The challenges for developing robots for horticulture

Josse De Baerdemaeker
KU Leuven
Value chain: input of precision and digital technologies

- Genetics & breeding
- Production
- Postharvest
- Marketing

- Cultivation technology:
  - Quantitative genetics
  - Mechanized crop management
  - Robotics
  - Sensor-based decision making

- Product segregation technologies
- Traceability technology
- Market access
- Consumer preference

Ian Ferguson: ACPA 2017, Hamilton, New Zealand
Robotics and technology in fruit/vegetable production

**Focus points**

- Reduce costs, increase yield and productivity
  - Labour shortage
    - Planting, pruning, crop care, harvest…
  - Environmental concerns and regulations
  - Grading, sorting and storage (facilities management)
  - The ‘ideal market’
- Harvest of high quality data
  - Better information
  - Better decisions
A few new names ...

Robots
Autonomous platforms
Mechanical weeding
Heat weeding
Steam weeding
Electric weeding
Selective spray / spread
Orchard treatments
Large fruit harvesting
Small/soft fruit harvesting
Vegetable harvesting

- **Bonirob**, platform, several applications in development, (Bosch, Stuttgart, Germany)
- **Vinescout**, platform, commercial prototype ready in 2019, (U. Polytechnica, Valencia, Spain)
- **Naio**, 4 different weeding robots, vegetables, vineyards, field tests FR, UK, US, > 100 units sold, (Toulouse, France)
- **Zasso**, electric weed control, near commercial, (Aachen, Germany)
- **Ecorobotix**, selective spray (Lausanne, Swiss)
- **Bilberry**, selective weed control, field tests in FR, NL, Aus, (Paris, France)
- **Jacto**, AgriBot platform, JAV II autonomous orchard sprayer, commercially used in Eucalyptus, (Pompeia, SP, Brazil)
- **Octinion**, soft fruit harvesting, world leader in performance, closest to commercial, (Leuven, Belgium)
- **Cerescon**, asparagus harvester, test market in 2018, orders in hand for 2019, (Eindhoven, Netherlands)
Outsiders coming in …

<table>
<thead>
<tr>
<th>Who?</th>
<th>$ Bn</th>
<th>Home base</th>
<th>Skill base</th>
<th>Entry in Ag.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOSCH</td>
<td>~$90</td>
<td>Stuttgart, Germany</td>
<td>Automotive, Appliances etc</td>
<td>Bonirob, Greenhouse management</td>
</tr>
<tr>
<td>AIRBUS</td>
<td>~$80</td>
<td>Toulouse, France</td>
<td>Aerospace, Remote sensing</td>
<td>Remote sensing, robots...</td>
</tr>
<tr>
<td>ENGIE</td>
<td>~$75</td>
<td>Paris, France</td>
<td>Energy production, efficiency</td>
<td>Processing plants, orchard automation</td>
</tr>
<tr>
<td>Panasonic</td>
<td>~$65</td>
<td>Osaka, Japan</td>
<td>Plant factories, refrigeration in retail</td>
<td>Seed-to-fork integration vegetables</td>
</tr>
<tr>
<td>ABB</td>
<td>~$35</td>
<td>Zurich, Switzerland</td>
<td>Engineering, automation, Energy grids, robots</td>
<td>Processing plants, automation</td>
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Marc Vanacht – July 2018
Crop Robotics

Effective automatic treatment, harvest...

Sensing (stress, maturity, disease, size, location...)

End effector (gripper, spray nozzle, contact sensor, ...)

Manipulation (movement of end effectors, detectors...)

Intelligence

Crop and user specifications

GIS, GPS, GAP
Prime mover

Logistics, Market information
Universal robot platform
Early floral bud thinning of fruit trees

- Reducing the excess number of floral buds
  - Increases regularity of the yield
  - Results in higher quality fruits

- Thinning of pear trees
  - Mostly done by hand
    - Labor intensive
    - Time-consuming
    - Health issues

- Evolution towards mechatronical thinning
Towards mechatronical solutions?

(Baugher et al., 2010)

(Rosa et al., 2008)

(Schupp et al., 2008)

(Damerow et al., 2009)
Flower bud thinning of pears

- Detection and counting of the buds
Bud removal using air puff

Compressed air → Nozzle type

Air pressure → Distance

Floral bud

Phenological Stage
Growing season

Main fruiting branch
Multi-nozzle field trials of pear bud thinning
Air puff field trials
Accurately count and grade apples while on the tree

http://www.omniaprecision.co.uk/fruit-vision/
Monitoring fruit development for better management

ADVANTAGE:

- HIGHER TEMPORAL RESOLUTION (Daily)
- HIGHER RESOLUTION OF BIOLOGICAL CHANGES
- AUTOMATED LOGGING time-lapse.
Evolution of the fruit weight

Estimated weight per bunch

weight (gr)

date


0,00 100,00 200,00 300,00 400,00 500,00 600,00 700,00

weight

P3 P5

Evolution of the fruit weight

weight
Precision Agriculture and Robotics Environmental Benefits: Integrated pest control

- Process:
  - Pest damage reduction in fruit or wine production based on population dynamics and IPM (Integrated Pest Management)

- PA Technology:
  - Detect crop damaging pests, insects
  - Monitor the spatial population dynamics
  - Link the level of pest to potential crop loss
  - Use predators

- Expected benefits:
  - Reduction in pesticide use up to ? %
  - Reduction of sprayed area of ? %
Selective spraying for disease control
Fungicide reduction 20-30% (max 80%)

Adapted from R. Oberti
UAV- Drones

• Flying robots?
  • Between rows in orchards?
    • Inspection
      • Disease detection
      • Crop protection
      • Crop load, quality
    • Harvest??
  • From above
    • Vigor
      • Stress (drought), weeds
      • Uniformity
  • Find potential frost pockets or problem areas for the irrigation system.
Detection of internal fire blight infections
Time to spray?
Send in the drones!

• An area of 4,000 to 6,000 square metres can be covered in just 10 minutes (Agras line of DJI, China)
• Can carry up to 10 kilograms of pesticide
• Battery life is only about 20 minutes
• How to deal with closed canopies?

https://www.youtube.com/watch?v=hEpaD6sbsoo
http://www.orchardandvine.net/innovations/time-to-spray-send-in-the-drones/
https://www.youtube.com/watch?v=dui89B7GqG0
Robots on land and in the air…

- Aerial observations of canopy for stress/no-stress assessment
- Below the canopy conditions for disease development may be favourable
- Coordinate observations and treatments
  - Small robots on the ground
  - Drones in the air
- Communication for decision making and deployment
Harvester concept: platform

- Portal tractor running over the rows:
  - Based on concept of existing grape and olive harvesters
  - Picking both sides of a row simultaneously
  - Tunnel for
    - Sensing under controlled illumination and background conditions
    - Shielded working space for the manipulators
    - Protection of sensors and manipulators from rain, wind,…

![Tractor Diagram](image)
Apple harvest (1)
Apple harvest (2)

Abundant Robotics
in The Good Fruit Grower

https://youtu.be/mS0coCmXiYU

Apple harvest (3)

https://www.youtube.com/watch?v=UaL3UxUcIKY
FFRobotics presents Robotic Fruit Harvester  https://www.ffrobotics.com/
Robotics for fruit harvest

• How to pick an apple
  • With/without stem: variety dependent
  • What does the market expect?

• Additional advantages for manager
  • Machine knows where the fruit is and in which part of the canopy
  • Detailed yield or production info, even within the canopy
  • Box-information is very precise: how much product is available and which quality
  • Canopy model and production model can refine the harvest strategy
Trees for robotic harvesting

Prepare the trees for robotic harvesting

• Tree shape and pruning
• High density planting
• High light interception
• Fruit or bud thinning
• All fruit have a good commercial value
• Uniformly ripe fruit simplifies harvesting

These tree adaptations also benefit manual picking!
Simpler Structure for Mechanization

4-D Structure  3-D Structure  2-D Structure

Q Zhang, Washington State University
Effect of tree on harvest success
Sweet pepper harvest robot

Sweet pepper harvest robot

Suggestions for improvement

- Conveyor belt + harvest trolley AGV
- Fingers to catch fruit may push plant away: a redesign is recommended.
- Certain sequences of arm movement can be easily speeded up.
- Adopted growing system will increase success rate (e.g. fruit and leave pruning, special variety).

Expected performance: 15 sec/fruit; detection 40-85%

Tomato harvesting robot: GRoW

16000 Greenhouse robotic workers?

Tomato harvesting robot: Panasonic

Strawberry harvest

RoboticsPlus Kiwi Picker

Sugar Pea Harvesting

Optical detection and image processing challenge

White Asparagus Harvest

https://www.cerescon.com/NL/home
Broccoli Harvest

RoboVeg

Uses a standard tractor,

https://youtu.be/zi0Zcxef1pI
Weed control

Transplanting vegetables

• Gives crop an early start over weeds
• Selectivity at planting may make better uniformity at harvest
• Early detection of diseases
• Planting under favourable soil conditions

• Large diversity of trays is challenging
Weed control: transplanting vegetables
A high capacity planting robot

• The robot picks a row of plants every 5 seconds.
• High capacity of the robot (depending on tray type): +/- 14 000 plants an hour.
• The robot handles small plants as well as big plants.
A high capacity planting robot

- Good ergonomics
- Easy to operate
- Highly maneuverable
Weeding

Bonirob from Bosch

- manipulator
- weed detection camera
- weeding tool
- visual servoing camera
Robotic micro-dose spraying: ecorobotics

- 20x less herbicide per application
- Rapid robotic arms with sprayers
- Up to 30% less expensive than standard treatments
- Improved yield: no herbicide left on the crops
- Conserves the organic life of the soil, with limited soil compaction (130 kg)

Switzerland
Digital Farmhand

Robotic weeding: NAIO

Digital Herbicide: using high-voltage electric power – the clean solution: zasso, rootwave


http://rootwave.com/technology/
Weed control and robotics

• The ‘convenience’ of herbicide use is under discussion

• Physical methods of weed control require:
  • Good detection and discrimination between crop and weed
  • High working rate either in one machine or in swarms (multiple machines)

• Expectations for robotic weed control:
  • Killing the weed ?
  • Slowing down weed growth rate and density such that crops can develop ?

• Smart robots make use of population dynamics
Large amounts of data require knowledge analytics, for farm information, integration and decision making. Check on the execution.
Precision (Bio-) Process monitoring

- Simple example: orchards, fruit size or number along a row

- Large INTER (between row) variability
- detect (often small) abnormal INTRA (within row) variability
Challenges

• Robotics has a better chance when we also look at the crop
  • Architecture
  • Fruit distribution
  • Uniformity of ripening or market-readiness
  • Detachment and harvesting mechanisms
• Cultivation method
  • Adaptation and innovation
  • Co-engineering of crop scientists and robotics specialists
• Methods for detection
  • Hardware, software…
  • Crop properties: color, gloss, NIR, fluorescence
Challenges

- Size of the market
  - Specialty crops, low production areas
  - Different cultivation in different locations
- Seasonality of robotics use
- Autonomous scouting robots in field conditions: changing weather/illumination
- Working rate and timeliness of operations
- Payload either by weight or volume, (especially for once over harvest)
  - Swarms of robots .....
Fear of Robots?

• ‘We'll have space bots with lasers, killing plants’: the rise of the robot farmer. Tiny automated machines could soon take care of the entire growing process. Fewer chemicals, more efficient? where’s the downside? Because its innovations (of The Small Robot Company) uncouple food growing from big machinery and huge fields, they should – in theory – allow small- and medium-sized farms to prosper, and strip vast agribusinesses of their competitive advantage. (The Guardian Sat 20 Oct 2018 08.00 BST)

• GeorgeMonbiot @GeorgeMonbiot (12:49 AM - 21 Oct 2018) https://twitter.com/georgemonbiot/status/1053916195005579264

A more likely outcome is that large, capital-intensive farms will use robots to gain further advantages over small, labour-intensive farms. When has automation favoured the artisan over the industrialist?
Conclusions

1. Robots have arrived, today and now, in many sizes, shapes & forms…
2. Robots challenge our current practices and knowledge
3. Robots challenge crop scientists (and the other way around)
4. Robots reshape the plantations
5. Robots reshape agriculture and the countryside
6. Robots will/must support management
7. The Future will accelerate …even more in agriculture
Thank you for your attention