A rapid prototyping design tool for pear harvest-aid platforms utilizing 3D fruit reachability and kinematic modeling

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‘Digital harvesting’

Tree training system & orchard layout

3D fruit distributions

Machine kinematics

Design tool

Worker/robot kinematics
Funding sources for 2014-15

- Canning Peach Mechanization Research Fund
- California Pear Advisory Board
Goals for 2014-15

- Develop tree digitization system
- Digitize trees and fruits
- Mass-harvesting analysis
- Robotic picking analysis
Digitization frame v1 and v2
Results: High-density trellised Bartlett trees; Ruddick Ranch, Ukiah, CA.
10 Digitized Trees and fruits in a row
2D distribution of fruits as a function of distance from the trellis plane into the canopy
Mass harvesting analysis
Mass harvesting

- Trunk shaking
  - Good fruit removal/trunk-safe (Topper Van Loben Sels)
  - Too much bruising.
  - What if fruits could be intercepted?
Insertable multilevel catching

- An old idea that should be revisited
  - Impact trunk shaking; improved design.

Mehlschau 1974

Millier 19743 (60-90%)
Insertable multilevel catching

- How many tines?
- What configuration?
- What sizes?
- Branch interference?
- Fruit drop collisions?
- ...
Falling fruit collision statistics
# Falling fruit collision statistics

<table>
<thead>
<tr>
<th>Height</th>
<th>Number of fruits</th>
<th>Bruised fruits</th>
<th>Intact fruits</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 0.5 m</td>
<td>4.33</td>
<td>84.6%</td>
<td>15.4%</td>
</tr>
<tr>
<td>0.5 - 1 m</td>
<td>22.33</td>
<td>76.1%</td>
<td>23.9%</td>
</tr>
<tr>
<td>1 - 1.5 m</td>
<td>43.33</td>
<td>57.7%</td>
<td>42.3%</td>
</tr>
<tr>
<td>1.5 - 2 m</td>
<td>50.67</td>
<td>63.8%</td>
<td>36.2%</td>
</tr>
<tr>
<td>2 - 2.5 m</td>
<td>23.00</td>
<td>62.3%</td>
<td>37.7%</td>
</tr>
<tr>
<td>0 - 2.5 m</td>
<td>143.67</td>
<td>62.8%</td>
<td>37.2%</td>
</tr>
</tbody>
</table>
Robotic harvesting analysis
Multiple-arm robots

- Could actuator arrays achieve high picking efficiency and speed?
- How many arms?
- Degrees of freedom?
- What configuration?
- What sizes/envelopes?
- How do branches interfere?
- ...
Robot reachability analysis

- Percentage of fruits reachable by a simple extending arm (1 dof).
## Robot reachability analysis

<table>
<thead>
<tr>
<th>Height</th>
<th>Number of fruits</th>
<th>Not reachable</th>
<th>Reachable</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 0.5 m</td>
<td>13</td>
<td>7.7%</td>
<td>92.3%</td>
</tr>
<tr>
<td>0.5 - 1 m</td>
<td>67</td>
<td>37.3%</td>
<td>62.7%</td>
</tr>
<tr>
<td>1 - 1.5 m</td>
<td>130</td>
<td>29.2%</td>
<td>70.8%</td>
</tr>
<tr>
<td>1.5 - 2 m</td>
<td>152</td>
<td>27.6%</td>
<td>72.4%</td>
</tr>
<tr>
<td>2 - 2.5 m</td>
<td>69</td>
<td>39.1%</td>
<td>60.9%</td>
</tr>
<tr>
<td>0 - 2.5m</td>
<td>431</td>
<td>28.2%</td>
<td>71.8%</td>
</tr>
</tbody>
</table>
Harvesting efficiencies

- Simulated models of robot arms
  - S4 ABB 2.8 (bottom), Puma 560.
Both robotic harvesters could reach 100% of fruits

Time to pick a fruit and place it in bin

- Puma 560: between 2.5 s and 3.5 s
- ABB S4 2.8: between 4.2 s to 7.8 s.
Next steps

- More data and analysis
- Proposal submitted to NRI-USDA with CMU
- Proposal will be re-submitted to USDA-AFRI
- Collaboration/proposals with WSU.
THANK YOU!

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