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Cloud-based harvest management information system for hand-harvested specialty crops

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ABSTRACT

The harvest process for specialty crops is generally one of intensive activity because many people are required for harvest and packing, and the harvest window is brief due to the high perishability of the produce. Herein we present a cloud-based Harvest Management Information System (HMIS) that combines a novel real-time Portable Labor Monitoring System (PLMS) with a cloud-based harvest management software. The PLMS comprised of three key elements (1) a self-leveling scale, (2) electronic control box, and (3) a frame that supports all hardware. The electronic control box includes: (i) a RFID reader, (ii) a LCD display, (iii) a thermal printer, (iv) a GPS module, and (v) a communication system. RFID tags, containing unique ID numbers, embedded within rubber wrist bands, are worn by pickers. This system can read a picker's ID (RFID bracelet), measure the weight of fruit, and record the time and location (optional) of every fruit 'transaction' (i.e., every time a picker brings a bucket of fruit to the collection bin). The collected data can be transmitted wirelessly to the server in real-time. The cloud-based software receives and processes the PLMS data on labor activities, visualizes the collected data, and can extract the data necessary for management information and automated filling of documents (e.g. payroll, yield maps). The HMIS is unique in its ability to: (1) accurately credit pickers for the fruit they have harvested in the field without impeding or altering the harvest process, (2) streamline data entry to payroll, (3) provide real-time tracking of harvest, yield mapping, and traceability, and, (4) generate precise and reliable harvest efficiency data. This integrated system was evaluated in sweet cherry, blueberry and apple orchards in Washington, USA. The weight of harvested fruit, time and location of every fruit drop were calculated accurately; all the data were transmitted wirelessly to the server and no errors were recorded.

1. Introduction

Specialty crops (fruits and vegetables, tree nuts, dried fruits and horticulture and nursery crops, including floriculture) have been identified as the fastest growing segment of agribusiness (Wall Street Journal, 2007). These crops generally require a significant amount of labor for planting, pruning, thinning, and, in particular, harvesting. They are characterized by high costs of production, and high crop value. Harvest costs are often the greatest expense for specialty crop producers, because harvest depends predominantly upon manual labor. The window for harvesting fruit crops at optimum maturity can be very short, placing great importance on the harvest process. For example, harvesting sweet cherries prematurely or beyond optimal timing undermines consumer satisfaction with the fruit (Chauvin et al., 2009).

The timely collection of pertinent data is the first step toward making better harvest-related decisions on the farm. Few systems and techniques have been developed and adopted for harvest/labor data monitoring for specialty crops. Schueller et al. (1999) developed and evaluated a yield monitoring system for citrus and Ampatzidis and Vougioukas (2009) developed a yield monitoring and traceability system for peach and kiwi-fruit using radio frequency identification (RFID) and barcode registration technologies. Additionally, Ampatzidis et al. (2011) designed and developed a wearable position recording system for orchard workers to track their position in relation to trees, where GPS data are typically unavailable. One of the main technical challenges for wireless data transfer in orchards is the interference from the tree structure

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(i.e., canopy and wood). Vougioukas et al. (2013) investigated the influence of foliage on radio signal losses for wireless sensor network (WSN) in a plum orchard. Using XBee Pro® transceivers (Digi, Inc., Minnetonka, MN, USA) they found that at a distance of 120 m the ratio of lost packets was around 20%, and they estimated that the reliable range of this system is 50–70 m within the orchard. Ampatzidis et al. (2015) developed a low-cost WSN using aerial systems in orchards. They evaluated the connection limitations, through the tree canopies, between a ground-based WSN and Unmanned Aerial Vehicles – UAVs. This integrated system can provide real-time access to high quality data in order to quickly and accurately identify problems. Wang et al. (2006) presented an overview on wireless sensors development in agriculture and food industry, and Ruiz-Garcia and Lunadei (2011) explored the advantages, limitations and challenges of the RFID-based systems for identification, tracking and timely data collection in agriculture. Cunha et al. (2010) developed a user-friendly system for exchanging contextualized information and accessing contextualized services in vineyards, using mobile devices and multi-tag technologies. It is important to develop an accurate data acquisition system to enhance real-time decision making. To streamline harvest operations, the number of workers and machines required to harvest, handle, and transport the product needs to be planned along with the execution of field operations (Ampatzidis et al., 2014).

We hypothesize that accurate data acquisition systems can also be used to improve accuracy of payroll. Various methods for reimbursing pickers have been employed worldwide, with most fruit growers now paying a piece-rate to small picking teams for bins (e.g. for pome fruit) or for buckets (e.g. for sweet cherries, blueberries). Regardless, paying piece-rate (pay pickers per full of fruit buckets or bins, assuming that their weights are similar; but might be under- or overfilled) is beset with inaccuracies that cause significant financial losses. Tests in commercial sweet cherry, apple and blueberry orchards revealed variability of 25–30% of final weight among bins and buckets (Ampatzidis et al., 2012a,b,c,d; Ampatzidis and Whiting, 2013a,b). For example, in sweet cherry orchards a range of more than 50 kg in bin weights (mean bin weight ≅ 200 kg) and 3 kg in bucket weight (mean bucket weight ≅ 10 kg) were recorded during these trials. These discrepancies can cause significant economic losses. A cherry grower found that pickers were overpaid $16,663 in 2010 and 2011 because of the variability in bucket weights (Growing Produce article, 2013). Additionally, a blueberry grower in Prosser, WA (USA) estimated that pickers were overpaid $20,000 in one week (2013).

Cloud computing (CC) is used worldwide, because it can improve flexibility, reduce infrastructure, streamline processes, improve accessibility, and efficiently handles large data sets. In general, it is a paid service usage model. In agriculture, CC has been used for real-time visual monitoring of crop growth (Zhang, 2011), and for constructing and improving agricultural products supply chain (Qiu et al., 2010). Additionally, Teng et al. (2012) developed a web-based service to manage livestock (herb management). This system can improve data accessibility and provide up-to-date information to users. Farm Management Information Systems (FMIS) are used for collecting and processing data to assist growers to manager their farms efficiently (Fountas et al., 2015). Kaloxylos et al. (2014) presented the architecture and implementation of a cloud-based FMIS that could serve as a marketplace for services for the farmers. These systems improve operational planning and optimize the work performed in the fields (Ampatzidis et al., 2014; Fountas et al., 2006; Sørensen et al., 2001).

In this paper, a Harvest Management Information System (HMIS) with the ability of collecting, processing and visualizing harvest data in real-time is presented. This system can be used as a management tool by providing real-time access to harvest data. It can improve accuracy of payroll by reimbursing pickers precisely for the weight of harvested fruit rather than the current system of piece-rate. Furthermore, it can improve accuracy of payroll by reimbursing pickers precisely for the weight of harvested fruit, create yield maps, and improve field and fruit handling logistics.

2. Materials and method

The HMIS combines a real-time Portable Labor Monitoring System (PLMS) with a cloud-based harvest management software. Below, we briefly present the PLMS and the main components of the cloud-based harvest management software.

3. Portable Labor Monitoring Systems (PLMS)

Generally, the portable PLMS consists of: (1) a self-leveling scale, (2) electronic control box (or Computational Unit – CU), and (3) a frame that supports all hardware. The electronic control box includes: (i) a RFID reader, (ii) a LCD display, (iii) a thermal printer, (iv) a GPS module, and (v) a communication system. RFID tags, containing unique ID numbers, embedded within rubber wrist bands, are worn by pickers. This system can read a picker's ID (RFID bracelet), measure the weight of fruit, and record the time and location of every fruit drop as pickers empty their buckets directly into bins.

A prototype system for measuring average harvest efficiency, per picking crew, was developed in 2010 (Ampatzidis et al., 2012a) and modified in 2011 (Ampatzidis et al., 2012b, Fig. 1) to a real-time Labor Monitoring System-LMS with the ability to track and record individual picker efficiency. Additionally, a Portable Labor Monitoring Systems (PLMS) were designed and developed for tree fruit crops (Fig. 2) (Ampatzidis and Whiting, 2014). All these systems/prototypes were utilized to collect real-time data during harvest of specialty crops. The collected data can be transmitted wirelessly to the server in real-time with an internet or GPRS connection. A detailed description of a LMS is given in Ampatzidis et al. (2012b) and of a PLMS in (Ampatzidis and Whiting, 2014).

A computational unit CU was developed to collect data from the sensors (RFID reader, GPS, weighing system), process and wirelessly transmit them to the cloud-based harvest management

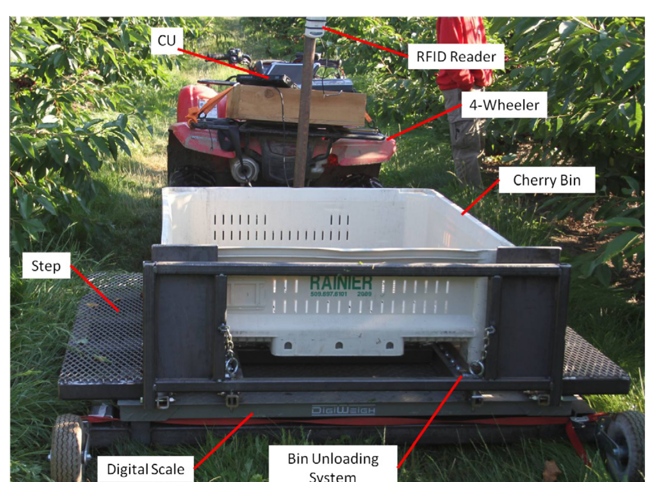

Fig. 1. Real-time novel Labor Monitoring System (LMS) (CU = computational unit, RFID = radio frequency identification) (Ampatzidis et al., 2012b).