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Development of a Crop Growth Detecting System

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Abstract: In order to monitor crop growth in real-time, a new crop detection system was developed to measure spectral reflectance of crop canopy, which was based on ground-based remote sensing and wireless sensor network (WSN) technology. The system mainly contains two parts: the controlling unit and the measurement unit. The controlling unit was a PDA in which was embedded a ZigBee wireless communication module. And as the coordinator of the whole wireless sensor network, the controller was used to receive, display, store and process all the data from different optical sensor nodes. The measurement unit, including four optical channels, was designed to collect, amplify and transmit the optical signals. The sensor node can measure the spectral reflectance at the wavelength of 550, 650, 766 and 850 nm. Calibration test was conducted. The result showed a good performance in terms of the wireless transmission ability and the sensor measurement precision. Field experiments were also conducted in a winter wheat experimental field, and the NDVI values calculated from the spectral data can reflect different nitrogen stress and the chlorophyll content of winter wheat. The result shows that the system can meet the demands of practical use in the field and has potential for field application.

Keywords: ground-based remote sensing; spectral reflectivity; WSN; crop condition detection

1. INTRODUCTION

Precision management of nitrogen fertilization plays a vital role in Precision Agricultural (PA) (Li et al. 2006), and the real-time acquisition of nitrogen condition is the primary prerequisite for precision management of nitrogen fertilizer. The traditional ways of nitrogen condition detection are always with destructive sampling and chemical test in the laboratory (Guo et al. 2008; Li et al. 2009). Nowadays, spectrum detection technology has become an effective way to get the information of crop nutrition status and growth conditions (McKinion et al. 2001). Compared with experience guide and chemical test, the spectrum detection technology is a rapid, convenient and non-destructive technique for crop growth monitoring.

In recent years, researches have been carried out on the variation of crop canopy spectral reflectance and nitrogen sensitive waveband selection (Xue et al. 2003). Simultaneously, a variety of portable crop canopy detectors based on vegetation indices had been developed. The Green Seeker, developed by Marvin et al (2003), collecting the crop canopy reflectance at the red and near infrared wavebands, with which, the Normalized Difference Vegetation Index (NDVI) was calculated to estimate the crop growth condition. Ni et al (2013) developed a portable crop growth detector by detecting the crop canopy reflectance at the wavelength of 710nm and 820nm. Zhang et al (2016) developed a handheld spectral instrument to estimate the growth status of the crop in a greenhouse using optical fibres. Noh (2003) developed precision variable management system of maize nitrogen content by using a ground multispectral camera. Cui et al (2005) developed a crop growth monitor based on two sensitive wavebands (610 nm and 1220 nm). Sui et al (2005) developed a device for detecting nitrogen status in cotton by measuring the spectral reflectance of cotton canopy at four wavebands (blue, green, red, and NIR).

However, there are many factors to affect spectral reflectance and the estimation of the nitrogen content of plants, such as geometric structure of plant canopy, soil cover rate and so on. Therefore, it’s necessary for further research in developing a more stable and reliable detecting system for the plant monitoring in different condition.

In this paper, a system for crop growth detection was developed. It was designed to work as a ZigBee wireless sensor network (WSN) with one controlling unit and several measurement units. The measurement unit is an optical sensor node which was used to measure the spectral reflectance of crop canopy at four wavebands respectively. And the controlling unit is developed to display, process, analyse and store the received data. Then some vegetation indices can be calculated by using the spectral reflectance including the normalized difference vegetation index (NDVI), the ratio of vegetation index (RVI) and the difference vegetation index (DVI). The system provides a technical support and some theoretical basis for crop growth detection and crop chlorophyll content estimation.

2. DEVELOPMENT OF THE SYSTEM HARDWARE

2.1 Structure of the Detection System

The system mainly consists of two parts: the controlling unit and the measurement unit. The controlling unit is a PDA in which is embedded a ZigBee wireless communication module. As the coordinator of the whole wireless sensor

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network, the controller is used to receive, display, store and process all the data from different optical sensor nodes. The measurement unit is a sensor node, which consists of four optical channels. It can be used to measure the spectral reflectance of crop canopy. The four optical channels are 550, 650, 766 and 850 nm respectively. Since the light source of the system is the natural light, so a reference board must be used for calibration before each spectral reflectance acquisition. In the process of collecting, the data is visible on the screen of a PDA in real-time. So, we can judge that whether the data is reasonable or not in time. The structure of the system is shown in Fig.1.

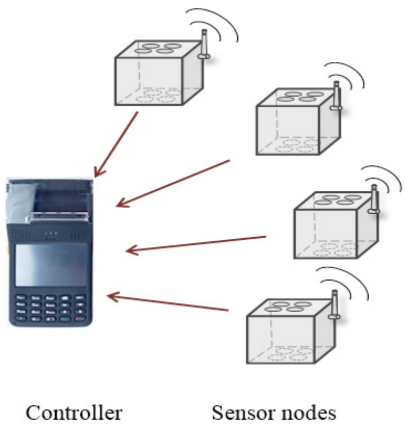

Fig. 1. The structure of the system

2.2 Controlling unit

The controlling unit was a CS350 type of PDA (Personal Digital Assistant) with an attached JN5139 module. As the coordinator of the wireless network, the controller is used to build and organize the wireless sensor network (WSN). Additionally, the PDA has the ability to display, process and store the data from the sensor node. The JN5139 module communicates with the PDA through the RS232 serial-port, as is shown in Fig.2.

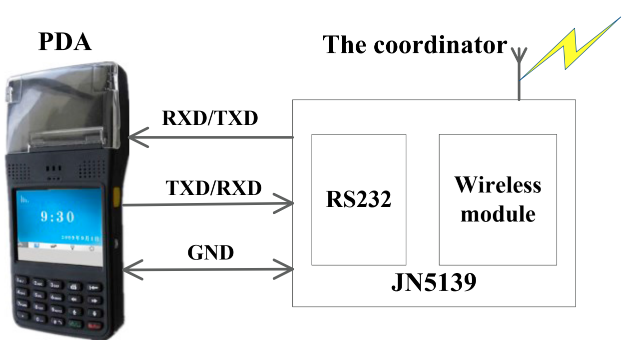

Fig. 2. The hardware diagram in a PDA

2.3 Measurement Unit

The measurement unit is an optical sensor node. The optical sensor node is designed to collect the sunlight and the crop canopy reflected light intensity signal, realize photoelectric conversion, amplify electrical signal, realize A/D conversion and send data to the controller. The whole sensor node mainly includes an optical system and hardware circuits.

The whole optical system includes four channels. Each channel had the same structure, which mainly consists of the convex lens, filters, photoelectric detector and mechanical enclosure. Convex lens, with a diameter of 12.5mm and a focal-length of 12.5mm, can gather the beam Filters can select the specified wavelength. Photoelectric detector can implement photoelectric conversion, converting optical signals into electrical signals. Convex lens and Filters are assembled by screws. In this design, the filters can be easily disassembled and replaced when another specified wavelength is needed. The centre wavelengths of each selected filter are 550nm, 650nm, 766nm and 850nm respectively with the bandwidth of 20nm. And all the photodiodes are PIN-Si photodiodes which have many advantages, including a wide response range, high sensitivity and fast response. The internal structure of the optical channel is shown in Fig.3.

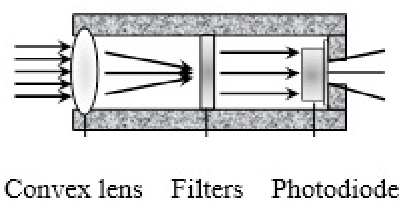

Fig. 3. The structure diagram of optical channel

In the hardware circuit, the current signals are converted to voltage signals. The chip ADG704, an analog multiplexer, is used to help four channels share the amplification unit. The chip OPA333 is selected to be the amplifier, which has the properties of high-precision, low quiescent current and low power consumption. After amplification, the signal is received by a wireless module with the microcontroller of JN5139. The microcontroller includes a 4-input 12-bit A/D converter which make the signal proceed to analog-to-digital conversion. Finally, the digital data will be transmitted to the control unit. The hardware circuit diagram is shown in Fig.4.

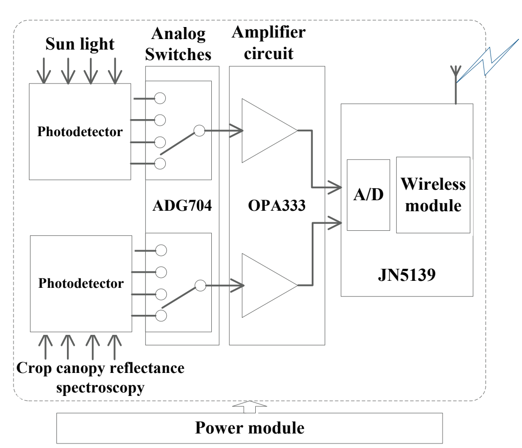

Fig. 4. The hardware circuit diagram