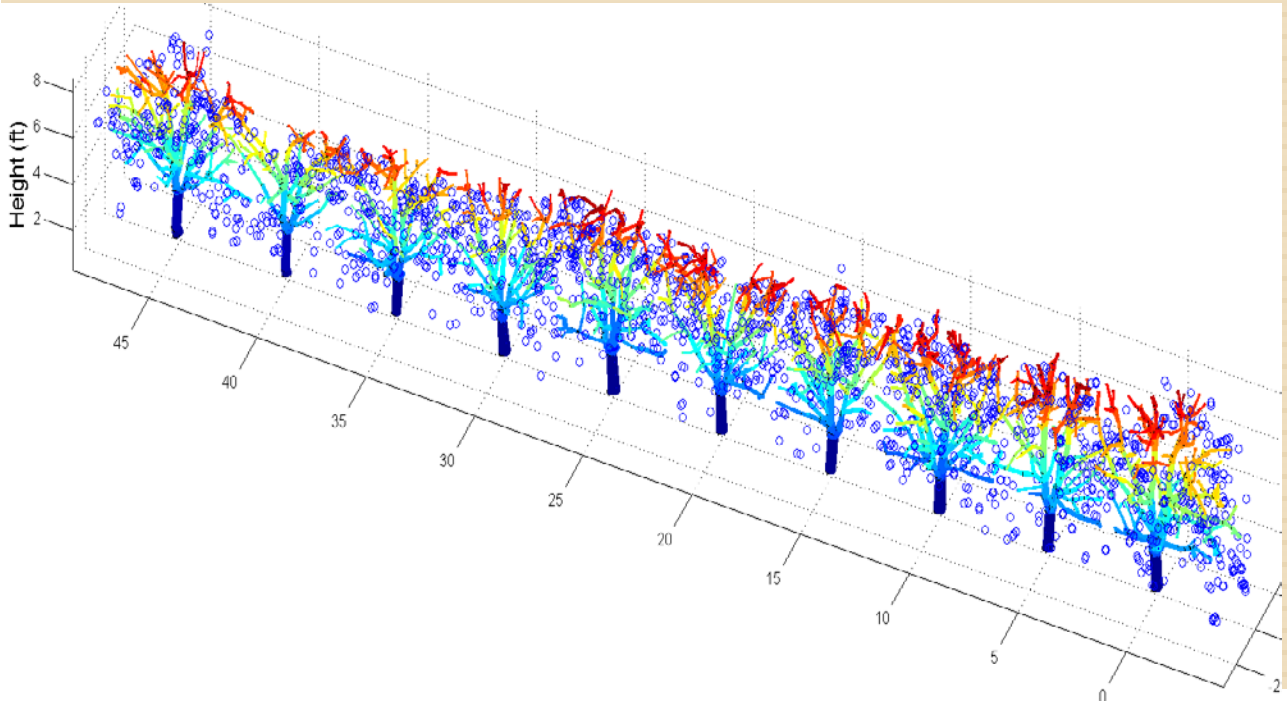


1

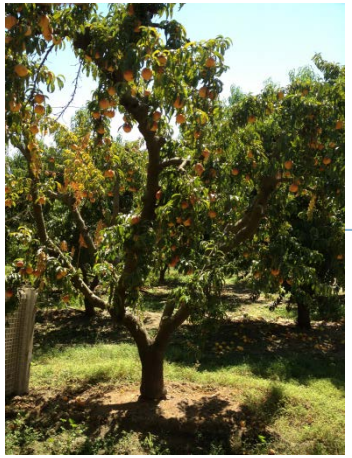
A rapid prototyping design tool for pear harvest-aid platforms utilizing 3D fruit reachability and kinematic modeling

Pis: Stavros Vougioukas[1], David Slaughter[1], Fadi Fathallah[1], Rachel Elkins[2], Chuck Ingels[3]
Ph.D. student: Rajkishan Arikapudi

[1]Biological and Agricultural Engineering Department, University of California, Davis.
[2]University of California Cooperative Extension, Lake and Mendocino Counties.
[3]University of California Cooperative Extension, Sacramento County.

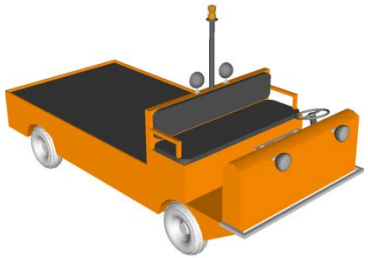
‘Digital harvesting’

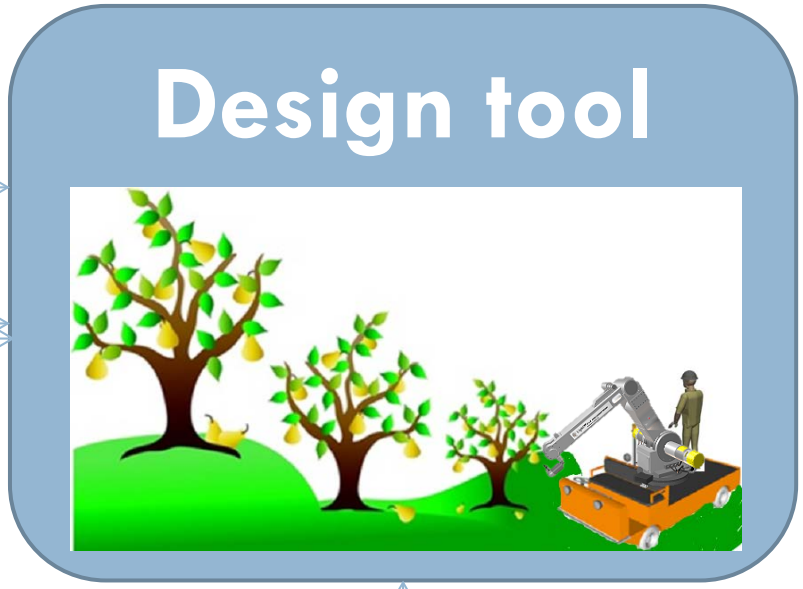
Tree training system & orchard layout



3D fruit distributions

Machine kinematics





Worker/robot kinematics

Funding sources for 2014-15

Canning Peach Mechanization Research Fund

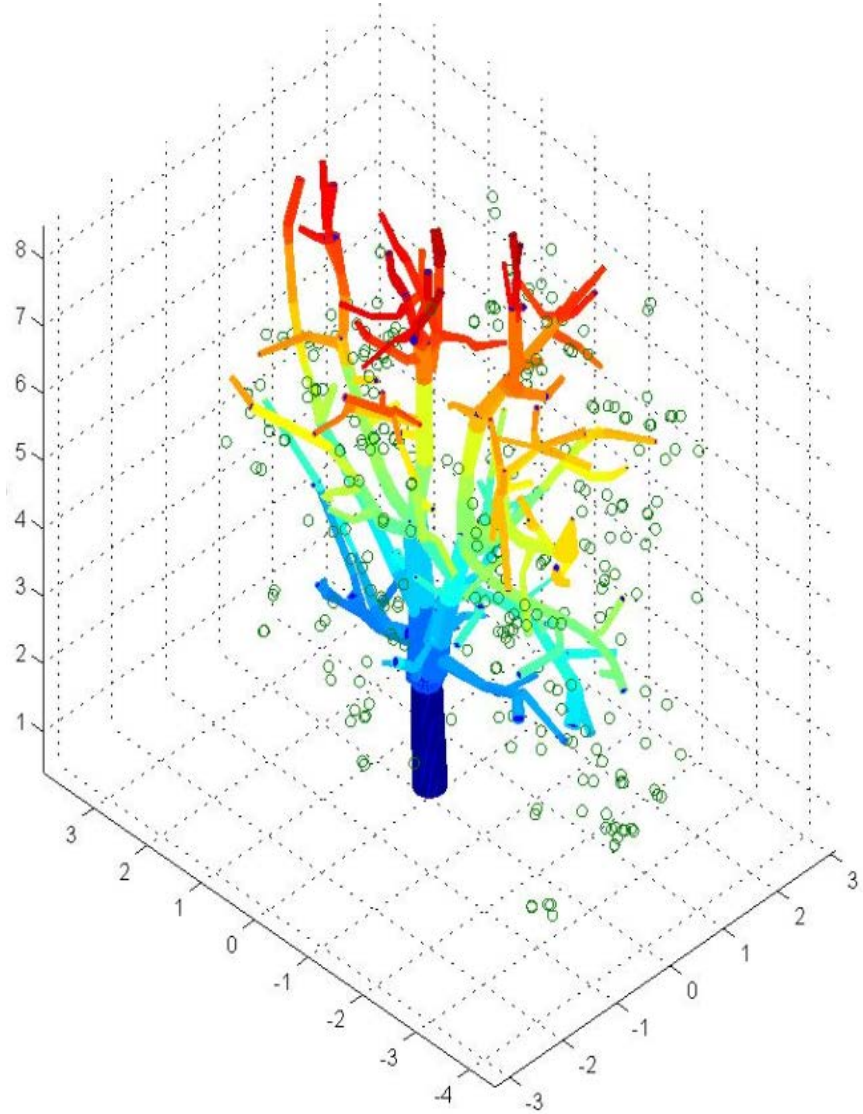
California Pear Advisory Board

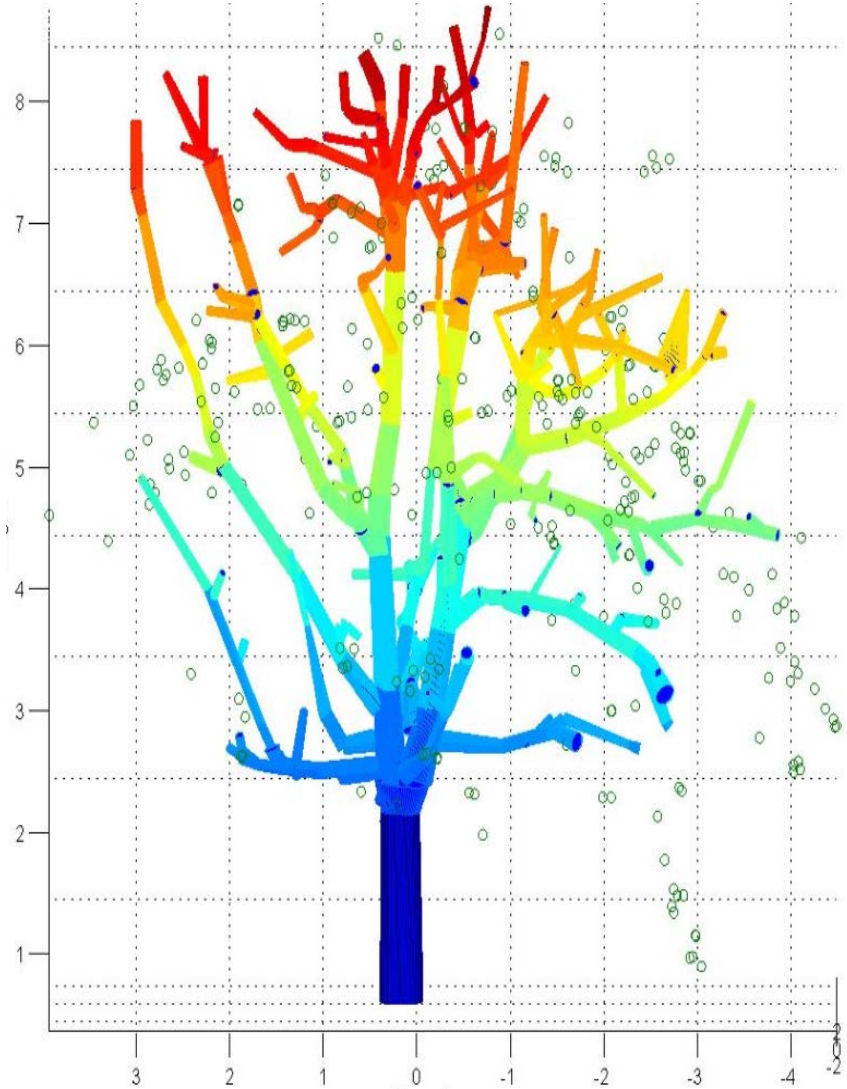
Goals for 2014-15

- Develop tree digitization system
- Digitize trees and fruits
- Mass-harvesting analysis
- Robotic picking analysis

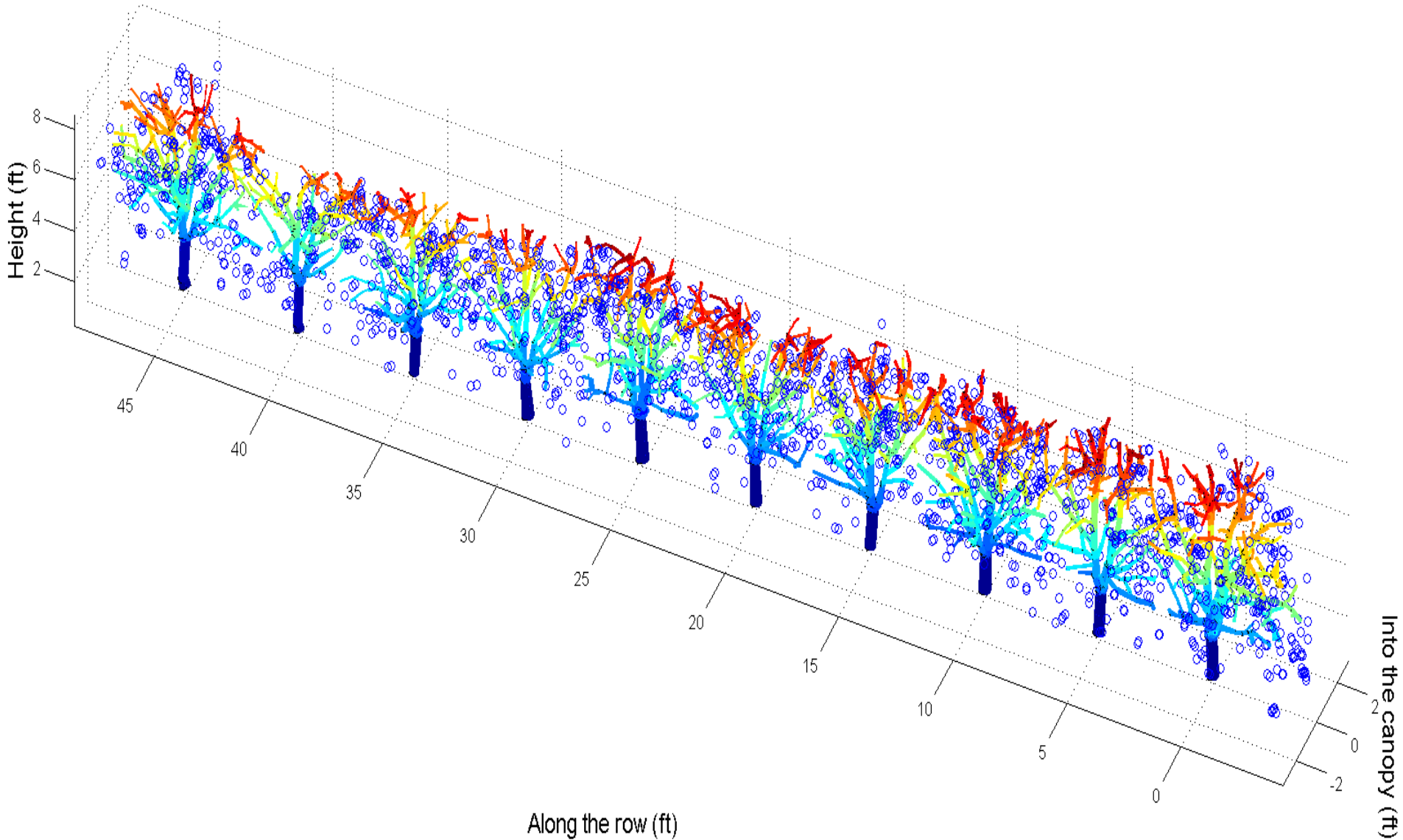
Digitization frame v1 and v2

Results: High-density trellised Bartlett trees; Ruddick Ranch, Ukiah, CA.

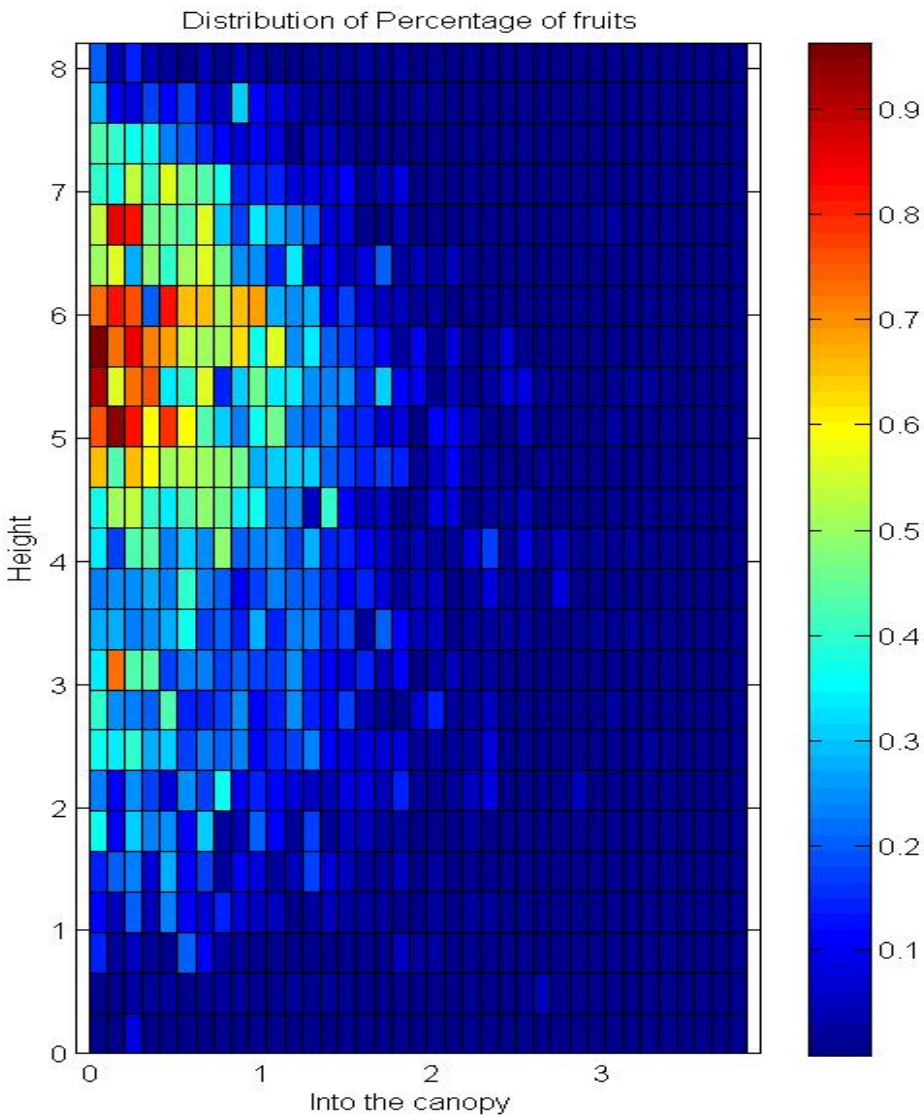


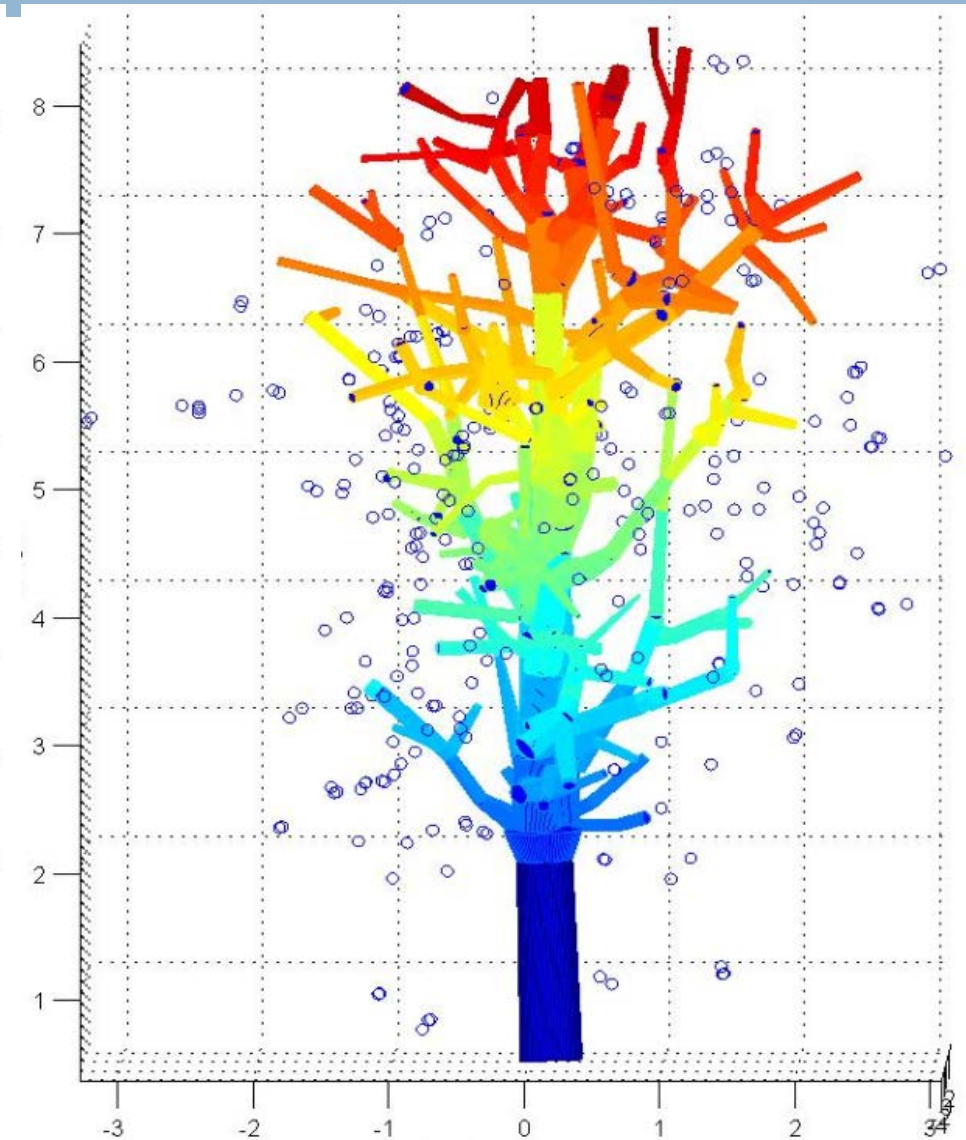


10 Digitized Trees and fruits in a row



2D distribution of fruits as a function of distance from the trellis plane into the canopy





Mass harvesting analysis

Mass harvesting

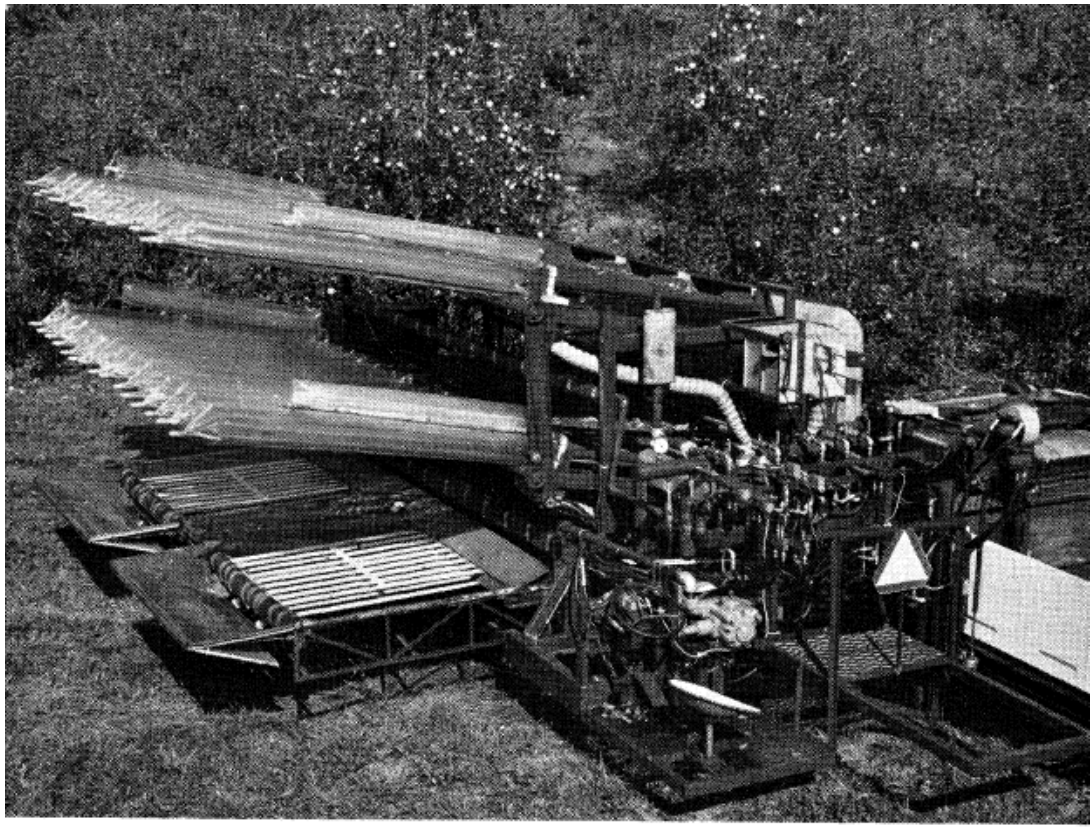
- Trunk shaking
  - Good fruit removal/trunk-safe (Topper Van Loben Sels)
  - Too much bruising.
  - What if fruits could be intercepted?

Insertable multilevel catching

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

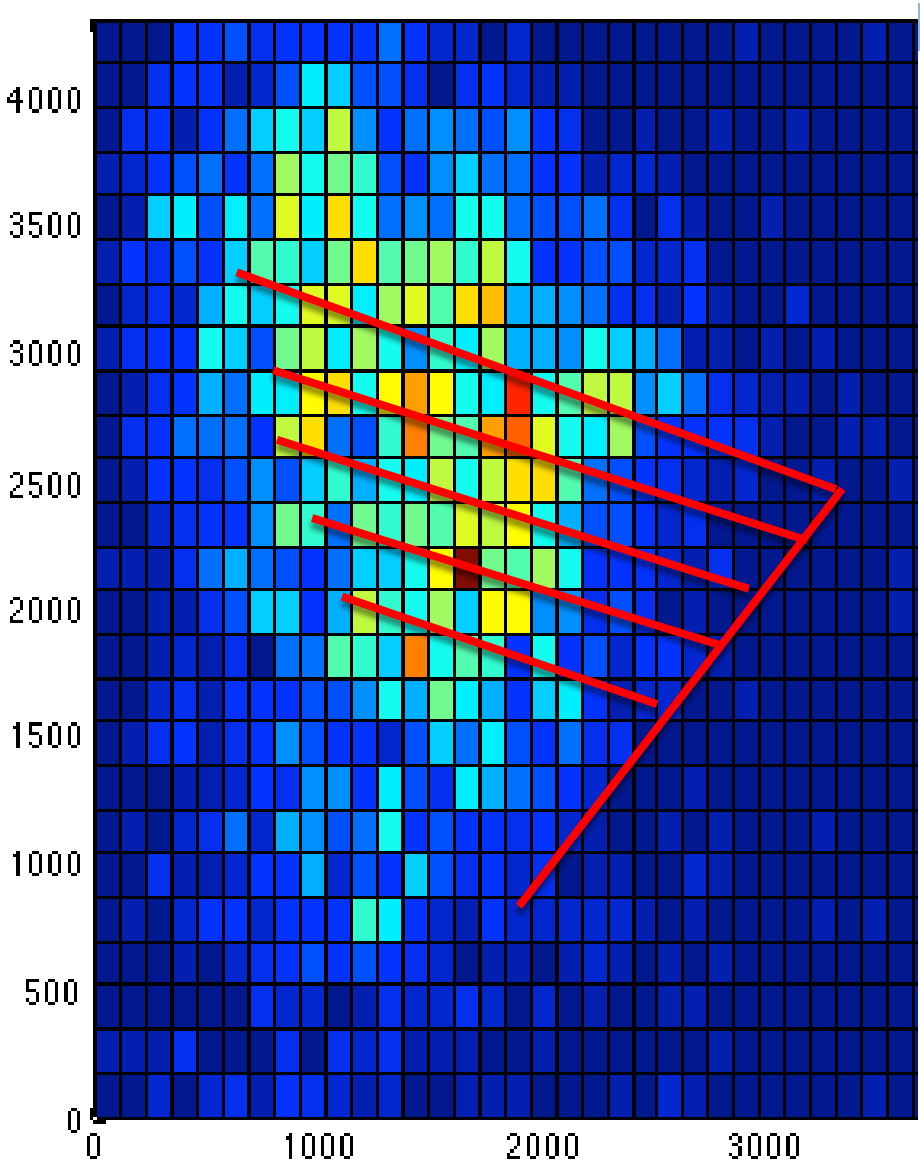
Mehlschau 1974

Millier 19743 (60-90%)

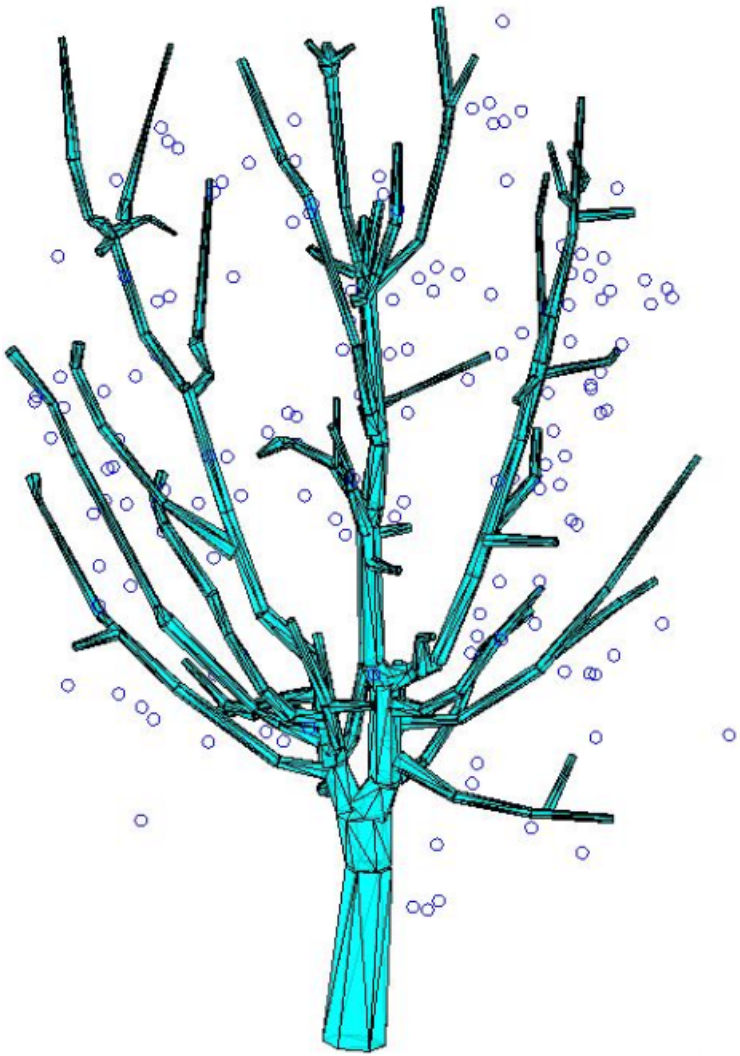


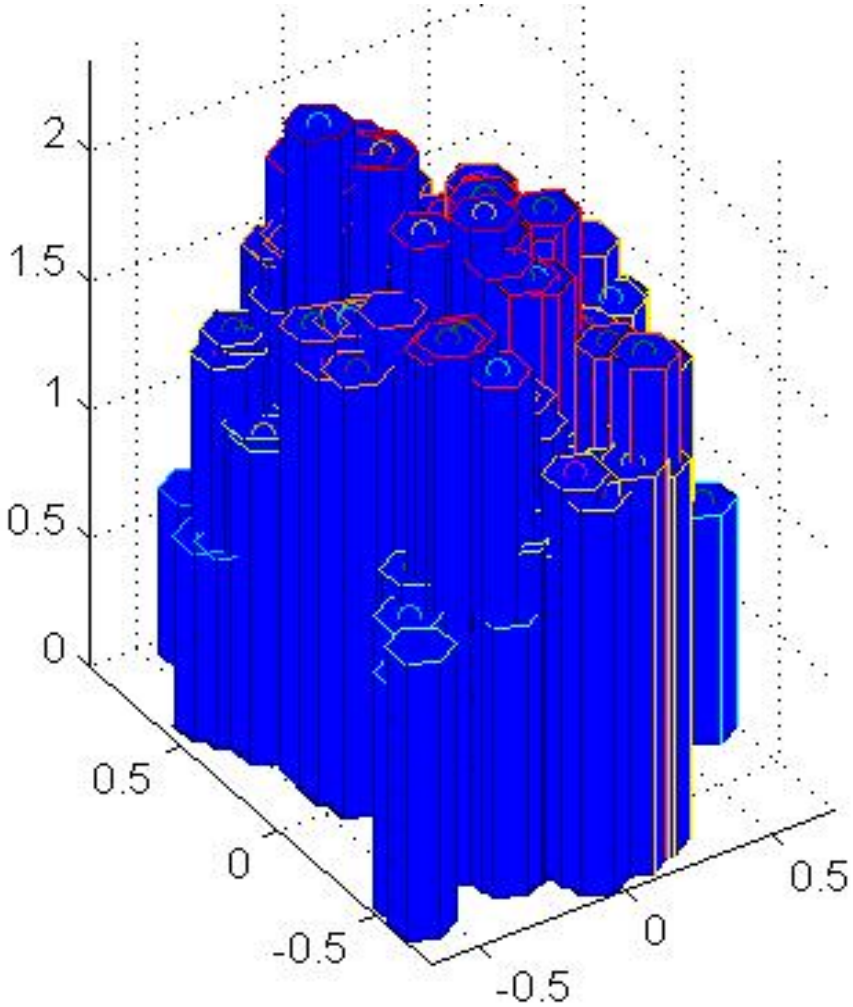
Insertable multilevel catching

- How many tines?
- What configuration?
- What sizes?
- Branch interference?
- Fruit drop collisions?
- …

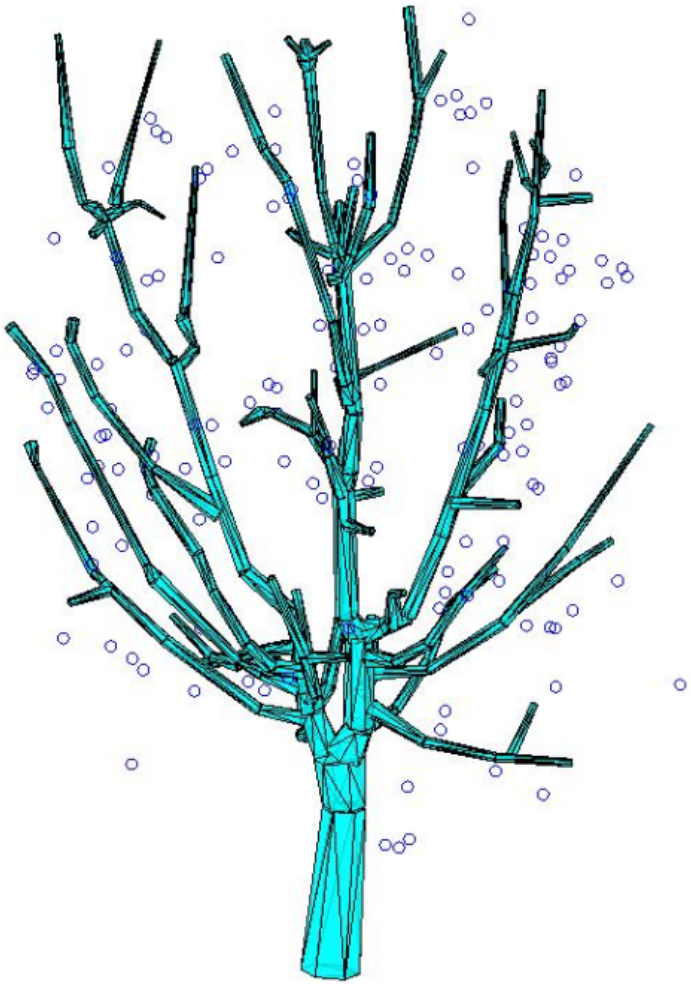


Falling fruit collision statistics





Falling fruit collision statistics



Height	Number of fruits	Bruised fruits	Intact fruits
0 - 0.5 m	4.33	84.6%	15.4%
0.5 - 1 m	22.33	76.1%	23.9%
1 - 1.5 m	43.33	57.7%	42.3%
1.5 - 2 m	50.67	63.8%	36.2%
2 - 2.5 m	23.00	62.3%	37.7%
0 - 2.5 m	143.67	62.8%	37.2%

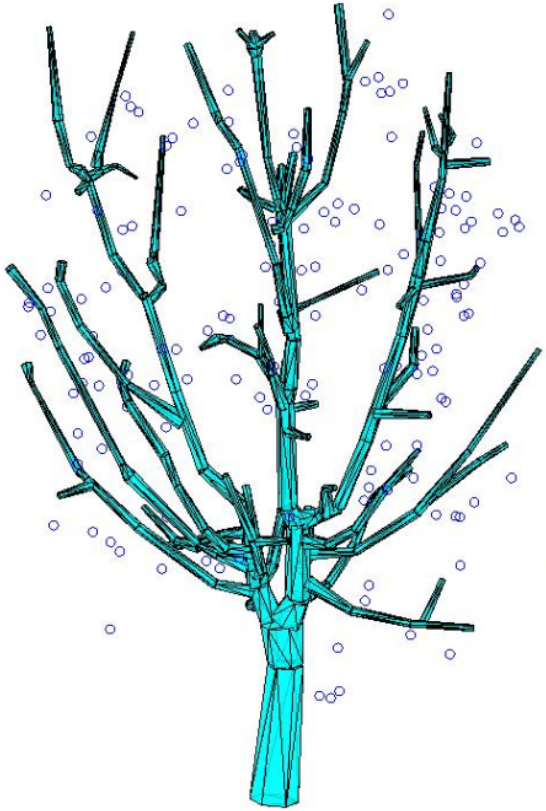
Robotic harvesting analysis

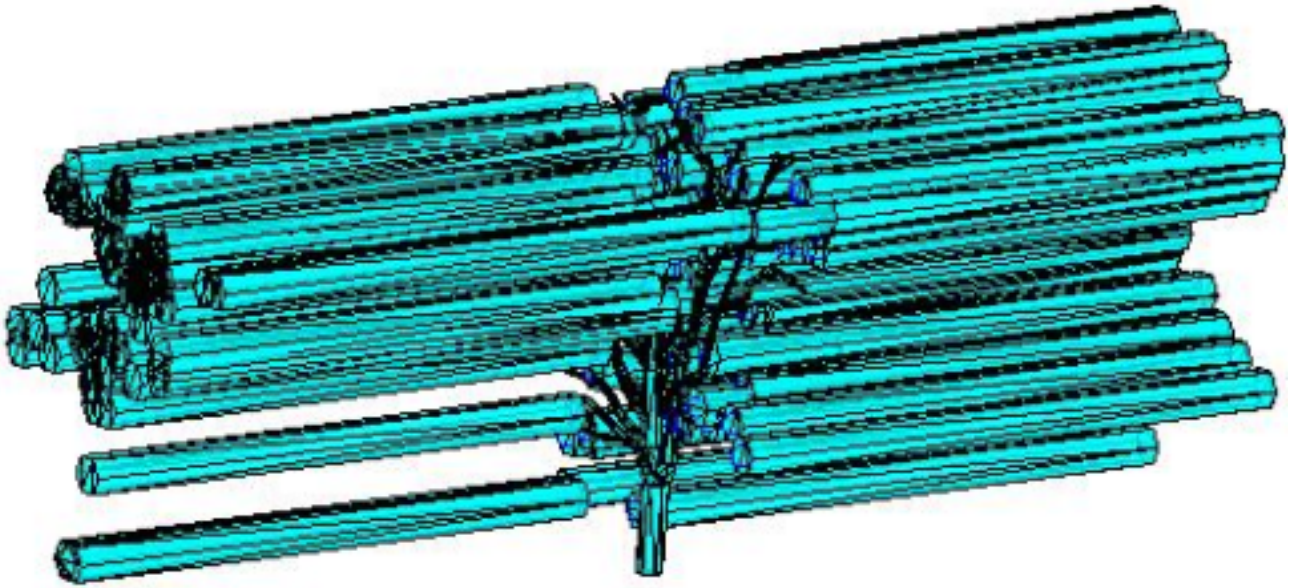
Mutiple-arm robots

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

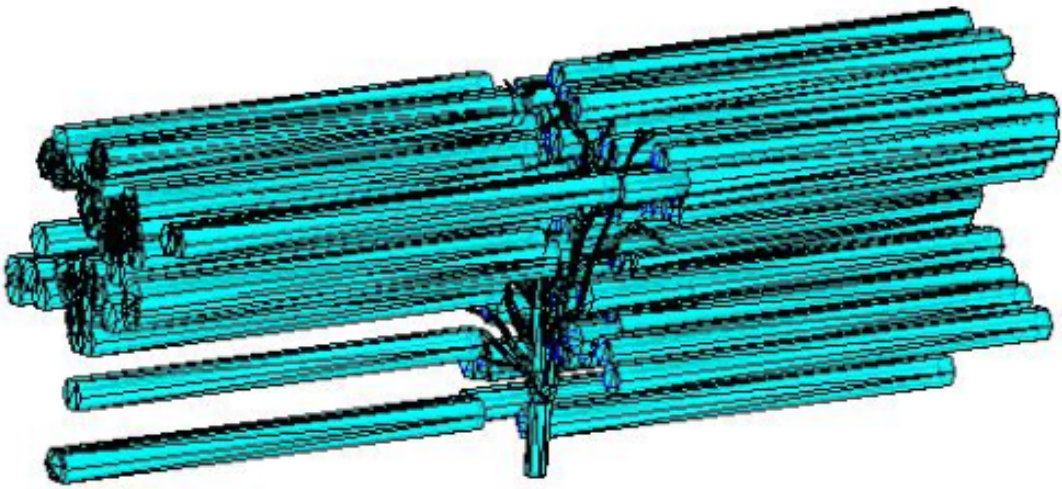
Robot reachability analysis

- Percentage of fruits reachable by a simple extending arm (1 dof).





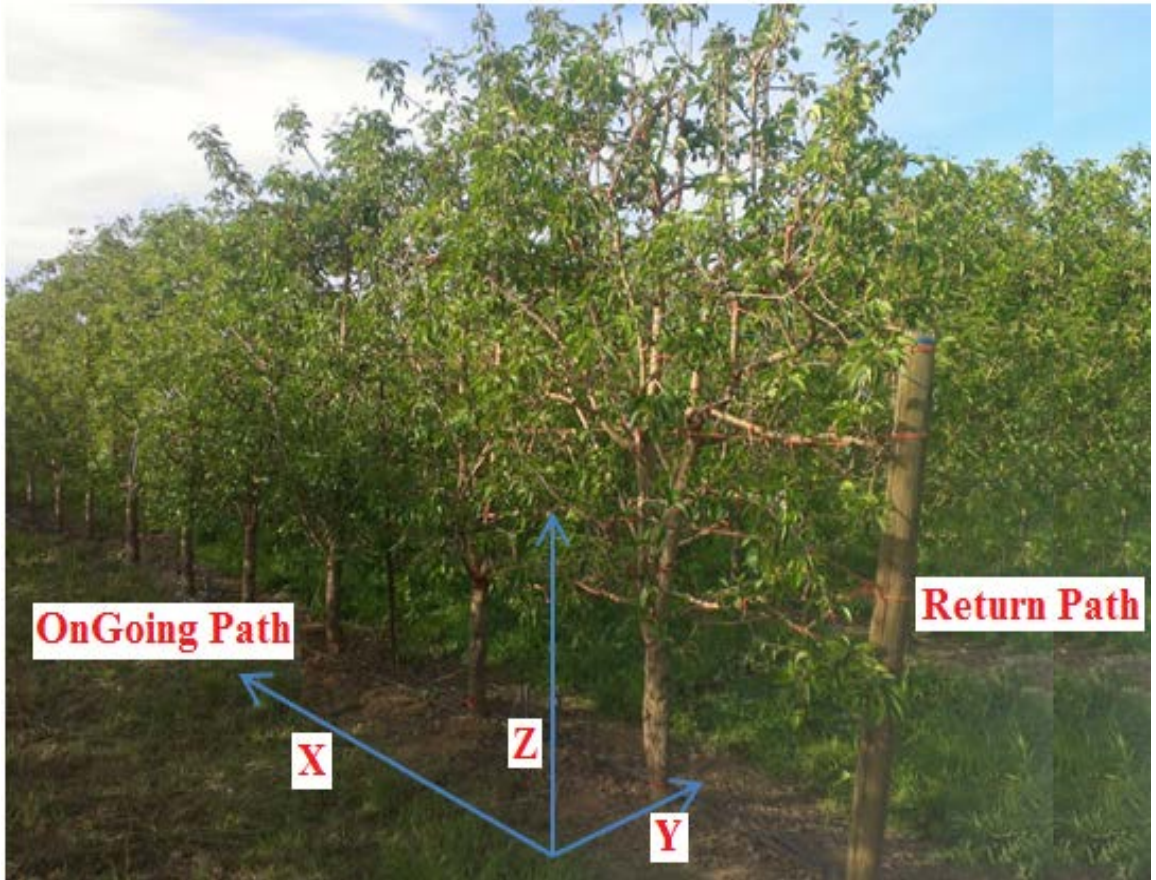
Robot reachability analysis



Height	Number of fruits	Not reachable	Reachable
0 - 0.5 m	13	7.7%	92.3%
0.5 - 1 m	67	37.3%	62.7%
1 - 1.5 m	130	29.2%	70.8%
1.5 - 2 m	152	27.6%	72.4%
2 - 2.5 m	69	39.1%	60.9%
0 - 2.5m	431	28.2%	71.8%

Harvesting efficiencies

- Simulated models of robot arms
  - S4 ABB 2.8 (bottom), Puma 560.



Harvesting efficiencies

- 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!

Acknowledgements:

Numerous California growers.

Farm advisors:
Rachel Elkins, UCANR Extension, Lake and Mendocino Counties
Chuck Ingels, UCANR Extension, Sacramento County

Students: Rajkishan Arikapudi.
Post-doctoral researchers: Adrien Durand-Pettiteville
Visiting scholars: Turker Saracoglu

svougioukas@ucdavis.edu