A NOVEL PORTABLE SYSTEM FOR IMPROVING ACCURACY OF REIMBURSEMENT FOR FRUIT PICKING

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ABSTRACT

In this paper, a portable Labor Management System (LMS) for paying fruit pickers individually and accurately is presented. This system utilizes a digital hanging-weight scale (S-type load cell) and a computational unit (CU). The CU consists of: (i) a microcontroller (arduino mega), (ii) a RFID reader; (iii) a thermal printer; (iv) a GPS module; (v) a wireless transceiver (Xbee pro); (vi) a display unit (LCD); (vii) real-time clock (RTC); and (viii) a memory card (sd card). Low-cost passive RFID wristbands, which contain unique ID numbers, are worn by pickers. A hanging-weight system was developed in order to be self-levelling, an important factor for open field environments (e.g. sloped orchards). Each picker places their bucket(s) on the suspended platform and initiates the weighing system with their RFID-wristband by passing it before the reader. The LMS immediately calculates the weight of fruit, associates it with the picker ID, and prints a receipt that outlines the picker's ID, date, time, bucket(s) weight, and accumulated weight (total weight). Additionally, all data are stored locally to an sd card and transmitted wirelessly to the cloud.

This portable LMS was field-tested for accuracy and reliability during commercial harvest of sweet cherries (*Prunus avium* L.) and blueberries (*Vaccinium corymbosum*) in the Pacific Northwest, USA. Using the LMS the overall accuracy of payroll was improved, by providing the ability to reimburse pickers individually, based on the actual weight of fruit they harvested. The economic benefits of paying for actual weight of harvested fruit will be discussed as well as the potential for this system to generate accurate yield maps and provide "in-field" traceability.

Keywords: Labor management, fruit harvest, payroll, arduino, RFID, Zbee.

INTRODUCTION

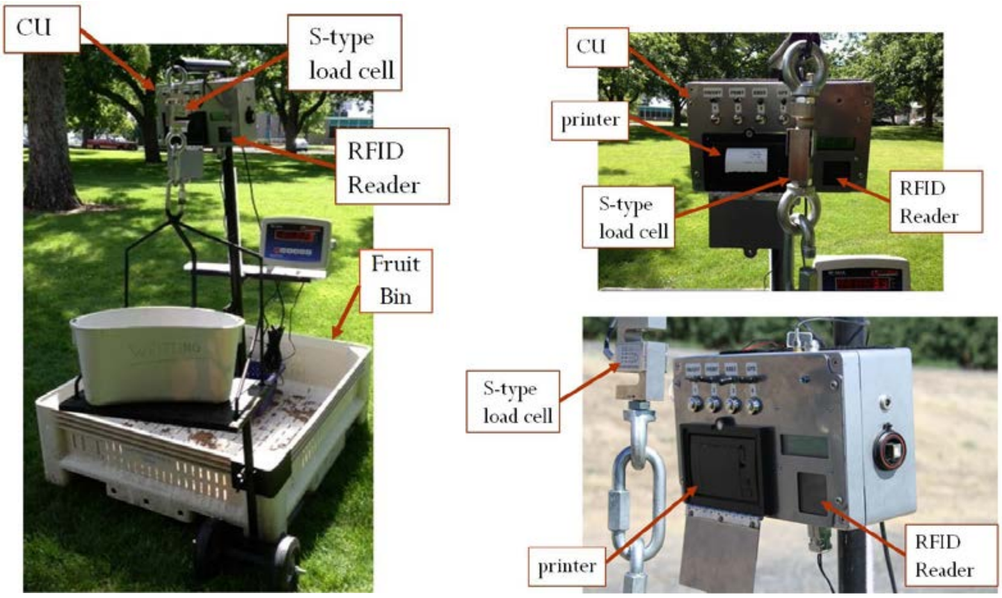
Fruit harvest is a labor-intensive operation and harvest expenses are significant for the producers. In sweet cherry (*Prunus avium* L.) harvest expenses account for more than 50% of annual production costs (Seavert et al. 2008). All sweet cherries for fresh market consumption are currently harvested manually (Seavert et al. 2008). As a result, horticultural, technological, and genetic solutions have developed to improve labor efficiency. These solutions have included the development of high density training systems, often pedestrian or planar, to simplify pruning and training (Whiting, 2009; Whiting et al., 2005). Tests revealed a significant effect of canopy architecture on labor efficiency (Ampatzidis and Whiting, 2013).

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 is beset with inaccuracies that cause significant financial losses. Our tests in commercial sweet cherry and apple orchards revealed variability of 25 – 30% of final weight among bins and buckets (Ampatzidis and Whiting, 2013; Ampatzidis et al., 2013; Ampatzidis et al., 2012). 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 (M. Omeg, The Dallas, OR, USA, personal communication). Additionally, a blueberry grower in Prosser, WA (USA) estimated that pickers were overpaid $20,000 in one week (2013). There is no accurate system for calculating labor efficiency or reimbursing pickers individually.

Data monitoring systems would help farmers understand and evaluate crop production, and inform their decision-making process (Ampatzidis et al., 2011; Ampatzidis and Vougioukas, 2009). Additionally, acquiring reliable data in the field is necessary for spatial-variability studies (e.g. precision agriculture). A prototype system for measuring average harvest efficiency, per picking crew, was developed in 2010 (Ampatzidis et al., 2013b) and modified in 2011 (Ampatzidis et al., 2012) to a real-time labor monitoring system with the ability to track and record individual picker efficiency. In the current study, a portable hanging-weight system was developed for self-levelling. This system can be used to pay fruit pickers individually and accurately, as well as, to generate accurate yield maps and provide "in-field" traceability.

MATERIALS AND METHODS

The portable Labor Management System (LMS) utilizes a digital hanging-weight scale (S-type load cell, Fig. 1) and a computational unit (CU). The CU consists of (Fig. 2): (i) a microcontroller (arduino mega), (ii) a RFID reader; (iii) a thermal printer; (iv) a GPS module; (v) a wireless transceiver (Xbee pro); (vi) a display unit (LCD); (vii) real-time clock (RTC); and (viii) a memory card (sd card). Low cost RFID tags, containing unique ID numbers embedded within rubber wrist bands, were worn by pickers.



a) b)

Figure 1. Portable Labor Management System (LMS) mounted on a cherry bin. It consists of a) a digital hanging-weight scale (S-type load cell), and b) a computational unit (CU).

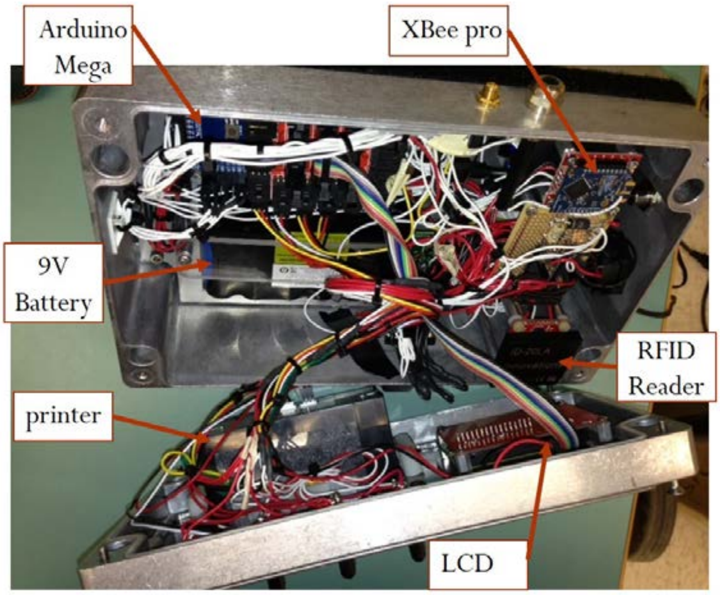


Figure 2. The computational unit (CU) consists of: (i) a microcontroller (arduino mega), (ii) a RFID reader; (iii) a thermal printer; (iv) a GPS module; (v) a wireless transceiver (Xbee pro); (vi) a display unit (LCD); (vii) real-time clock (RTC); and (viii) a memory card (sd card).

Each picker places their bucket(s) on the suspended platform and initiates the weighing system with their RFID-wristband by passing it before the reader. Figure 3 presents the LMS work flow. The LMS simultaneously reads the picker ID (RFID tag), measures the weight of fruit, associates it with the picker ID, and prints a receipt (Fig. 4) that outlines the picker's ID, date, time, bucket(s) weight, and accumulated weight (total weight). The collected data are stored locally to an sd card and transmitted wirelessly to the cloud (in real time). A cloud-based harvest management software has developed to receive, process and visualize the LMS data (Ampatzidis et al., 2013a). It includes a web portal through which any LMS can transmit harvest data wirelessly to the cloud-based system. The cloud-based harvest management software extracts the data necessary for management information and automated filling of documents (e.g. payroll, yield maps).

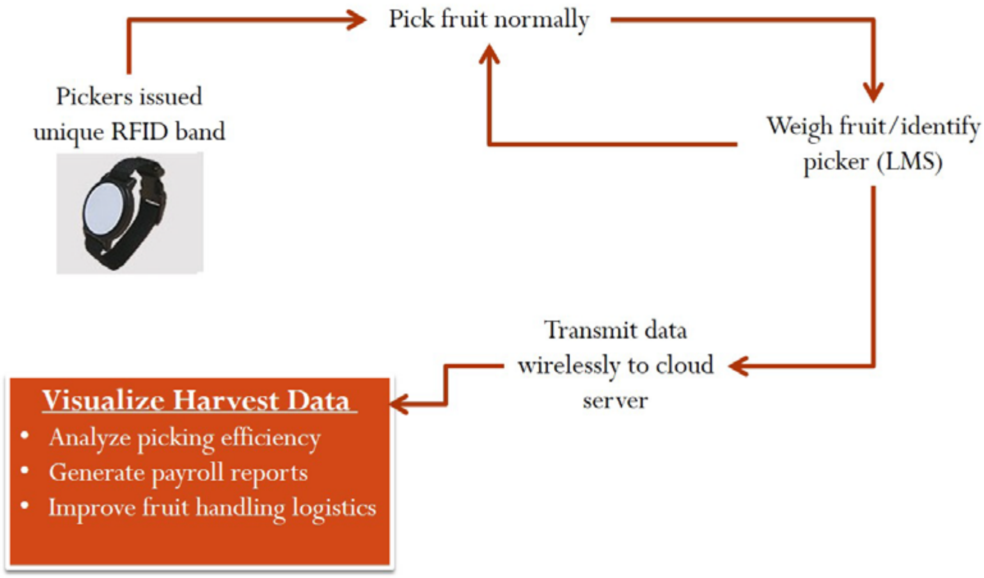


Figure 3. The LMS work flow.

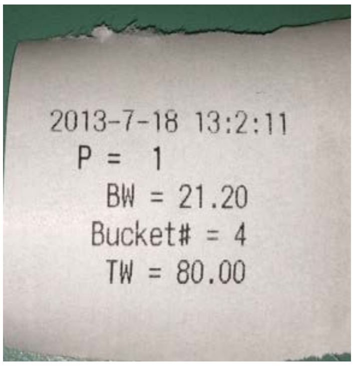


Figure 4. The outlines the picker's ID (P), date, time, bucket(s) weight (BW in kg or lb), and accumulated weight (total weight, TW in kg or lb).

Experimental Design

System functionality and variability were evaluated in a sweet cherry (*Prunus avium* L.) orchard and a blueberry (*Vaccinium corymbosum*) orchard in the Pacific Northwest, USA.

The first orchard (sweet cherry) at the WSU Roza experimental farm, near Prosser, WA, contained 6-year-old 'Selah'/'Gisela®6' trees trained to a planar architecture comprised of unbranched vertical fruiting wood (Upright Fruiting Offshoots-UFO). Trees were spaced 3 m between rows and 2 m within a row; the average height of the trees was 2.5-3 m and the width of the trees canopy 0.5 m. On 13 July, 2012, nine pickers harvested fruit for two rows of trees. The picking crew, using 3 m ladders, moved along tree rows picking into buckets secured over their shoulders with straps. The capacity of the picking bucket generally is 9.5 kg and the capacity of a cherry bin is ca. 180 kg. The portable LMS was used to calculate individual picker efficiency.

The second orchard (blueberry), near Prosser, WA, was comprised of 3 year old 'Liberty' bushes planted at 3 m x 1 m. On 15 July, 2013, five pickers harvested fruit using three bucket per picker. The capacity of the picking bucket (when full) generally is 6.2 lbs. One additional employee was present to check that pickers filled the buckets to a similar degree, check the quality of the fruit and measure the numbers of buckets for each picker in order they will be paid based on this number. Pickers had to give their bucket(s) to this additional employee to properly dump fruit into bin, so the bins get filled properly, avoiding unnecessary handling. Pickers could even return one filled bucket (out of three) when convenient. The pay rate was $2.70/bucket.

RESULTS AND DISCUSSION

In both orchards the LMS revealed significant variability among final bucket and bin weights. In the experimental sweet cherry orchard, the final bin weight (ostensibly full) varied between 151.30 kg to 173.95 kg, a difference of almost 23 kg (mean=162.80 kg ± 8.6 kg). The final bucket weight, among all pickers, varied between 7 kg to 10.9 kg (mean=8.1 kg ± 1.34 kg). The pay rate in orchard 1 was $3.50/bucket and hence, the picking cost varied between $0.50 to $0.32 per kg, respectively. Currently, tree fruit growers pay pickers by piece-rate – for full bins or buckets which are judged to be full visually by the orchard manager or an additional employee. Our testing proved that this system is not accurate. For example, the average fruit weight per bucket for picker 1 (picking experience= 10+ years) was 9.18 kg (±0.57 kg) and she picked 22 buckets (total 202.05 kg), whereas for picker 2 (picking experience= 6 years) was 8.45 kg (±0.87 kg) and he picked 21 buckets (total 177.6 kg). Given that the expected fruit weight per bucket was 9.5 kg, picker 1 should be paid $74.4 instead $77 and picker 2 $65.4 instead $73.5 (Table 1).

Table 1. Harvest data for the sweet cherry orchard. Nine pickers harvested fruit on 13 July, 2012.

Picker	Weight of harvested fruit (kg)	Number of harvested buckets	Picking cost ($) [pay by number of harvested buckets]	Picking cost ($) [pay by weight and number of harvested buckets=9.5 kg]
1	202.05	22	77.0	74.4
2	177.55	21	73.5	65.4
3	179.85	21	73.5	66.3
4	110.75	11	38.5	40.8
5	158.05	18	63.0	58.2
6	140.4	16	56.0	51.7
7	170.85	19	66.5	62.9
8	148.65	17	59.5	58.4
9	160	18	63.0	58.9

In the blueberry orchard (Fig. 5) the final bucket weight, among all pickers, varied between 4.2 lb to 6.55 lb (mean=6.18 lb ± 0.42 lb). Table 2 presents the harvest data for this orchard and Fig. 6 visualizes the weight of fruit for every fruit drop, for the five pickers, during harvest. Even this preliminary research proved that the payroll system is not accurate (Table 2).

The collected data (from LMS) can be transmitted wirelessly to the cloud (in real time); the cloud-based harvest management software visualizes the LMS data, generating yield map and producing payroll records (Ampatzidis et al., 2013a).

Figure 5. A blueberry picker places his buckets on the suspended platform, initiates the weighing system with his RFID-wristband by passing it before the reader, and collects the receipt.

Table 2. Harvest data for the blueberry orchard. Five pickers harvested fruit on 15 July, 2013. The pay rate was \$2.70/bucket (bucket = 6.2 lb).

Picker	Weight of harvested fruit (kg)	Number of harvested buckets	Picking cost (\$) [pay by number of harvested buckets]	Picking cost (\$) [pay by weight and number of harvested buckets=6 kg]
1	95	15	40.5	41.4
2	86.8	14	37.8	37.8
3	69.7	11	29.7	30.4
4	122.5	20	54.0	53.3
5	85	14	37.8	37.0

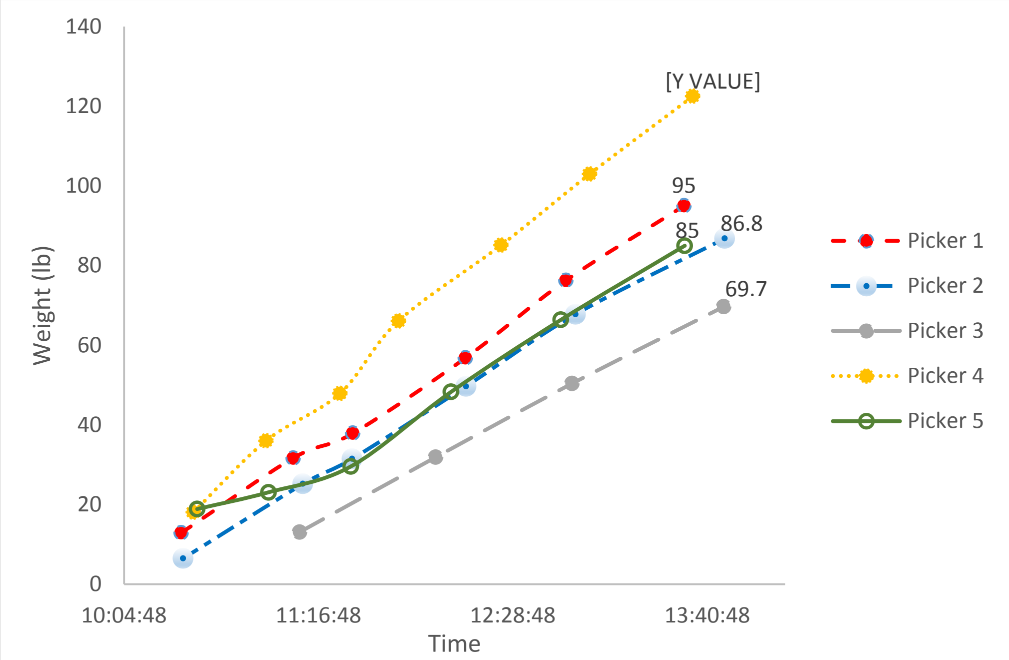


Figure 6. The weight of harvested fruit for each picker during blueberry harvest. There were five pickers in the crew.

CONCLUSION

Currently, there is no accurate system for calculating labor efficiency or reimbursing pickers individually and accurately. The proposed portable Labor Management System (LMS) can be used to pay fruit pickers individually based on the actual weight of harvested fruit rather than the current system of piece-rate. Additionally, it can be used to generate accurate yield maps (using the geo-referenced labor data) and provide real-time access to harvest data. Finally, the LMS can provide "in-field" traceability, associating fruit-producing tree(s), with bins, pickers and field location (using the GPS data).

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