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Farm and environment information bidirectional acquisition system with individual tree identification using smartphones for orchard precision management

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ABSTRACT

An orchard precision management system plays an important role in improvement at the management level and the enhancement of decision abilities. A single orchard tree or an orchard tree microcommunity is the basic management unit, and bidirectional information on the environment and plants is the important content for precision management. A type of RFID label was applied with a UHF chip in the core and a QR code in the surface for single tree identification. A bidirectional acquisition system for orchard production, which included farming information collection for the forward direction and environmental information acquisition for the backward direction, was designed with smart phones. In the farming information collection part, information collection flow that included QR code image acquisition, image preprocessing, barcode decoding and farming information collection was established. An improved local threshold method was adopted to improve the QR code identification rate in the smart phone platform. In the environment information acquisition part, a sensor search rule on the single tree position and a multi-point environment value model were designed. The orchard information bidirectional acquisition system was developed on an Android platform with the Java language, which has the function of QR decoding, farm record information collection, environment information acquisition, data uploading and statistical analysis. The system was tested in an apple orchard. A total of 144 trees were chosen to decode the QR codes in the tree label. The success rate was approximately 96.52%. The identification time of 85% of the trees was less than 4 s for the 20 chosen trees. In taking the temperature, for example, the difference between the computed temperature value and the measured temperature value around each tree was small. The system could decrease the cost of the professional equipment, such as portable RFID readers and writers, which was a low-cost and high-efficiency solution for orchard production information collection.

1. Introduction

China is a country with a large fruit production in the world. For apples, the production in 2010 exceeded 30 million tons (Qian et al., 2013). However, the fruit quality and yield has undergone large fluctuations from year to year because of extensive issues in management (Qi et al., 2011).

Precision agriculture has the characteristic of high technology content, advanced production means and strong technology integration (Zhang et al., 2002). Flexible management is the key idea of precision agriculture. The idea can be used in orchard management. A different method at a different time is performed in the orchard according to the individual and population diversity, which has been an efficient way to improve extensive management (Cunha et al., 2010). In orchard precision management, a single orchard tree or an orchard tree microcommunity is the basic unit, and information collection and management is the important content. The information includes two parts, one of which is the plant environment information, such as the temperature and humidity, and another is the farming operation information, such as irrigation and insecticides (Jiang et al., 2008).

A WSN (Wireless Sensor Network) provides effective support for environmental information quick acquisition and real-time monitoring (Wang et al., 2006; Fernandes et al., 2013). A WSN

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consists of non-intrusive communication devices of small size, to which one or more precision sensors for data collection are adapted. Sensors usually measure parameters such as the soil-moisture, salinity or pH, among other factors (Garcia-Sanchez et al., 2011). Regional and on-farm sensor networks were developed and implemented in two agricultural applications in Washington State, an agricultural weather network and an on-farm frost monitoring network (Pierce and Elliott, 2008). López Riquelmea et al. successfully implemented a WSN on a crop of ecological cabbage (*Brassica oleracea*), and the result was a low-cost, highly reliable and simple infrastructure for the collection of agronomical data over a distributed area in horticultural environments (López Riquelmea et al., 2009).

With the development of mobile communication technology, the information collecting and uploading time using portable devices (mobile phone, PDA, tablet PC) has become an effective means for farming operation information collection (Tseng et al., 2006; Qian et al., 2012; So-In et al., 2014). Steinberger et al. (2009) developed mobile farming information collection equipment that transmitted the information to the server through the internet. Amiama et al. (2008) developed an automatic acquisition system that collects information that concerns herbage reaping. This system transmits the information that is collected through an SMS module and fixes the reaper's position using GPS. Finally, the relationship between the output and plot area was found. Fang and He (2008) developed a real-time field information collection and processing system in the Pocket PC, which realizes data acquisition and a dynamic display function using GPS and GIS. Li et al. (2010) developed farming information acquisition and a decision support system (PRDS) in a PDA for cucumber traceability, which was applied in two production companies in Beijing and proved to improve the production efficiency.

Combining environment information and farming operation information, the establishment of a decision support system is an effective way to improve the management and decision level in orchard precision performance. However, the existing studies and applications with WSNs and mobile devices cannot integrate the two types of information. The limitations in single tree precision orchard management are obvious in three respects: (1) the environment information is collected and transmitted to the monitor and cannot been searched or inspected in the orchard scene; (2) the most similar environment information cannot been searched based on the identified tree; (3) the farm operation information cannot been corresponded with the environment information in the mobile device. To overcome these shortcomings, a bidirectional information acquisition system with single-tree identification was developed on the smart phone platform. The system framework was designed, and the system functions were implemented with key technologies. The two important indexes of the 2d-barcode decoding and system were tested. The system was proved to be an effective method for orchard precision management.

2. Single-tree identification

Every fruit tree was identified by an RFID card with a two-dimensional barcode, as shown in Fig. 1. The card adopts the Web™ UHF chip produced by UPM. The frequency range of the chip is between 860 and 960 MHz. The chip supports the protocol of ISO 18000-6C and EPC Class 1 Gen 2 and has a TID memory of 64 bits. The reading and writing radius ranges from 4 m to 6 m (The bio Company UPM, 2011). Visible information, including the tree number, manager, species and two-dimensional barcode, was printed on a label attached to the card. The QR code, which included the tree number and tree position, was adopted. The tree

Fig. 1. RFID card with barcode sample.

marked by this type of card can be identified by both a professional RFID reader for the chip and a smart phone for the barcode. Because of its high cost, the professional RFID reader is not suitable for a medium-size or small-size orchard. Decoding the two-dimensional barcode on the RFID card with the smart phone, which is a low-cost application for precision management, is focused on in this paper.

3. System framework

The bidirectional acquisition system for orchard production included farming information that was collected in the forward direction and environmental information acquisition that moved in the backward direction. As shown in Fig. 2, three parts were included. The QR code on the tree card was the basis for the single orchard tree identification. The bidirectional information acquisition system in the smart phone was the key for scanning the barcode, information collection and data access from the remote server. The remote server deployed in the orchard management center was the support for storing the information.

In the case of the farming information collection, the steps can be described as follows: (1) taking a photo of the QR code on the tree card with the camera in the smart phone; (2) decoding the barcode to obtain the tree number; (3) collecting farming information, such as irrigation, pesticide, and fertilization, and establishing the relationship between the farming information and the tree number; and (4) uploading the information to the remote data server for precision orchard management. In the case of environmental information acquisition, the steps can be described as follows: (1) taking a photo of the QR code on the tree card; (2) decoding the barcode to obtain the tree position; (3) transmitting the tree position to the remote data server; (4) querying the environment information in the server according to the tree position with the rule of Near the Tree; and (5) feeding back the environment information to the smart phone and displaying it.