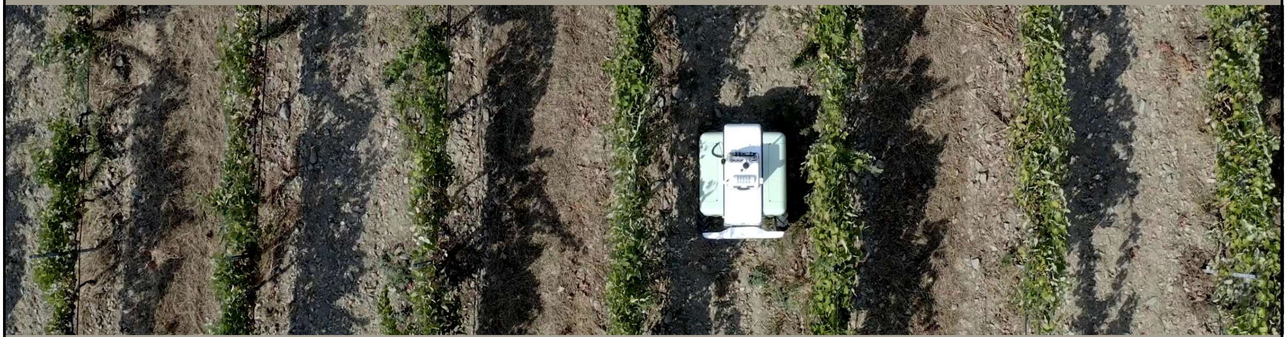
Phenotyping Strategies for Agricultural Robots: Massive Sampling and Real-time Fruit Assessment



AGRICULTURAL ROBOTICS LABORATORY

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17th INTERNATIONAL WORKSHOP ON NONDESTRUCTIVE QUALITY EVALUATION OF AGRICULTURAL, LIVESTOCK AND FISHERY PRODUCTS

29 October 2024

Study cases on non-invasive phenotyping

Grape & wine Properties

Grape & wine Quality

Selective harvest

Smart Crop protection

Field data and agronomical knowledge for decision-making

Crop production → **Crop harvesting**

Biotic stress | **Abiotic stress** | **Crop yield** | **Fruit quality**

Intelligence ... ability in dealing with **knowledge**

AI ... ability in dealing with **data** and **sensors**

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Artificial Intelligence Algorithm Family Tree

Solving by Searching
- **Tree search**
- **Genetic algorithms**
- **Heuristic search**
  {Cost of solution}
  {A* algorithm}

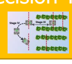
Probabilistic Reasoning (Bayesian)
- **Markov processes**
  {Monte Carlo particle filter}
- **Kalman filter**
  {Dealing with uncertainty}
- **Fuzzy Logic**
  {Representing vagueness}

Statistical Learning
- **Neural Networks**
  {ML: Deep Learning}
- **Kernel machines**
  {Support Vector Machines}
- **Clustering**
  {K-means algorithm}
  {Unsupervised}

Domain-specific knowledge (rules) allows larger reasoning steps (Russell & Norvig, 2003)

Logical Agents
{Need knowledge about the world}

Learning from Observations
{Decision Trees}



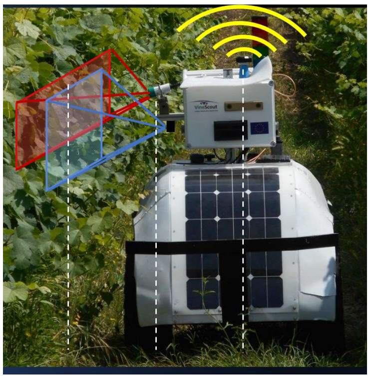
Reinforcement Learning

Perception & Machine Vision

(big) Data precedes Artificial Intelligence

The idea of massive sampling in agricultural fields

Proximity



Frequency - rate

Date (in 2020)	Period
7 Aug	Morning
7 Aug	Midday
9 Sep	Morning
9 Sep	Midday
10 Sep	Morning 1
8 Aug	Midday
10 Sep	Morning 2
10 Sep	Midday
9 Sep	Predawn
8 Aug	Night
8 Aug	Predawn

unlimited

user-set

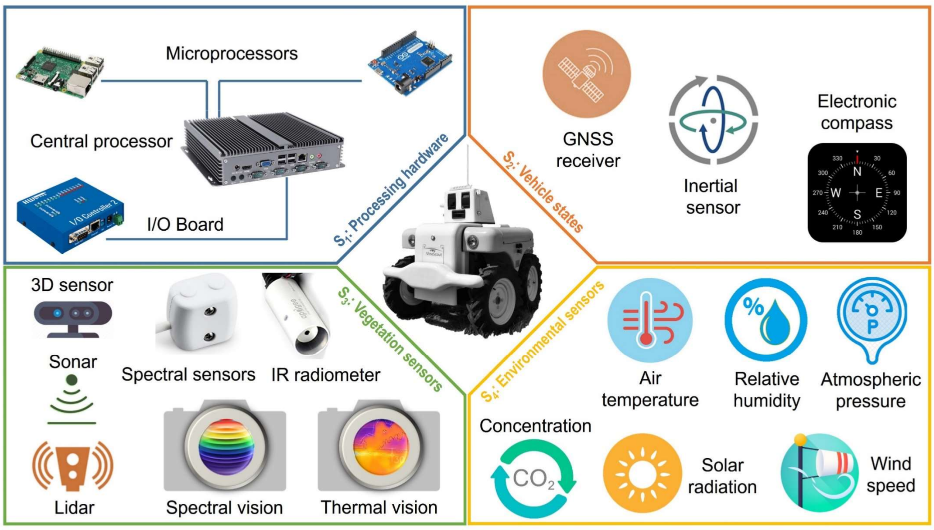
Density

$> 2 \dfrac{\text{points}}{m^2}$

$> 20{,}000 \dfrac{\text{points}}{\text{ha}}$

(big) Data precedes Artificial Intelligence

Using robots for *mechanizing* data acquisition in the fields

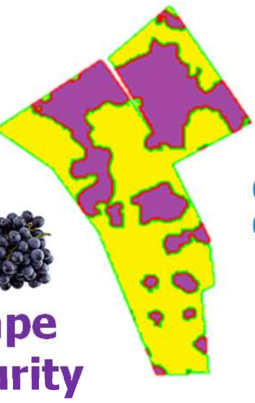


Case I: Crop sensing for wine making

Relationship between field data and crop properties

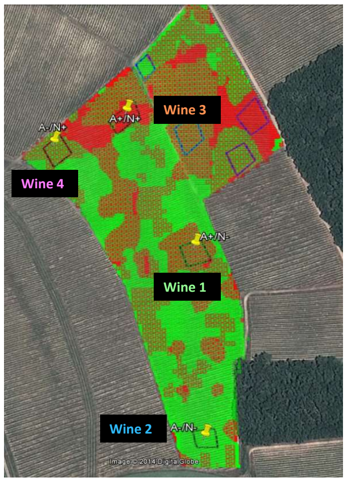
Vine Vigor

+



Grape Maturity

=



- High N content
- Low N content
- High Anthocyanins content
- Low Anthocyanins content

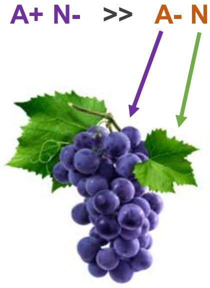
Courtesy Les Vignerons de Buzet, France

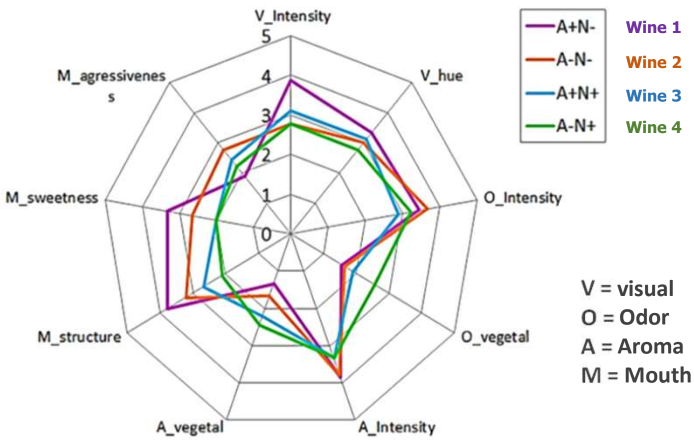
Case I: Crop sensing for wine making

Relationship between crop data and consumer feelings

Customer perception

A+ N- >> A- N- >> A+ N+ >> A- N+



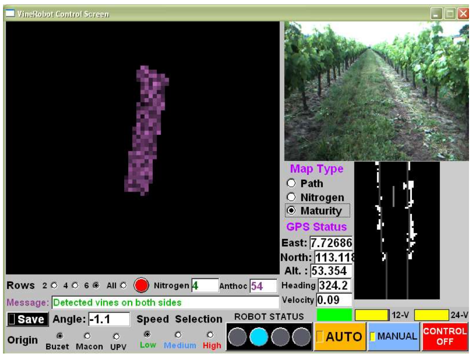


V = visual
O = Odor
A = Aroma
M = Mouth

Courtesy Les Vignerons de Buzet, France

Case I: Crop sensing for wine making

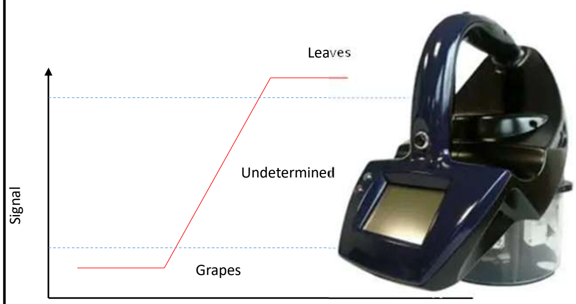
Field experience with the VineRobot project (2014-2016)



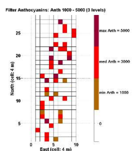
Case I: Crop sensing for wine making

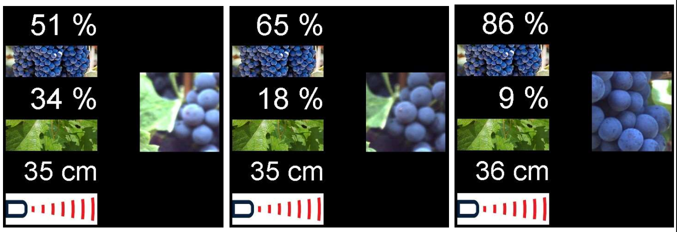
Big challenges with the VineRobot project (2014-2016)

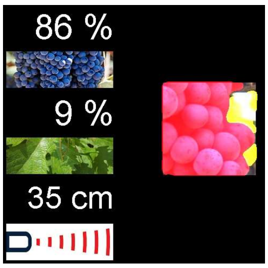
Non-destructive anthocyanin content with fluorescence

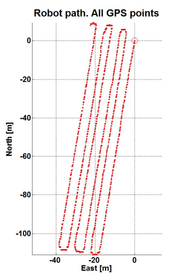


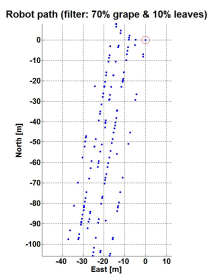
State-of-the-art sensor: Force A Multiplex 330







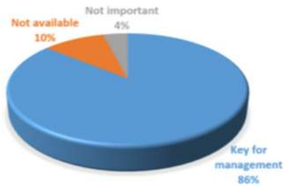


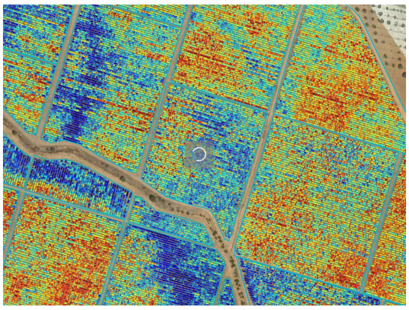


Case II: vineyard water stress

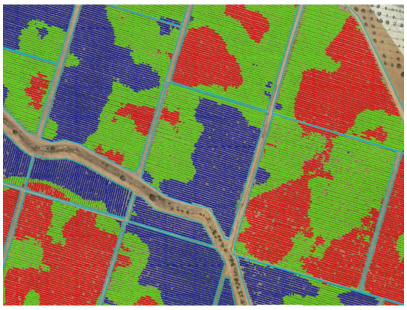
Crop data & consumers: Water status as indicator of wine quality

Canopy information





Vigor map: UAV NDVI map



Clustering: 3 zones

Clustering: 2 zones = 2 wines

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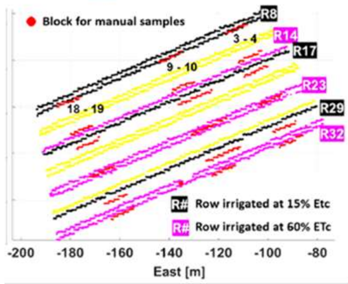
Case II: vineyard water stress

The problem of ground truth validation in agriculture

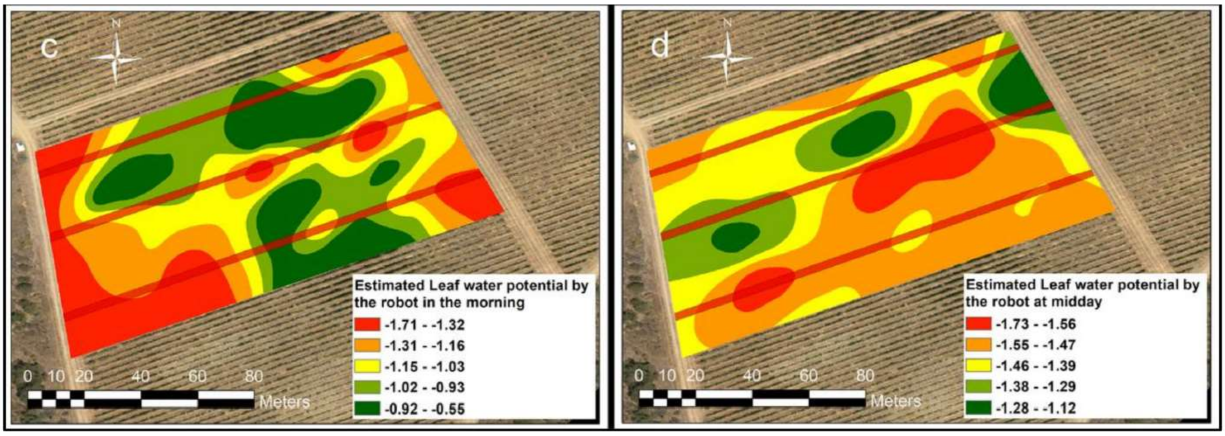


Test name	AGV data points	Manual data points	Date (in 2020)	Period
T1	1 556	36	7 Aug	Morning
T2	1 557	36	7 Aug	Midday
T3	9 533	12	9 Sep	Morning
T4	9 484	12	9 Sep	Midday
T5	8 989	12	10 Sep	Morning 1
T6	11 135	–	8 Aug	Midday
T7	10 914	–	10 Sep	Morning 2
T8	10 199	–	10 Sep	Midday
T9	4 053	–	9 Sep	Predawn
T10	2 259	–	8 Aug	Night
T11	3 643	–	8 Aug	Predawn

Saiz-Rubio et al. Robotics-based vineyard water potential monitoring at high resolution. 2021 Computers and electronics in agriculture..

Case II: vineyard water stress

Statistical modeling of water potential



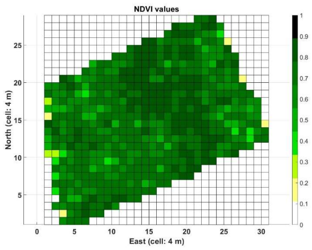
Fernández-Novales et al. Monitoring and mapping vineyard water stress using non-invasive technologies by a ground robot. 2021 Remote Sensing.

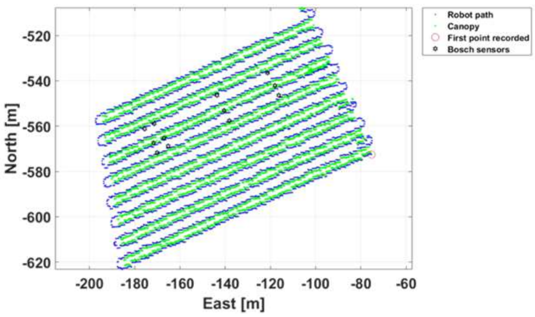
Case II: vineyard water stress

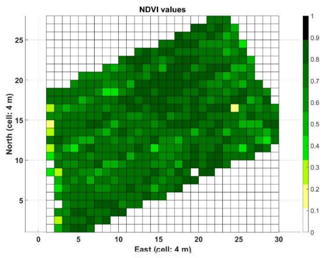
AI selection of water stressed zones: massive (raw) data

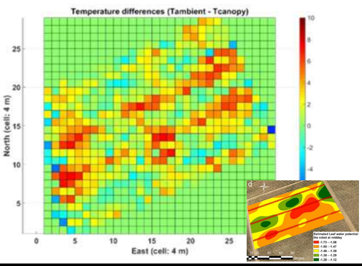
Stress conditions (afternoon)

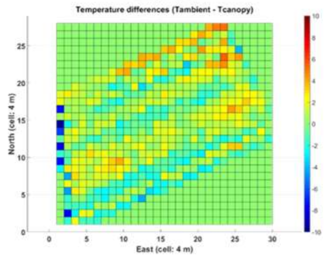
After irrigation; moderate temperature





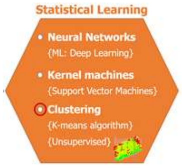




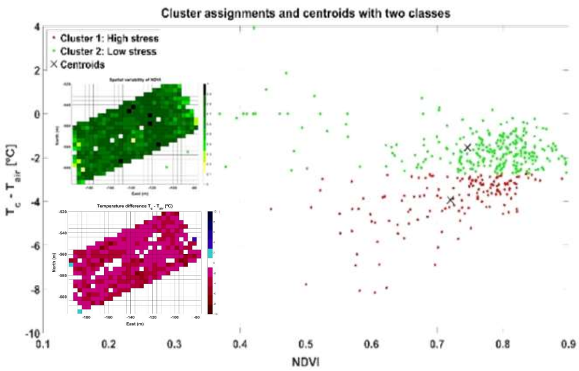


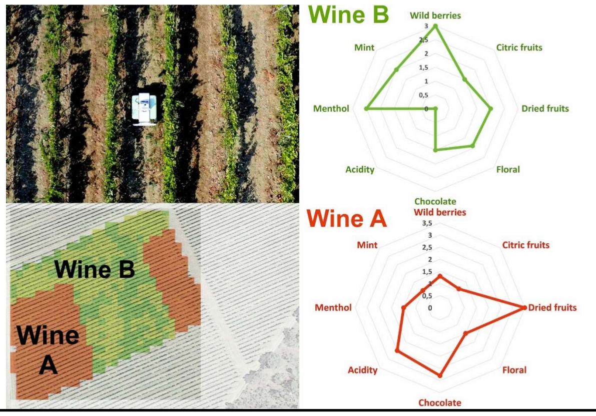
Case II: vineyard water stress

AI selection of water stressed zones: non-supervised clustering



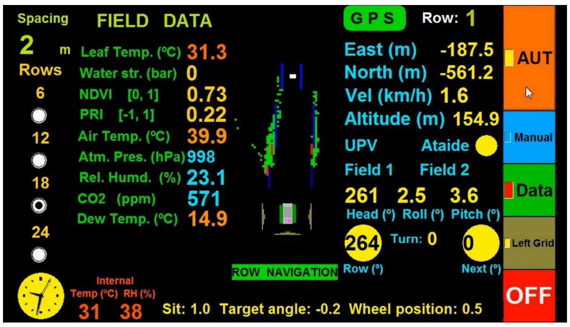
Map	Date	Initiation Time	Duration (min)	Number of Points	Number of Rows	Area m²	DP (points/m²)
A	11 June 2019	15:50	171	20,124	17	5421	3.7
B	22 July 2019	15:34	124	21,367	20	7991	2.7
C	9 September 2020	14:29	71	14,856	14	6475	2.3





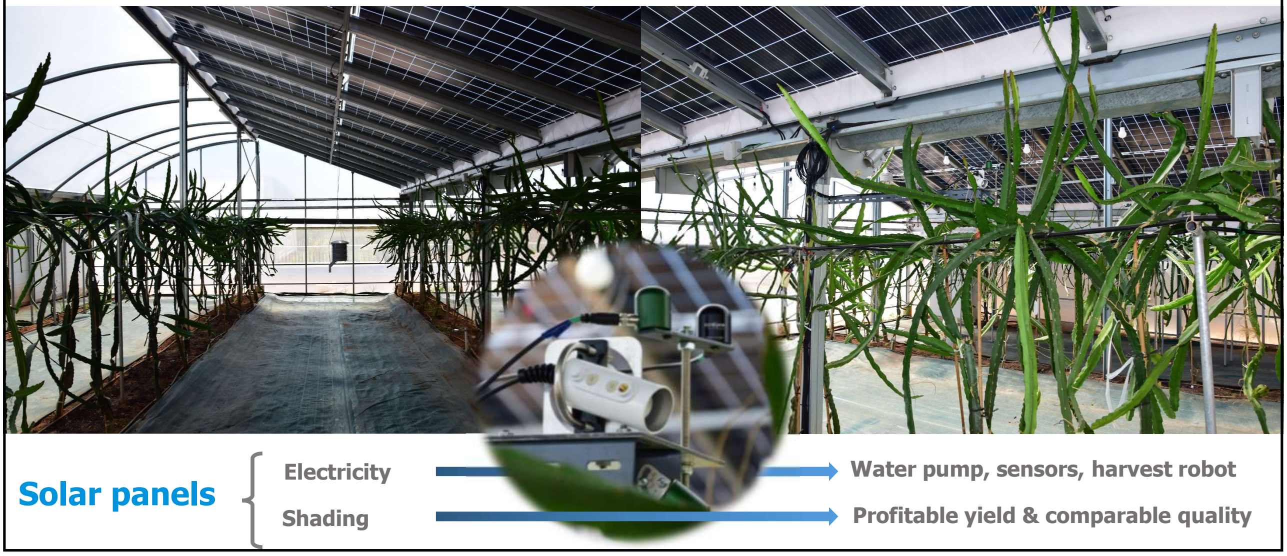
Case II: vineyard water stress

How the robot monitored the vineyards



Case III: dragon fruit robotic harvesting

Goal: high-tech high-value circularity production



Solar panels
- Electricity → Water pump, sensors, harvest robot
- Shading → Profitable yield & comparable quality

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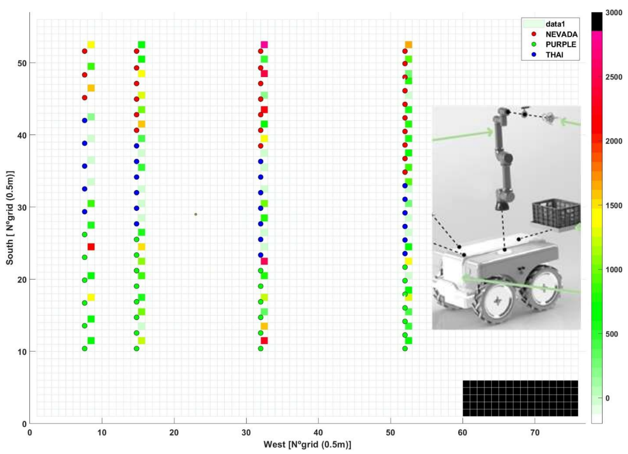
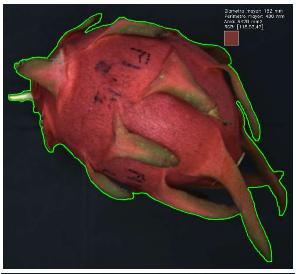
Case III: dragon fruit robotic harvesting

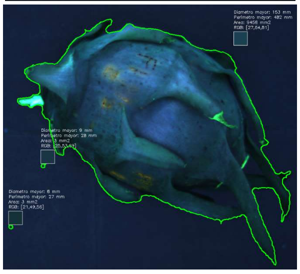
Robot mobility and harvesting strategy: stop-and-go



Case III: dragon fruit robotic harvesting

Non-destructive in-plant assessment of fruit quality



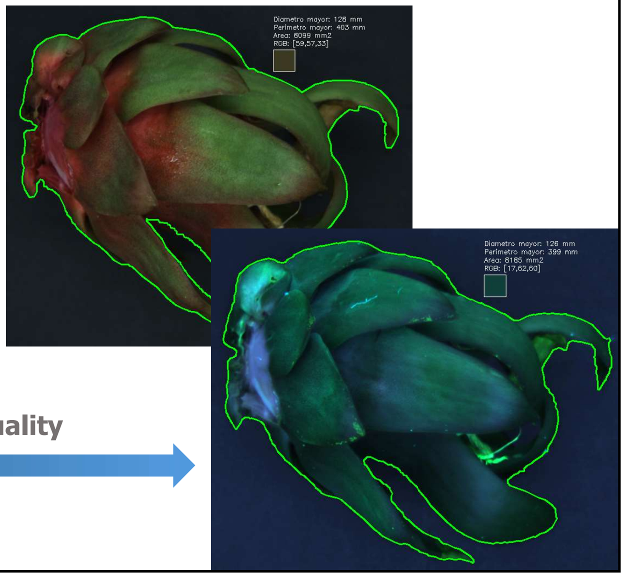


Size → yield & quality (sorting)

Size { Self-pollinated / Cross-pollinated }

Ripeness → yield

Defects → quality



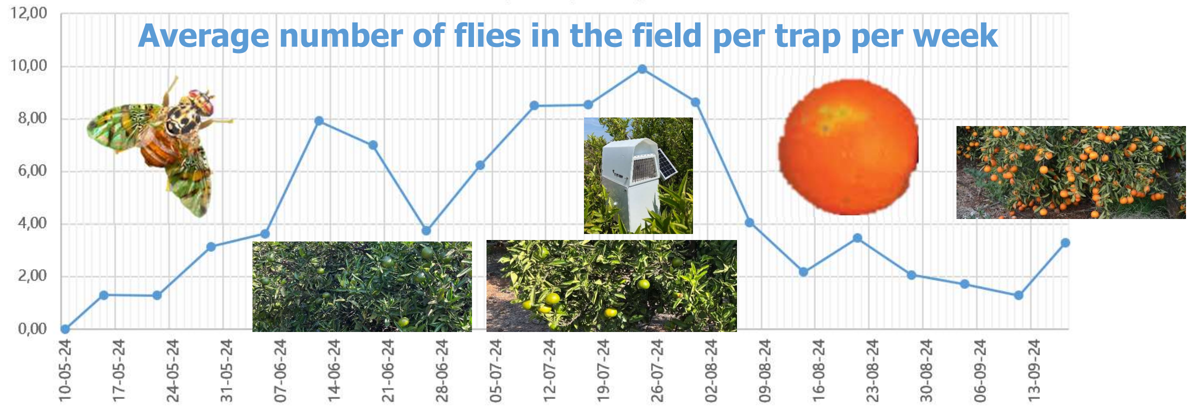
Case III: dragon fruit robotic harvesting

Challenge I: detection of pedicle and cut orientation

Challenge II: pedicle cut and fruit detachment

Case IV: pest attack risk

Challenge: non-invasive large-scale fruit maturity maps



Risk

Spray

Conclusions

- ❑ **AI requires high-quality Data…** in addition
  - ❑ Machine Learning (ANN) requires **high-quantity Data**
- ❑ **Field Data requires systematic Field Sensing**
- ❑ **Field Data is (arguably) not yet Big Data**
- ❑ **Data-driven agriculture can enhance its potential…**
  - ❑ With **AI**
  - ❑ With **robotics** and **automation**
- ❑ **Ag digitization requires close & permanent field contact**

Conclusions

Ground truth validation is the key for successful adoption

Conclusions

Orchard farmer ways

Yes

Yes

NO!

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