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Compost Environmental Parameter Acquisition System Based on a Miniature Remote-Controlled Mobile Platform

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Abstract

The rapid detection of organic fertilizer compost maturity is not only beneficial for controlling the quality of fertilizer production, but also ensures the application safety of organic fertilizers. However, traditional detection technologies require significant resource investment and have limited application scope. To achieve frequent acquisition of compost pile images and environmental parameter information during the composting process, we propose a unique wireless acquisition system. This system consists of a remote-controlled toy car, a data acquisition system, a communication and control system, and other components, which solves the problem that manual work cannot frequently collect compost pile data during the composting process. System test results show that the compost surface images collected by this system are complete and clear, and the average error of environmental parameter data is less than 2.55%. Compared with manual collection, the data acquisition efficiency is greatly improved, and the system basically meets the design requirements.

Keywords

Compost, data acquisition, sensor, mobile platform.

1. Introduction

Compost maturity is a key parameter for evaluating compost quality[1-4], which can fully characterize the toxic substances in compost. Immature compost competes with soil and crops for oxygen and nitrogen. Moreover, the degradation of unstable organic matter may generate heat and toxic substances, exerting adverse effects on seed germination, plant growth, and soil quality[5-7].Compost maturity can be determined by conducting physicochemical analysis of material components and gas emission rates, examining the carbon-to-nitrogen ratio (C/N ratio), or measuring the seed Germination Index (GI) [8-9]. However, this detection method is time-consuming and must be carried out in a laboratory, which is quite difficult for farmers and workers in composting plants. Therefore, it is necessary to develop a rapid and direct evaluation method to assess compost maturity.

During the composting process, the texture and color of compost usually undergo significant changes, which can be used to determine compost maturity [10-11]. Currently, many scholars have conducted relevant research on predicting compost maturity using image information [12-14] and achieved favorable results. In the process of predicting compost maturity, most studies tend to only focus on improving the accuracy of algorithms, while neglecting the upgrading and optimization of automatic compost data acquisition systems. Therefore, the current image recognition methods can only be applied to ton-bag compost or small-scale composting. For large-scale composting scenarios, rapidly obtaining the maturity of each part of the compost pile remains a challenging task.

Therefore, this study develops a miniature mobile platform system integrated with sensors and a camera. This system can collect data from multiple composting areas, transmit the temperature, humidity, pH, and image data of the compost pile to the cloud, and allow viewing on a mobile application simultaneously. By doing so, it breaks through the bottleneck of scenario application and promotes the application of image recognition in compost maturity assessment.

2. Materials and methods

2.1. Experimental materials

(1) Compost pile

Image data collection experiments were conducted in three composting environments: open-air compost piles, indoor trough compost piles, and ton-bag compost piles.

(2) System Construction

In accordance with the experimental requirements, a composting environment information acquisition system was built (as shown in Figure 1). The main components required for the system are as follows:①32-bit STM32F103ZEM6 controller: It has 114 universal and reusable pins, which can be used to connect various sensors and actuators for controlling other devices. ②ESP8266 Wi-Fi wireless transmission module: The main function of this module is to enable a mobile phone (host) to connect and communicate with the single-chip microcomputer system via Wi-Fi signals.③Portable power pack: Used to supply power to the system.④DC power conversion module: Converts the DC voltage of the power pack into the specific DC voltage required by the controller system.⑤Sensor module: Quickly acquires the temperature, humidity, and pH data of the compost.⑥OV7725 image acquisition module: It has the advantages of small size and low power consumption, and supports the output of multiple image data formats.⑦Telescopic rod module: Composed of a miniature electric telescopic rod, a power adapter, and a remote controller.⑧Miniature remote-controlled mobile platform: Modified from a remote-controlled toy car model, it can carry components such as sensors to collect data at different points of the compost pile.

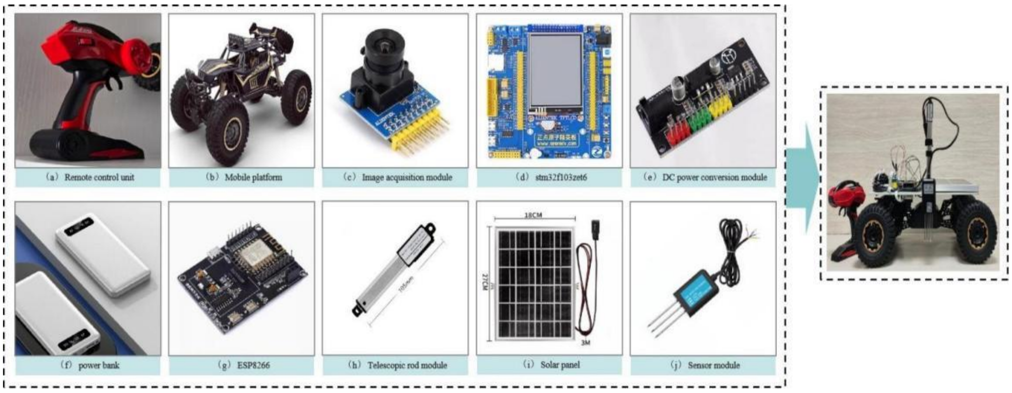


Figure 1: Compost Environmental Parameter Acquisition System

(3) System Workflow

When the system starts working, both the single-chip microcomputer and the WeChat mini-program on the Android phone are in the system initialization state. After initialization, each module enters a normal working state. At this point, the single-chip microcomputer begins to establish communication with the cloud, transmits the data collected by the modules to the single-chip microcomputer for processing, and then uploads the processed data to Alibaba Cloud. Once the data is uploaded to Alibaba Cloud, it is displayed in real time on the WeChat mini-program.

2.2. Experimental grouping

(1) Experimental grouping

The field experiment was conducted at the Agricultural Crop Straw Waste Utilization Base of the Institute of South Subtropical Crops, Chinese Academy of Tropical Agricultural Sciences. Compost piles from different composting methods were selected as test objects, with a total of three types of compost piles (Pile A, Pile B, and Pile C) chosen. For each type of compost pile, 60 sample points were selected for image collection and compost environment data acquisition.

Pile A (Open-air compost pile): It had an average width of 4 meters, a height of 2 meters from the top of the pile to the ground, and a length of 20 meters.

Pile B (Indoor trough compost pile): It had an average width of 8 meters, a height of 2.2 meters from the top of the pile to the ground, and a length of 40 meters.

Pile C (Ton-bag compost pile): The pile had a diameter of approximately 1 meter, a height of about 1 meter from the top to the ground, and a length of around 1 meter.

The distribution of sample points in different compost piles during the experiment is shown in Figure 2 and Figure 3. To achieve better image collection results, the data acquisition test was carried out at 10:00 a.m. when the lighting conditions were good.

Pile A Pile B Pile C

Figure 2: Compost Environmental Parameter Acquisition System in Different Compost Pile

Figure 3: Distribution of Sample Points in the Compost Pile

2.3. Measurement method

After the function of the test system became stable, the system was placed in various different compost piles for testing experiments. The camera acquisition module was aligned with the compost material, while the temperature, humidity, and pH sensors were inserted into the material to collect surface images of the material and record experimental data. The wireless data receiving end was connected to a computer to check whether the upper computer software could successfully open the serial port, monitor the temperature, humidity, and pH data of the compost piles, and observe whether the data and images displayed on the LCD screen of the system were normal. Finally, the consistency between the data obtained by the conventional method and the test system was compared.

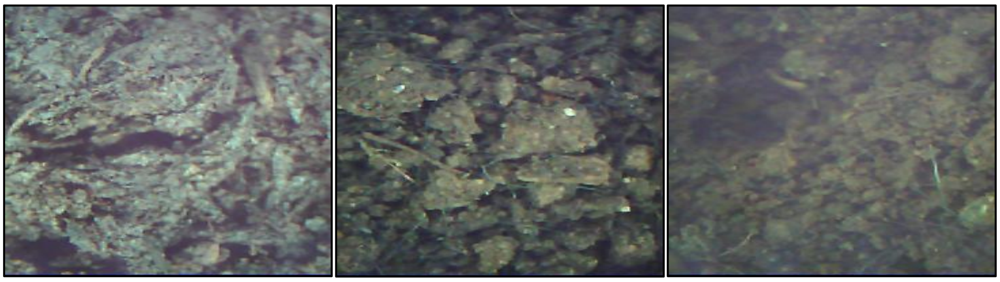
2.4. Data analysis

Microsoft Excel 2007 software was used for data processing and correlation analysis.

3. Experimental results

3.1. Results of System-acquired Image Information

During the testing process, the distance between the OV7725 camera of the detection system and the surface of the compost pile was approximately 5 cm, allowing direct acquisition of surface images of the sampling points on the compost pile. During the acquisition process, the system automatically completed image collection in accordance with the operating instructions. Sample images randomly selected from Groups A, B, and C among the acquired data are shown in Figure 4. The size of the original compressed image for each sample was approximately 150 KB, and the image acquisition time for 60 sampling points was about 15 minutes. Experiments show that the quality of images acquired by this system meets the requirements of post-processing: the images of each sample are uniform and consistent, and compared with manual methods, the acquisition efficiency is greatly improved.



Pile A Pile B Pile C

Figure 4: Acquisition of Compost Pile Surface Images

3.2. Results of System-Acquired Environmental Information

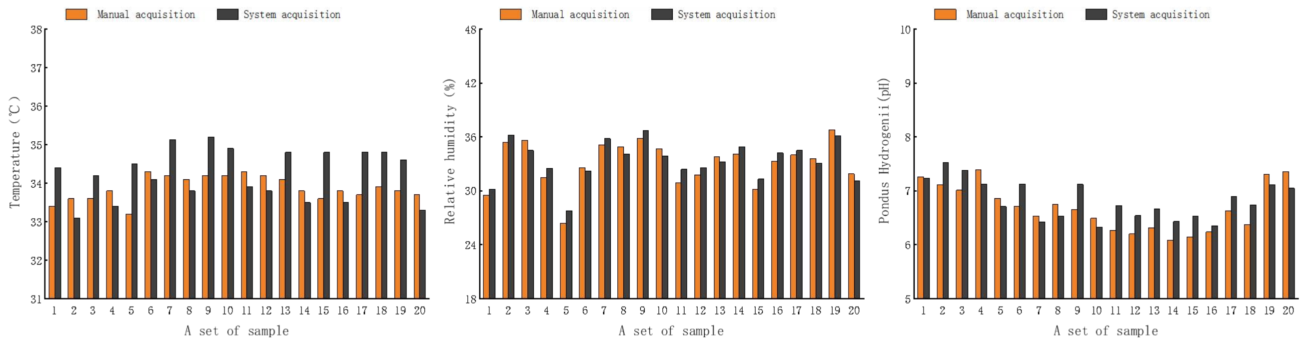
To verify the accuracy of the environmental information collected by the system, we randomly selected 20 samples from each of Groups A, B, and C. The environmental information data of the samples was manually collected using a soil integrated sensor, and this data was compared with the data collected by the system.The above comparative experiments show that when using the two data collection methods:

For the 20 samples in Group A, the average errors of temperature, humidity, and pH value were 1.04%, 0.93%, and 2.52% respectively (as shown in Figure 5).

For the 20 samples in Group B, the average errors of temperature, humidity, and pH value were 1.37%, 1.52%, and 2.12% respectively (as shown in Figure 6).

For the 20 samples in Group C, the average errors of temperature, humidity, and pH value were 1.51%, 2.55%, and 1.26% respectively (as shown in Figure 7).

Although both collection methods can collect the environmental information data of samples via soil integrated sensors, manual measurement is time-consuming and labor-intensive, and cannot cover the entire area of the compost pile for detection. In contrast, the mobile platform detection system can easily overcome the limitation of regional detection.The results of the above 9 groups of comparative experiments indicate that the data collection accuracy of this system can meet practical requirements.



(a). A set of sample temperature contrast (b). A set of sample relative humidity contrast (c). A set of sample pondus hydrogenii contrast

Figure 5: Comparison of Experimental Results for Group A

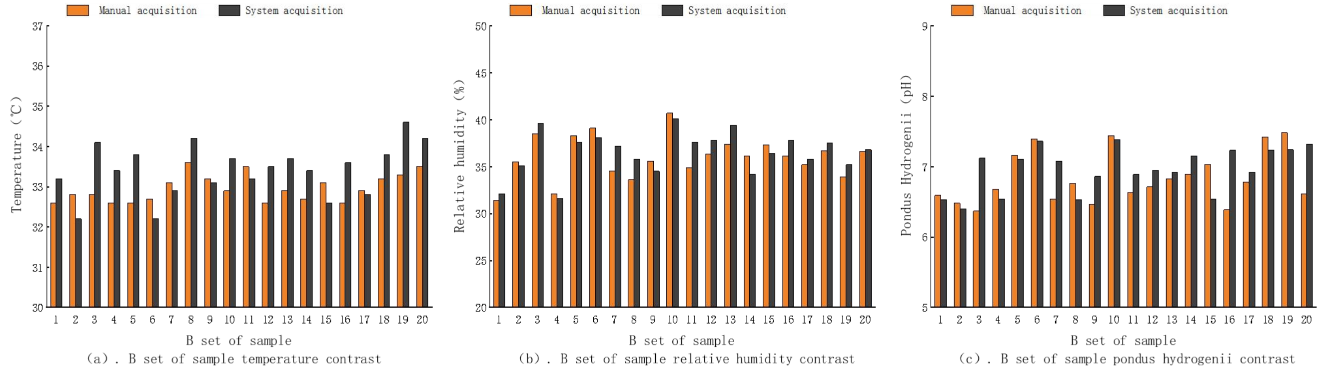


Figure 6: Comparison of Experimental Results for Group B

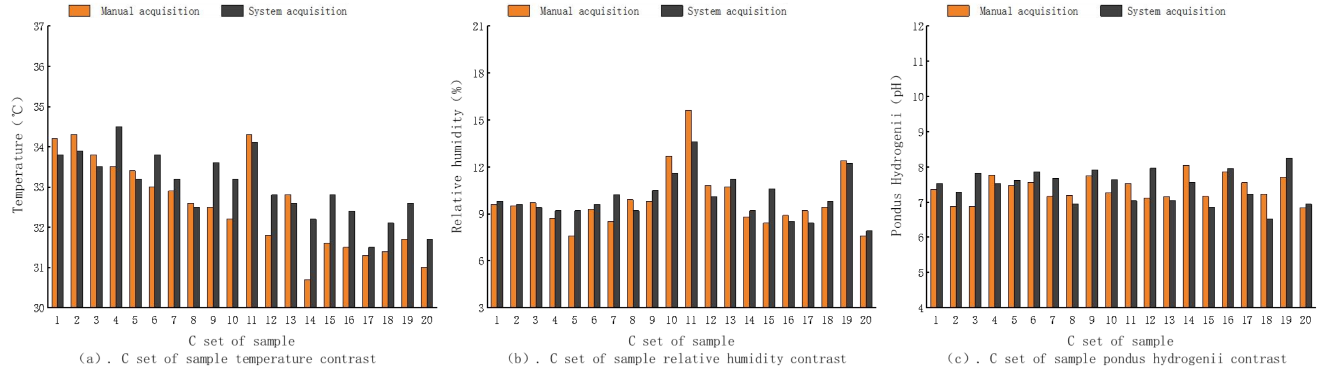


Figure 7: Comparison of Experimental Results for Group C

4. Conclusion

Combining a micro mobile platform with embedded technology, this paper designs an environmental parameter acquisition system for aerobic composting fermentation. Controlled by the remote controller of a WeChat mini-program on an Android phone, the system can automatically and quickly collect surface images of the compost pile and environmental information at selected sampling points. Experimental results show that:The miniature mobile platform operates stably and achieves accurate sampling point positioning； The compost surface images collected by the system are complete and clear, with an average error of environmental data not exceeding 2.55%； It takes approximately 15 minutes to collect image data from 60 sampling points. Compared with manual collection, the data acquisition efficiency is significantly improved, and the system basically meets the design requirements. This system can not only be used for monitoring environmental factors during the organic fertilizer composting process but also be applied to environmental factor monitoring needs in fields such as greenhouse cultivation and breeding. It realizes remote real-time monitoring, display, and abnormal alarm of environmental factors, and has broad application prospects.

Acknowledgements

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