SMARTHORT

AHDB

SmartHort 2019

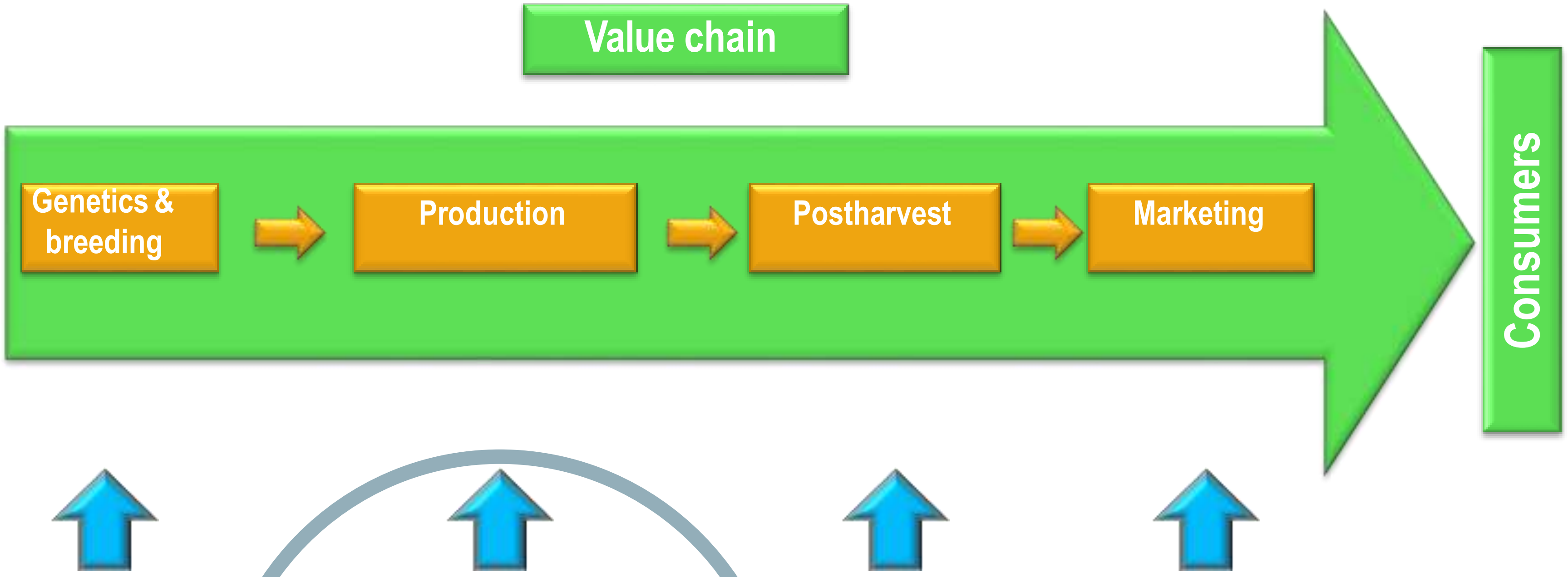
The challenges for developing robots for horticulture

Josse De Baerdemaeker

KU Leuven

HORTICULTURE

Value chain: input of precision and digital technologies



Quantitative genetics

High throughput screening

Cultivation technology

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)

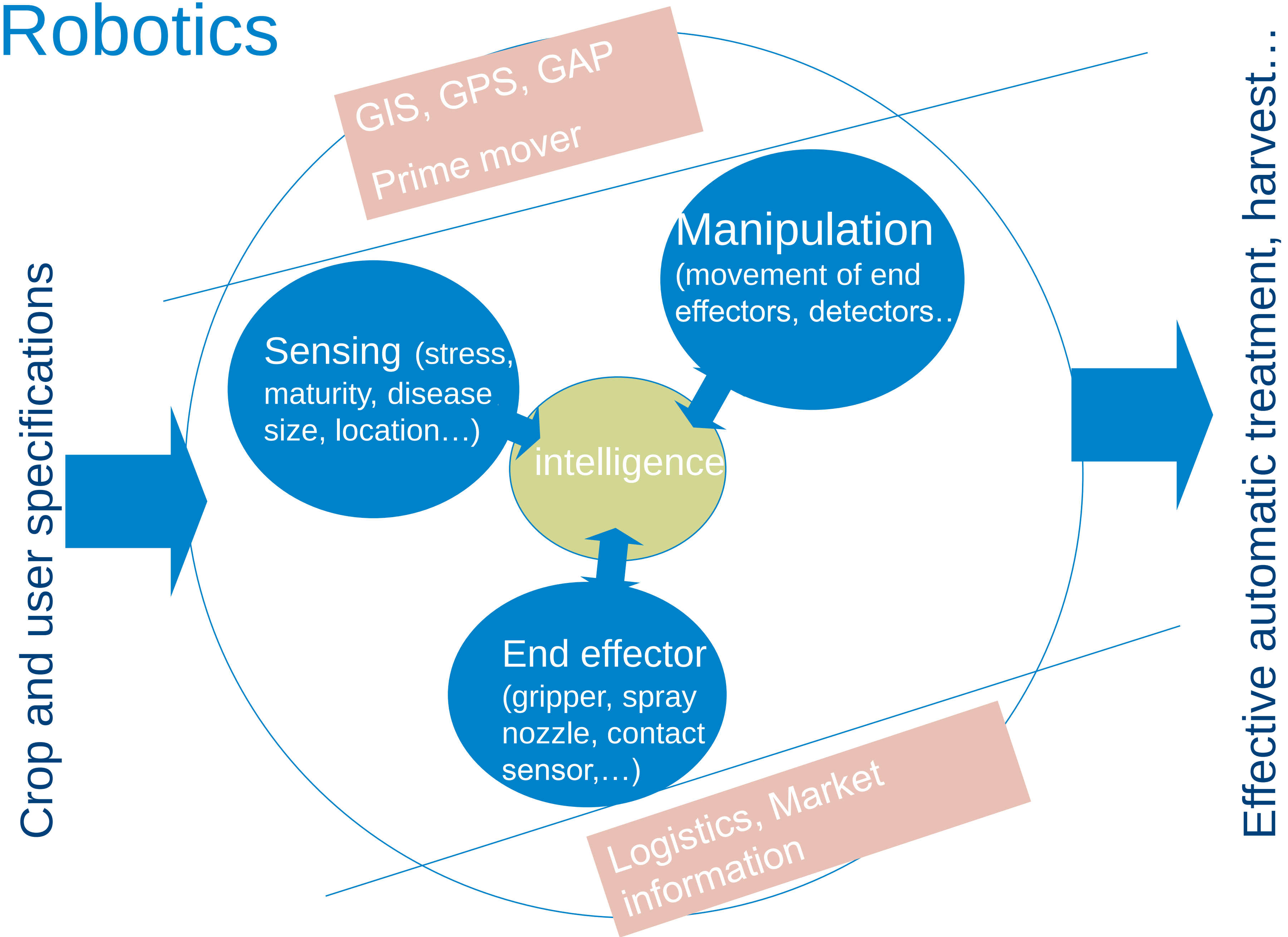
Outsiders coming in …

AHDB

Who?	$ Bn	Home base	Skill base	Entry in Ag.
BOSCH Invented for life	~$90	Stuttgart, Germany	Automotive, Appliances etc	Bonirob, Greenhouse management
AIRBUS	~$80	Toulouse, France	Aerospace, Remote sensing	Remote sensing, robots…
engie	~$75	Paris, France	Energy production, efficiency	Processing plants, orchard automation
Panasonic	~$65	Osaka, Japan	Plant factories, refrigeration in retail	Seed-to-fork integration vegetables
ABB	~$35	Zurich, Swizerland	Engineering, automation, Energy grids, robots	Processing plants, automation

NVIDIA? Amazon? Siemens? Hitachi? Fujitsu? IBM?
Google? Unimog? Bombardier? Samsung? M Benz? Toyota?

Crop Robotics



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)

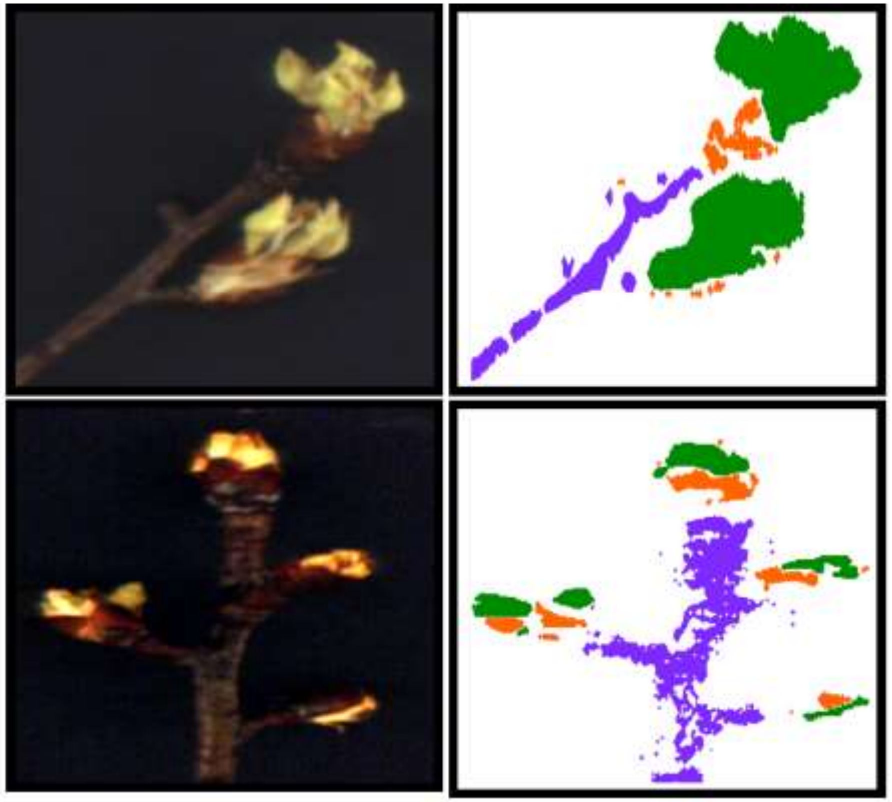
(Rosa et al., 2008)

(Schupp et al., 2008)

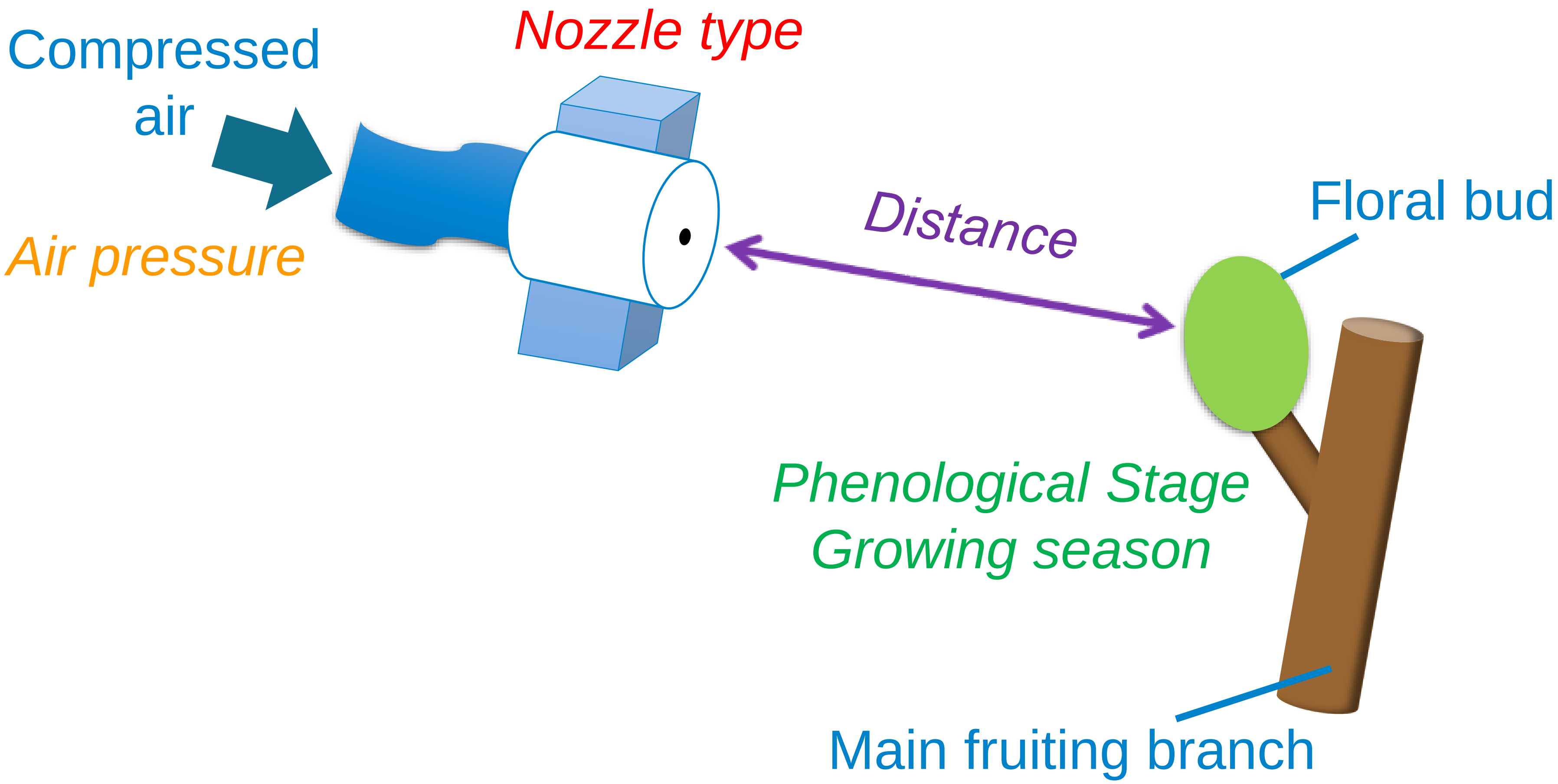
(Damerow et al., 2009)

Flower bud thinning of pears

- Detection and counting of the buds



Bud removal using air puff

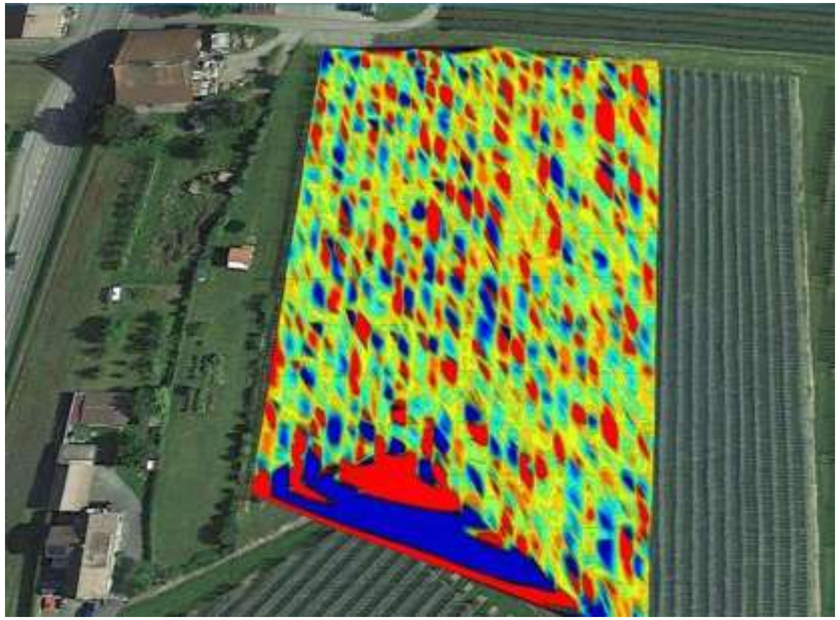


Multi-nozzle field trials of pear bud thinning

Air puff field trials

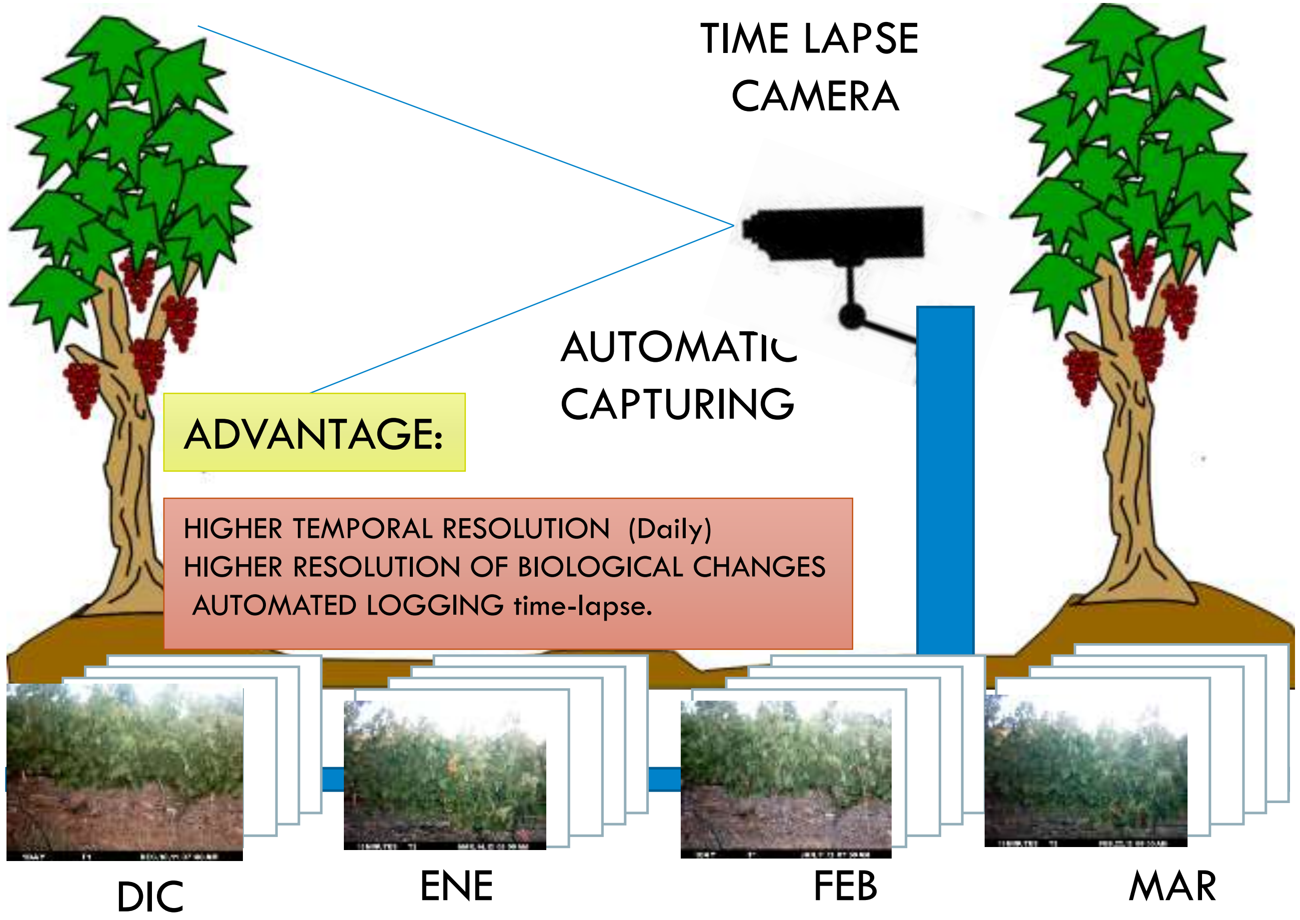
Accurately count and grade apples while on the tree

http://www.omniaprecision.co.uk/fruit-vision/

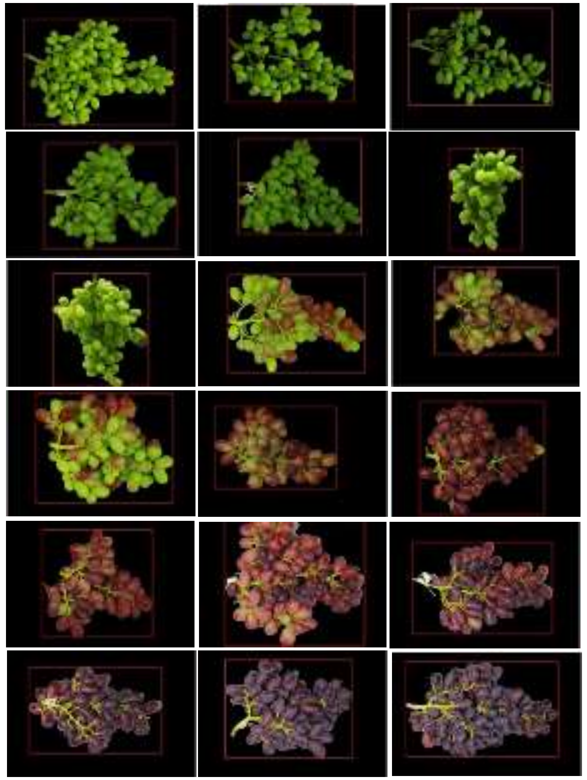


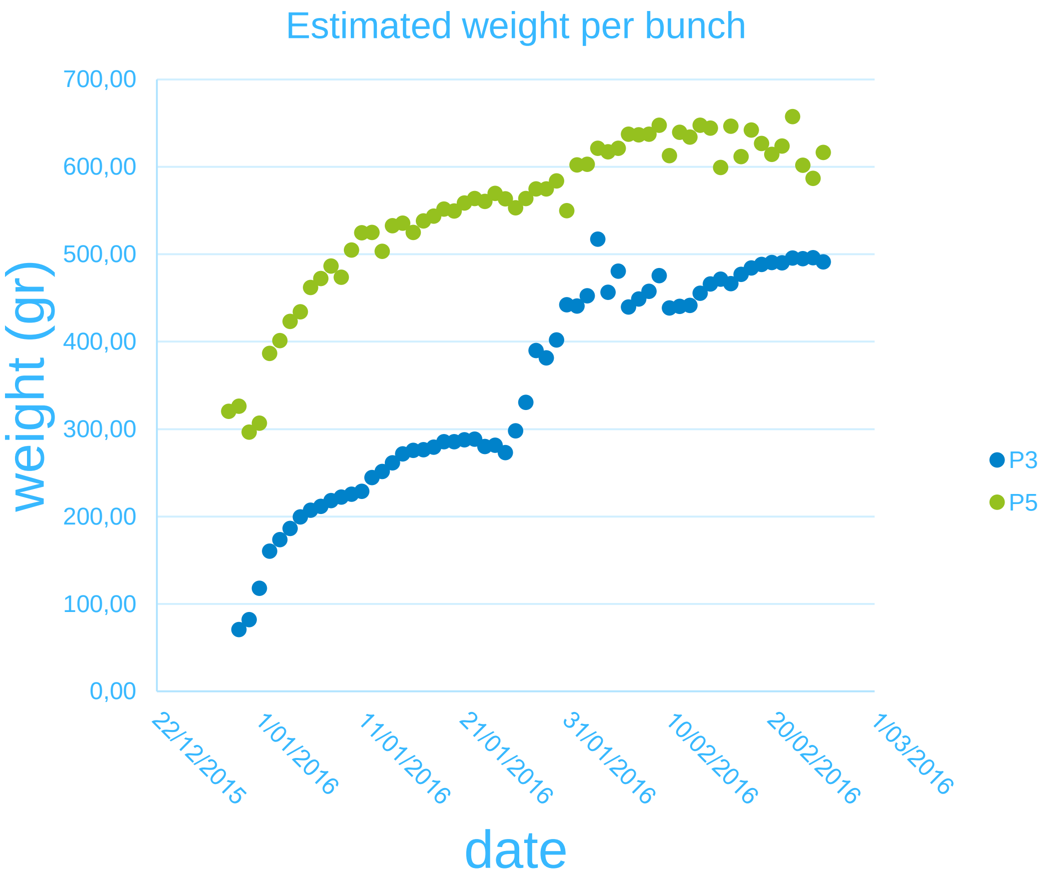
http://www.intelligentfruitvision.com/solutions/

Monitoring fruit development for better management



Evolution of the fruit weight





Precision Agriculture and Robotics
Environmental Benefits: Integrated pest control

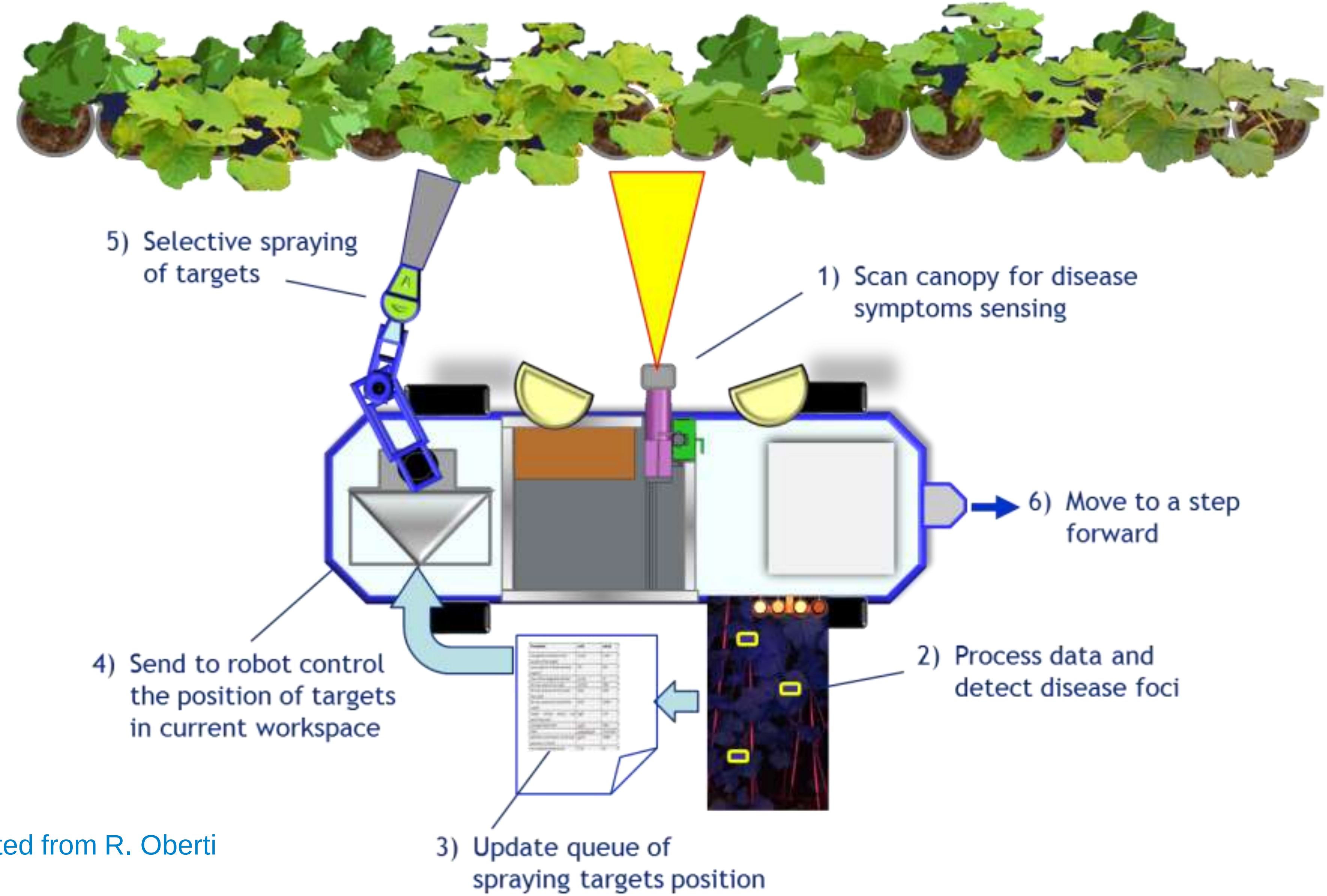
- Process:
    - Pest damage reduction in fruit or wine production based on population dynamics and IPM (Integrated Pest Management)

- 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%)

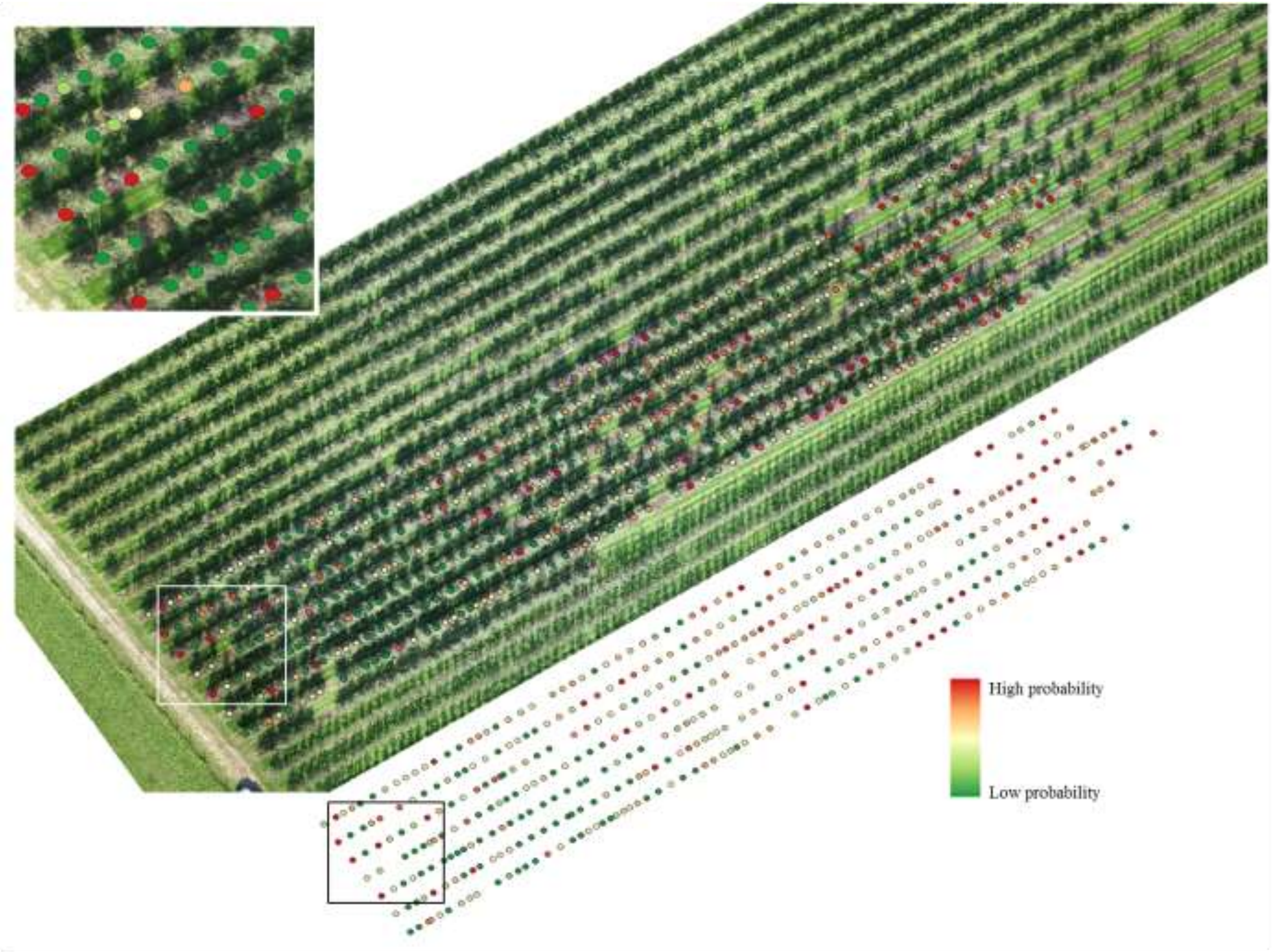


Adapted from R. Oberti

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



https://blog.vito.be/remotesensing/drones-for-early-fire-blight-detection, **Stephanie Delalieux** 23.05.2017

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 https://www.youtube.com/watch?v=dui89B7GqG0

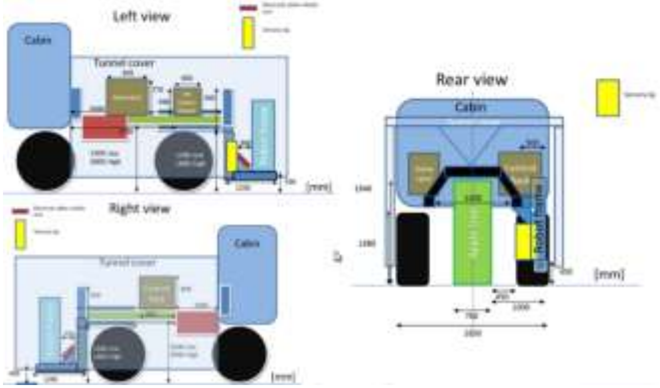
http://www.orchardandvine.net/innovations/time-to-spray-send-in-the-drones/ 1 July 2017

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,…



3-finger gripper KU Leuven

Apple harvest (1)

Apple harvest (2)

Abundant Robotics
in The Good Fruit Grower

https://youtu.be/mS0coCmXiYU

http://home.bt.com/tech-gadgets/future-tech/abundant-robotics-apple-picking-robot-11364178851823#

Apple harvest (3)

https://www.youtube.com/watch?v=UaL3UxUclKY

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

http://www.sweeper-robot.eu/11-news/48-sweeper-demonstrated-its-harvesting-robot-for-the-first-time - accessed 16/08/2018

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%

http://www.sweeper-robot.eu/dissemination/presentations/6-Sweeper_pitch_results-Jos-handout.pdf - accessed 16/08/208

Tomato harvesting robot: GRoW

METOMOTION

16000 Greenhouse robotic workers ?

https://metomotion.com/

http://www.freshplaza.com/article/196826/New-tomato-harvest-robot-GRoW-being-tested-in-the-greenhouse 6/20/2018

Tomato harvesting robot: Panasonic

https://news.panasonic.com/global/stories/2018/57801.html - May 23, 2018

Strawberry harvest

Octinion

http://octinion.com/news/press-release-octinion-presents-world%E2%80%99s-first-strawberry-picking-robot

RoboticsPlus Kiwi Picker

ACPA 2017, Hamilton, New Zealand

http://www.roboticsplus.co.nz/robotic-hands-snatch-kiwifruit-future

Sugar Pea Harvesting

Optical detection and image processing challenge

Stoelen et al., Low-Cost Robotics for Horticulture: A Case Study on Automated Sugar Pea Harvesting. ECPA July 2015

White Asparagus Harvest

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

CERESCON
HARVESTING INNOVATION

http://vcbt.be/wp-content/uploads/2018/03/groentecongres-tips-voor-witte-asperge.pdf

https://www.colruyt.be/nl/lekker-koken/de-kijker/lentegroenten/asperges

Broccoli Harvest

https://youtu.be/zi0Zcxef1pI

Weed control

Young S.L., Meyer G.E., Woldt W.E. (2014) Future Directions for Automated Weed Management in Precision Agriculture.
In: Young S., Pierce F. (eds) Automation: The Future of Weed Control in Cropping Systems. Springer, Dordrecht

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

AHDB

A high capacity planting robot

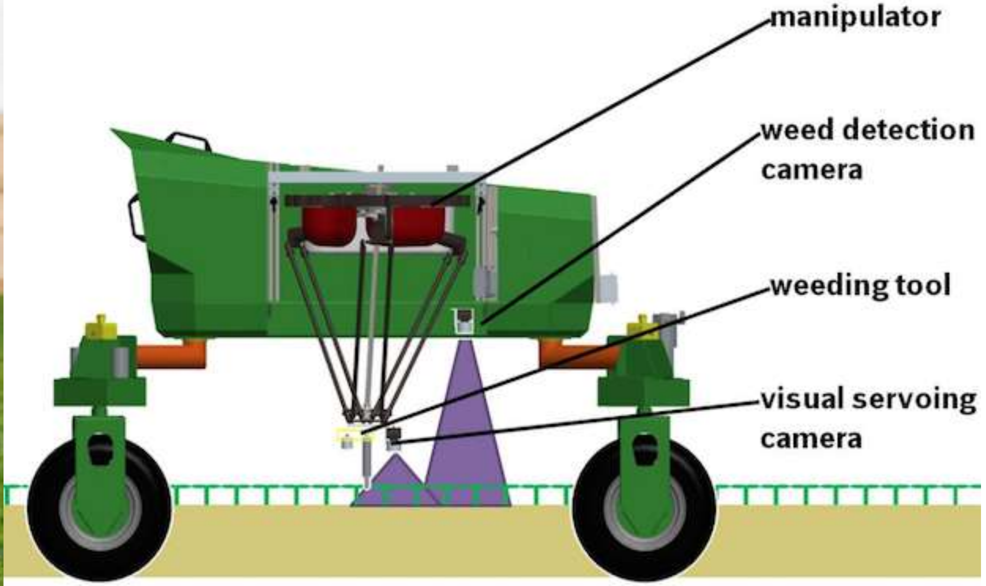
- The robot picks a row of plants every 5 seconds.
- High capacity of the robot (depending on tray type): +/- 14 000 plants an hour.
- The robot handles small plants as well as big plants.

A high capacity planting robot

- Good ergonomics
- Easy to operate
- Highly maneuverable

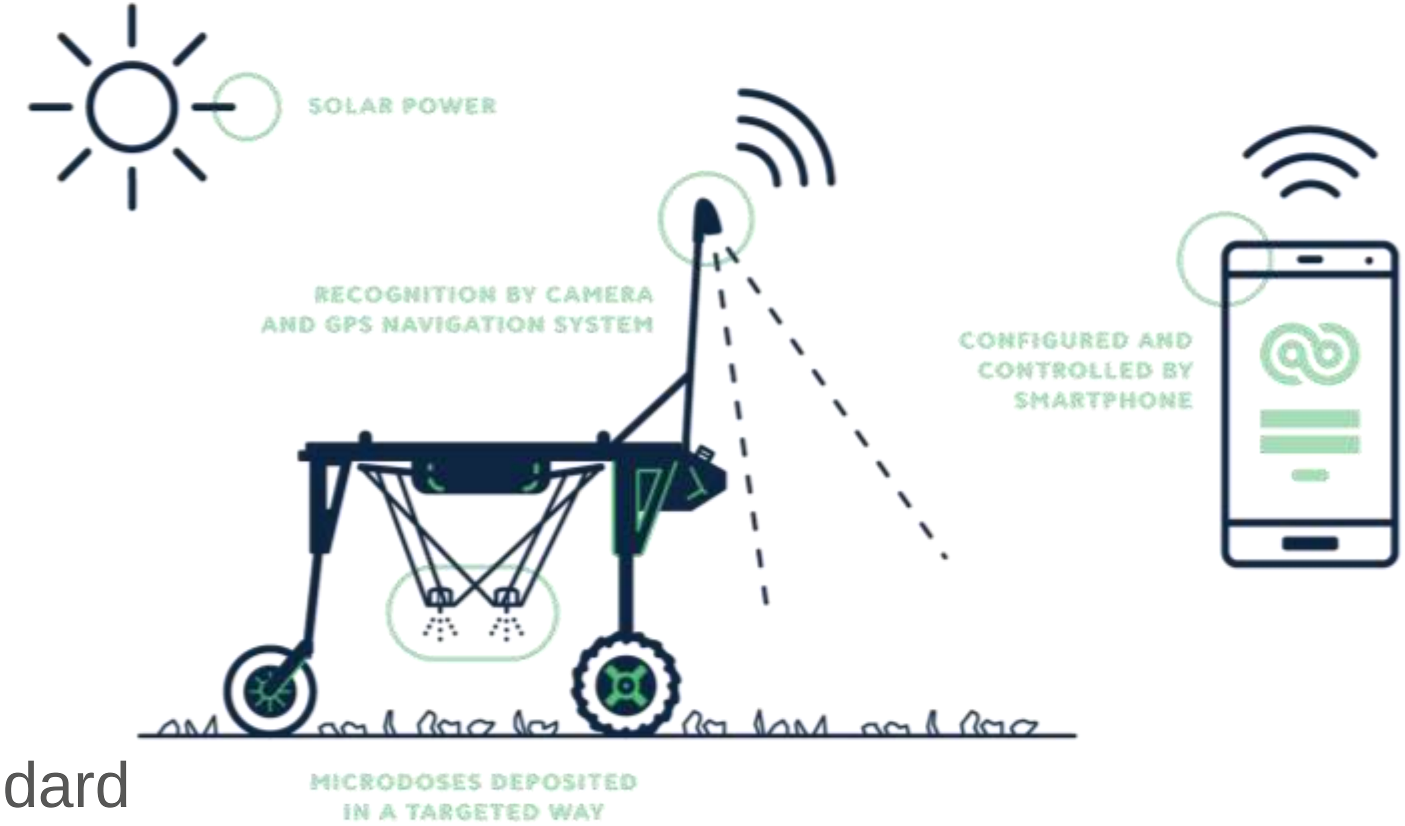
Weeding

Bonirob from Bosch
Deepfield Robotics
BoniRob



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)

https://www.ecorobotix.com/en/autonomous-robot-weeder/

Switzerland

Digital Farmhand

https://sydney.edu.au/engineering/news-and-events/2018/08/03/digital-farmhand-boosts-food-security-in-the-pacific.html

Robotic weeding: NAIO

https://www.naio-technologies.com/en/agricultural-equipment/large-scale-vegetable-weeding-robot/

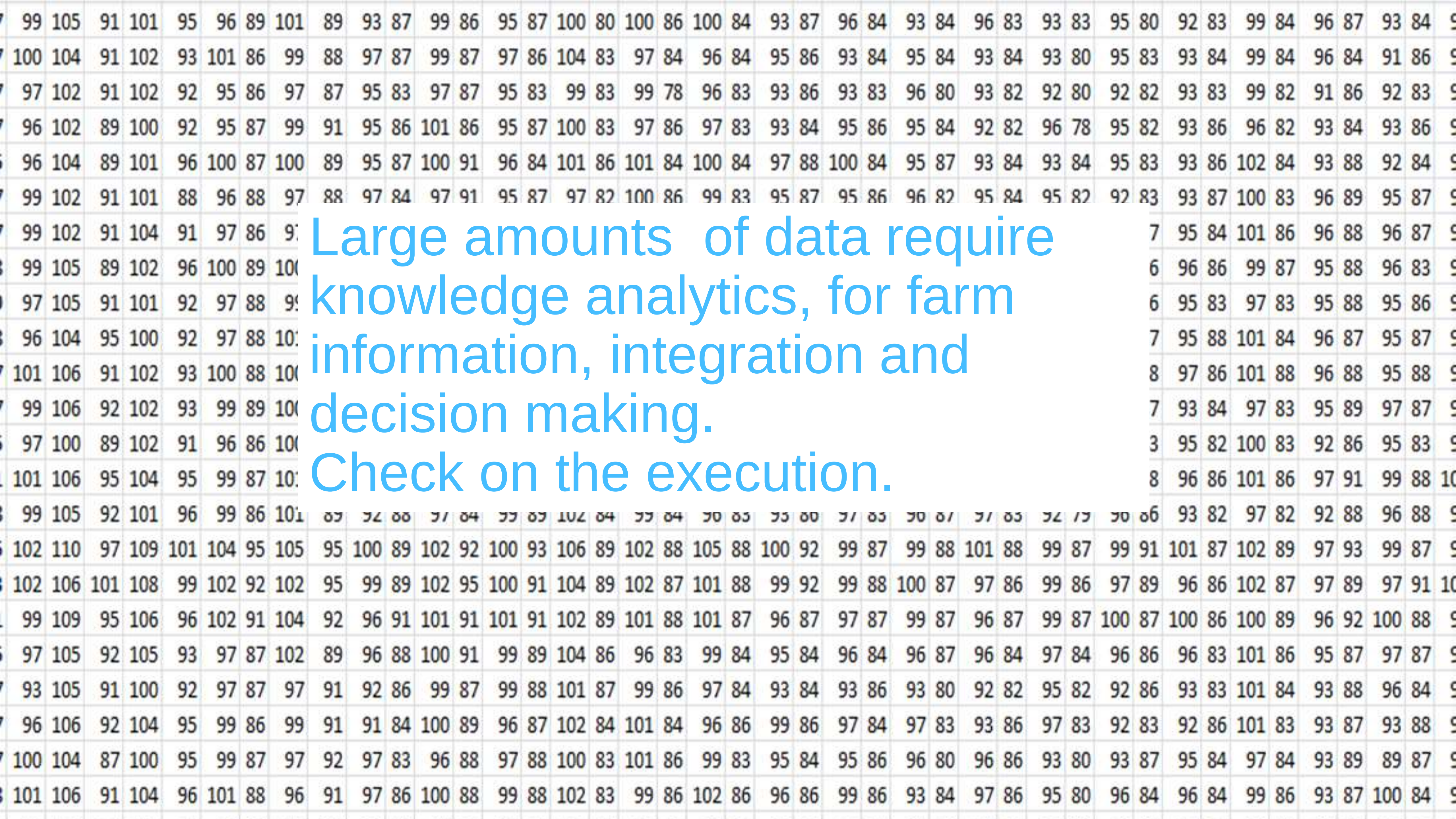
Digital Herbicide: using high-voltage electric power – the clean solution: zasso, rootwave

https://zasso.eu/en/agriculture-en/

http://rootwave.com/technology/

Weed control and robotics

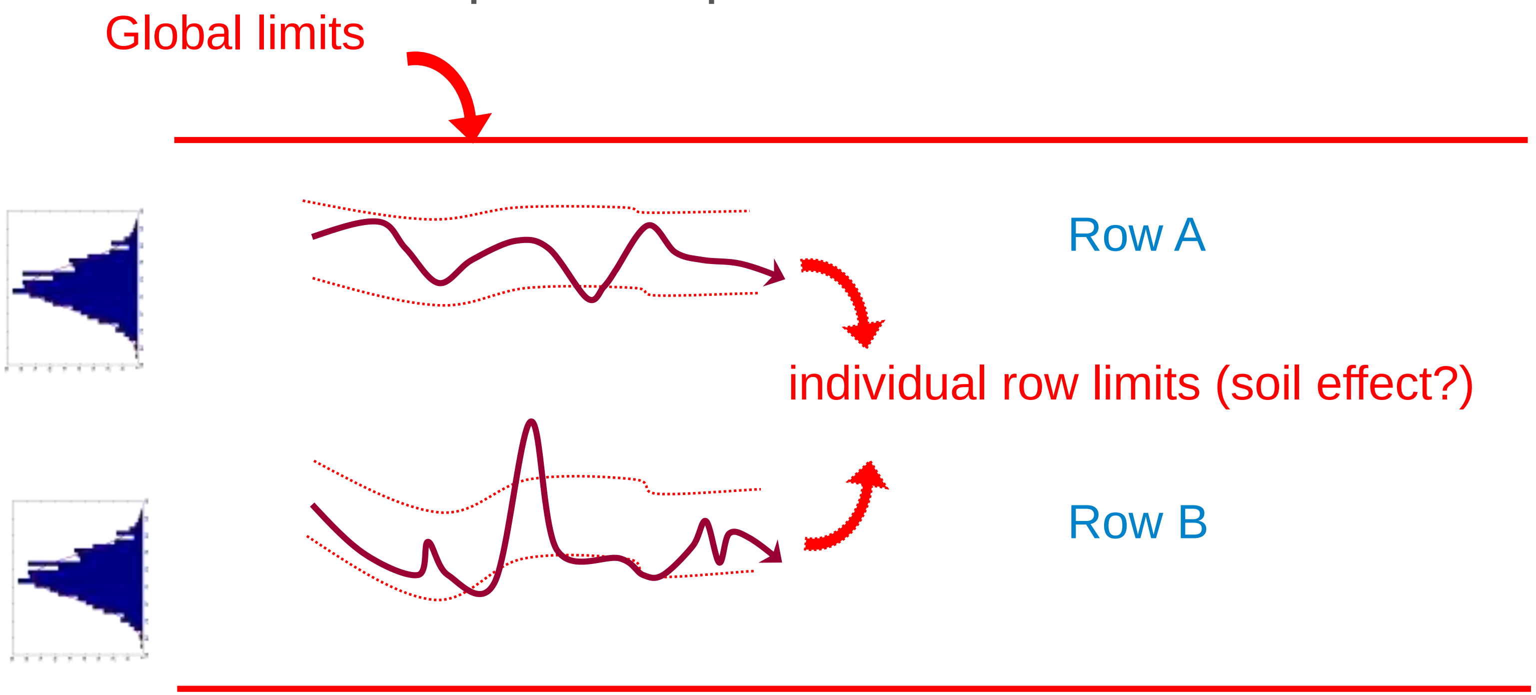
- The ‘convenience’ of herbicide use is under discussion
- Physical methods of weed control require:
  - Good detection and discrimination between crop and weed
  - High working rate either in one machine or in swarms (multiple machines)
- Expectations for robotic weed control:
  - Killing the weed ?
  - 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 …..

AHDB

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