STUDY ON MECHANICAL MASS-HARVESTING OF PEARS

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ABSTRACT

Harvesting is one of the most labor-intensive operations in pear production. The manual harvesting cost for green Bartlett pears amounts to 13% of the total operating cost and to 85% of the total harvest cost per acre, which includes hauling to the packinghouse. 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, pear 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 pears 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 pear production. A 2012 UC ANR pear production cost report (Norton et al., 2011) estimated the manual harvesting cost for green Bartlett pears at $1,239/acre. This translates to 85% of the total harvest cost, which includes hauling to the packinghouse, and 13% of the total operating 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, pear growers face a great need for mechanical harvesting solutions.

In principle, pears could be harvested mechanically using tree shaking and fruit catching systems. However, excessive fruit damage is the major obstacle in adopting such methods. Although improvements in the design of shaker and the catching systems can somewhat improve fruit quality, it is well known that the 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. In other crops like apples, cherries and peaches, tree architectures, like Y-shaped trees with few overlapping scaffolds are easier to harvest mechanically. Prototype limb-shaking harvesters for such trees have been developed. However, existing pear orchards consist of traditional, large trees, and such systems cannot be applied.

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

Four objectives were pursued. 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. Preliminary pear drop experiments were performed to verify the feasibility of the conceived approach. Finally, an SCRI mechanical harvesting pre-proposal was submitted in fall 2017.

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.

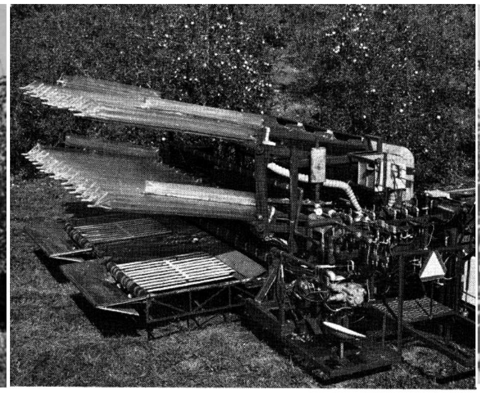
Fig. 2. Millier et al., 1973.

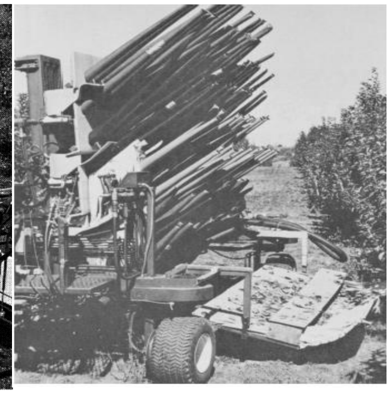
Fig. 3. Mehlschau et al., 1977.

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 fruits (pear, apple, orange). The prototype and recorded video frames from the pear drop experiments are given in Fig. 2.

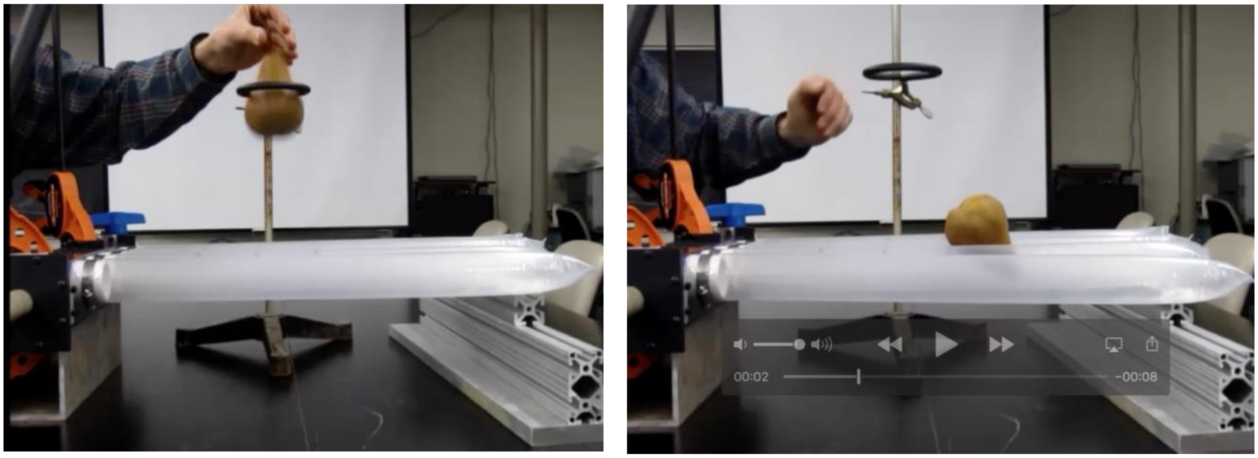

Fig. 2. Pear drop experiment; first and last frame of experiment's video.

A Bosc pear of diameter equal to 3'' (7.62 cm) and weight 0.61 lbs (278 gr) 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 the pear. The 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 heavy fruits, such as pears, and explore ranges of parameters for doing so. The drop results are given in Table 1.

Table 1: Pear 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 base (inches)		
Pressure: Max, 34 inwc	Drop #	4	7	10
Drop Height: 8''	1	b,c	c	c
	2	b,c	c	c
	3	b,c	b,c	c
	4	b,c	c	t
	5	b,c	b,c	b,c
		Distance from finger base (inches)		
Pressure: Max, 34 inwc	Drop #	4	7	10
Drop Height: 12''	1	b,c	c	c
	2	b,c	b,c	t
	3	b,c	b,c	t
	4	b,c	c	c
	5	b,c	b,c	c

DISCUSSION

The preliminary results were very promising. It seems that inflated fingers at pressure 1.2 psi could intercept pears 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 fruit fell through in some cases; these fruits would be intercepted by fingers at one level below. This provides also design guidelines on finger length and required number of booms along the canopy. Due to the shape of the pear, no rolling was observed, as with other fruits. Some limited bouncing did occur before the pear 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 two months of this one-year project, which ends on March 31, 2018. Also, pear tree canopies are being digitized in order to quantify the canopy penetration resistance of boom-finger systems. Finally, a pre-proposal was submitted for SCRI funding and evaluation is pending.

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