Development of an automatic control system for pot-grown rice inspection based on Programmable logic controller

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Abstract. Rice improvement breeding is one of the most important research fields in China. With the development of modern rice breeding technology, hundreds to thousands of new varieties are produced daily, creating the impetus for rapid plant phenotyping evaluation. However, traditional measurement is inefficiency, contact-interferential, and lack-objectivity. Thus a high-throughput and automatic extraction system for rice plant is imperative. In this article we developed a rice phenotyping automatic extraction system and designed the automatic control for the system based on programmable logic controller (PLC). Subsequently, the prototype was test under industrial conditions continuous 24 h workdays and the error probability was less than 0.01%. In sum, base on PLC, we provide an efficient and stable automatic control system for pot-grown rice phenotyping inspection.

Keywords: Rice breeding, phenotyping inspection, automatic control system, programmable logic controller, phenomics.

1 Introduction

Rice is the supreme production and consumption food in China, and thus rice improvement breeding is one of the most important research fields in China [1]. During every breeding stage, plenty of phenotyping parameters, such as plant height, green leaf area, tiller numbers, and leaf temperature et al., must be extracted and evaluated prior to next breeding stage. With the development of modern rice breeding technology, hundreds to thousands of new varieties are produced daily, creating the impetus for high-throughput phenotyping evaluation [2].

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However, the conventional measurement, including counting and recording, is still manual, which is inefficiency, contact-interferential, lack-objectivity and lack-repeatability. The prevalent commercial instruments, such as seed counter and leaf area meter, are inefficiency and single function. The Plant Accelerator (University of Adelaide, Australia), is designed for plant phenotyping with the throughput of 2400 plants per day. With the facility, the plant mass, tissue water content, leaf temperature, photosynthetic machinery, and protein content et al., are extracted equipped with color image, near IR imaging, far IR imaging, fluorescence imaging, and hyperspectral imaging technology, respectively [3]. However, each imaging instrument is designed and fixed with one chamber, and thus five imaging chambers are necessary, which would lead unwanted time-consumption and unstable factors due to the interacting of each imaging chamber. What is more, the spatial and money cost would be incremental and unaccepted in some developing countries [4].

Programmable Logic Controller (PLC) is widely used in agriculture automatic control, such as efficient management of greenhouse [5], temperature-humidity control [6], and so on. Previously, we designed a novel facility to count tillers equipped with X-ray CT, termed the high-throughput system for measuring automatically rice tillers (H-SMART) [7]. In order to incorporation with color imaging technology and far IR imaging technology, we developed a rice phenotyping automatic extraction system and this article focus on the design for the system automatic control based on programmable logic controller (PLC), which provides higher efficiency, higher spatial utilization, and lower cost.

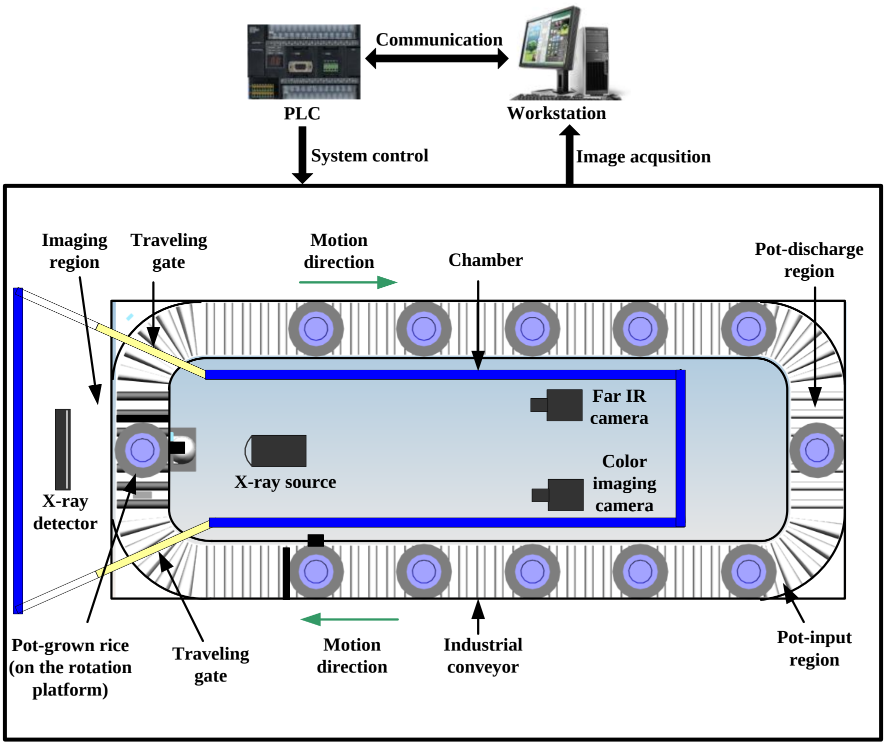

Fig. 1. Schematic drawing of the rice phenotyping automatic extraction system.

2 System description

The schematic drawing (top view) of the rice phenotyping automatic extraction system is shown in Fig.1. In order to describe the imaging device of the system more clearly, the top of the chamber is treated transparently. The system consists of four units: imaging unit, industrial conveyor, chamber, and control unit.

2.1 Imaging unit and industrial conveyor

To acquire the different phenotyping parameters of the rice plant, three imaging devices, including color imaging camera, far IR camera, and X-ray system, are fixed into the imaging module. When the pot-grown rice plant (each pot with one pallet) is fed in the pot-input region, the pot is transported to the imaging region automatically.

In order to acquire image with different angles while the imaging devices remain stationary, a rotation platform is designed on the centre of the imaging region. The pot-grown rice plant is transported onto the rotation platform driven by the servo motor (MBDDT2210, Panasonic Corporation, Japan). What is more, before rotation, to jack the pot from the pallet, a jacking device, including jacking motor and ball screw, is designed and fixed under the rotation platform. Both the rotation platform and jacking device are driven via synchronous belts. The structure diagram of the jacking-rotation device is shown in Fig.2.

After imaging acquisition, the examined rice is transported to the pot-discharged region. The motion direction of the conveyor is indicated as the arrow in Fig.1.

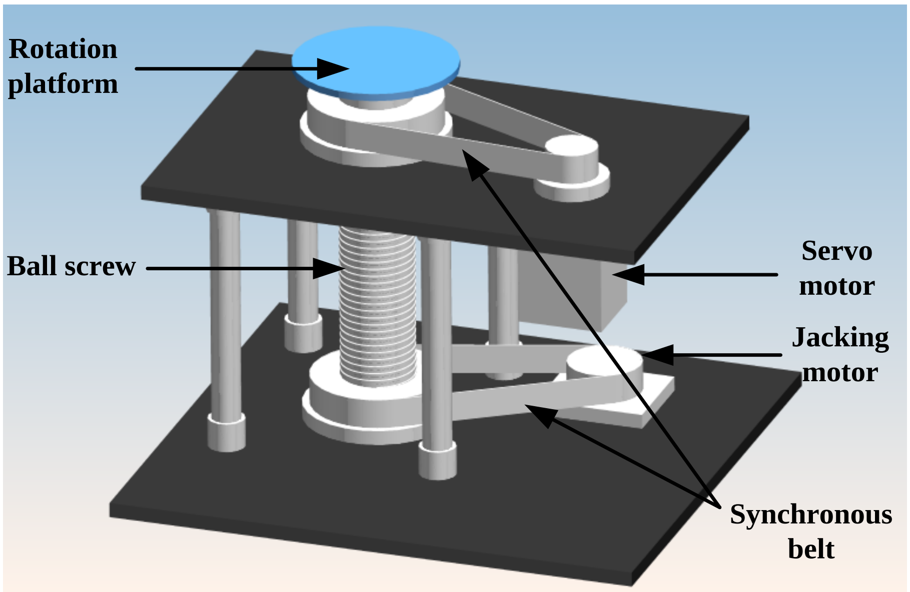

Fig. 2. Structure diagram of the jacking-rotation device.

2.2 Chamber and control unit

For ensure the safety of the work area, a lead chamber is constructed for x-ray radiation shielding. And to avoid the interference of the external light, two traveling gates, which are open except the pot arrives at the rotation platform, are designed in the chamber. The whole system is controlled with PLC (CP1H-Y20DT-D, Omron Corporation, Japan) and computer workstation (HP xw6400, Hewlett-Packard Development Company, USA).

3 System control

As mentioned above, the automatic control core of the system are programmable logic controller (PLC) and computer workstation, which control the conveyer unit, imaging unit, and traveling gates.

3.1 Workstation communication

The system allows the user control the system via a friendly interface, provided in computer workstation. Once receiving the protocol “ON”, transmitted by the workstation, PLC controls the system starts. Then the computer sends the instruction “R?” (every 2 seconds) and judges whether the pot arrives in the imaging region via the instruction returned by PLC. Once receiving the protocol “OF”, representing the measurement task is finished, PLC controls the system stops. Additionally, the rotation angles and rotation speed could be predefined by the value sent by the workstation. The communication instructions are transmitted via the serial port (RS-232), and the communication protocol between workstation and PLC is illustrated in Table.1.

Table 1. Communication protocol between workstation and PLC

Instruction		Message
Workstation	PLC	
ON	-	System starts
	Y	New pot with rice plant arrives in imaging region
R?	P	New pot without rice plant arrives in imaging region
	N	No pot arrives in imaging region
S+	-	The rotation platform rotates with a predetermined angle
PU**	-	The predetermined value (**) of rotation angle
SP**	-	The predetermined value (**) of rotation speed
OF	-	System stops

3.2 PLC control

Besides indirectly controlled by workstation, the system control is mainly designed and accomplished with PLC. As described in Fig. 3, photoswitch 1 and baffle 1 are used to block the path of next pot while the previous pot has arrived in imaging region. And the photoswitch 3 and baffle 2 are fixed to keep the awaiting-inspection pot in the centre of the rotation platform. The photoswitch 2 is used for detecting whether here is one pot in the coming pallet.

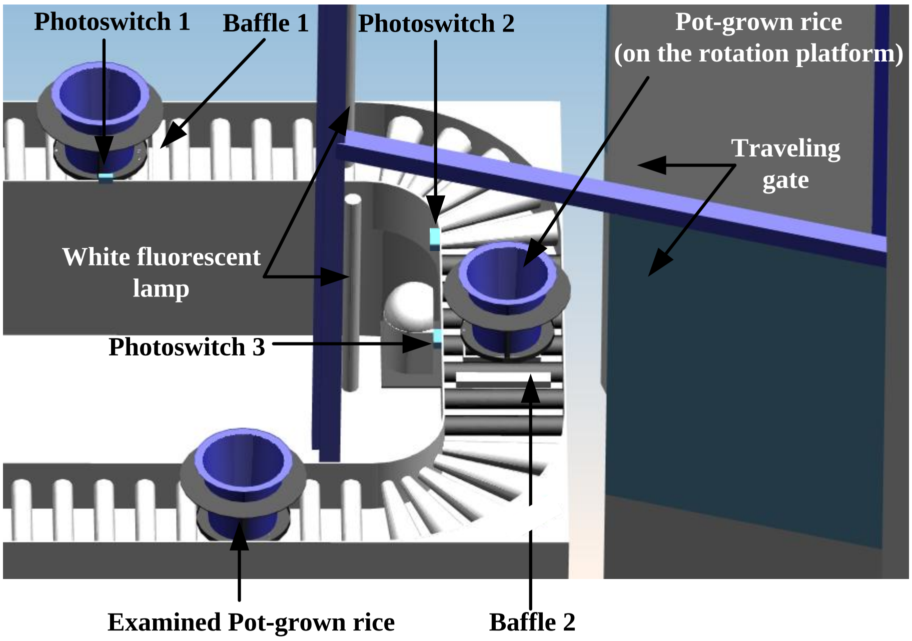

Fig. 3. Control details of imaging region.

In order to avoid the interference of the external light, two traveling gates are closed when the awaiting-inspection pot has arrived in the imaging region. It is noticed that when the rice is jacked up for far IR imaging, the lamps must be turned off to eliminate the interference of the white fluorescent lights. After IR image acquisition, the lamps should be turn on for color imaging. The control flow chart based on PLC is shown in Fig. 4.

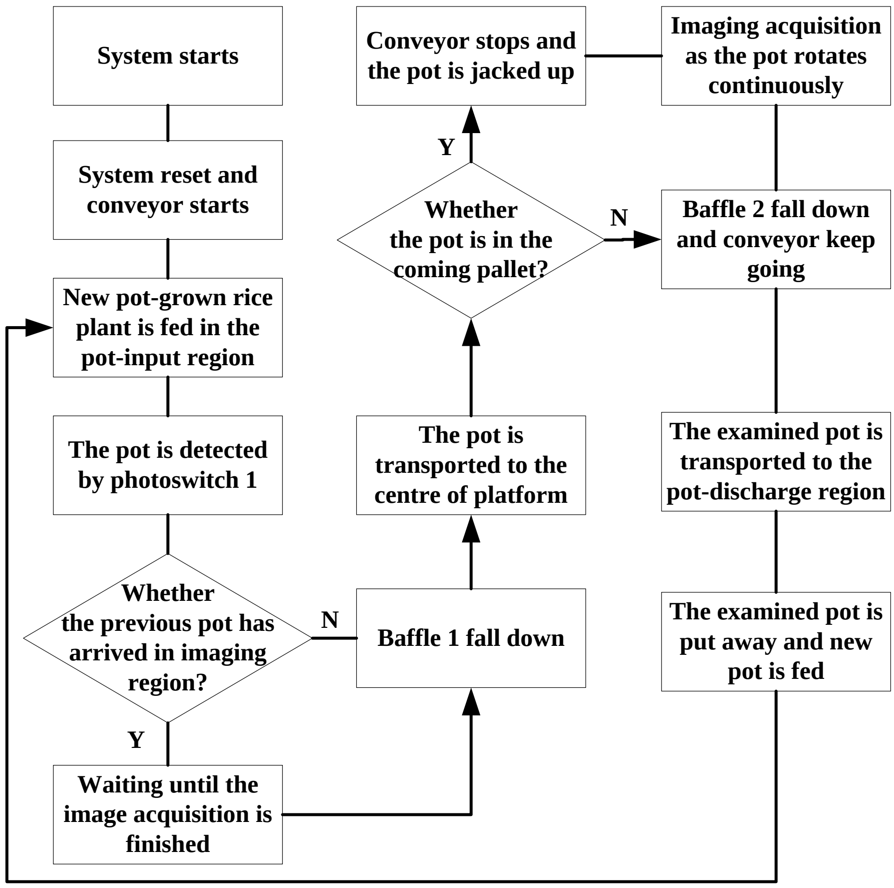

Fig. 4. Control flow chart based on PLC.

4 Results and discussions

To evaluate the efficiency and stabilization of the system, 12 pot-grown rice plants were fed and test in the system continuous 24 hours workday. Without manual intervention, these pots were measured successively and cyclically. After 3 days continuous test, there was no error and approximate 12965 pot-data were inspected and stored in the system. Thus, with the error probability less than 0.01%, the facility has the throughput of 4320 pots per continuous 24 hours workday. What is more, merging the three imaging technologies in one chamber, the system is designed with high spatial utilization. Correspondingly, the cost is lower with this compact design.

5 Conclusion

In this article, we demonstrate a rice phenotyping automatic extraction system and design the system automatic control based on programmable logic controller (PLC). Under the condition of industrial test, the facility provides high efficiency and high stability. Additionally, more modern imaging technologies, such as near IR imaging and hyperspectral imaging, could be incorporated into the system. In sum, base on PLC, we provide an efficient and stable automatic control system for pot-grown rice phenotyping inspection.

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