while filtering the damage to the detection sensor caused by the uneven surface of the greenhouse in the greenhouse.



1 Front Overhang 2. Inverter 3 PLC Modules And Parts 4 Drive Motor 5 rear Overhang 6 Carframe 7 Lithium Battery

Figure 2. The structure of the independent suspension chassis of the mobile detection platform

In order to meet the needs of cruising monitoring of the growth of bell peppers, lettuce and other crops, and to improve the stability of the chassis to adapt to the bumpy road surface of the greenhouse, the research

team developed a crawler mobile detection platform with two section manipulator, as shown in Fig. 3.



Figure 3. Crawler crop information monitoring system

Compared with the wheeled system, this system can ensure the stability of the car body due to the large weight of the chassis, and can adapt to different greenhouse roads. At the same time, it is designed for the collection of small plant crops such as lettuce and seedling information. The two-section manipulator not only reduces the center of gravity of the platform and improves stability, but also improves the operating efficiency of the platform due to its relatively simple structure.

Control system of mobile platform

The multi-sensor monitoring system of the facility based on the mobile platform uses PLC as the main control unit, and its cruise motion control part uses electromagnetic navigation sensors, landmark sensors, and ultrasonic barrier sensors as PLC inputs. The PLC detects whether the mobile platform's walking trajectory through the navigation sensors, combined with the landmark sensor to determine whether the detection position is reached, to achieve automatic trajectory control of the car cruising the ultrasonic barrier detector can automatically determine whether there is an obstacle at the car boundary to correct the cruising path.

After the trolley reaches the detection position, the robot arm chassis and electric push rod are controlled by PLC to reach the detection position. Greenhouse multi-information acquisition mainly includes environmental information and crop information acquisition. The output of the environmental humidity and light sensor is used as the input of the NI data acquisition card and uploaded to the on-site host; the crop growth and nutrition information are combined with the main view image sensor Image, infrared image and spectrum detection are realized.

Fig. 4 is a structural block diagram of a mobile detection platform control system. Multi-sensor information is calculated based on the aforementioned fusion detection model to achieve multi-information fusion detection

of crop nutrition and moisture.



Figure 4. Block diagram of the mobile detection platform control system.

Suspended rail type crop information detection equipment

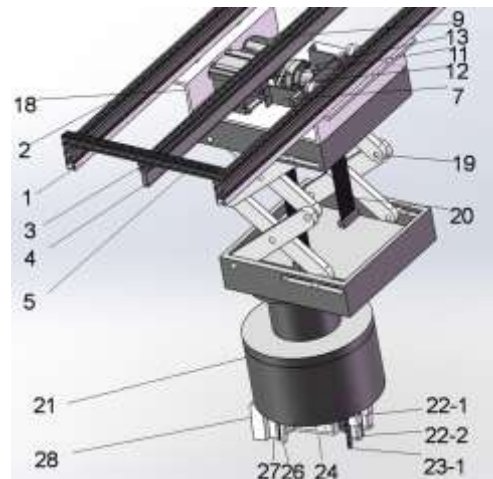
Structure composition of suspended rail crop information detection system

Although the self-propelled detection system has high flexibility, it has certain requirements for the greenhouse pavement, especially under dense planting conditions, the walking path will interfere; when detecting tall plants, it will also be due to the extension of the robot arm, leads to instability of the center of gravity. To this end, the research group has developed a suspension rail type crop information detection system, as shown in Fig.5. The suspension rail of the detection system is mounted on the truss of the main beam of the greenhouse, The detection device moves along the slide rail fixed on the truss to realize the cruise detection of the crop information.



Figure 5. Cantilever type crop information monitoring system

The suspension rail system consists of track beam assembly, walking mechanism, sliding platform and multi-sensor system. The track assembly consists of three parts from left to right. The left, center, and right parts are composed of two layers of upper and lower structures, which are suspended and fixed on the spanning structural beams of the greenhouse. The detailed structure is shown in Fig. 6.



1. Sliding track; 2. Suspension main beam; 3. Suspension auxiliary beam; 4. Rack; 5. Cross brace; 6. Track connecting plate; 9. Gear motor; 10. Gear shaft; 11. Gear; 12. Bearing; 13. Photoelectric encoder; 14. Pulley; 15. DSP motion controller; 16. Power supply of lifting mechanism; 17. Terminal limit switch; 18. Suspension; 19. Lifting mechanism; 20. Lifting reel; 21. Electronically controlled rotating gimbal; 22-1. Visible light multi-function imaging system; 22-2. Near-infrared multi-function imaging system; 23-1. Sensor Bracket A; 23-2, sensor bracket B; 24, cloud platform; 25, infrared temperature sensor; 26, temperature and humidity sensor; 27, laser ranging sensor; 28, light intensity sensor

Figure 6. Overall structure of the suspended rail crop information monitoring system

The walking mechanism is connected with the track part, including a set of rack and pinion mechanism and a set of pulley slide rail mechanism. The main body of the sliding platform is mainly composed of a lifting mechanism and an electronically controlled rotating pan-tilt, and the walking mechanism drives the walking. The multi-sensor system is installed at the bottom of the electronically controlled rotating pan-tilt head to detect the comprehensive information of the greenhouse environment and crops. The control cabinet part is independently fixed at the front of the greenhouse. The control cabinet is connected to the walking mechanism, sliding platform and multi-sensor system through the 1394 data bus to carry out information interaction to realize the motion control and data processing analysis of the system.

Principles and characteristics of suspended rail crop information detection system

Based on the suspended sliding track movement detection platform, by installing the multi-sensor system on the suspended sliding platform, combined with the lifting mechanism and the electronically controlled rotating gimbal, not only can it achieve accurate positioning and detection of the stagnation point in the direction of detection travel, but also It can realize multi-sensor information cruise detection with different detection distances, different top-view fields and different detection angles. It can not only detect large plants such as tomatoes and cucumbers, but also meet the detection needs of lettuce and small and medium-sized plants of different growth periods.

The suspended automatic cruise detection platform can cruise online to monitor the comprehensive information of crops and the environment in the entire greenhouse, provide a scientific basis for the regulation and management of greenhouse water, fertilizer and environment, can reduce the investment of

detection equipment and personnel, and effectively avoid the operation errors of personnel. The detection accuracy and operation efficiency of the greenhouse environment and crop growth information are improved.

Crop information multi-sensor detection system

The crop information multi-sensor system includes visible light - near-infrared binocular multi-spectral camera, infrared detection sensor, laser ranging sensor and environmental temperature, humidity and light sensor. Multifunctional growth information detection using binocular vision camera, combining with the method of matrix grid scanning laser range sensor, obtain plant of binocular stereo vision image and laser ranging height coordinate matrix, the extracted information based on binocular vision of plant height, crown breadth and fruit, and the height of the laser ranging obtaining coordinates lattice area plant height and crown amplitude information of the plant, through the integration of the two correction, which can realize accurate detection of greenhouse plants grow. Its detection principle is shown in Fig.7.

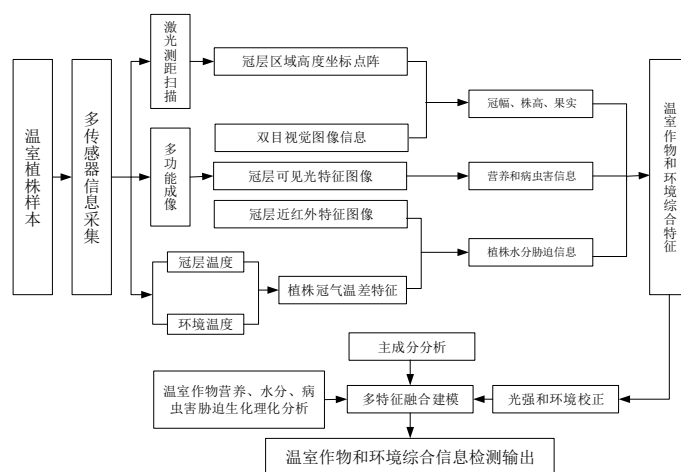


Figure 7. detection principle of multi-sensor detection system

Nutrient characteristics were detected by visible light multi-spectral imaging device based on pre-filter set to obtain the feature images of 472nm, 556nm and 680nm of the plant canopy. Combined with raster scanning imaging and step and sequence imaging analysis of the multi-sensor system, the nutrient stress information of Nitrogen, Phosphorus and Potassium was identified and diagnosed by multi-information fusion. Water detection using near-infrared multispectral imaging equipment based on a set of prefilters to obtain the characteristics of plant near-infrared images of 930 nm and 1420 nm water pressure. Combined with the detection of canopy temperature difference, canopy infrared temperature and ambient temperature and humidity, the water stress state of greenhouse plants can be accurately identified and detected (Zhao et al., 1999). Combining with the biochemical and physical and chemical detection, the feature extraction and accurate detection of the comprehensive information of crop nutrition, water and growth can be realized by the fusion of multi-source information.

The crop growth information detection system has been tested by the statutory agency. The measurement error of crop nutrition information is $\leq 5\%$, and the detection error of crown width is $\leq 1.31\%$. The error of stem thickness detection $\leq 6.55\%$, the error of plant height detection $\leq 2.88\%$, and the error of fruit diameter detection $\leq 4.32\%$.

Existing problems and development direction

Intelligent detection equipment for facility horticultural crop growth and environmental information, as a key link for intelligent water and fertilizer and environmental regulation, is the premise and basis for achieving dynamic regulation based on crop growth needs. According to the testing needs of different types of crops, this research has developed mobile intelligent testing equipment that can adapt to the unstructured environment of the greenhouse, and has achieved preliminary research results (Lei et al., 1999). Due to the huge difference between the objects and environment of greenhouse operations and traditional industrial products: (1) object polymorphism: under the influence of biodiversity, there are huge differences between individual crops and the detection of standardized industrial products. (2) the degree of structured environment, industrial products generally work in a structured, controlled environment detection, and intelligent monitoring facilities agricultural crops growth process, although some are structured environment to a certain extent, but still is a relatively more diverse, complex environment, be shaded part such as testing object, the environment light conditions unstable influence on intelligent perception system and so on. (3) the timing acquisition and repeated measurement of plant growth information in facilities are also more difficult compared with the industrial environment. Due to the influence of road surface and operating environment, the precision of mobile platform during repeated positioning is often difficult to be guaranteed, which also affects the detection accuracy. This article explores the intelligent monitoring of the growth and environmental information of facility horticultural crops. In order to achieve accurate detection of facility crop growth information, we must rely on the integration of agricultural machinery and agronomy, combined with structured cultivation methods and operating environment, to further improve the detection accuracy and equipment performance of the system, and realize the commercial application of intelligent detection equipment.

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