Advanced Mechanization and Automation for Specialty Crop Production

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What decade was each machine built in?

1968

2008
One more typical example...

Courtesy of: Ernst Van Eeghen, Church Brothers/True Leaf Farms
Mechanization for specialty crops – harvesting in particular – is lagging..

- **Societal and political reasons**
  - Federal and state R&D funding had stopped for ~ 30 yrs.

- **Economics**
  - Huge variety of crops demands custom solutions;
  - Fragmentation discourages private investment in R&D;
  - Labor has been cheap and available.

- **Technical**
  - Fresh market fruits and vegetables:
    - Must be harvested gently to look ‘perfect’ on the shelf;
    - Must be often harvested selectively;
    - Must be harvested efficiently and quickly.
• Shake-catch causes unacceptable damage.

• Robotic fruit picking efficiency & throughput are low.

• Harvest-aids are often inefficient.
Current research projects

- Robot-aided harvesting.
- Virtual harvesting.
FRAIL-BOTS:
Fragile cRop hArvest-alding mobiLe roBOTS

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Manual harvesting

An expensive, labor-intensive operation associated with:

- Non-productive crop transport time in excess of 20%.
- Slipping accidents during crop transport.
- Ergonomics related musculoskeletal disorders.
Approach

Adopt and extend concepts from *Flexible Manufacturing Systems.*
Robot-aided harvesting: Project Goals

- Lay the scientific and technical foundation for teams of co-robots that:
  - Act as an intelligent courier service that transports harvested crops;
  - Reduce non-productive time;
  - Protect worker health by reducing slipping accidents;
  - Attend to harvesting ergonomics;

- Explore economic feasibility;
- Demonstrate prototype system in field conditions.
Worker awareness

- Worker positions, postures, body motions, and picking rate assessed via wearable and robot sensors.
Robot dispatching

• **Minimize:**
  - Worker waiting times (efficiency);
  - Vibration & crop-transport time (postharvest quality);
  - Energy consumption (robot field-life).
Virtual harvesting

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Canning Peach Mechanization Research Fund

California Pear Advisory Board
Can we build cost-effective fruit harvesting machines for existing tree architectures?
How do different training systems affect mechanized harvesting?

- Standard
- Double leader
- V-hedge
- Open tatura
- Palmette
- Super Spindle
3D fruit-map (Bartlett pears)
Methodology
Estimated 3D fruit distribution
Large Open-Vase Trees

Radial distance of fruits from trunk
Harvesting Large Open-Vase Trees

• Robotic picking at high speed is ‘challenging’;
  ➢ Arms with reach of 8-10 ft would be too massive to be fast enough;
  ➢ Significant fruit-to-fruit travel;
  ➢ Severe branch interference.

• How can we evaluate alternative designs?
High-density Trellised Trees (Bartlett pears)
High-density Trellised Trees (Bartlett pears)
High-density Trellised Trees (Bartlett pears)

- Robot arms with reach of ~ 3ft can be fast (1 cycle/s).
Design Issues

- Could actuator arrays achieve high picking efficiency and speed?
- How many arms (~ 30k/arm)?
- How much do branches interfere?
- What types of arms?
- In what configuration?
- ...
- How can we evaluate alternative designs?
Machine development process

- Relies heavily on field testing.
- Costly & slow.
- Funding usually runs out...
Model-based design

- Machine design
- Model
- Virtual Machine
- Breeding
- Cultivation/training
Virtual harvesting

Tree geometries & orchard layout

3D fruit distributions

Machine & worker models

Design tool
Virtual harvesting
Picking efficiency and throughput
What could the future bring?

• Functional-structural plant models.
Thank you!

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