10TH INTERNATIONAL TABLE GRAPE SYMPOSIUM
26 NOV TO 1 DEC 2023
SOMERSET WEST SOUTH AFRICA

Novel monitoring technologies, data processing and modelling for the management and quality evaluation of table grapes

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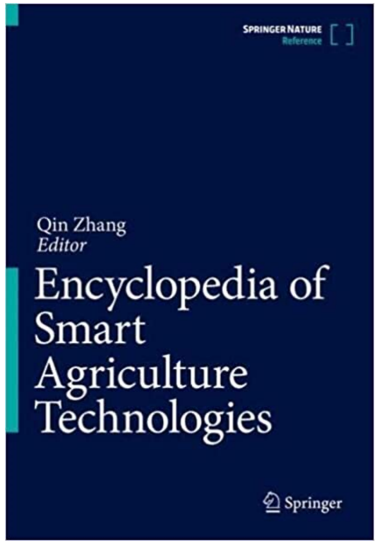
Conceptual background

Traditional viticultural practices Uniform management: application of the same intensity or the same dose in operations such as pruning, fertilization, phytosanitary treatments, irrigation, etc., regardless of the exact location and variability.

- **Monitoring**
- **Data management**

1. **Novel monitoring technologies**
2. **Data processing**
3. **Modelling**



"**Digital viticulture** can be defined as a group of new technologies (sensors, platforms, and algorithms) used to provide technology solutions to handle **spatial** and **temporal variability** of viticulture variables and site conditions in order to provide useful information for **optimizing management practices**"

(Poblete-Echeverria and Tardáguila, 2023)

Conceptual background

4. Modern data management

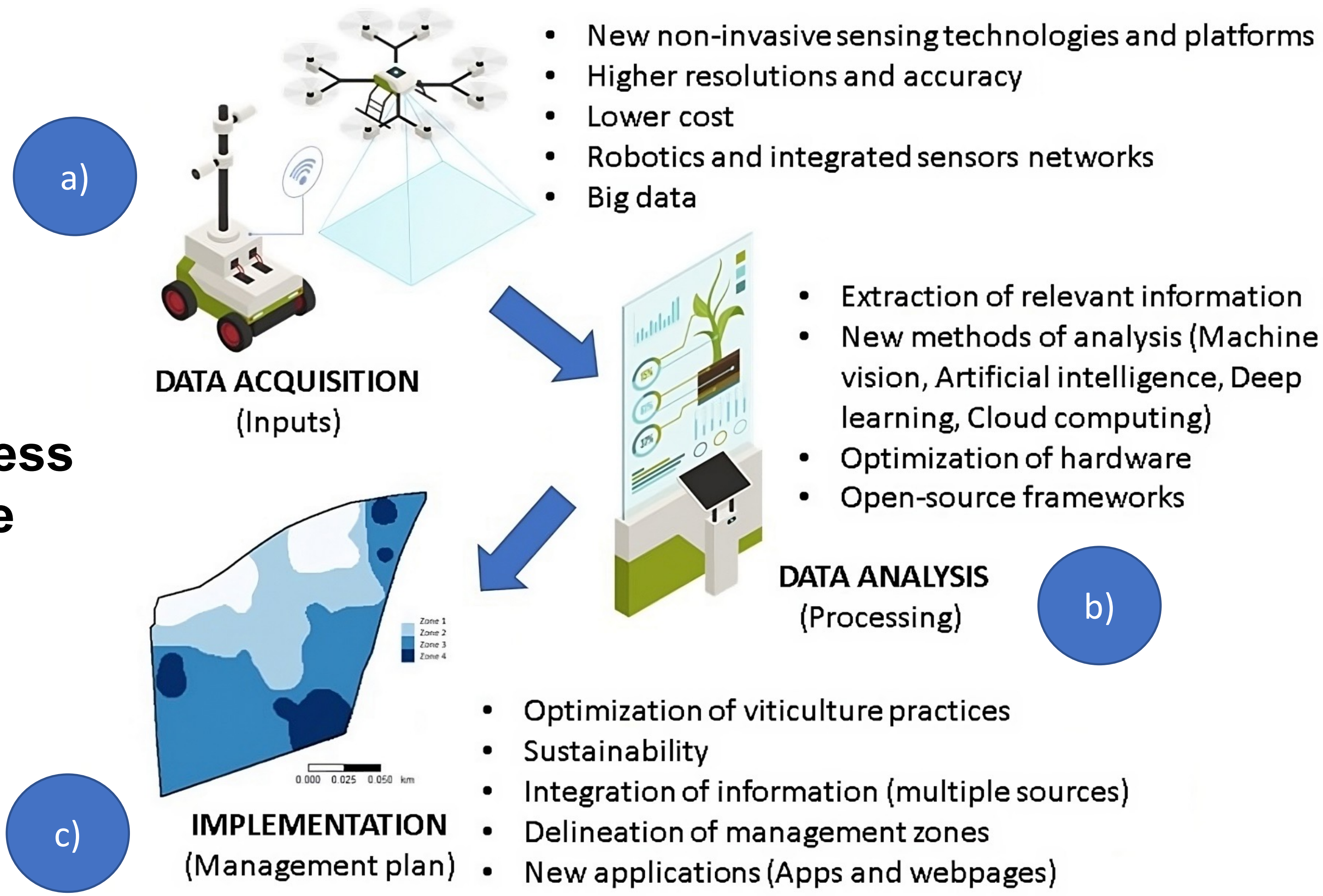
Data-driven digital agriculture can improve every element of the agri-system value chain and create **better links** between farms and consumers.

Data is power. Tools that collect, store, and share data along the agricultural value chain can contribute to exponential **income growth**, better decision-making, enhanced products and services, and greater efficiency, productivity, and profitability.

https://www.worldbank.org/en/programs/food-systems-2030/overview

Conceptual background

The adoption process of digital viticulture



(Poblete-Echeverria and Tardáguila, 2023)

Data acquisition – Novel monitoring technologies

Data acquisition – Novel monitoring technologies

Non-invasive Sensing Technologies - Remote and Proximal sensing

- **RGB imaging (RGBi):** *Digital images captured by RGB cameras. These images replicate human vision, capturing light in red, green, and blue wavelengths (RGB) for accurate colour representation.*
- **Spectroscopy:** *Spectral reflectance data measured by spectrometers. VIS (400-750 nm) and NIR (750-2500 nm) spectral wavelengths are particularly important in viticulture since multiple processes are associated with these spectral signals.*
- **Multispectral imaging (MSI):** *While conventional spectroscopy usually records the response of a small 'spot' size to a continuous spectrum, MSI registers the radiation on an image with typically four or six narrow wavelengths (e.g., RGB and NIR).*
- **Hyperspectral imaging (HSI):** *The spectral resolution is the main characteristic that distinguishes HSI from MSI. HSI deals with narrower wavelengths over a continuous spectral range, thereby generating the spectra of all pixels of the object.*
- **Chlorophyll fluorescence:** *The principle underlying this technology is based on the various fates that light energy absorbed by Chl molecules in living plant tissues can follow.*
- **Infrared thermography (IRT):** *IRT is a technique which uses a camera to produce visible images showing the amount of infrared energy emitted by an object. This energy is converted to temperature to display an image of the temperature distribution of the targeted area.*
- **Electrical resistivity and conductivity:** *An EMI sensor allow depth-weighted average measurement of apparent soil electrical conductivity (ECa) by inducing an electrical current in the soil which is determined by the relative amounts and types of clay, salts, rock, and water in the soil.*
- **Laser imaging detection and ranging (LiDAR):** *LiDAR is a technology that measures the distance to a target by illuminating the target with pulsed laser beams and measuring the reflected pulses with a sensor. Differences in laser return times and wavelengths can then be used to make digital 3-D reconstructions of the target.*

Data acquisition – Novel monitoring technologies

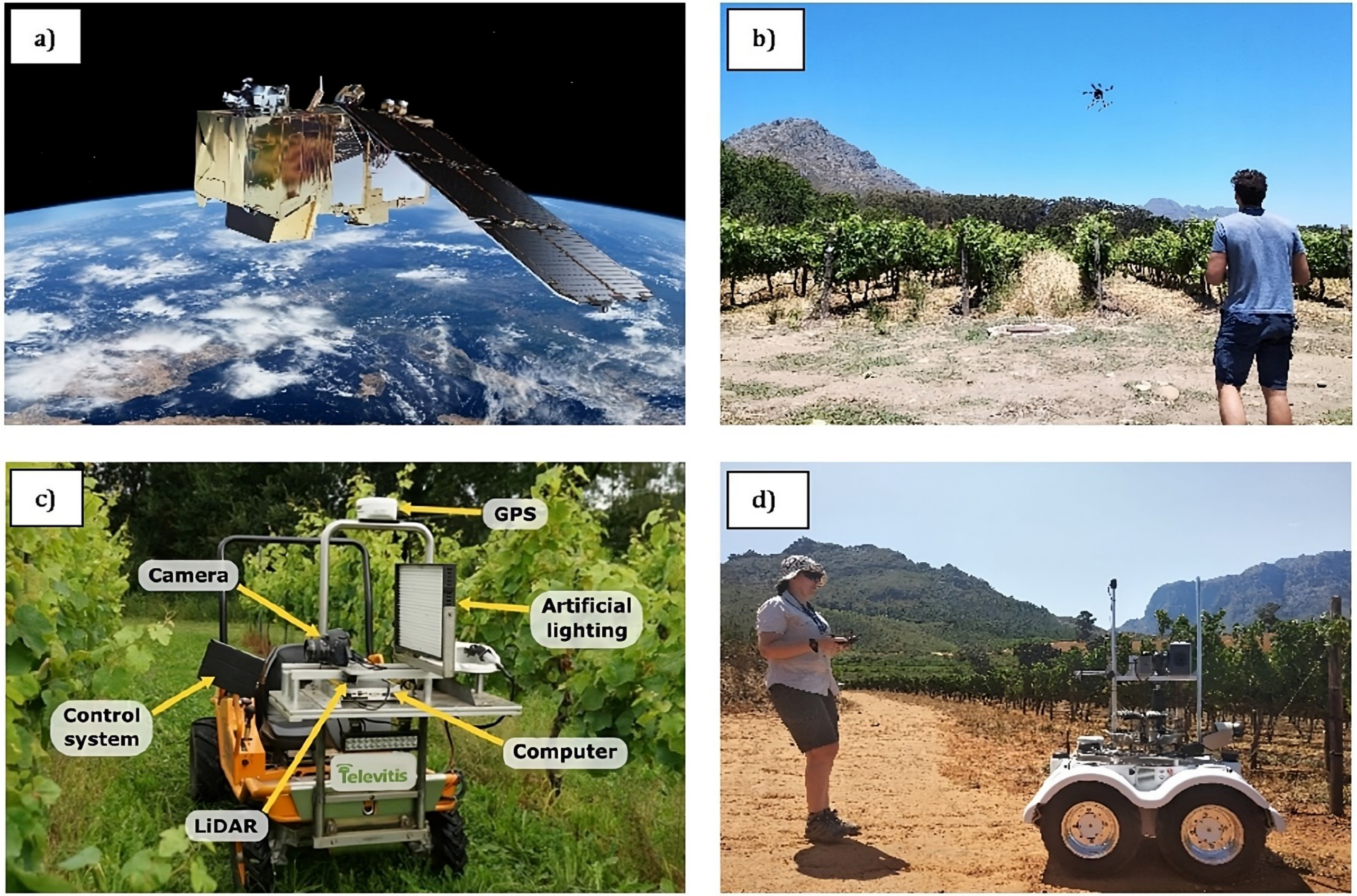
Sensing platforms

- **Space-based platforms:** *The traditional remote sensing approach used in agriculture is based on satellite platforms. There are numerous types of satellite platforms which vary according to the type of sensors, spatial resolution, revisited frequency, spectral resolution, radiometric resolution, and accessibility of the images (freely available versus paid images). All these characteristics define the potential applications of each type of satellite imagery.*
- **Air-based platforms:** *Aircraft operating at altitudes between 600 and 1,700 m. In more recent times, UAVs or drones have been used to acquire data, as well as conduct other tasks in vineyards. UAVs offer a useful alternative to satellites and aircraft in relation to flight availability and image resolution. The spatial resolution (i.e., pixel size) that can be provided by a light aircraft typically ranges from 0.1 to 0.5 m/pixel. For UAVs, ultra-high resolutions of up to 0.01 m/pixel can be achieved.*
- **Ground-based platforms:** *Portable sensors, especially those which are GPS-enabled, have the advantage of being able to acquire geo-referenced data across large sample areas. Proximal sensors can be embedded into robots or attached to agricultural machinery such as ATVs, tractors, harvesters, and sprayers for on-the-go data acquisition. Sensors can be used for controlling machine guidance, while other sensors can be used for a range of vineyard monitoring tasks such as measuring yield during harvest operations or taking plant-based measures while they are travelling along each row of the vineyard completing other tasks.*
- **Robots:** *Robots are emerging ground-based platforms with great potential to change all forms of agricultural production systems, including viticulture. Autonomous robots use laser scanner technology for automation of navigation and as a safety feature. There are numerous projects in this domain and several companies and research institutions are developing robots for monitoring vineyards (e.g., VineRobot, VineScout, Dassie robot, VinBot and Phenobot).*

Data acquisition – Novel monitoring technologies

Sensing platforms

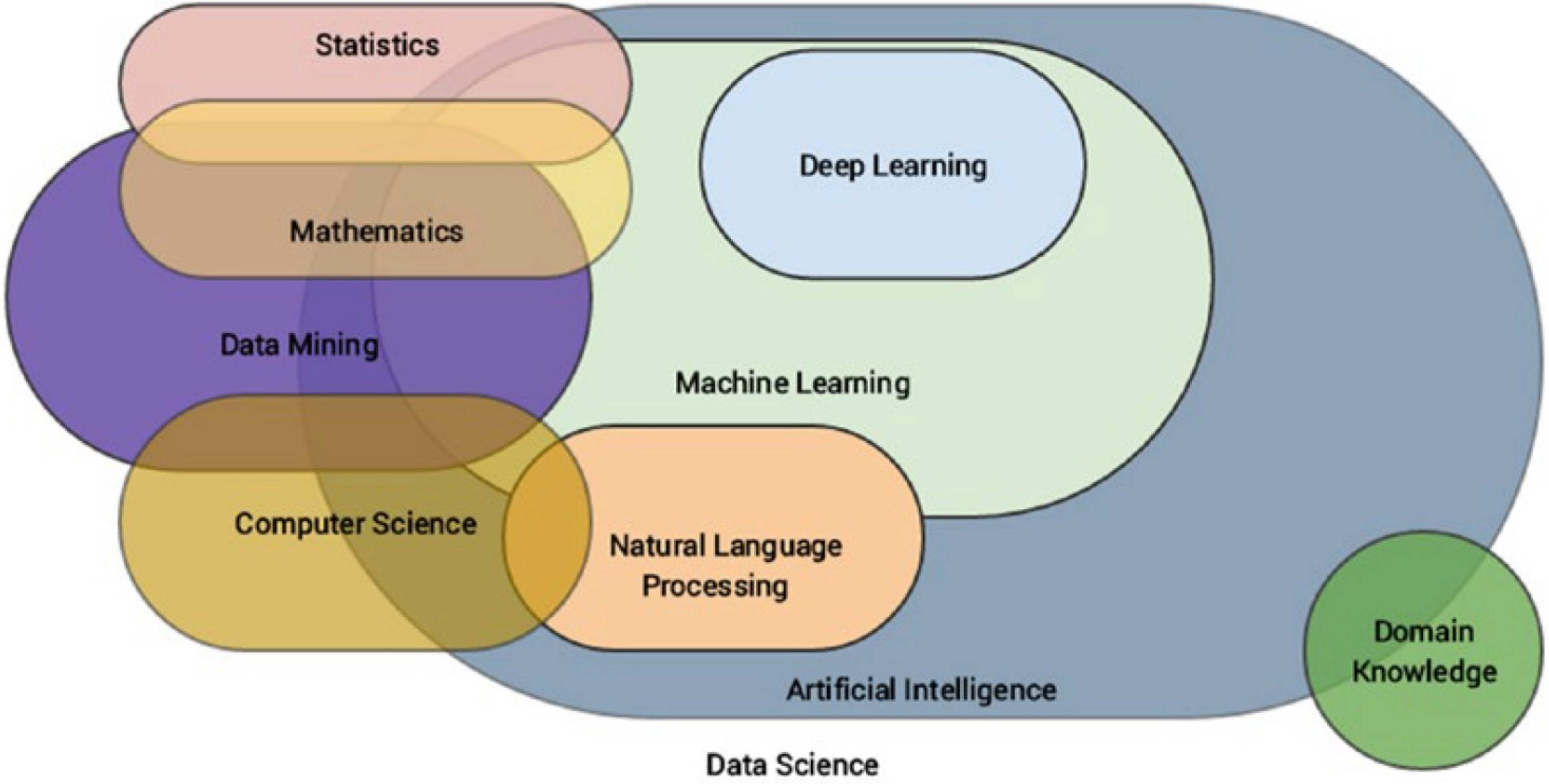
Examples of sensing platforms used in viticulture: (a) Satellite (Sentinel 2); (b) Drone; (c) Ground-based platform (Televitis mobile lab) and (d) Robotic platform (Dassie robot).



(Poblete-Echeverria and Tardáguila, 2023)

Data analysis – Processing

Data analysis – Processing



Machine Learning: a true multi-disciplinary field

(Sarkar et al., 2018)

Data analysis – Processing

Computer vision (CV)

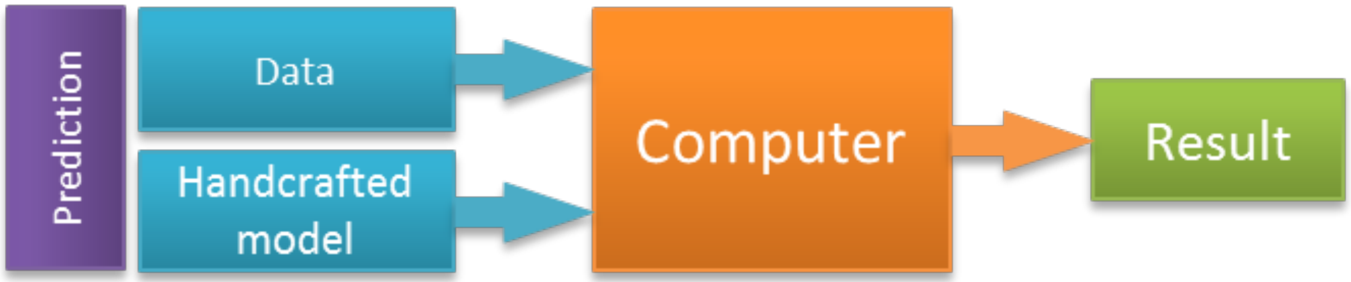
- Technology that acquires, processes, analyses, and extracts data from images to provide numerical or symbolic information.
- CV offers an automated approach that enables the assessment of properties of the target object in a fast, contactless, repeatable, and accurate way

Artificial Intelligence (AI)

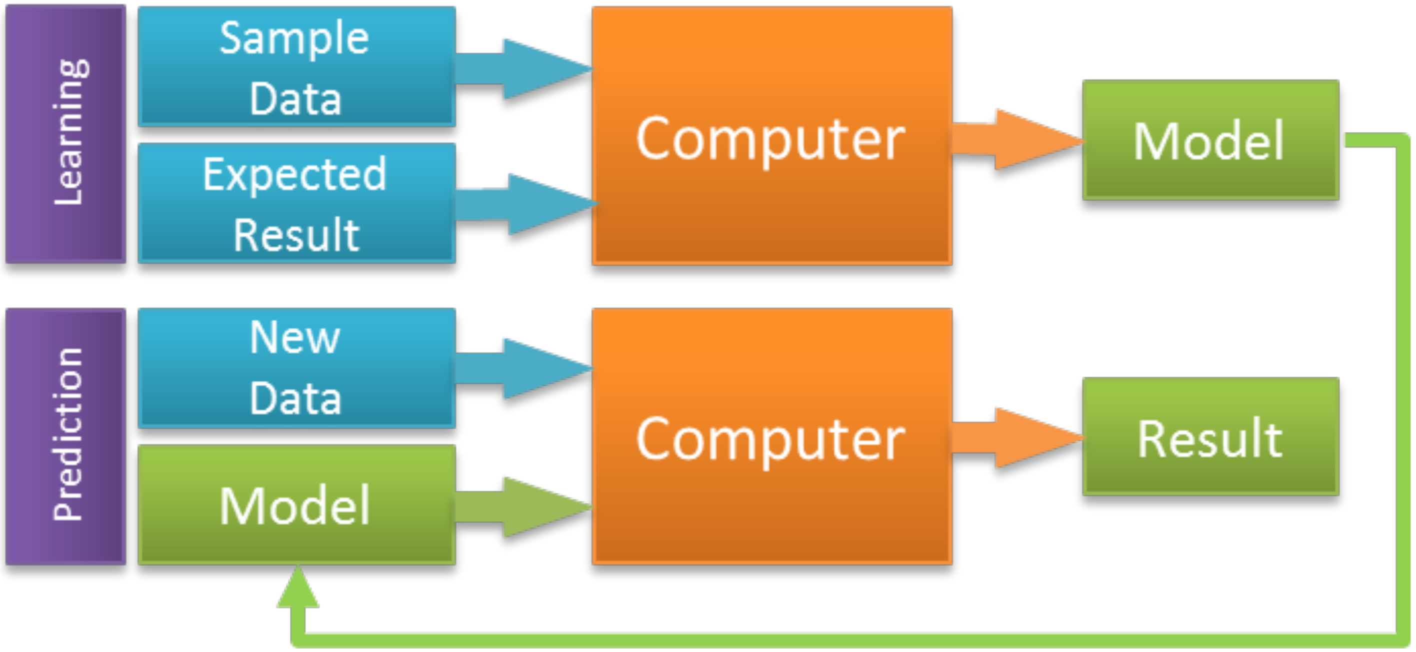
- Discipline within computer science that consists of the development of a type of algorithms at the software and hardware level for imitating human reasoning and being able of drawing conclusions from a set of data.
- **Machine Learning (ML)** part of the AI process where people "train" machines to recognize patterns based on data and make predictions
- **Deep Learning (DL)** type of ML in which the machine is capable of reasoning and drawing its own conclusions, learning by itself.

Data analysis – Processing

Traditional programming paradigm



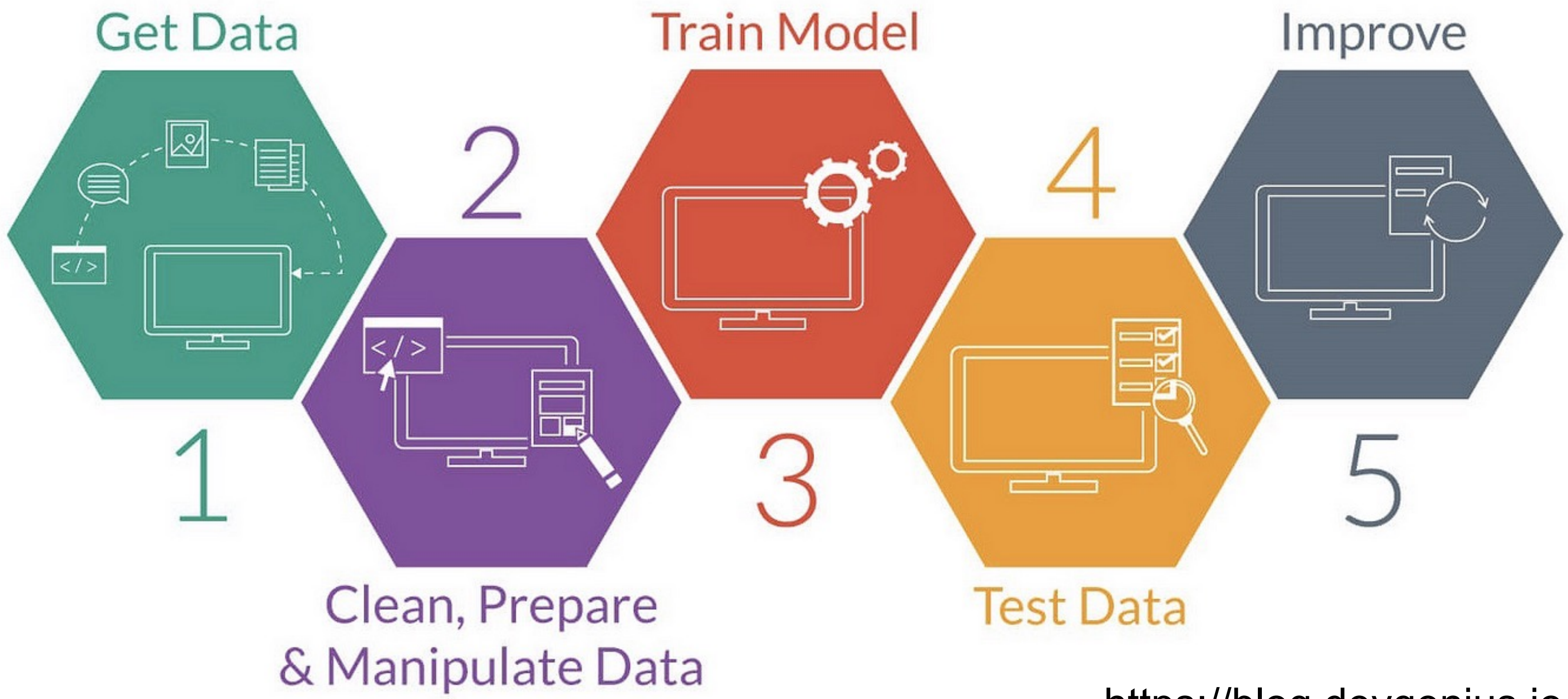
Machine Learning paradigm



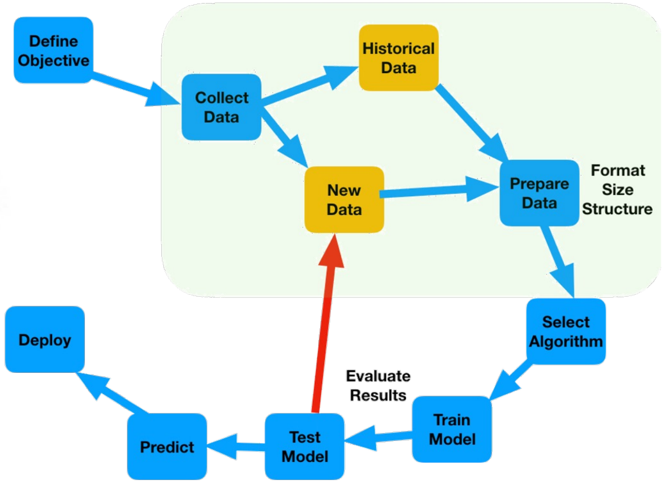
(Sarkar et al., 2018)

Data analysis – Processing

Basic Steps of Machine Learning



https://blog.devgenius.io/

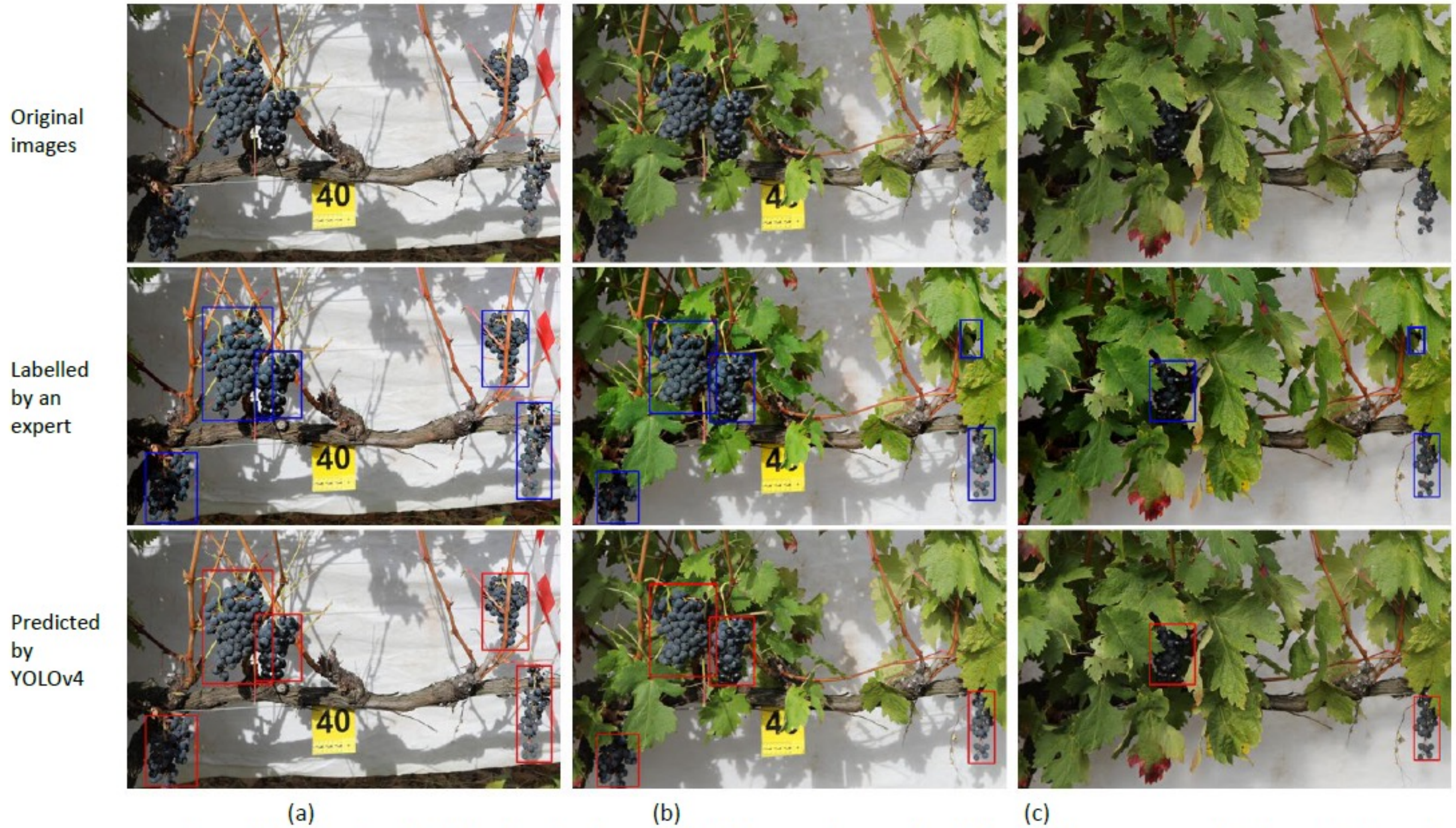


https://wvuhpc.github.io/

Implementation – Smart applications

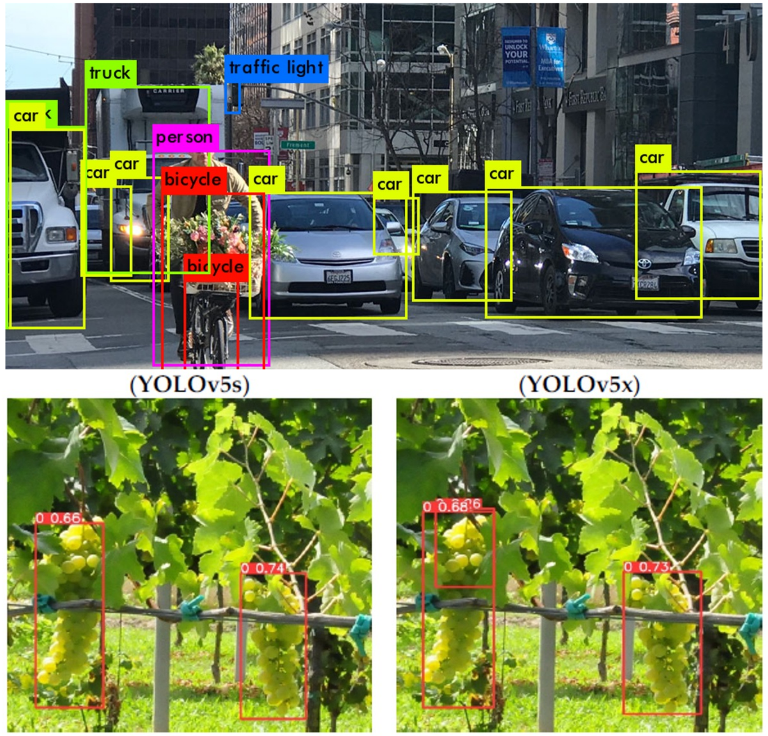
Implementation – Smart applications

Management: Yield forecast – Bunch detection



Artificial intelligence

YOLO "You Only Look Once"

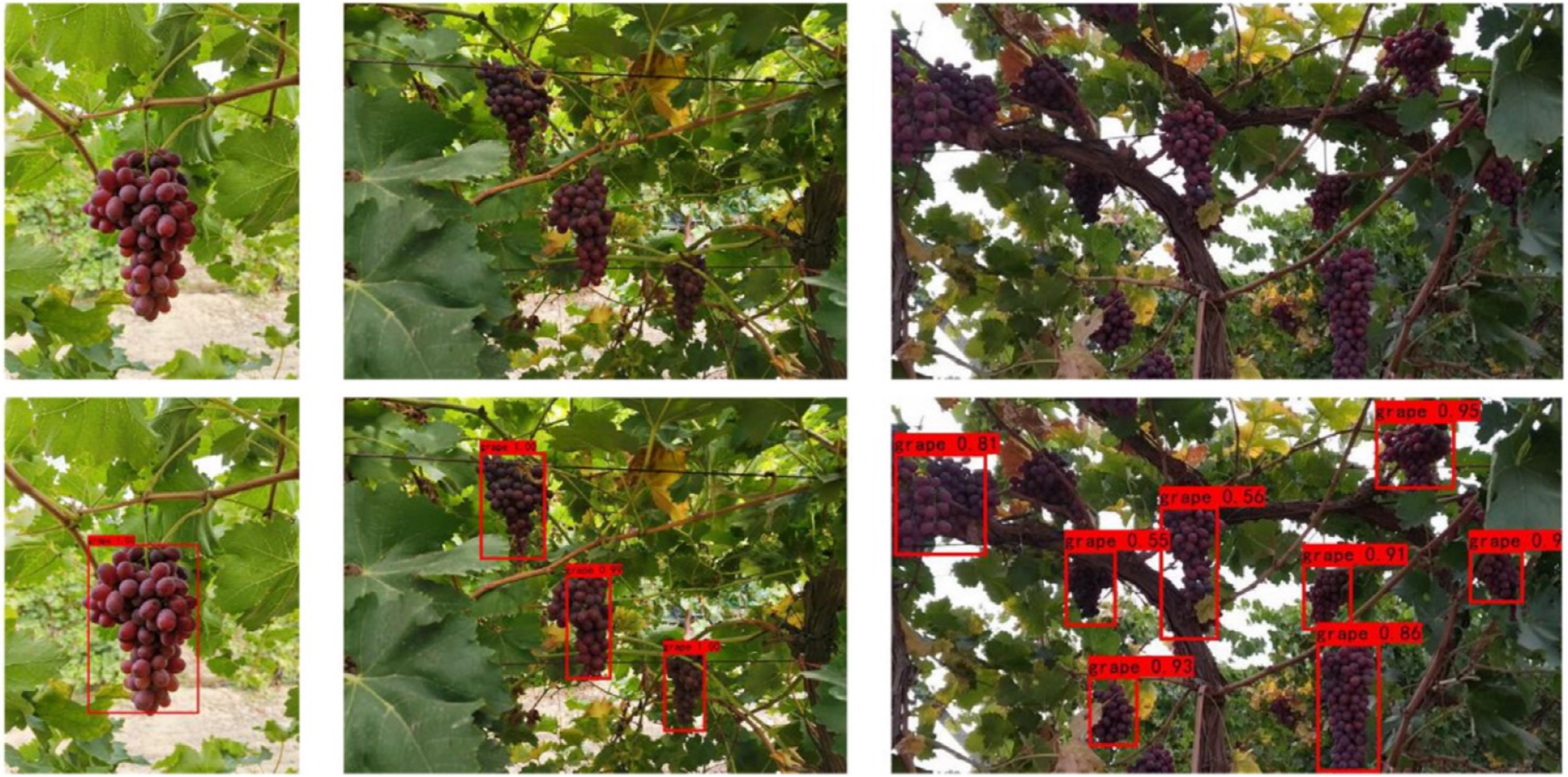


Comparison of the number of visible bunches in an original image, detected and labelled by an expert (blue bounding boxes) and predicted bunches using YOLOv4 (red bounding boxes)

(Iñiguez et al., 2023)

Implementation – Smart applications

Management: Yield forecast – Bunch detection



(1) Single (2) Multiple (3) Intensive

YOLOv4-tiny
Accuracy ≅ 92%

1. Kyoho grape
2. Muscat grape
3. Shine-muscat
4. Crimson seedless
5. Green grapes
6. Red grapes

(Li et al., 2021)

Implementation – Smart applications

Management: Yield forecast – Bunch detection

(a) (b) (c)

Detection of the condition of grape bunches in samples from the test set. Red bounding boxes present the predictions from YOLOv5. Green bounding boxes present the predictions from YOLOv7. Blue bounding boxes present the predictions from YOLOR.

Optimal grape bunch.

Damaged grape bunch

Bunch condition

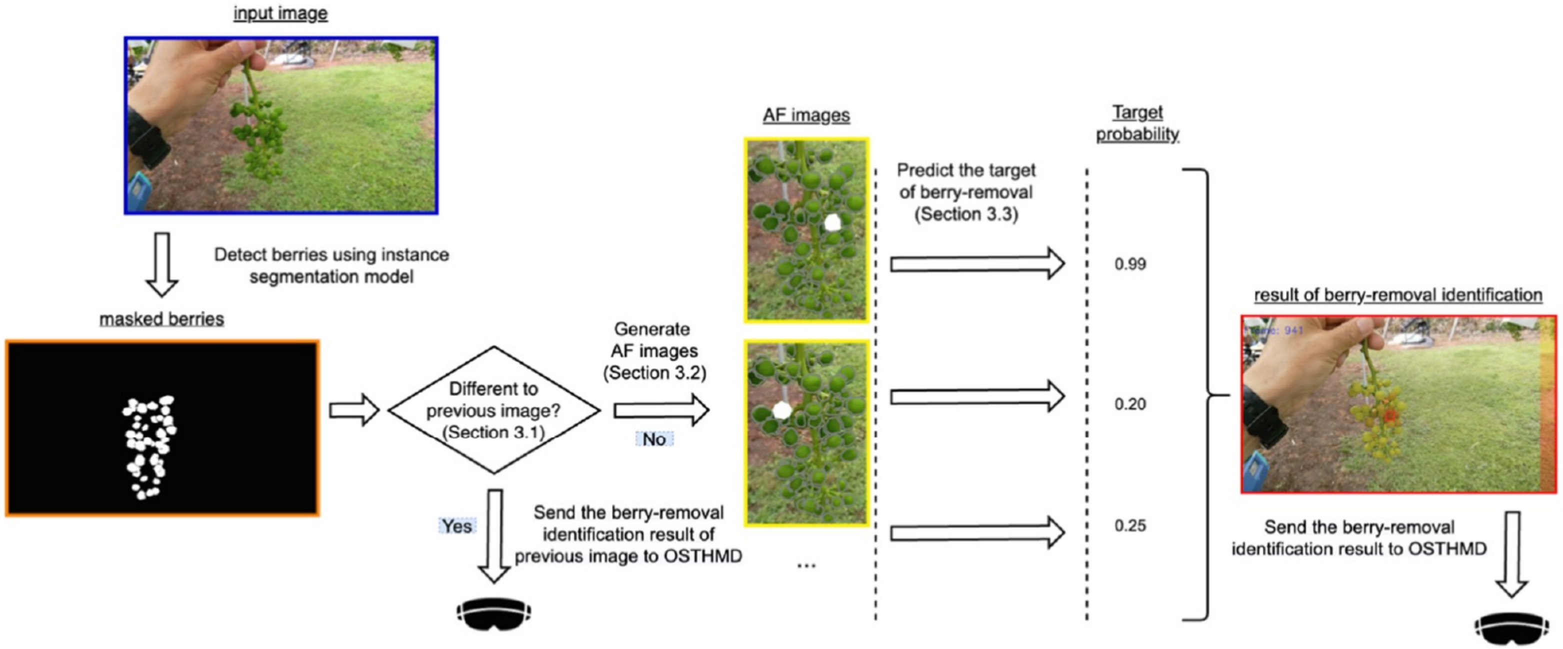
(Pinheiro et al., 2023)

Implementation – Smart applications

Management: Berry thinning

Visualization supporting berry thinning via OSTHMD. The yellow berries indicate a low probability of removal, while the red berries show a high probability of removal.

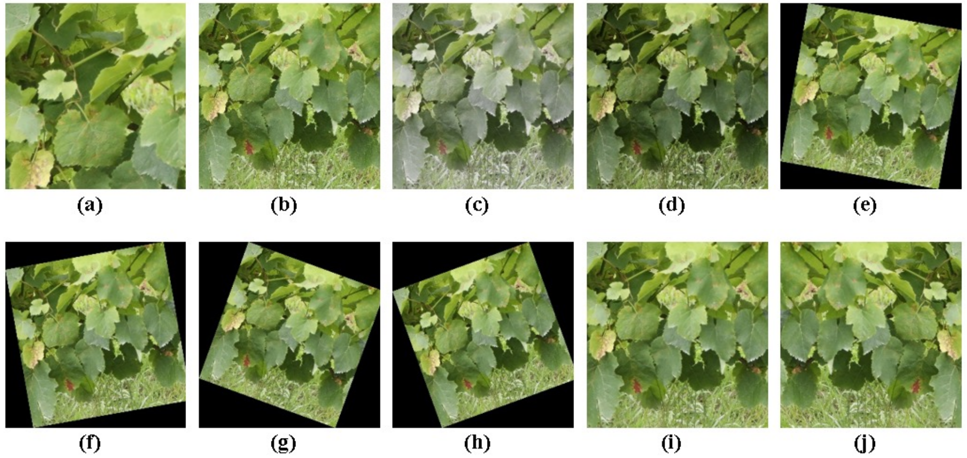
(Buayai et al., 2023)

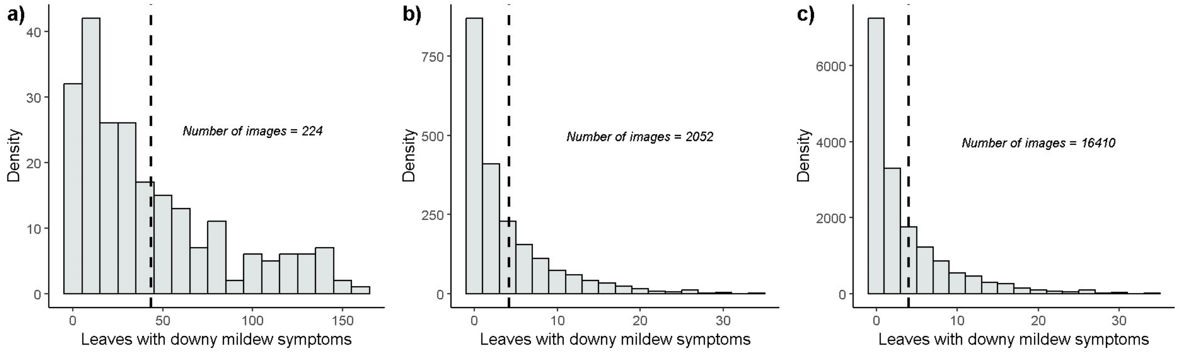


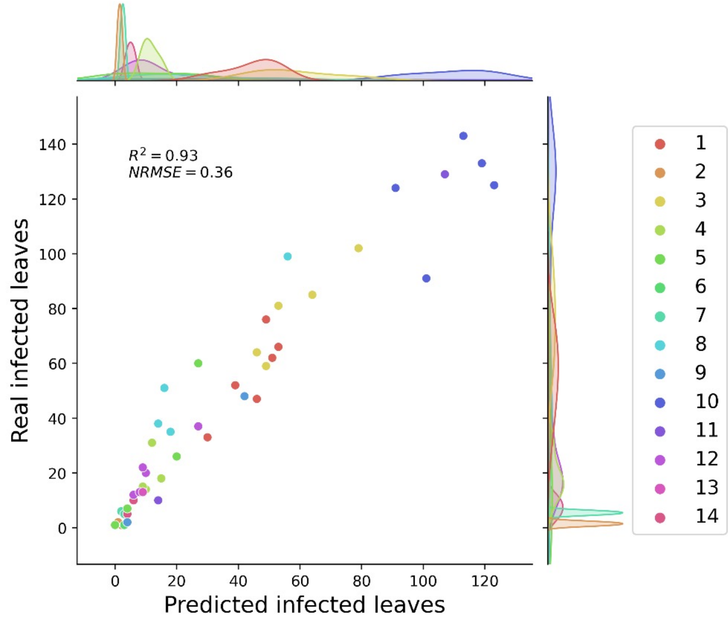
Deep neural network and Augmented reality technologies

Disease monitoring

Using Artificial Intelligence for automatic and fast detection of downy mildew symptoms in grapevine canopies





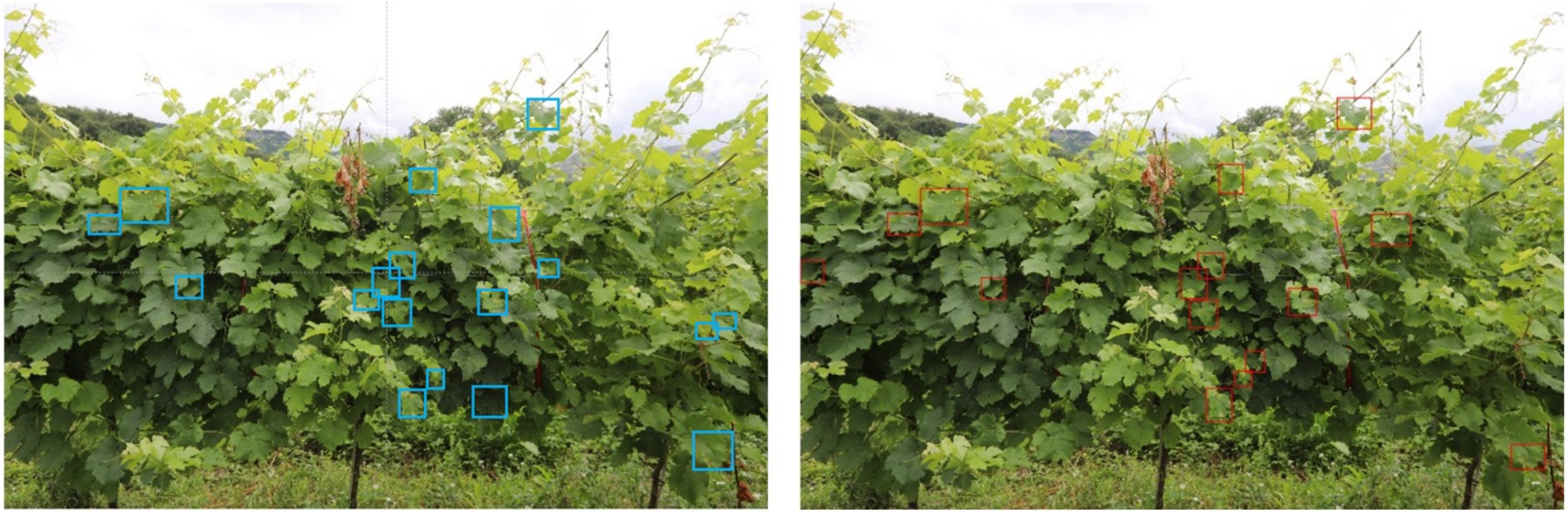


(Poblete-Echeverria et al., 2023 In-press)

Implementation – Smart applications

Disease monitoring

Using Artificial Intelligence for automatic and fast detection of downy mildew symptoms in grapevine canopies

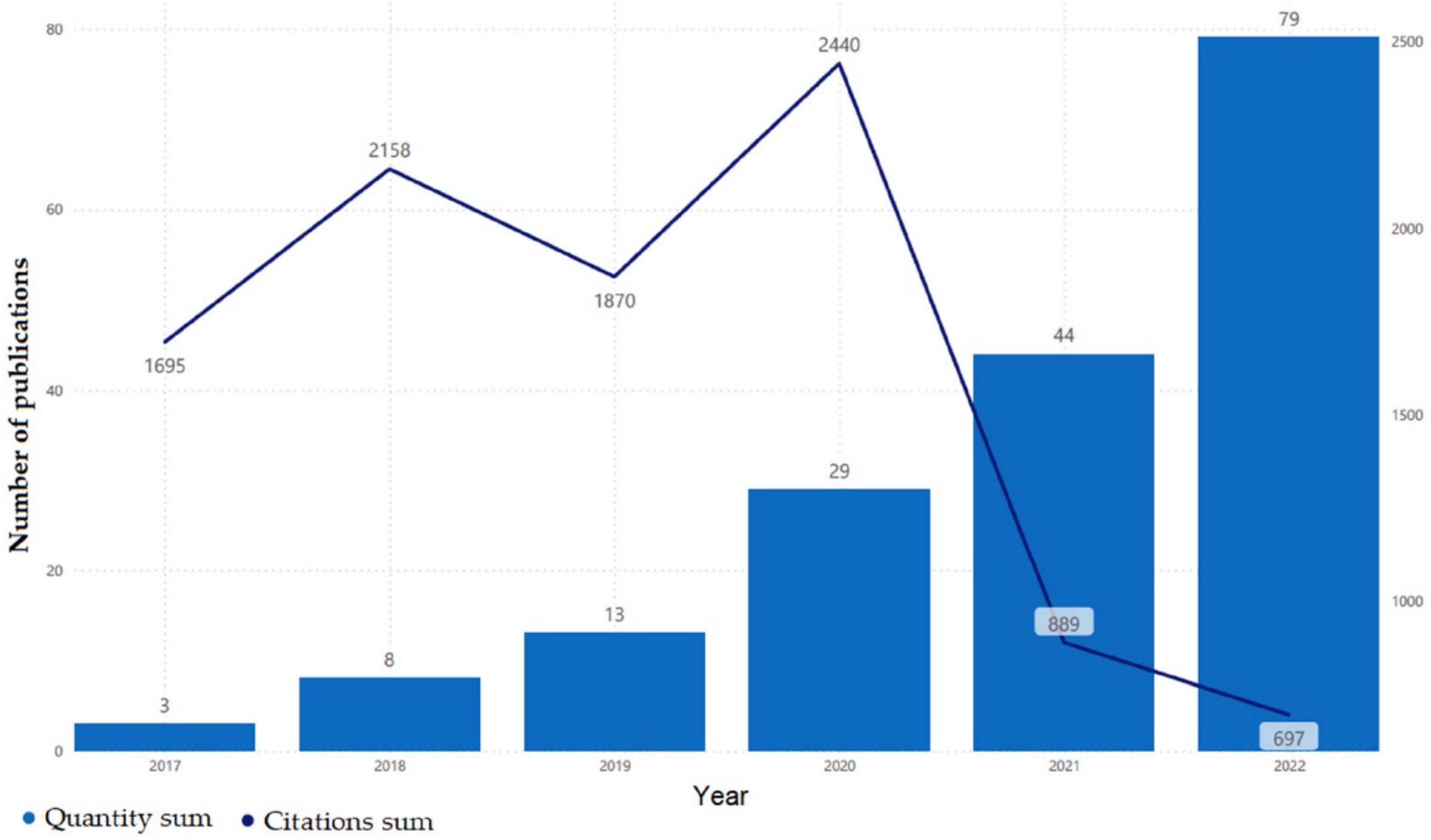


(a) (b)

(Poblete-Echeverria et al., 2023 In-press)

Implementation – Smart applications

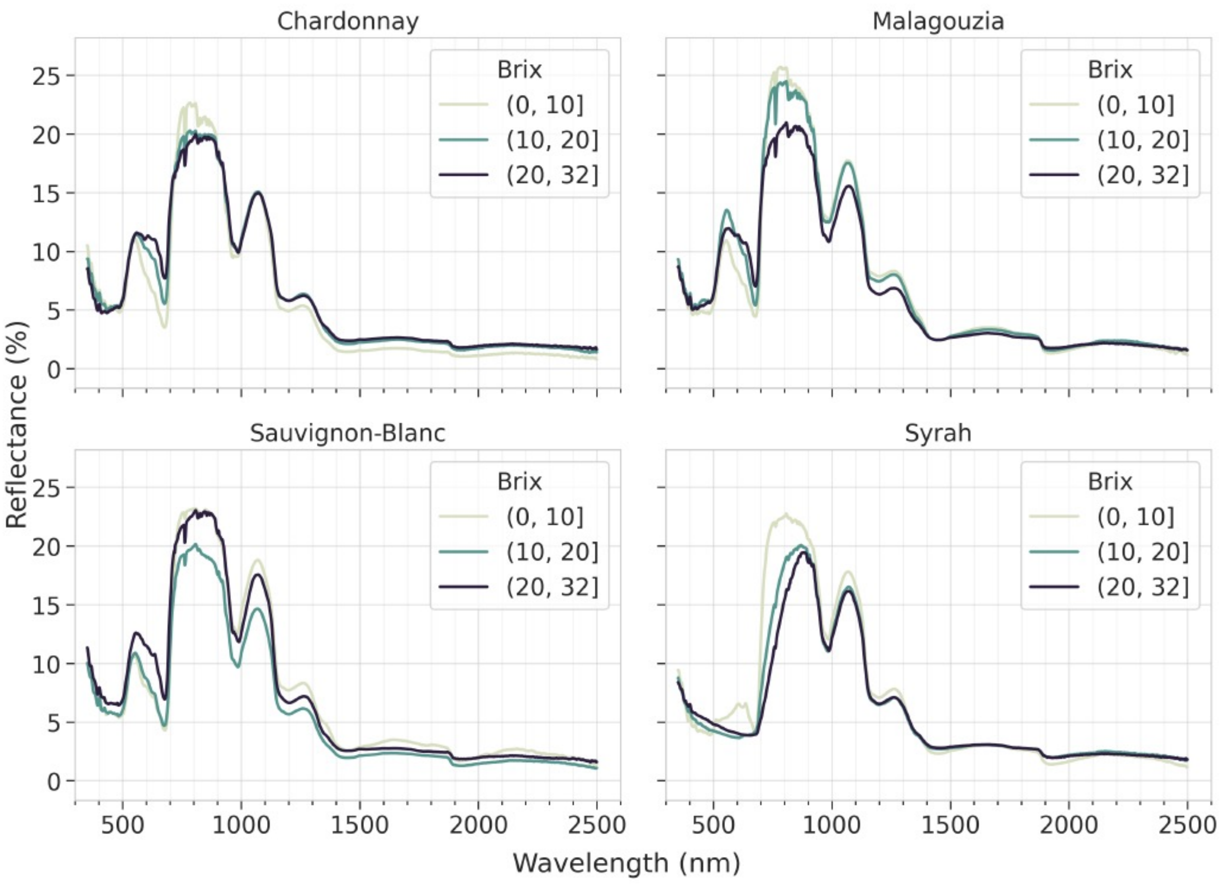
Quality evaluation



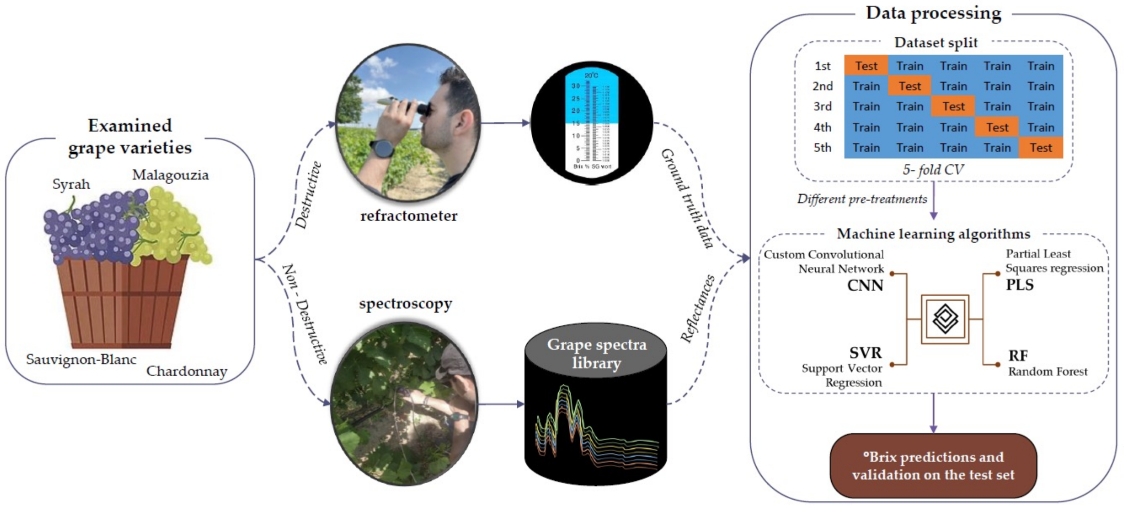
(Cavalcante de Oliveira et al., 2023)

Implementation – Smart applications

Quality evaluation



Portable contact probe spectrometer to PSR+3500 (Spectral Evolution Inc., Lawrence, MA, USA)



The effect of the change the °Brix content (grouped into three arbitrary classes) has on the mean reflectance spectra of each grape variety.

(Kalopesa et al., 2023)

Quality evaluation

Non-Invasive methods MSI and HSI for determining total soluble solids (TSS) and total acidity (TA) in table grapes considering berry, bunch and plant variability.

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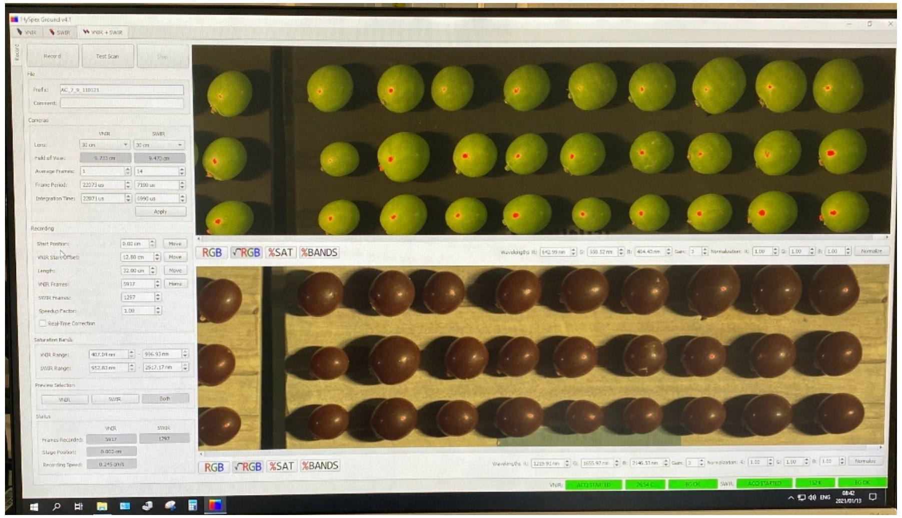
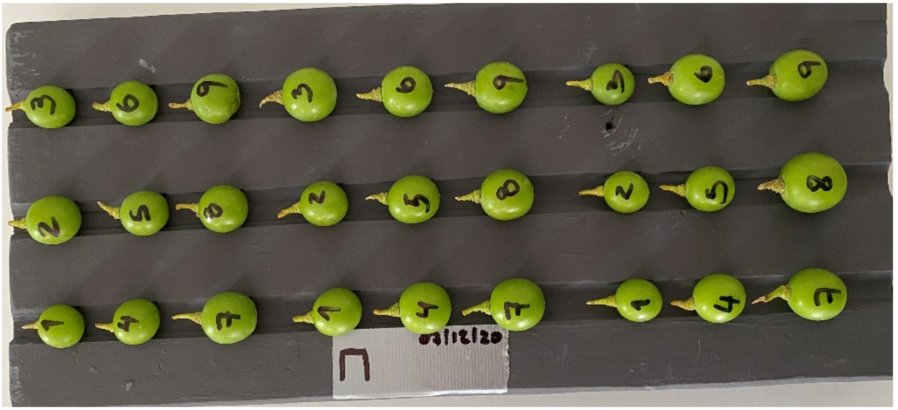
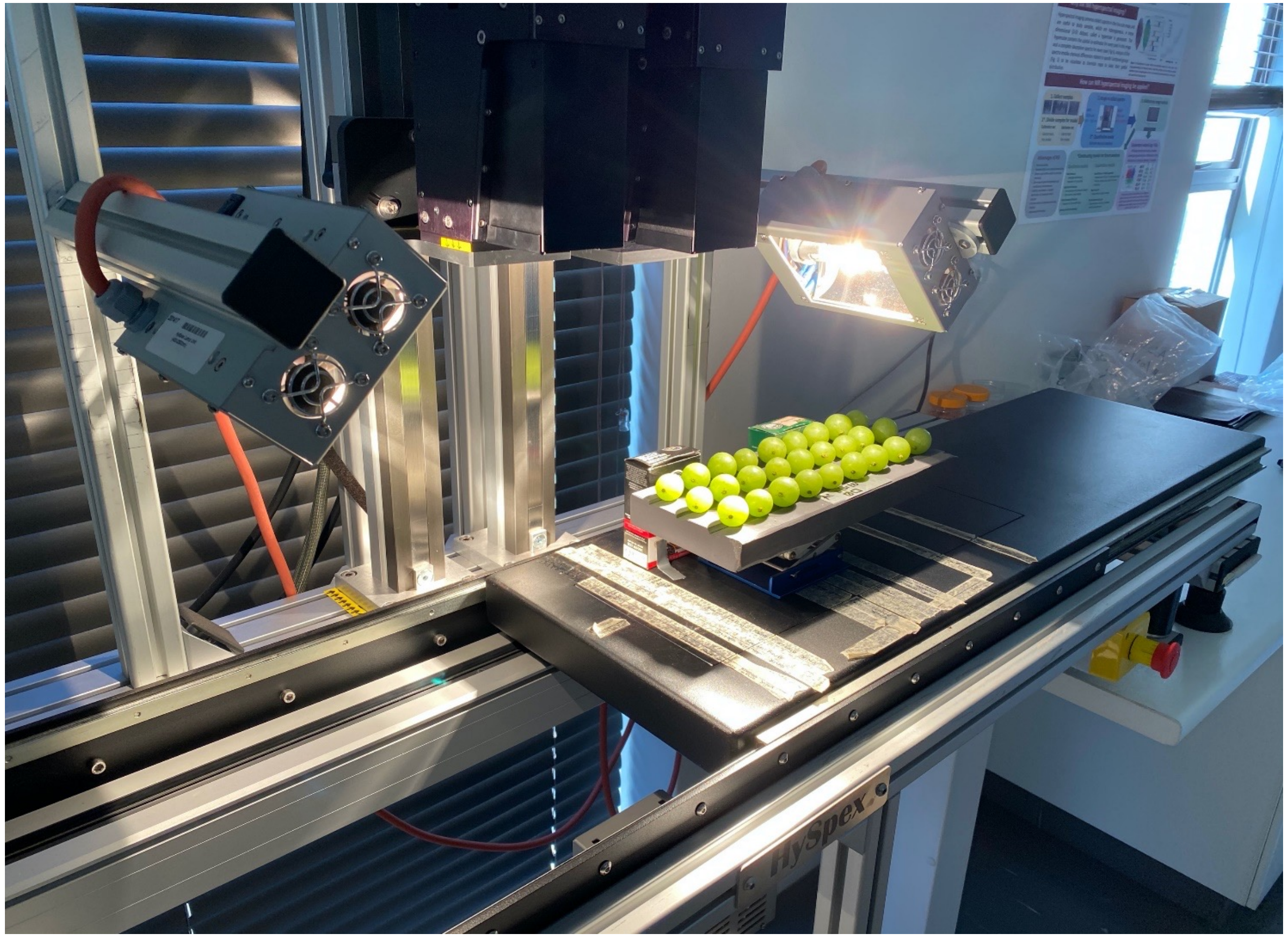
Implementation – Smart applications

HIS recollection process Autumn Crisp (about 6 minutes per picture).

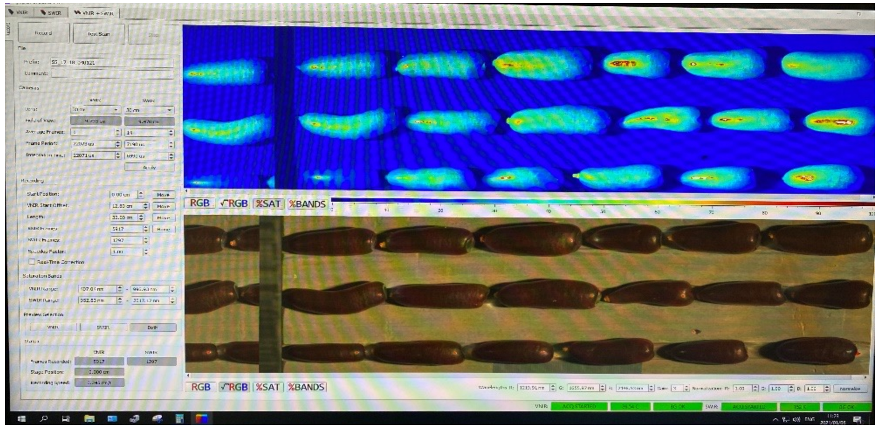


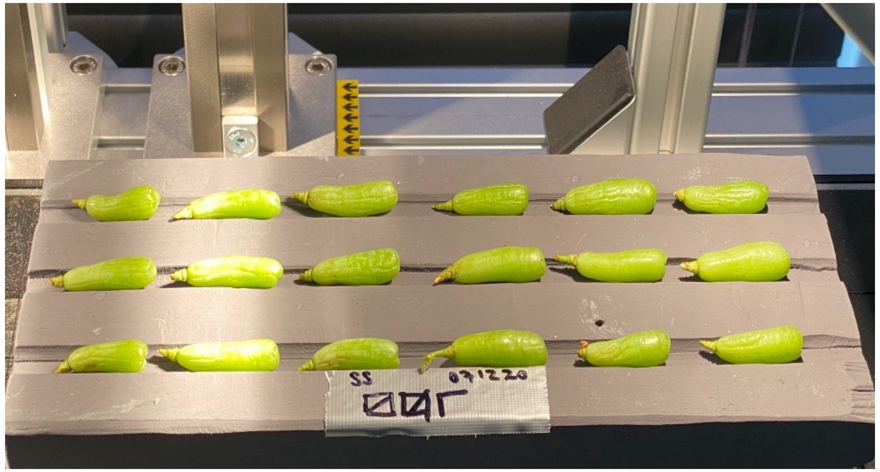


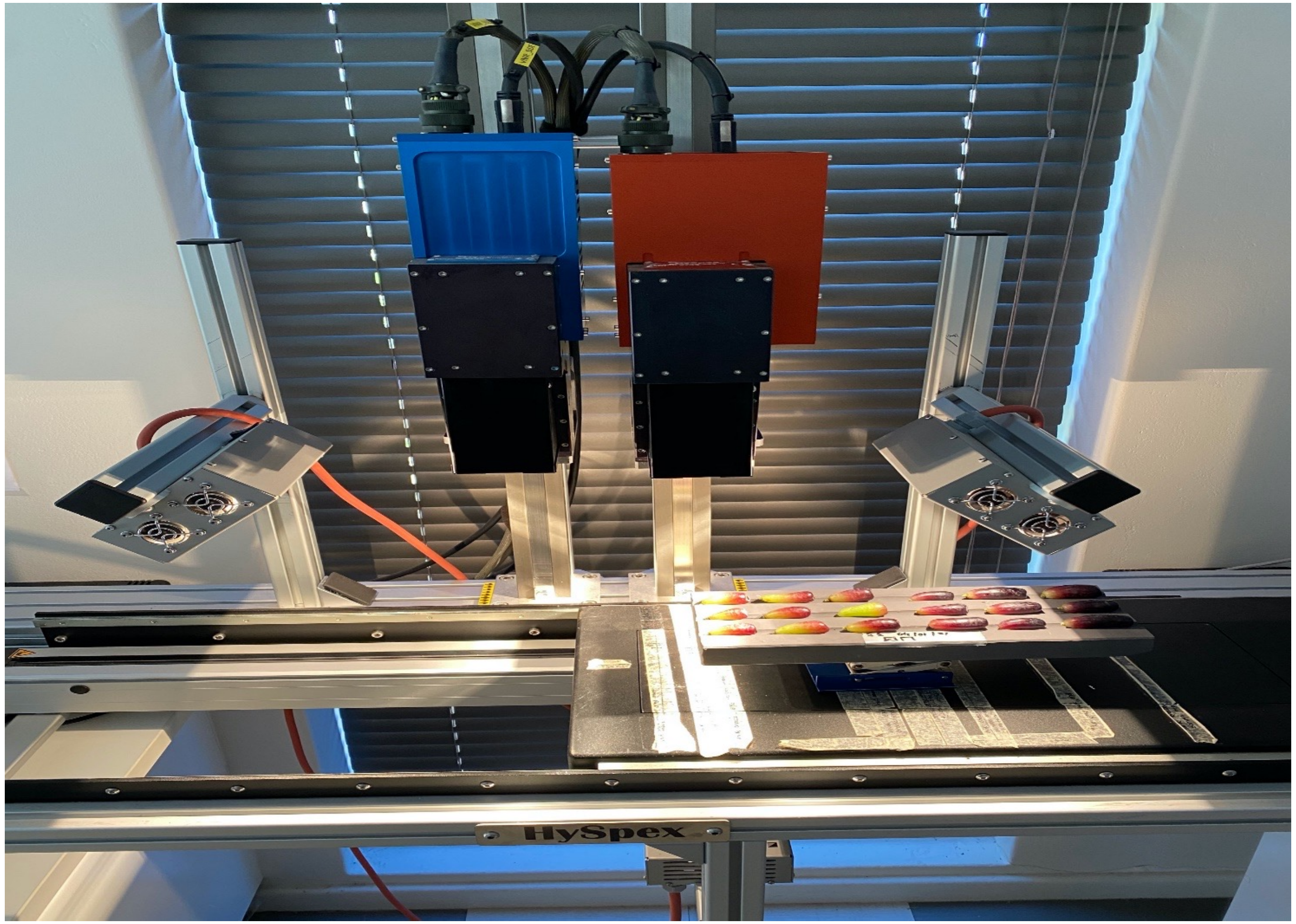


Implementation – Smart applications

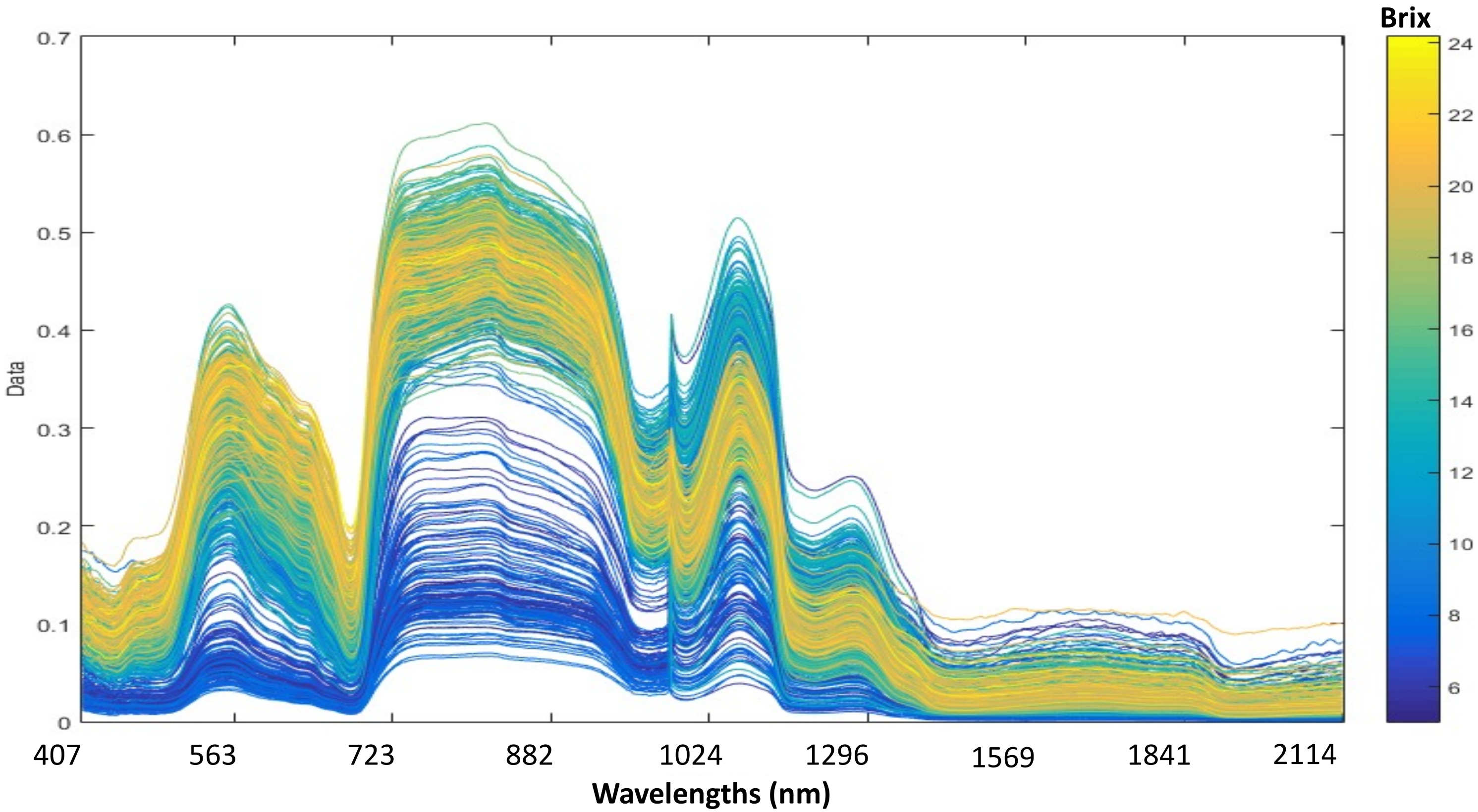
HSI recollection process Sweet Sapphire (about 6 minutes per picture).



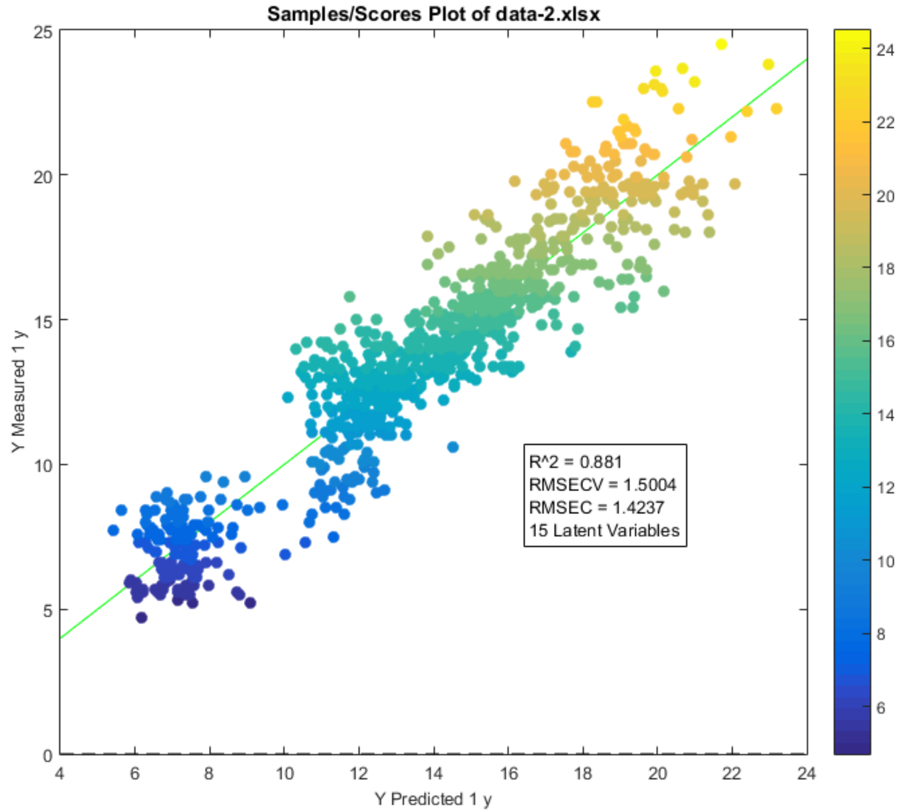




Implementation – Smart applications



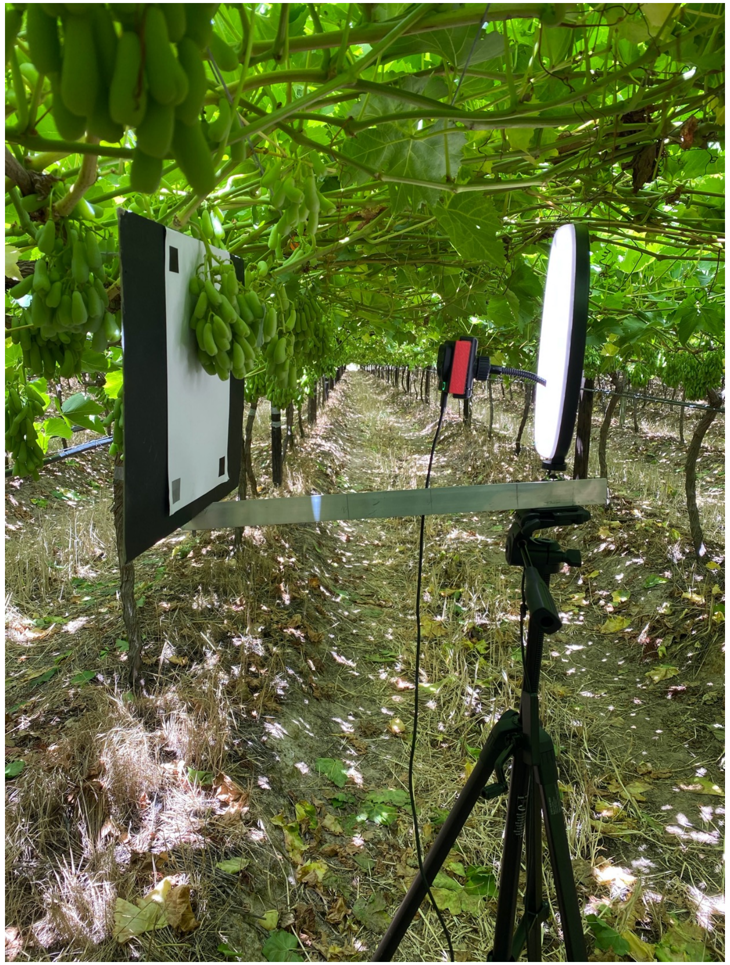
Spectra signature per band according level of sugar (Brix) in Autumn Crisp Table grape.



Sugar content measured vs sugar predicted content coloured by Brix level in Autumn Crisp table grape.

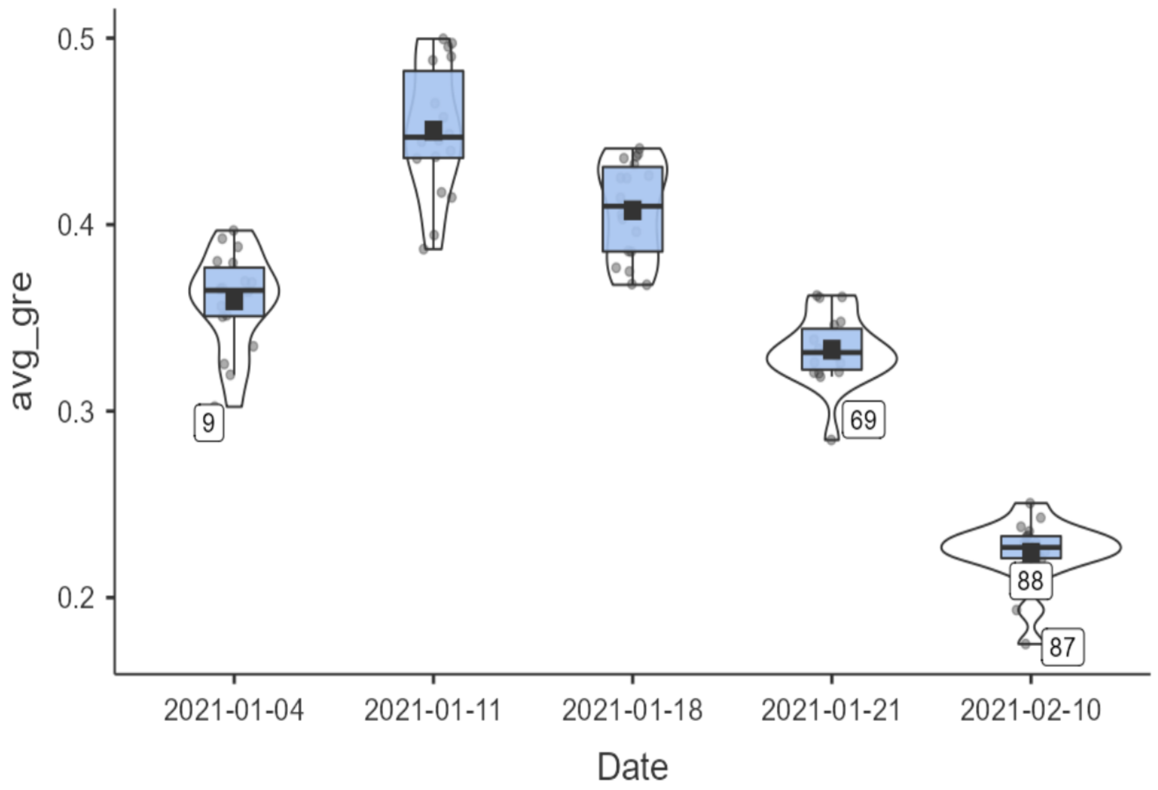
Implementation – Smart applications

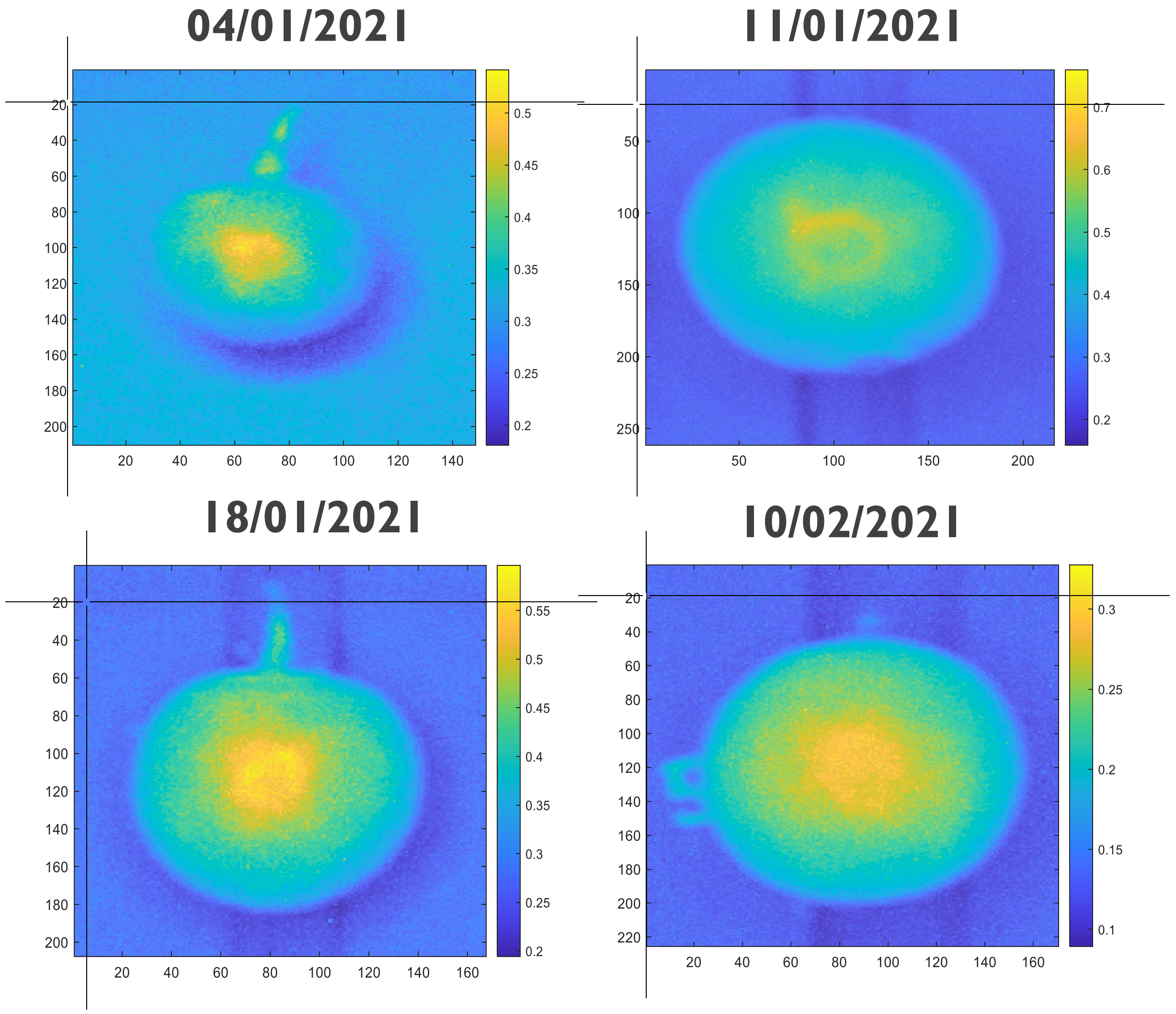
MSI collection



Implementation – Smart applications

Evolution MSI imaging of green lens (wavelength 550 nm) take it from a central berry of Autumn Crisp table grape bunch in 4 progressive harvest dates.





Implementation – Smart applications

Quality evaluation

Physical and chemical bunch characterization of table grapes using machine vision

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Implementation – Smart applications

Quality evaluation

Chemical parameters

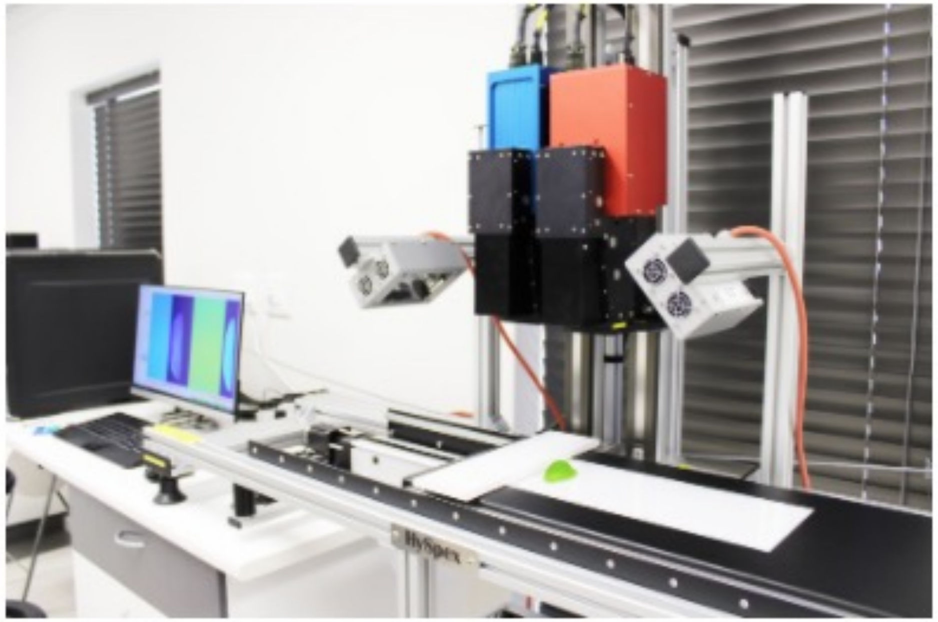
- TSS (Brix)
- pH
- TS
- Sugar/Acid ratio

Physical parameters

- Colour
- Bunch size
- Compactness
- Berry size
- Firmness

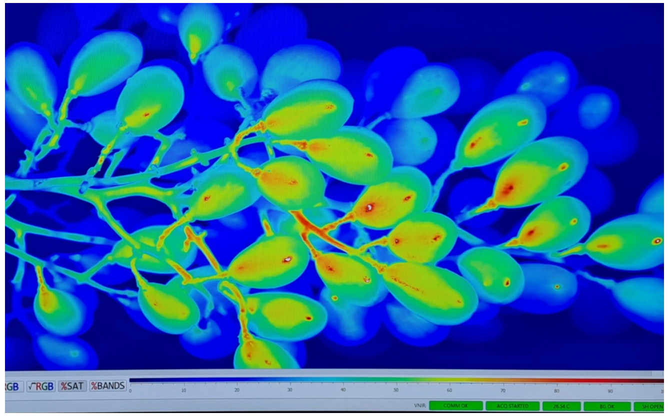
Quality evaluation

Hyperspectral Cameras

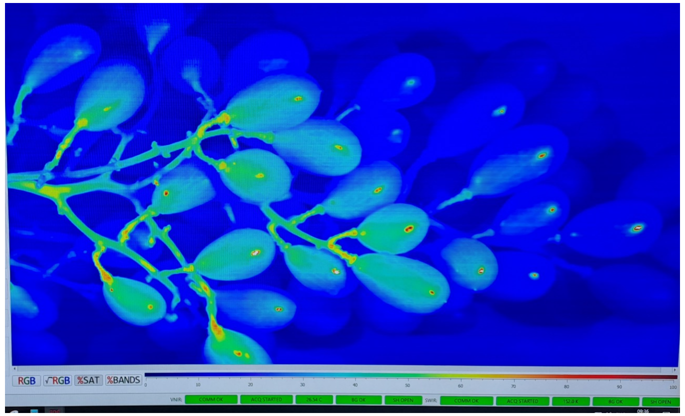


Tested protocols:

A) Visible-Near Infrared (VNIR) – intact bunch



B) Short-Wave Infrared (SWIR) – intact bunch



Implementation – Smart applications

Quality evaluation

MAPIR Survey 3

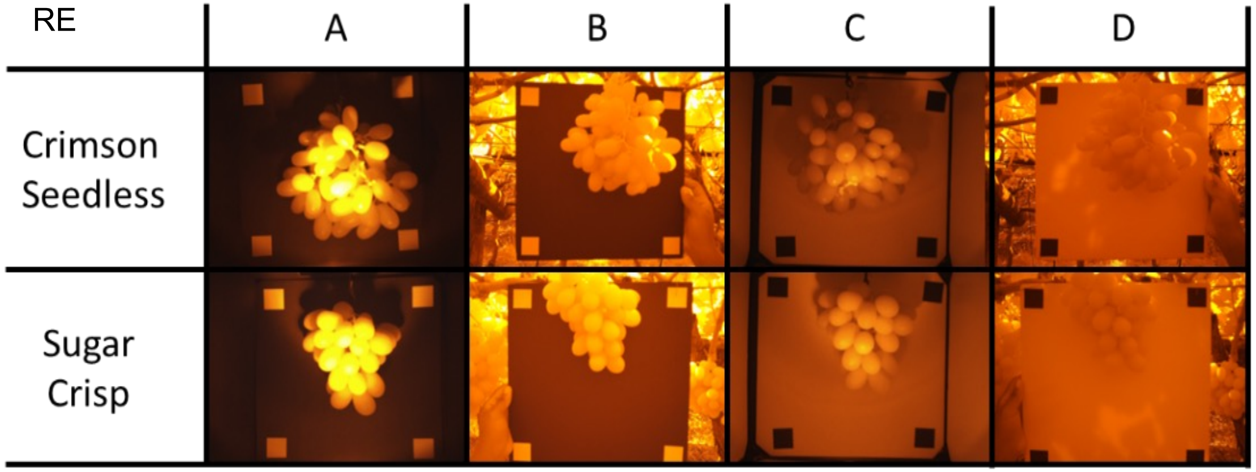
Multispectral camera
RGB (375-650nm)
RE (725nm)
NIR (850nm)

Tested protocols:

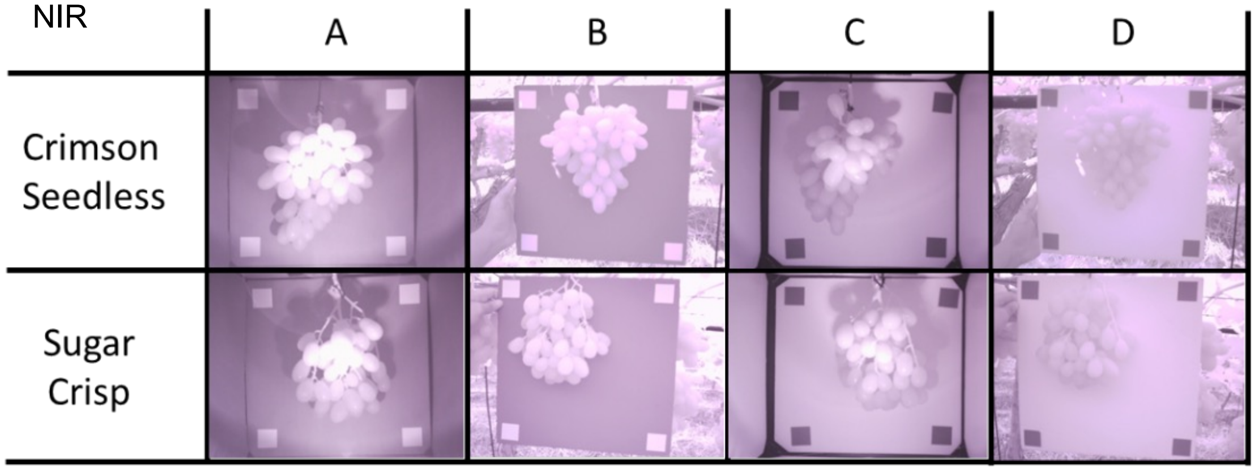
A) Black box & halogen light source
B) Black background & natural light
C) White box & halogen light source
D) White background & natural light

Black light box showing single lamp arrangement (bottom centre lamp) and double lamp arrangement (side lamps).

Quality evaluation



Examples of images acquired using RE multispectral camera and the four different protocols (A-D) for both Crimson Seedless and Sugar Crisp



Examples of images acquired using NIR multispectral camera and the four different protocols (A-D) for both Crimson Seedless and Sugar Crisp

Future perspectives

- Supporting current traditional agricultural practices with the latest technologies for data capturing and analysis can improve performance, quality and productivity capacity of the table grape industry.

- New concepts and ideas (smart applications) can be implemented to optimize management practices and solve technical problems.

- AI models should be trained and tested properly before being released for practical use.

- The collection, digitalization, storage, visualization, and management of historical data, together with modern data analysis tools (AI and machine vision), can reduce decision-making uncertainties.

- Collaboration among growers, service providers, and research institutions can accelerate the implementation and adoption of new technologies by the industry.

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