Project Title: Study on Mechanical Mass Harvesting of Cling Peaches
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Duration: 01-Jun-17 - 31-May-18
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ABSTRACT

Harvesting is one of the most labor-intensive operations in cling peach production. The manual harvesting cost for cling peaches amounts to 29.2% of the total operating cost and to 78% of the total harvest cost per acre. Labor cost will increase significantly due to recent legislation. In addition to cost, supply of skilled pickers is decreasing; hence, risk of losing crop is increasing too. Therefore, cling peach growers face a great need for mechanical harvesting solutions. The proposed research investigates a novel approach to intercepting fruits during a shake-and-catch operation, so that they are caught before they hit tree branches. A literature review of systems developed in the past was performed to identify promising approaches. Alternative catching surface designs and insertion mechanisms were explored and some were fabricated and tested. A novel design of a canopy-penetrating boom with inflatable side fingers was conceived. Preliminary fruit drop experiments were performed and verified the feasibility of intercepting falling fruits with inflated fingers. Also, an SCRI mechanical harvesting pre-proposal was submitted in fall 2017 to further promote this research.

INTRODUCTION

Harvesting is one of the most labor-intensive operations in cling peach production. A 2011 UC ANR production cost report for processing peach (cling and freestone) estimated the hand-picking and field-sorting cost for processing peaches at $1,200/acre, using $10.97 per hour for general labor including payroll overhead at 33% (Norton, Hasey, Duncan, Klonsky, & De Moura, 2011). This translated to 78% of the total harvest cost, which includes hauling to the packinghouse, and 29.2% of the total operating per acre cost. Labor cost will increase significantly due to recent legislation. Perhaps the greatest problem though, is that in addition to cost, supply of skilled pickers is decreasing; hence, risk of losing crop is increasing too. Therefore, cling peach growers face a great and urgent need for mechanical harvesting solutions.

Cling peaches can be harvested mechanically using tree shaking and fruit catching systems. However, excessive fruit damage is still a problem. Although improvements in the design of the shaker and the catching system can somewhat improve fruit quality, it is well known that a major source of mechanical damage is due to limb-fruit collisions during fruit-fall through the canopy. Existing shake-and-catch systems cannot address this problem. Some tree architectures, like Y-shaped trees with few overlapping scaffolds are easier to harvest mechanically (Peterson et al., 2005). Prototype limb-shaking harvesters for such trees have been developed (cherries: Peterson, Wolford, 2003b; apples: Peterson, Wolford, 2003b) with encouraging results. However, the majority of existing cling peach orchards in California have not adopted such architectures and solutions for existing orchards are needed.

The proposed research aims to investigate a novel approach to intercepting fruits at multiple heights during a shake-and-catch operation, so that they are intercepted before they hit tree branches. The long-term goal is to design, build and test a prototype system that inserts multiple catching surfaces into the canopy before shaking, and effectively reduces fruit damage during shaking and falling. The envisioned system would be compatible with existing fruit tree architectures and – as much as possible – with existing shaking operations and equipment, if with minor modifications. As prior work has shown, the principle of using multiple catching surfaces can be applied to various crops and tree architectures. Therefore, a key aspiration of our work is to develop a multi-fruit harvesting system, i.e., a system that can be customized and adopted to work with several fruit tree types.

OBJECTIVES

Three objectives were pursued. First, a detailed literature review of systems developed in the past was conducted, and designs were analyzed for their pros and cons. Alternative catching surface designs and insertion mechanisms were explored and some were fabricated and tested in the lab (1). Preliminary fruit drop experiments were performed to verify the feasibility of the conceived approach (2). Finally, an SCRI mechanical harvesting pre-proposal was submitted in fall 2017 (3).

LITERATURE REVIEW

A review of fruit harvesting systems reported in the literature was performed. Although there were many different approaches, most of them did not prove practical enough to be commercialized. For reasons of brevity, all these approaches are not included in the report. Three systems were found that were relevant to our proposed approach, i.e., use multiple-catching surfaces. Multi-level catch systems have been tried in the past for apples by Rehkugler & Markwardt, (1971) and Millier et al., (1973). Mehlschau et al., (1977) developed a similar system for plums and pears. Systems that intercepted and collected fruits at intermediate heights (Fig. 2, Fig. 3) had better performance compared to systems where fruits just ‘trickled down’ to be collected on a single catching surface Fig.1.


Fig. 1. Rehkugler & Markwardt, 1971.

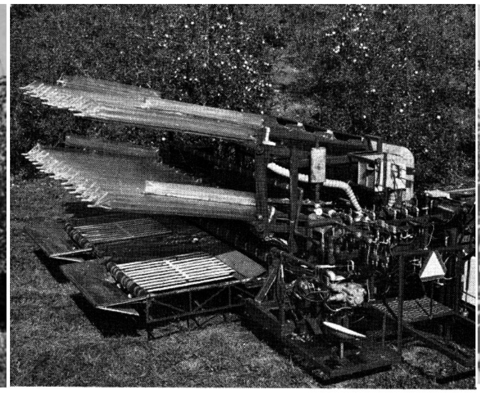
Fig. 2. Millier et al., 1973.

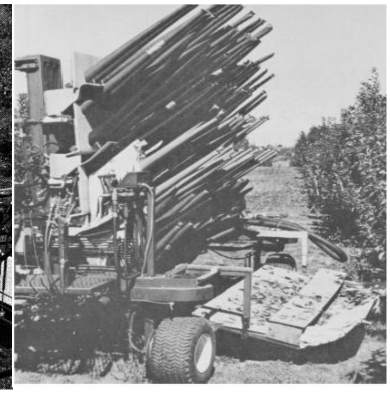
Fig. 3. Mehlschau et al., 1977.

However, labor availability and social issues at the time did not allow for more R&D on such machines. Further iterations on their design are very costly and to our knowledge have not been reported in literature.

Using funding by the Pear Advisory Board, the Cling Peach Mechanization Fund, and USDA-NIFA, the Bio-Automation Lab at UC Davis has built detailed models of pears and cling-peach trees and the positions of their fruits (Arikapudi, Vougioukas, Saracoglu, 2015; Arikapudi, Vougioukas, Jiménez- Jiménez, Khosro Anjom, 2016). We have also developed and utilized simulation models to confirm that properly deployed multi-level rods that penetrate into the canopy can intercept up to 90% of falling fruits before they hit any (digitized) tree branch (Munic et al., 2016). Of course, this number is an "optimistic" estimate, which however can be used to guide the design process. These results prompted the investigation of alternative designs for multi-level fruit catching surfaces.

PRELIMINARY DESIGN AND FRUIT DROP EXPERIMENTS

Alternative catching surface designs and insertion mechanisms were explored and some were fabricated and tested. Our team has converged to a novel design of a canopy-penetrating boom with inflatable side fingers. The particular design should have small penetration resistance during insertion into the canopy; this will be evaluated during the remaining period of this project. Preliminary fruit drop results are given next.

A prototype small boom with inflated side fingers was built, and drop experiments were conducted with different objects (pear, apple, and orange fruits). Fresh cling peaches were not available in December, when the experiments took place. However, the objects used spanned size (2.5'' – 5.5'') and weight ranges (115 – 348 gr) that include cling peaches.

Fig. 2. Subjects of drop experiments.

The prototype and two recorded video frames from an apple drop experiments are shown in Fig. 3.

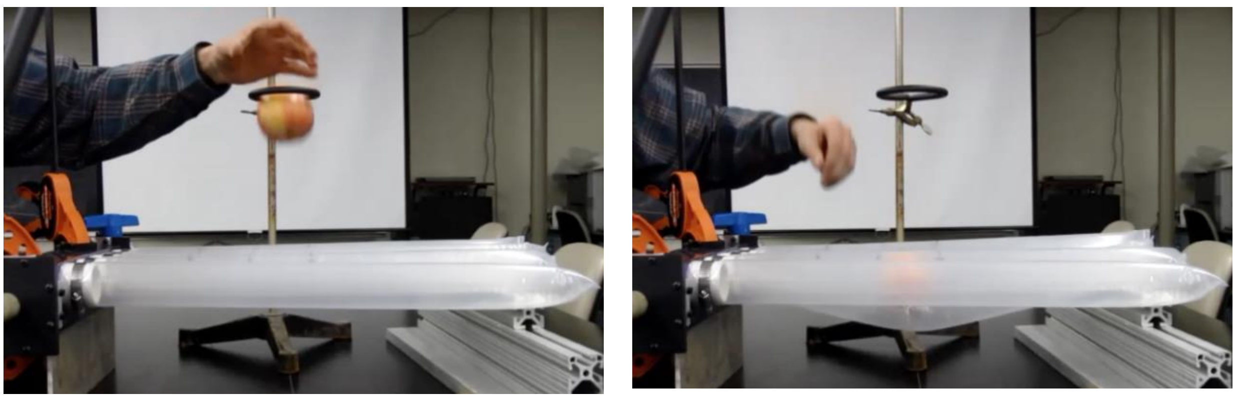

Fig. 3. Apple drop experiment; first and last frame of experiment's video.

Each object was dropped five times from heights of 8 and 12 inches respectively. The air pressure inside the fingers was 34 inches water (1.23 psi). Lower pressures were tested, but were not adequate to intercept reliably larger fruit. Each fruit was dropped at three different distances along the fingers (4, 7 and 10 inches respectively). These tests were not aimed at assessing fruit damage. The goal was to investigate the feasibility of intercepting lighter and heavier fruits, and to explore ranges of parameters for doing so. The drop results are given in Tables 1, 2 and 3.

Table 1: Small apple drop experimental results

t = thru; fruit dropped straight thru, though may have slowed down considerably
c = caught; fruit caught on tubes
r = roll; fruit hit tubes and rolled lengthwise down tubes before either falling thru or being caught
b = bounce; fruit bounced significantly before either falling thru or being caught

		Distance from finger edge (inches)			
Pressure: Max, 34 inwc	Drop #	4	7	10	Small Apple
Drop Height: 8 inches	1	b,c	b,c	b,c	
With Support on far end	2	b,c	b,c	b,c	
Small Apple, 2.5" diam, 115 g	3	b,c	b,c	b,c	
	4	b,c	b,c	b,c	
	5	b,c	b,c	b,c	

		Distance from finger edge (inches)			
Pressure: Max, 34 inwc	Drop #	4	7	10	Small Apple
Drop Height: 12 inches	1	b,c	b,c	c	
With Support on far end	2	b,c	b,c	b,c	
Small Apple, 2.5" diam, 115 g	3	b,c	b,c	b,c	
	4	b,c	b,c	b,c	
	5	b,c	b,c	b,c	

Table 2: Large apple drop experimental results

		Distance from finger edge (inches)			
Pressure: Max, 34 inwc	Drop #	4	7	10	Large Apple
Drop Height: 8 inches	1	b,c	b,c	c	
With Support on far end	2	b,c	b,c	b,c	
Large Apple, 3.05" diam, 185 g	3	b,c	b,c	c	
	4	b,c	b,c	b,c	
	5	b,c	b,c	b,c	

		Distance from finger edge (inches)			
Pressure: Max, 34 inwc	Drop #	4	7	10	Large Apple
Drop Height: 12 inches	1	b,c	b,c	c	
With Support on far end	2	b,c	b,c	c	
Large Apple, 3.05" diam, 185 g	3	b,c	c	b,c	
	4	b,c	b,c	c	
	5	b,c	b,c	t	

Table 3: Orange drop experimental results

		Distance from finger edge (inches)			
Pressure: Max, 34 inwc	Drop #	4	7	10	Orange
Drop Height: 8 inches	1	b,c	b,c	c	
With Support on far end	2	b,c	b,c	c	
Large Orange, 3.5" diam, 348 g	3	b,c	c	c	
	4	b,c	b,c	t	
	5	c	c	b,c	

		Distance from finger edge (inches)			
Pressure: Max, 34 inwc	Drop #	4	7	10	Orange
Drop Height: 12 inches	1	b,c	b,c	t	
With Support on far end	2	b,c	b,c	t	
Large Orange, 3.5" diam, 348 g	3	b,c	c	b,c	
	4	b,c	b,c	t	
	5	b,c	c	c	

DISCUSSION

The preliminary results were very promising. It seems that inflated fingers at pressure 1.2 psi could intercept all fruits falling from heights ranging from 8 to 12 inches above the fingers. This height provides design specifications for the number of vertical booms of a large-scale fruit interception system. Fruits could be intercepted reliably up to 7'' away from finger base. At 10'' distance the fruits would fall through the fingers, in some cases; however, these decelerated fruits would be intercepted by fingers at one level below. This outcome provides design guidelines on finger length and required number of booms along the canopy. When lower pressure (e.g., 20'' water column) was used, some rolling was observed. Some limited bouncing did occur before the fruits would get caught and rest on the finger surfaces. This could be reduced with slightly decreased pressure. However, such limited bouncing is not expected to result in fruit damage.

More fruit drop tests will be conducted during the last months of this one-year project, which ends on May 31, 2018. Also, cling peach tree canopies will be digitized using a 3D scanner to quantify the canopy penetration resistance of boom-finger systems. Finally, a pre-proposal was submitted for SCRI funding; evaluation results are pending.

REFERENCES

Arikapudi, R., Vougioukas, S., Saracoglu, T. (2015). Orchard tree digitization for structural-geometrical modelling. Proceedings of the 10th European Conference on Precision Agriculture (ECPA), pp.: 329 – 336, Volcani Center, Israel.

Arikapudi, R., Vougioukas, S.G., Jiménez- Jiménez, F., Farangis Khosro Anjom, F. (2016). Estimation of Fruit Locations in Orchard Tree Canopies Using Radio Signal Ranging and Trilateration. Computers and Electronics in Agriculture (125):160-172.

Norton, Hasey, Duncan, Klonsky, & De Moura. 2011. SAMPLE COSTS TO ESTABLISH AND PRODUCE PROCESSING PEACHES. Cling and Freestone Late Harvested Varieties. Un. of California Cooperative Extension.

Mehlschau, J., Fridley, R., Brazelton, R., Gerdts, M. and Mitchell, F., 1977. Mechanical harvester for fresh-market plums. California Agriculture, 31(3), pp.11-11.

Millier W. F., Rehkugler G. E., Pellerin R. A., Throop J. A., Bradley R. B. (1973). Tree Fruit Harvester with Insertable Multilevel Catching System. Trans. ASABE 16(5), 844-850.

Munic, J.P., Vougioukas, S.G., Arikapudi, R. (2016). A Study on Intercepting Falling Fruits with Canopy Penetrating Rods. 2016 ASABE Annual International Meeting. Paper Number 162456923, Orlando, Florida.

Peterson, D.L., Whiting, M.D. and Wolford, S.D., 2003a. Fresh–Market Quality Tree Fruit Harvester Part I: Sweet Cherry. Applied engineering in agriculture, 19(5), p.539.

Peterson, D.L. and Wolford, S.D., 2003b. Fresh–Market Quality Tree Fruit Harvester Part II: Apples. Applied engineering in agriculture, 19(5), p.545.

Peterson, D.L., 2005. Harvest mechanization progress and prospects for fresh market quality deciduous tree fruits. HortTechnology, 15(1), pp.72-75.

Rehkugler, G. E., & Markwardt, E. D. (1971). An evaluation of limb padding to reduce apple damage in mechanical harvesting. Trans. ASAE, 14(4), 734-737.