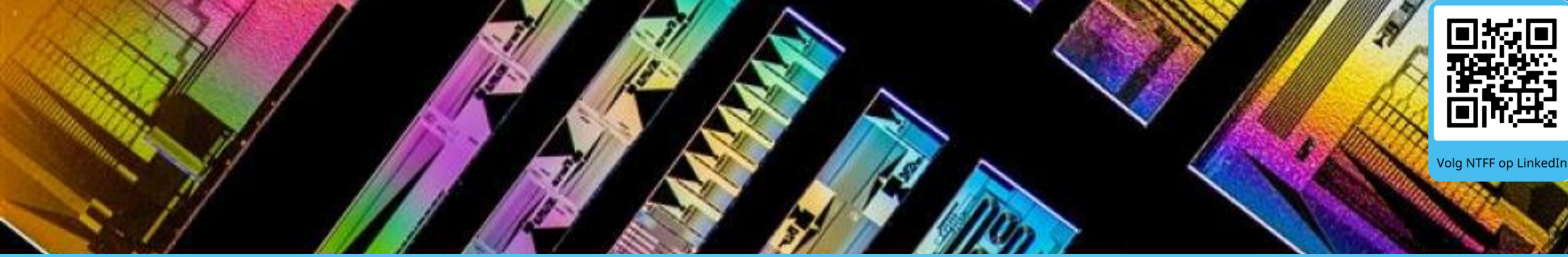


Volg NTFF op LinkedIn

Feeding the current and future possibilities of photonics –

Photonics Meets Handsfree Food Processing

20 september

NEXT TECH FOOD FACTORIES

NXT GEN HIGHTECH

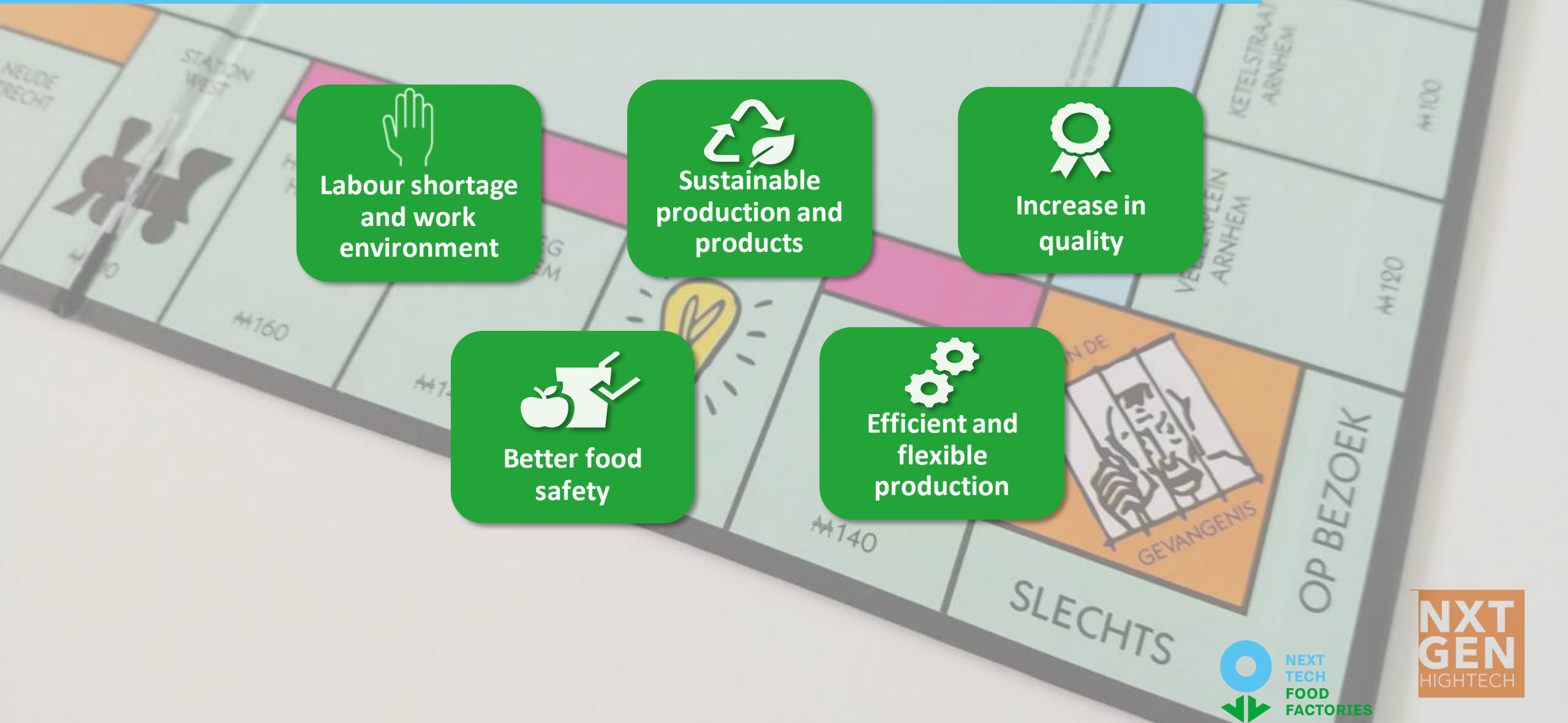
Dutch Photonics Event

GREEFA

perClass BV

OnePlanet Research Center

Challenges on the plate of food processors



NEXT TECH FOOD FACTORIES

NXT GEN HIGHTECH

Leave your questions and remarks during the presentations here

What will we talk about?

- Lex Oosterveld (OnePlanet) on the International roadmap integrated photonics (IPSRI) and the role in food processing
- Pavel Paclik (PerClass) on easy-to-use Spectral Imaging in food quality
- Henk Reitsma (Greefa) on the use of different types of photonics applications in sorting and packaging of fruits and vegetables
- Questions and Discussion on challenges, possibilities and follow-up

Lex Oosterveld – OnePlanet

NXT GEN HIGHTECH

PhotonDelta
Gateway to Integrated Photonics

NXT GEN HIGHTECH

OnePlanet Research Center

empowered by
imec, Wageningen University & Research, Radboud University and Radboudumc

Integrated photonics: an opportunity for Food Processing 4.0

Lex Oosterveld, Principal member of the technical staff, OnePlanet Research Center

Food processing 4.0

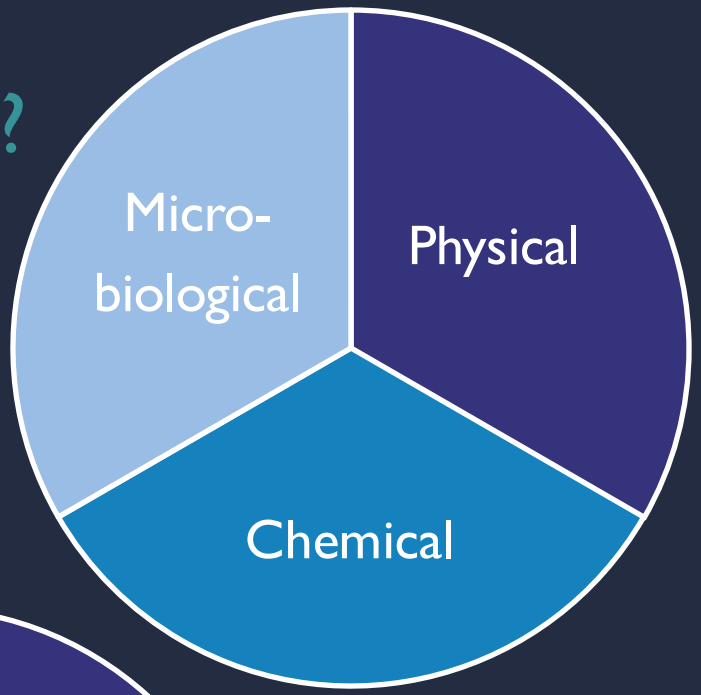
"Food processing 4.0" concept denotes processing food in the current digital era by harnessing fourth industrial revolution (called Industry 4.0) technologies to improve quality and safety of processed food products, reduce production costs and time, save energy and resources, as well as diminish food loss and waste

Hassoun et al., 2023
Food Control 145, 109507

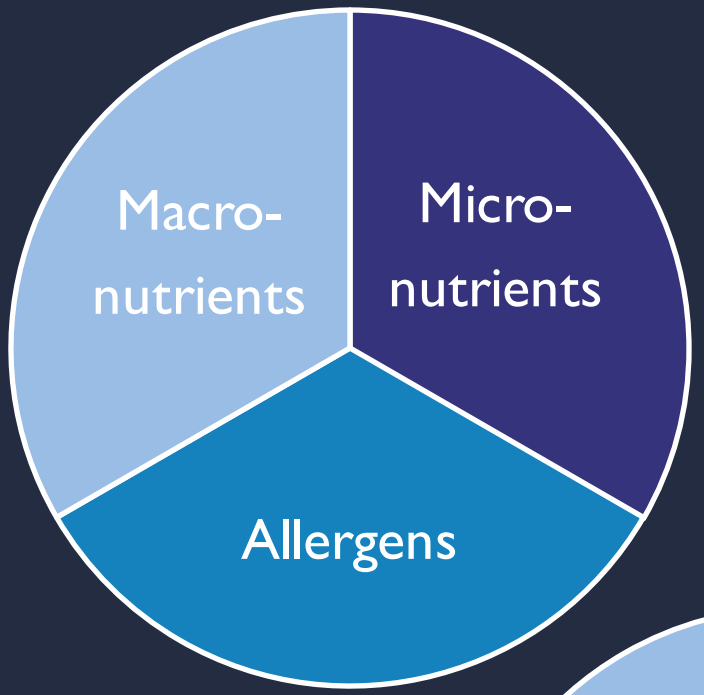
Relevant technologies are:

- Sensors
- Software
- Connectivity
- Robotics
- Data analytics

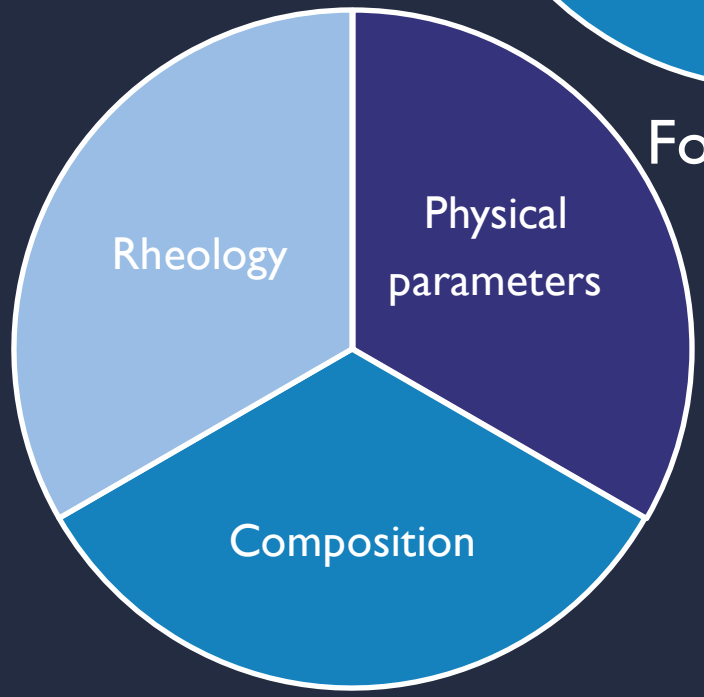
Why sensing?



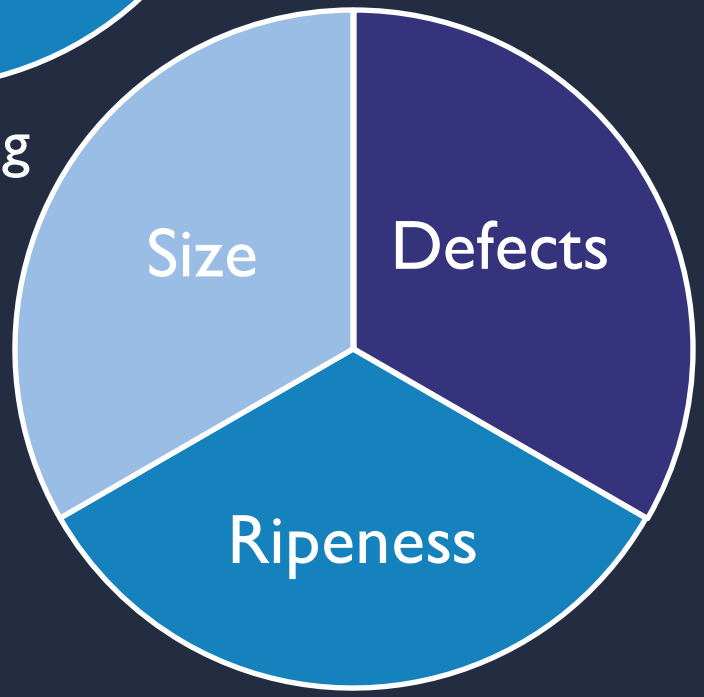
Food safety



Labelling



Process control

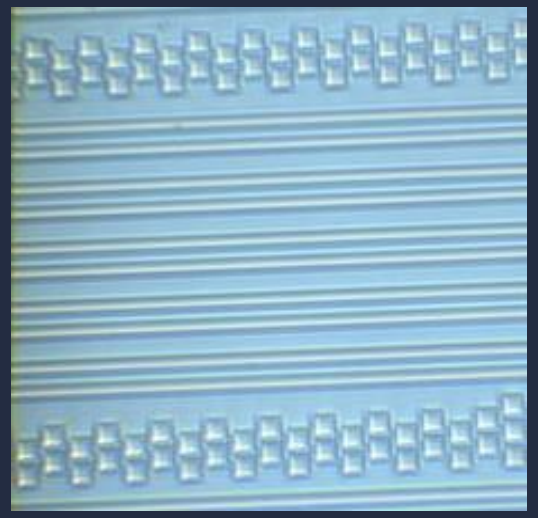


Sorting

Photonic integrated circuits

- A photonic integrated circuit (PIC) is a microchip containing two or more photonic components which form a functioning circuit.
- This technology detects, generates, transports, and processes light.
- Photonic integrated circuits utilize photons (or particles of light) as opposed to electrons that are utilized by electronic integrated circuits.
- A photonic integrated circuit provides functions for information signals imposed on optical wavelengths typically in the visible spectrum or near infrared (850–1650 nm).

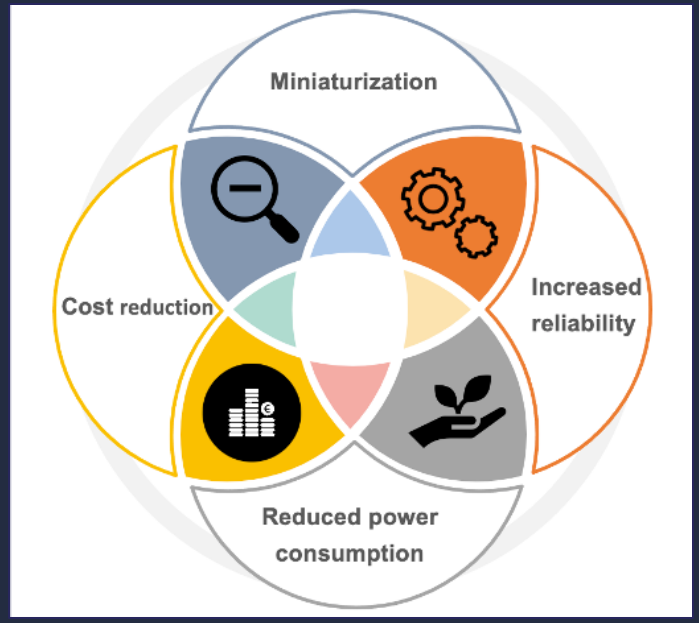
Source:Wikepedia



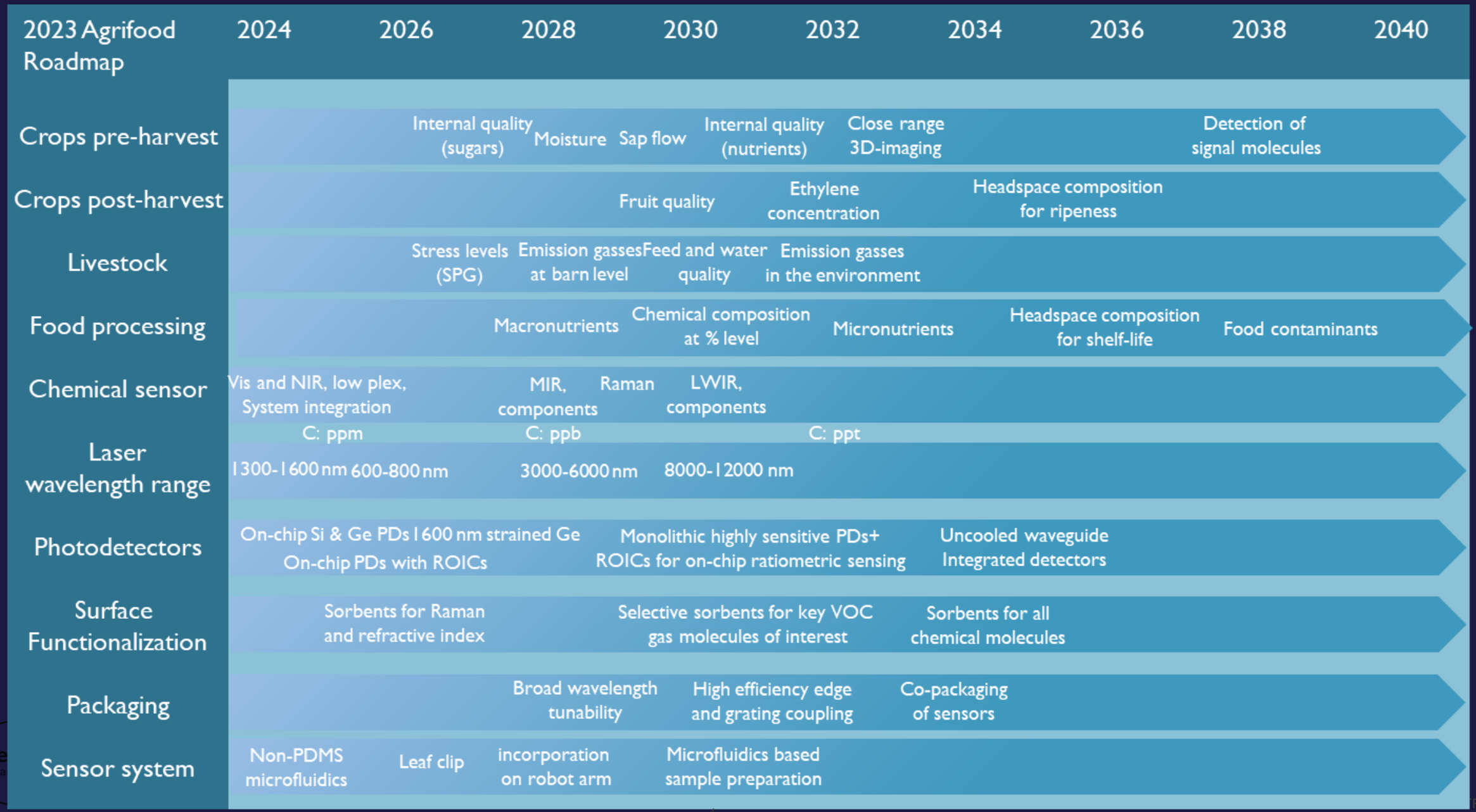
The benefits and possibilities of integrated photonics for agrifood

- It allows a wide variety of optical sensing technologies suited for agrifood
  - real-time remote sensing of food composition
  - miniaturization, robustness and low power: suitable at point of use

- Scalability and integration allows low cost at high volume
- Sensor fusion and powerful computing support quantitative analysis and ease of use



IPSR-I Photonic Integrated Circuits raodmap for agrifood 2023



Supply chain and photonic applications

- Plant growth - Nutrients, moisture - Plant stress - Pests and disease - Soil conditions - Moisture, sugar - Livestock emissions - Livestock produce	- Handling and harvest damage - Storage conditions - Controlled ripening - Produce selection - Pests, moulds and diseases	- Ingredient inspection - Ingoing mould/disease inspection - Produce characterization and selection - Food processing control - Quality control	- Damage inspection - Transport control - Point of sales quality control	-Damage inspection -Produce quality -ripeness -sellability quality control
- NIR spectroscopy - Raman spectroscopy - THz spectroscopy - Photoacoustic spect. - Speckle imaging	- NIR spectroscopy - Raman spectroscopy - THz spectroscopy - Photoacoustic spectroscopy	- NIR spectroscopy - Raman spectroscopy - THz spectroscopy - Biochips	-NIR spectroscopy - (Photoacoustic) gas detection	-NIR Spectroscopy -Gas detection -

Photonic Application

Photonic Sensing

* (Hyperspectral) cameras are assumed ubiquitous.

PhotonDelta
Gateway to Integrated Photonics

OnePlanet
Research Center

PhotonDelta
Gateway to Integrated Photonics

NXT GEN HIGHTECH

OnePlanet Research Center

empowered by
imec, Wageningen University & Research, Radboud University and Radboudumc

Integrated photonics: an opportunity for Food Processing 4.0

Lex Oosterveld, Principal member of the technical staff, OnePlanet Research Center

Dr. Pavel Paclik - PerClass

NXT GEN HIGHTECH

perClass BV

User-friendly spectral image interpretation in food quality

Dr.Pavel Paclik

20 September 2023

perClass BV introduction

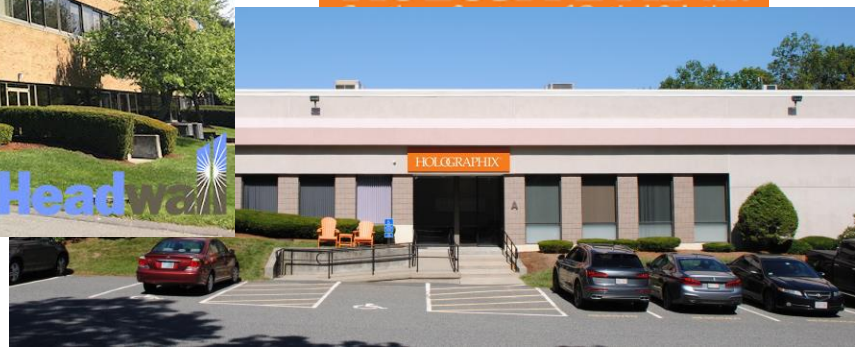
We provide software enabling anyone to interpret spectral images

- perClass BV is a spin-off from TU Delft (2007)
- 15+ years of experience with industrial machine learning
- in 2018 we introduced specific product for spectral imaging – perClass Mira
- in 2022 acquired by Headwall Photonics

perClass

Headwall

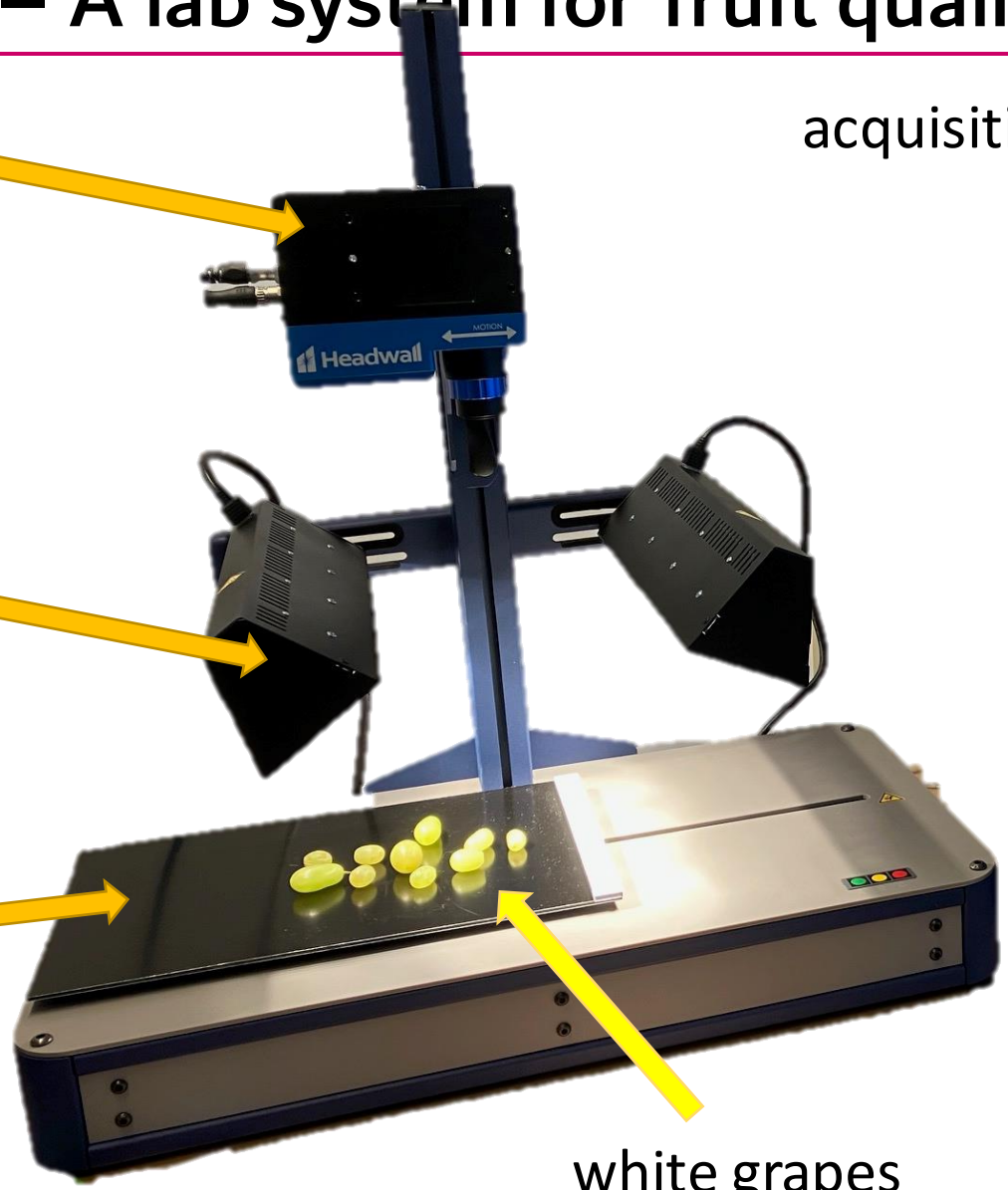
HOLOGRAPHIX LLC



Outline

- Introduction
- Spectral imaging
- Example applications in food
- Regression / quality estimation
- Latest developments in quality work-flows
- Summary

perClass Mira Stage – A lab system for fruit quality testing



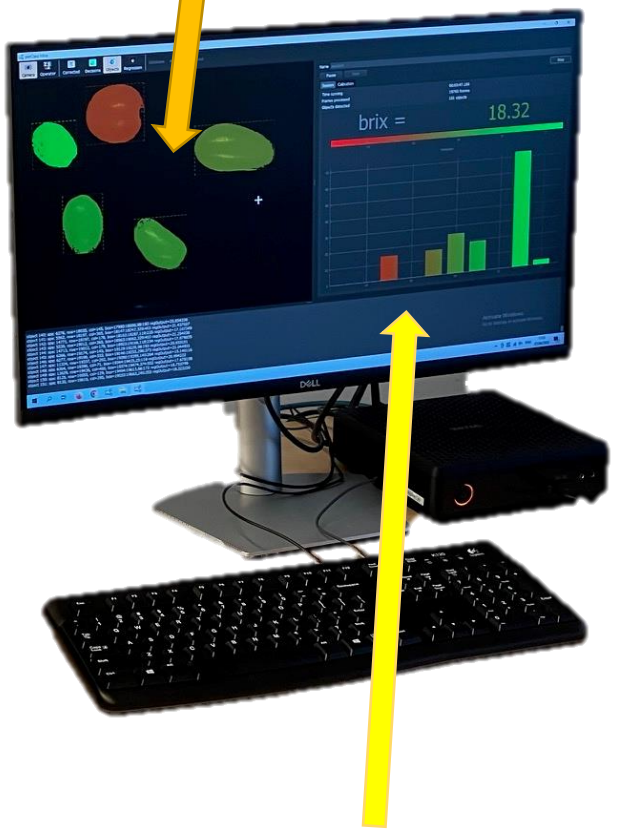
hyperspectral camera

illumination

scanning stage

white grapes

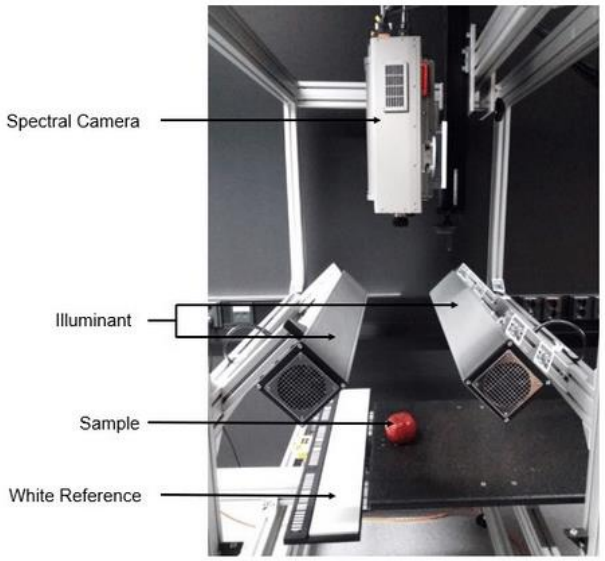
acquisition and interpretation software



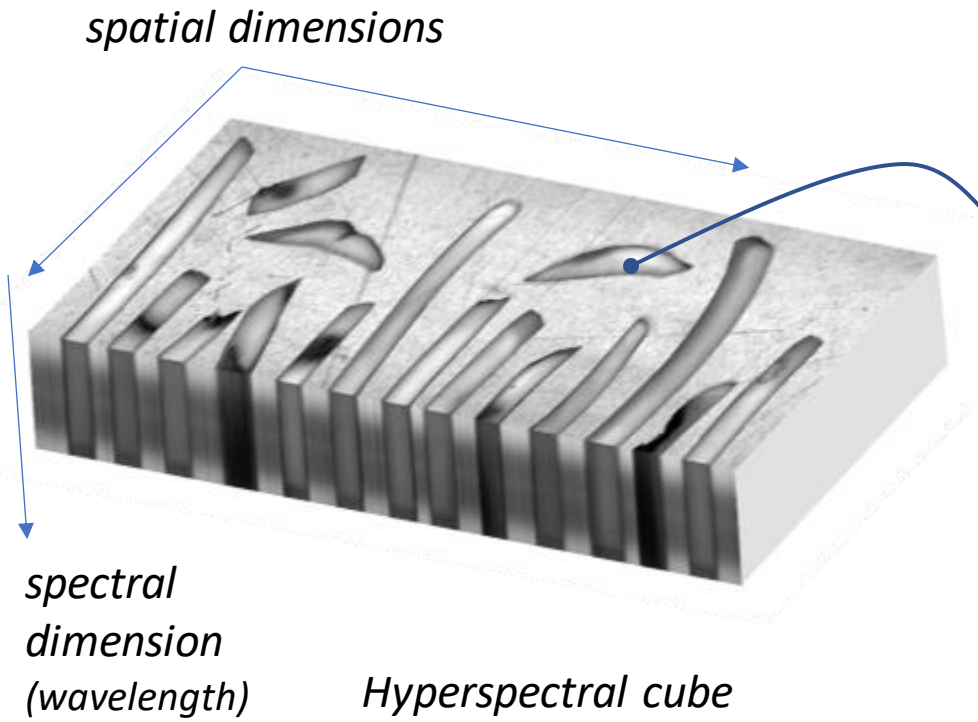
estimated brix

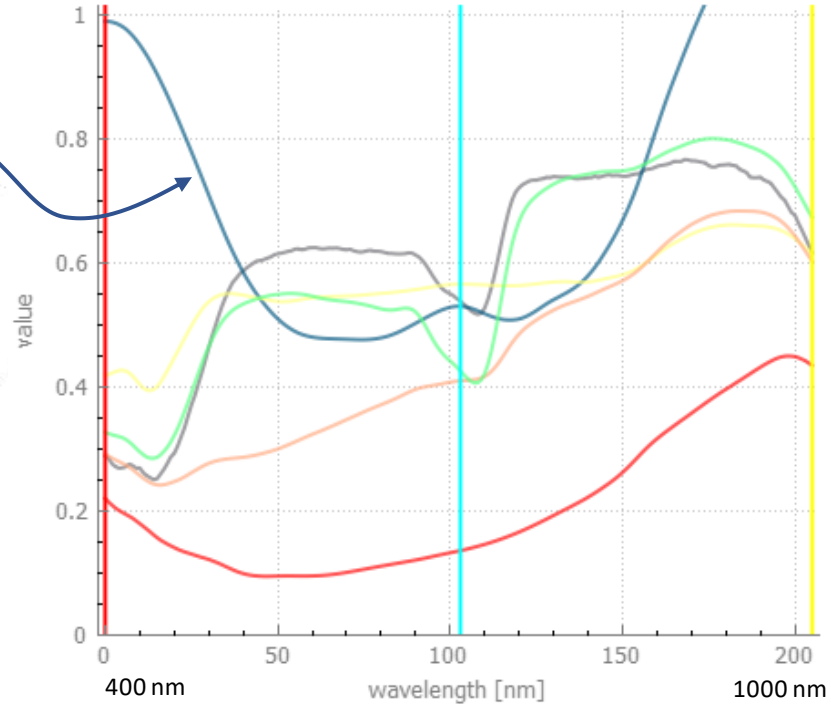
What is spectral imaging?

- Collecting light reflected from the sample over a range of spectral wavelengths
- Producing spatially and spectrally resolved data (spectral cubes)



source: thesis of Asif Setu

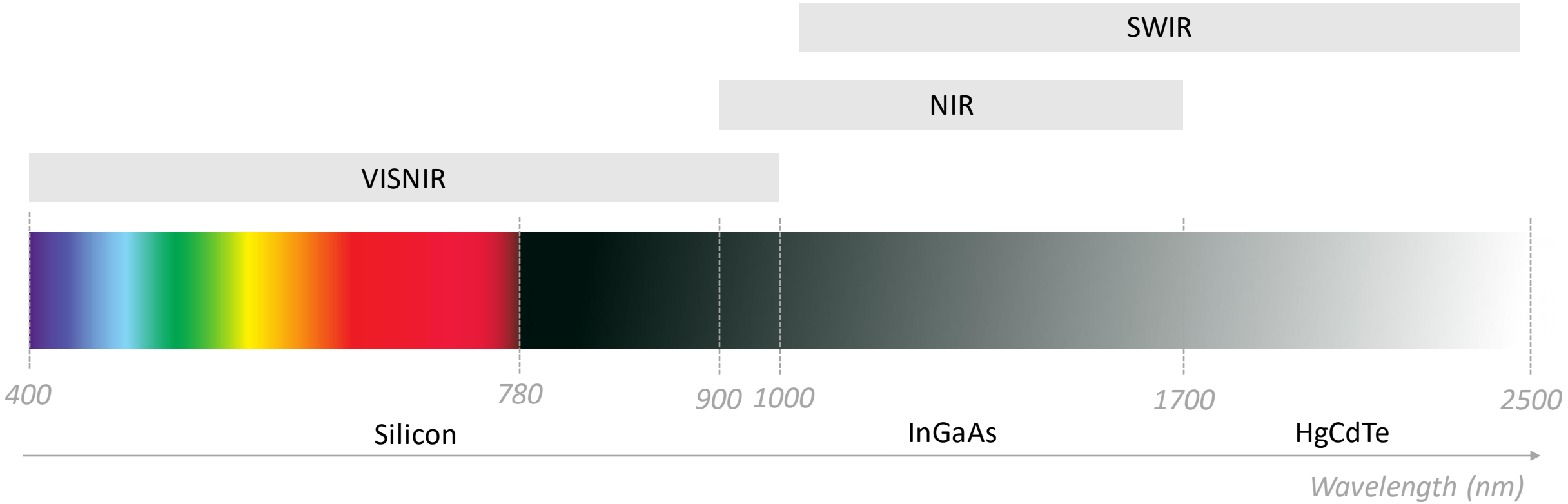




200 bands

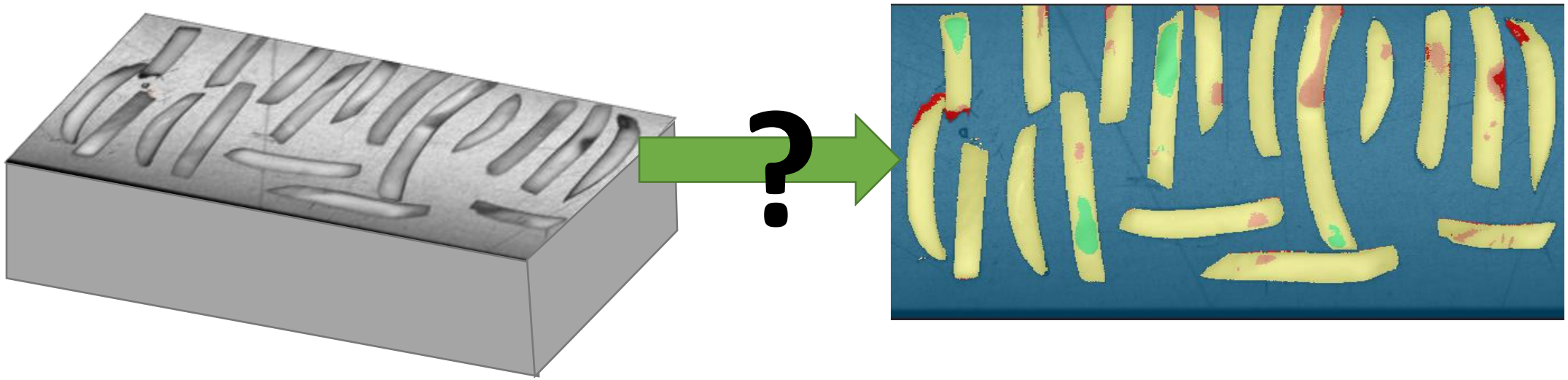
Spectral ranges

- Each spectral range provides different information for different type of applications



Challenge

How to get from a spectral cube to application-specific interpretation?



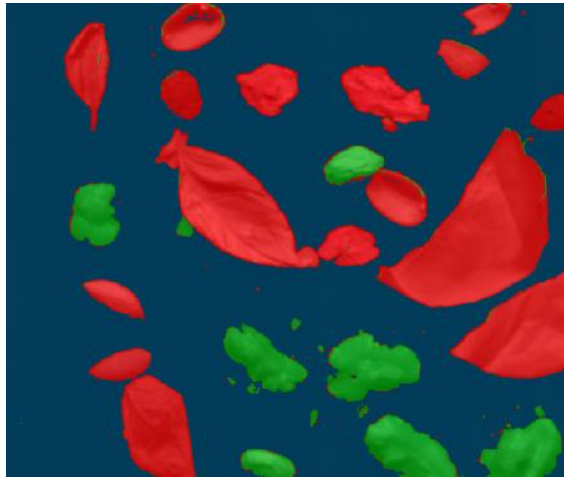
What sensor technology to choose? What wavelength range? Where to start? What software to use? How to correct data? How to annotate? How many scans? How to clean data? What models to use? How to set up experiments? How to estimate performance? How many and what bands to choose? How to fine-tune performance? How to apply models to real-time data stream? Is it fast enough?

Spectral image interpretation in food applications

- Classification

- *Detect foreign objects*
- *Identify objects or parts by material*
- *Find defects*

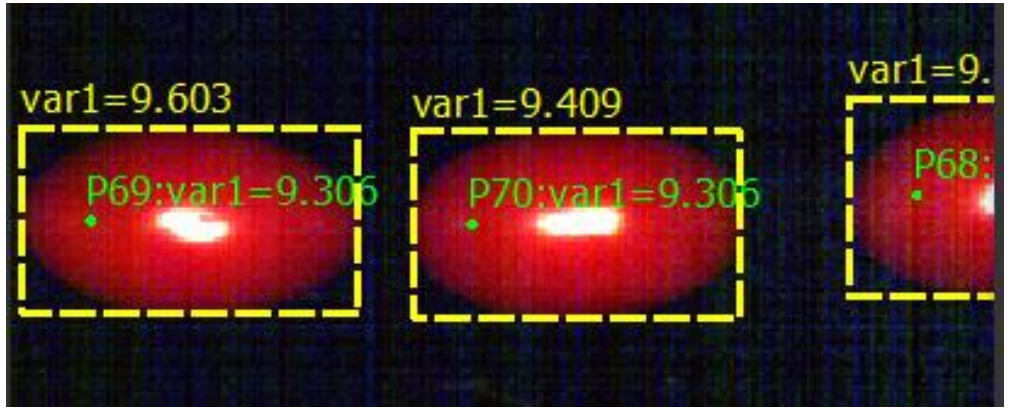
Make decisions



- Regression

- *Estimate sugar content*
- *Sort by moisture content*
- *Visualize protein distribution*

Estimate numerical value

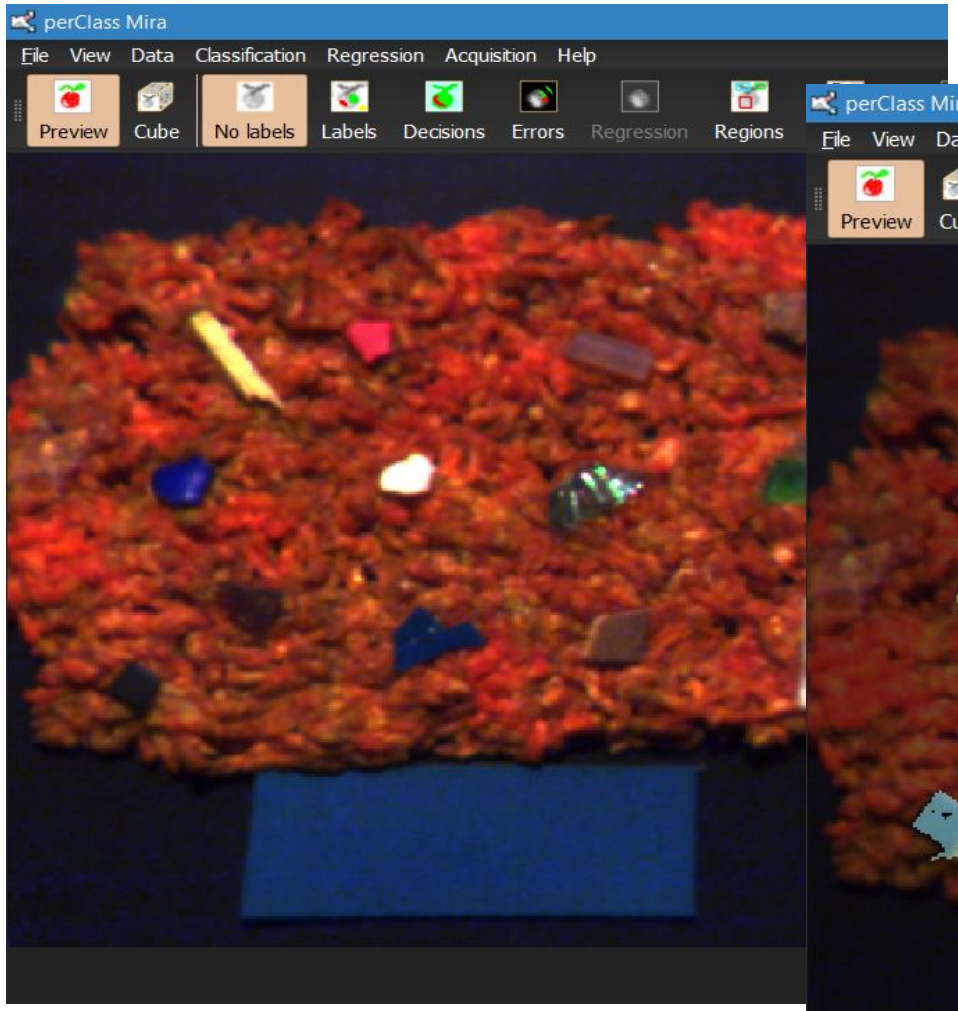


Unknown foreign object detection in minced meat

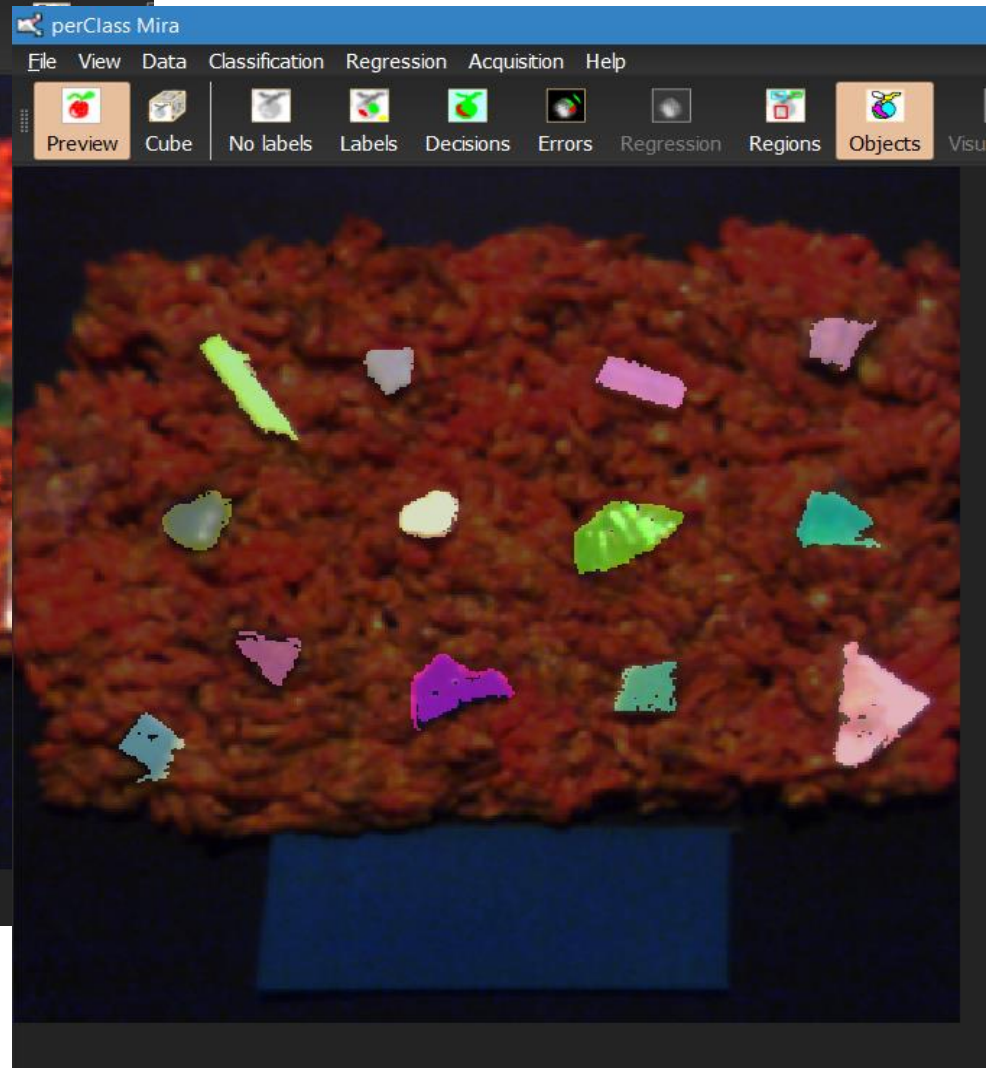
Ultris X20
350-1000nm

cubert

➢ Foreign objects detection



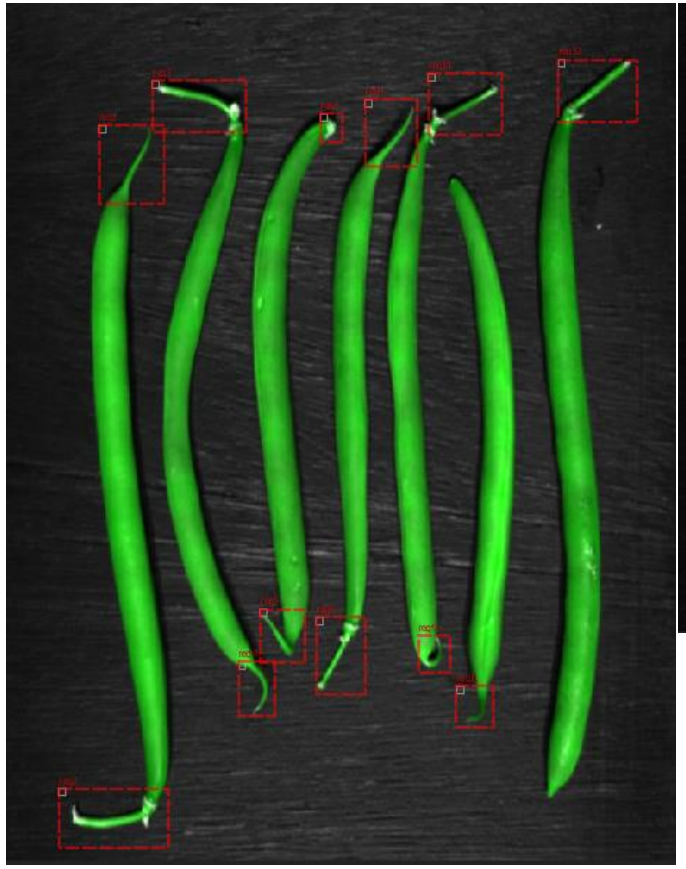
False RGB preview



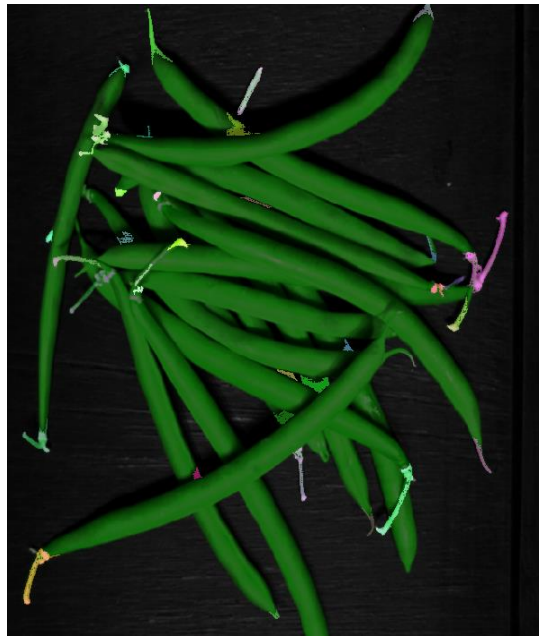
Decisions per object

Detecting green bean stem ends

Test image 1



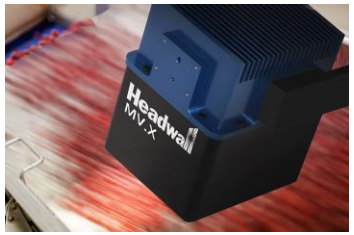
Test image 2



1 tail	labeled regions found	not-found	total
1: tail	12	0	12
decisions matched	12		12
decisions not-matched	0		0
total decisions	12		12

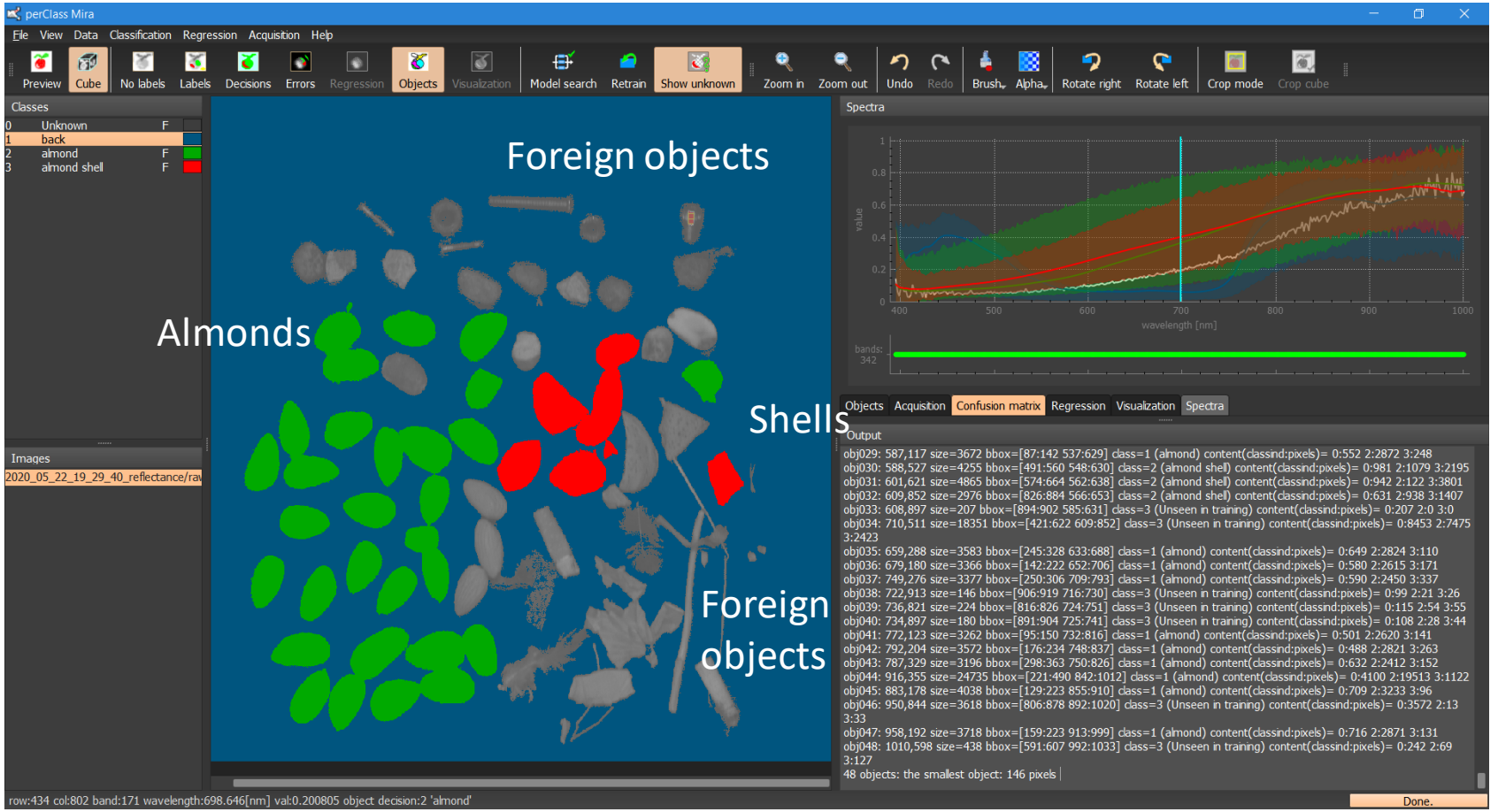
- Detection by material, not by appearance
- Confusion matrix **per object**
  - True detections
  - Make sure there are no false positives

Foreign object detection in almond sorting



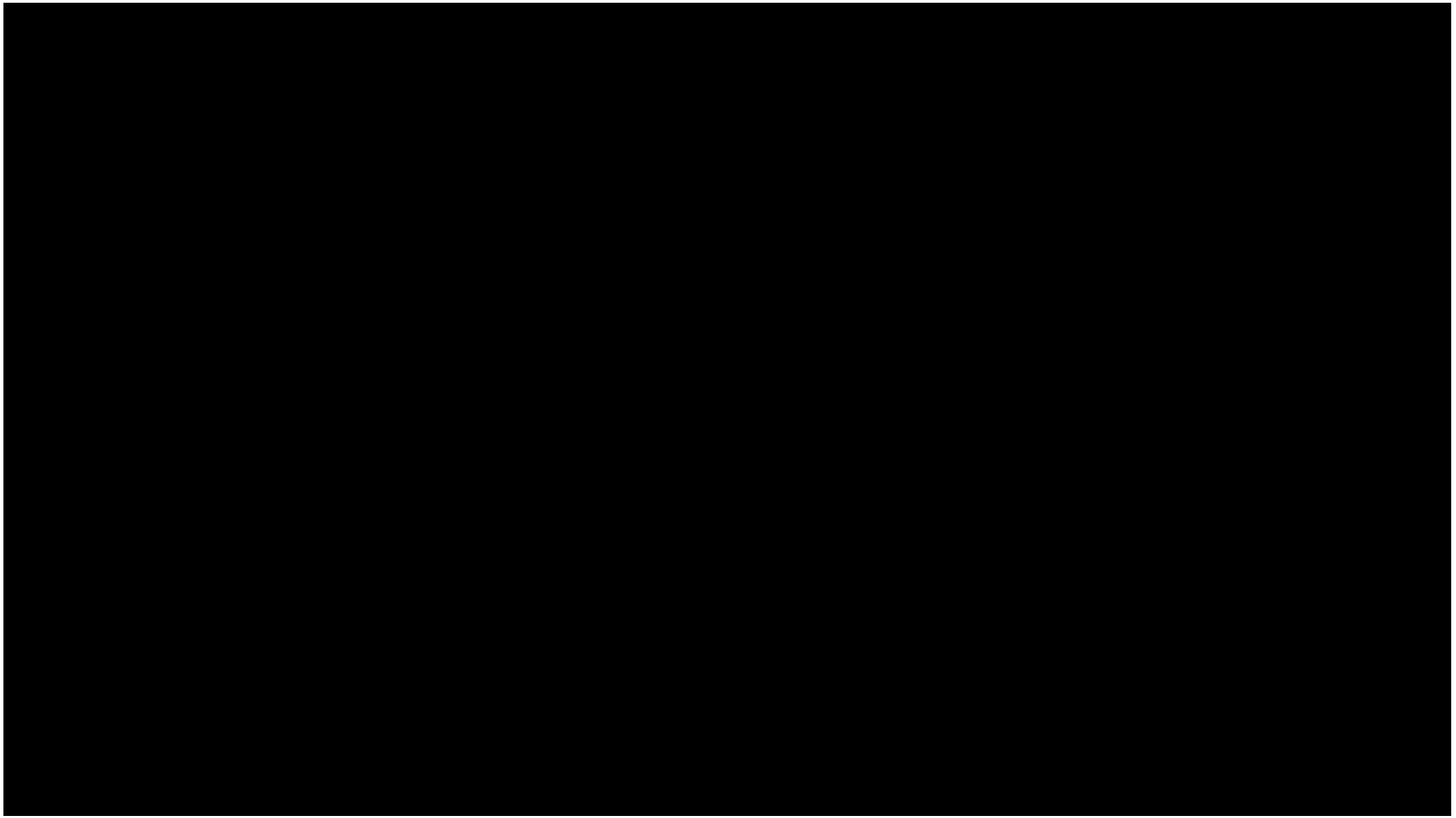
- Rejection of unknown (not trained) foreign objects

RGB picture

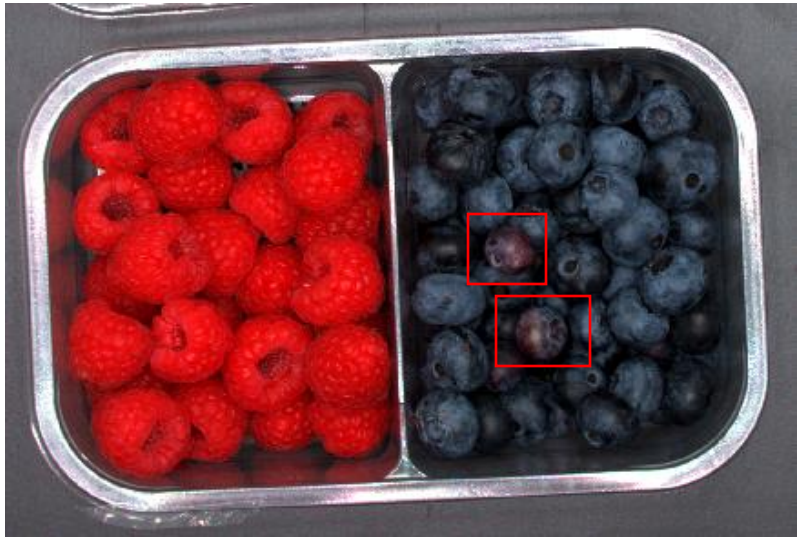


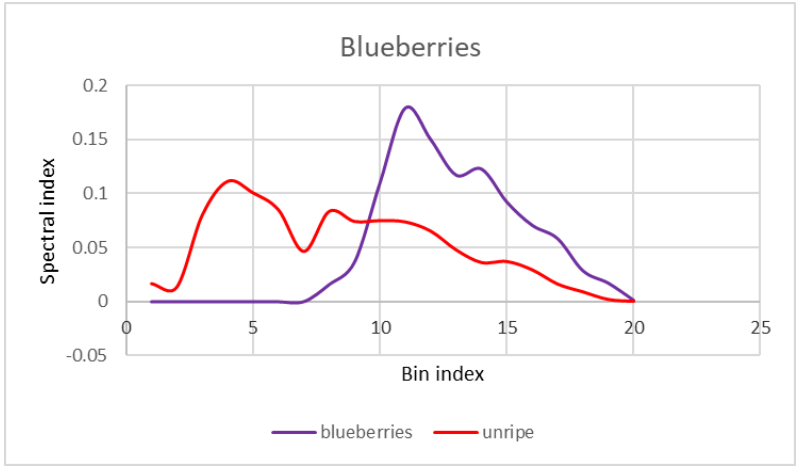
Decisions per object

Foreign object removal from cashew nuts



Detecting unripe fruit with Aris TopView

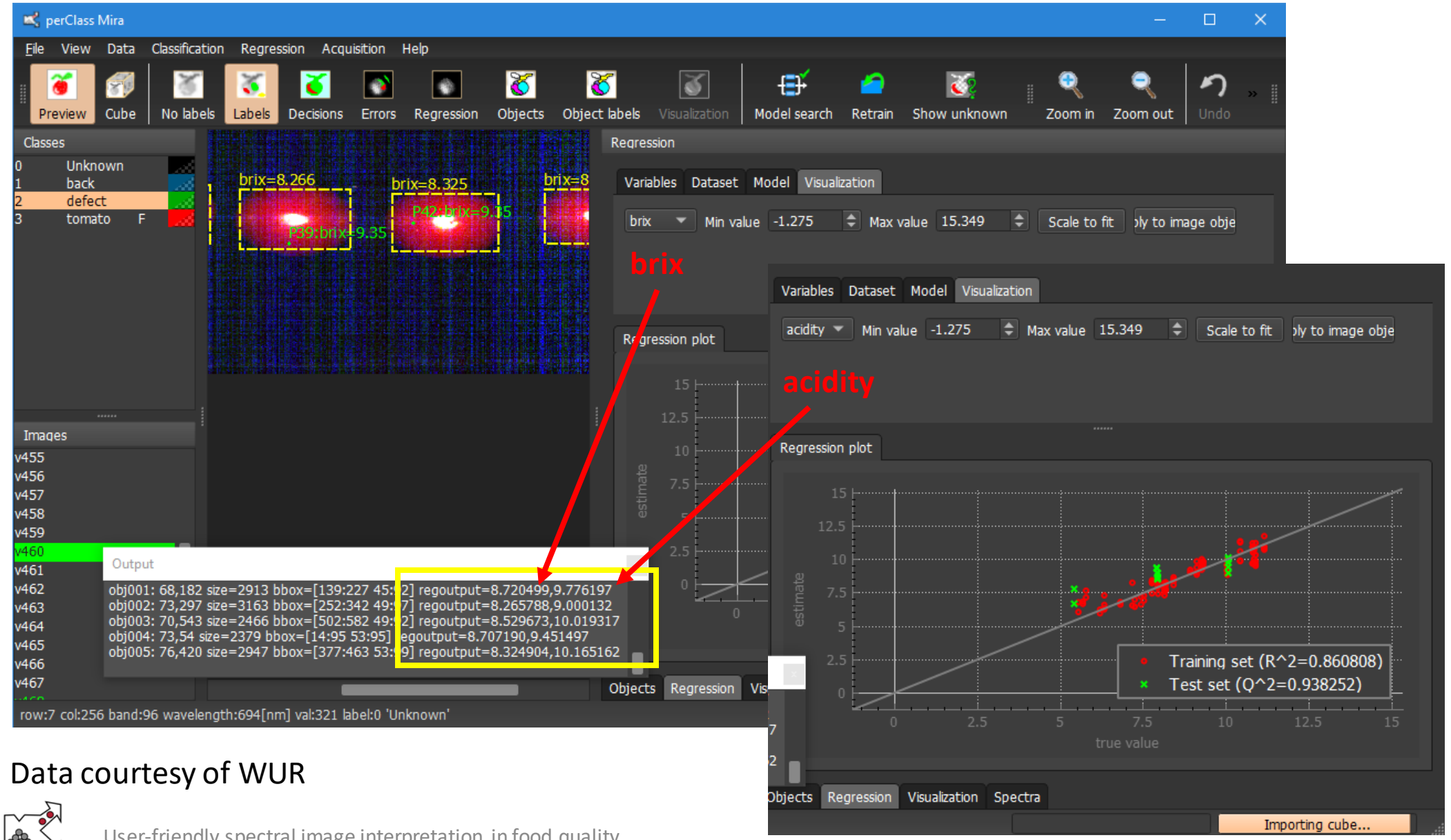




Aris TopView

High resolution multispectral camera

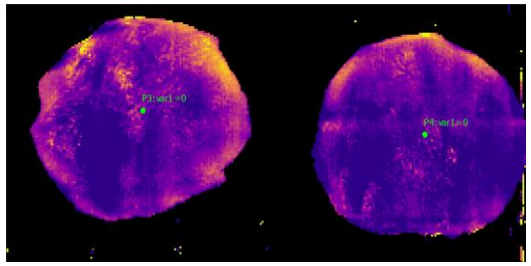
Estimating tomato brix and acidity

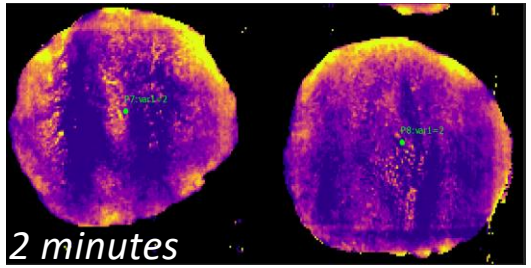


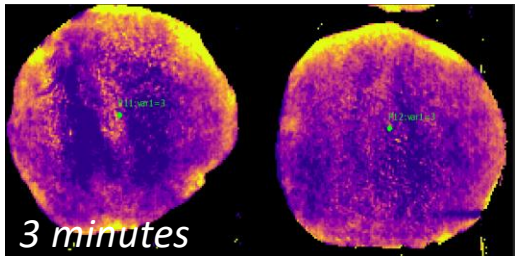
Data courtesy of WUR

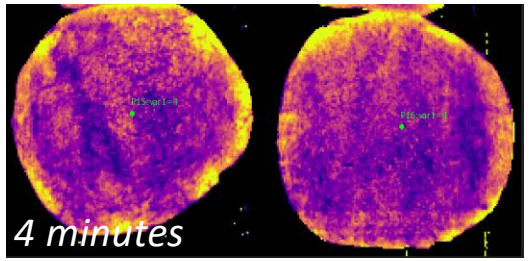
Baking time estimation for cookies

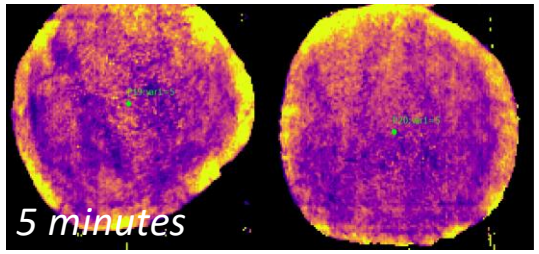
Entered in oven

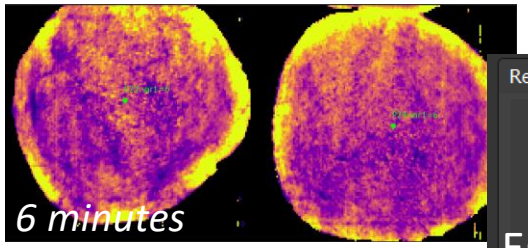


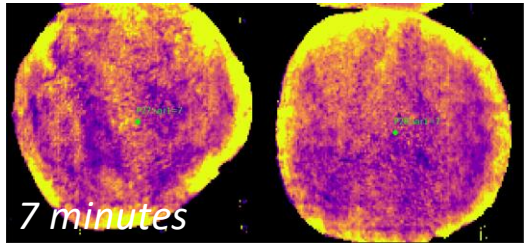


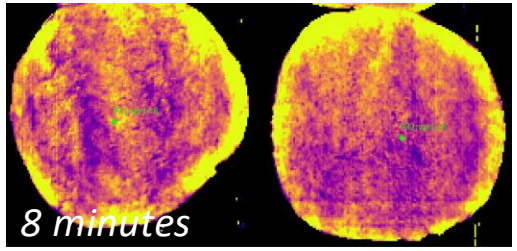


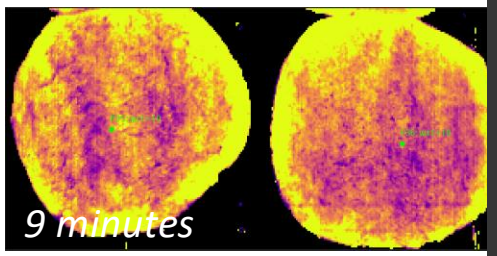






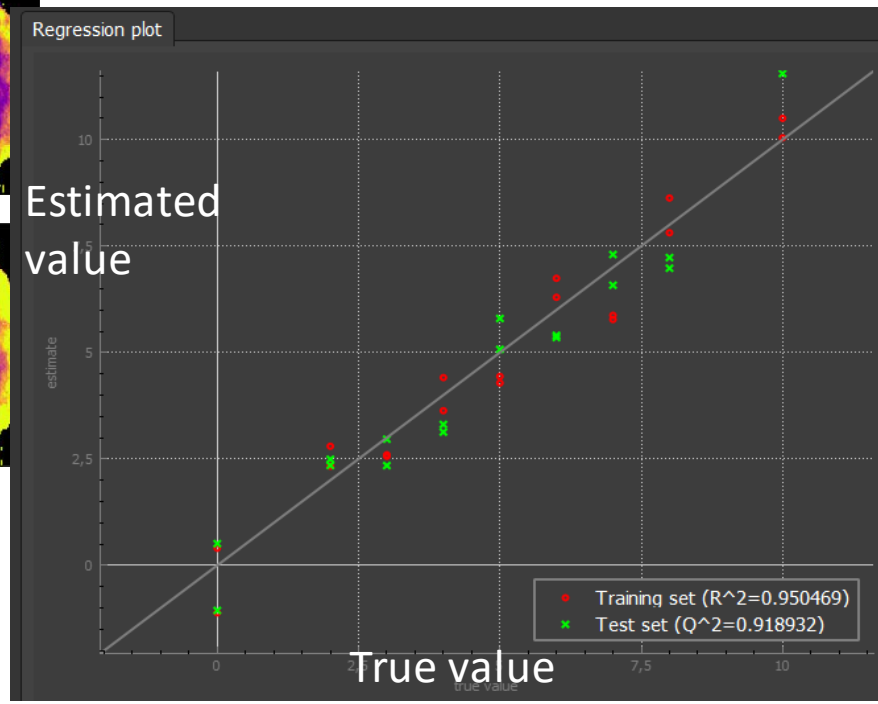






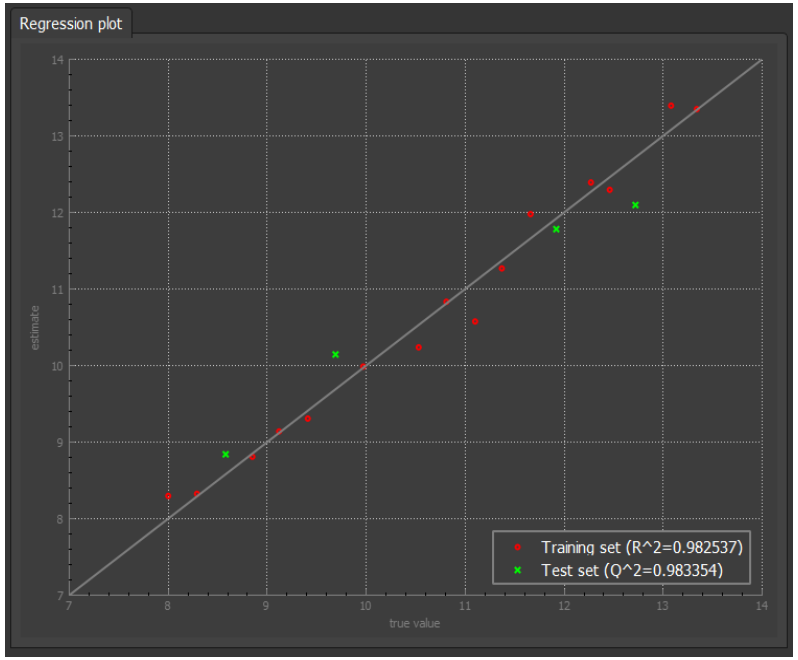
Mapping time estimates **per pixel**.

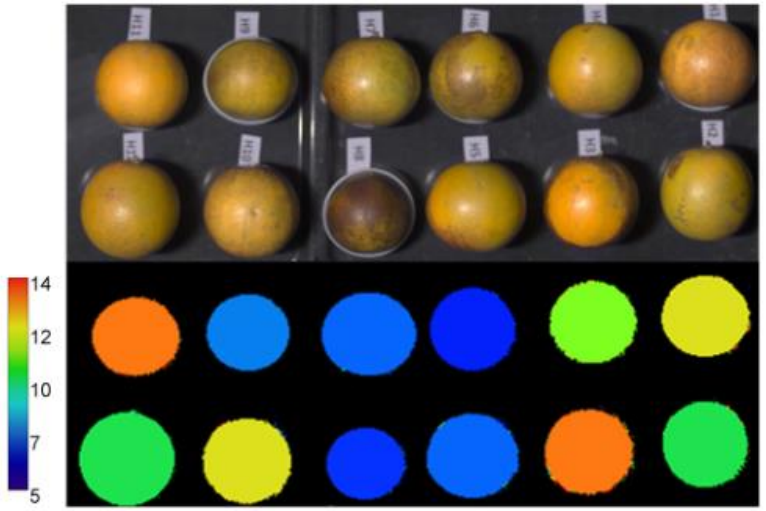
Estimating time **per object**
(red = training, green = unseen test objects)



Example: Orange brix estimation

- Measuring brix value of Hamlin oranges in Florida
- Developing models estimating brix directly from the truck passing under the MV.X camera

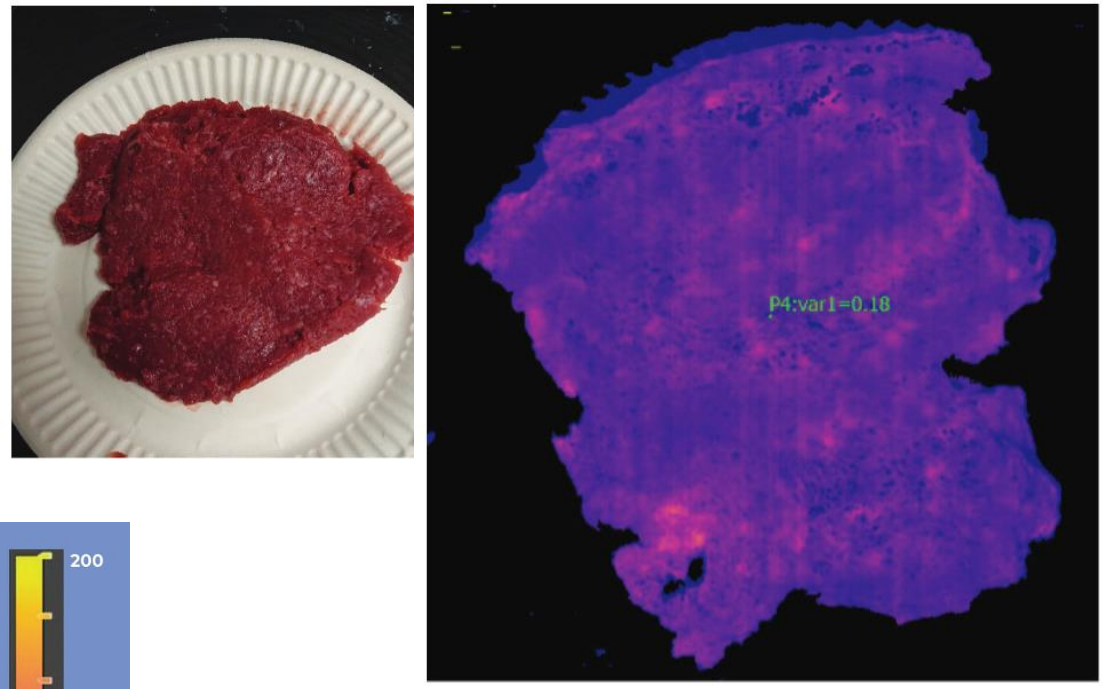




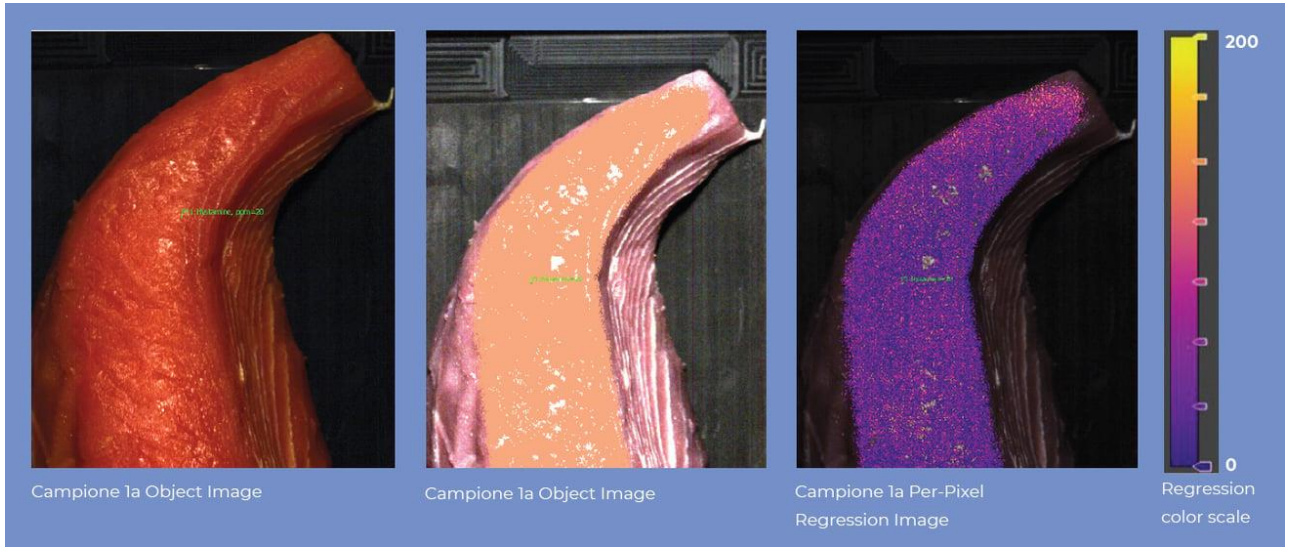
Headwall

Object quality estimation use-cases

- Brix, acidity, limonin, ...
- Fruit firmness
- Moisture/dry matter
- Fat content in meat
- Protein content in animal feed
- Fat acids
- Histamine content



Fat content estimation in minced meat using perClass Mira
Source: Specim.fi



Histamine in tuna fish, Source: Headwall Photonics

Building quality estimation solutions

Design phase:

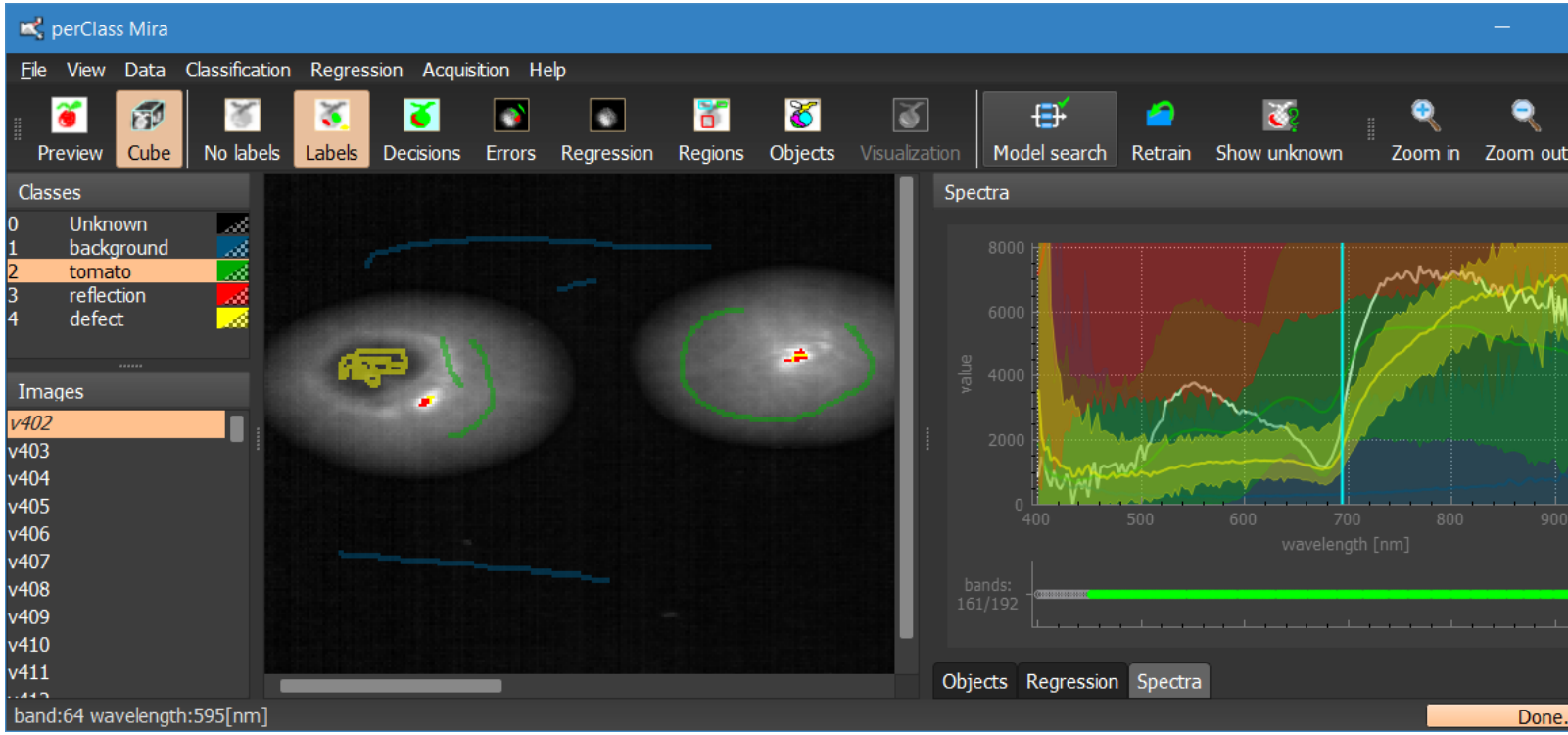
1. Scan fruit
2. Perform destructive testing
3. Attach the quality parameters back to scans
4. Build a regression model

Deployment phase:

1. On new scans of fruit
2. Estimate quality parameters

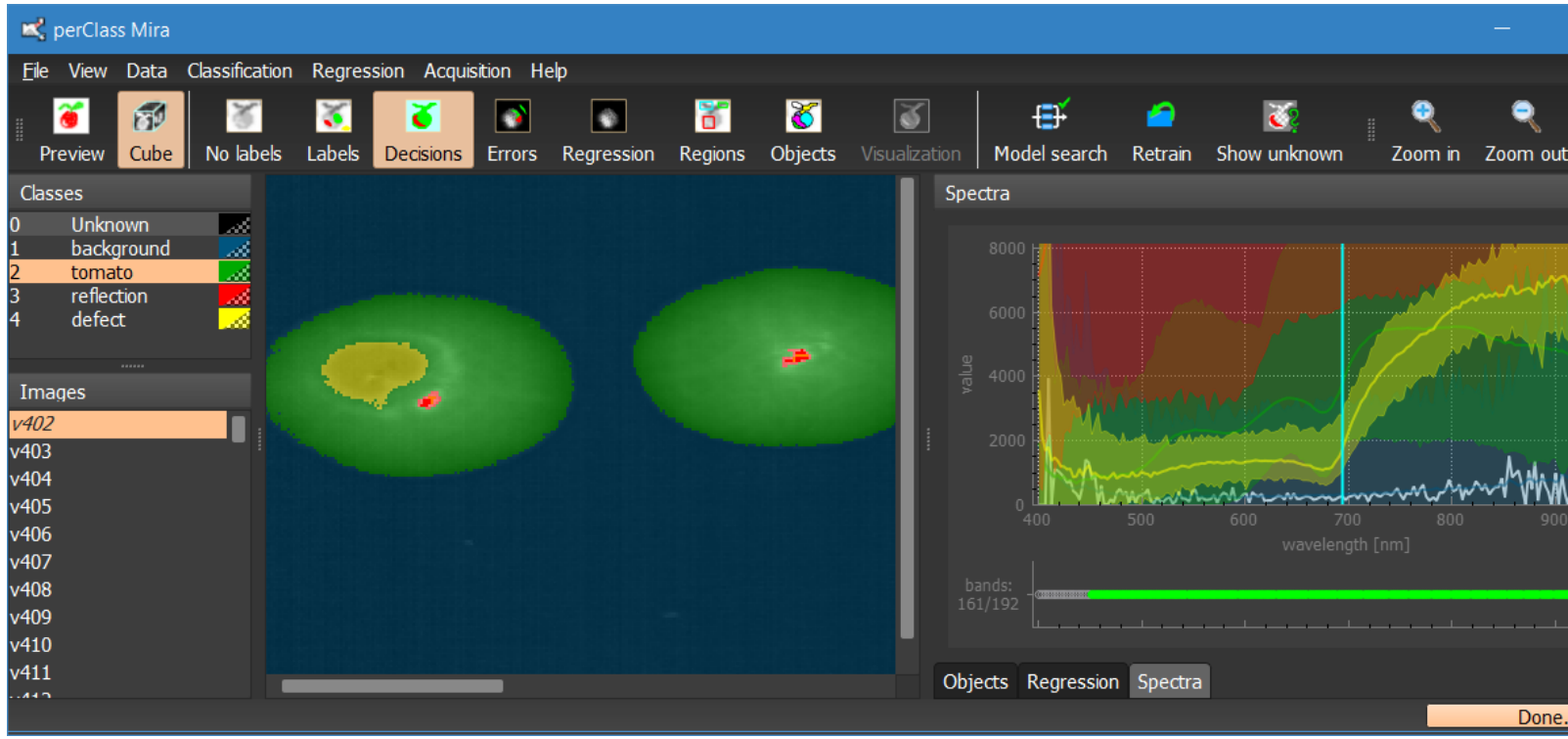
Object quality estimation work-flow

1. **Build pixel classifier**
2. Segment objects of interest
3. Annotate objects with numerical characteristics
4. Train regression model
5. Apply to new objects



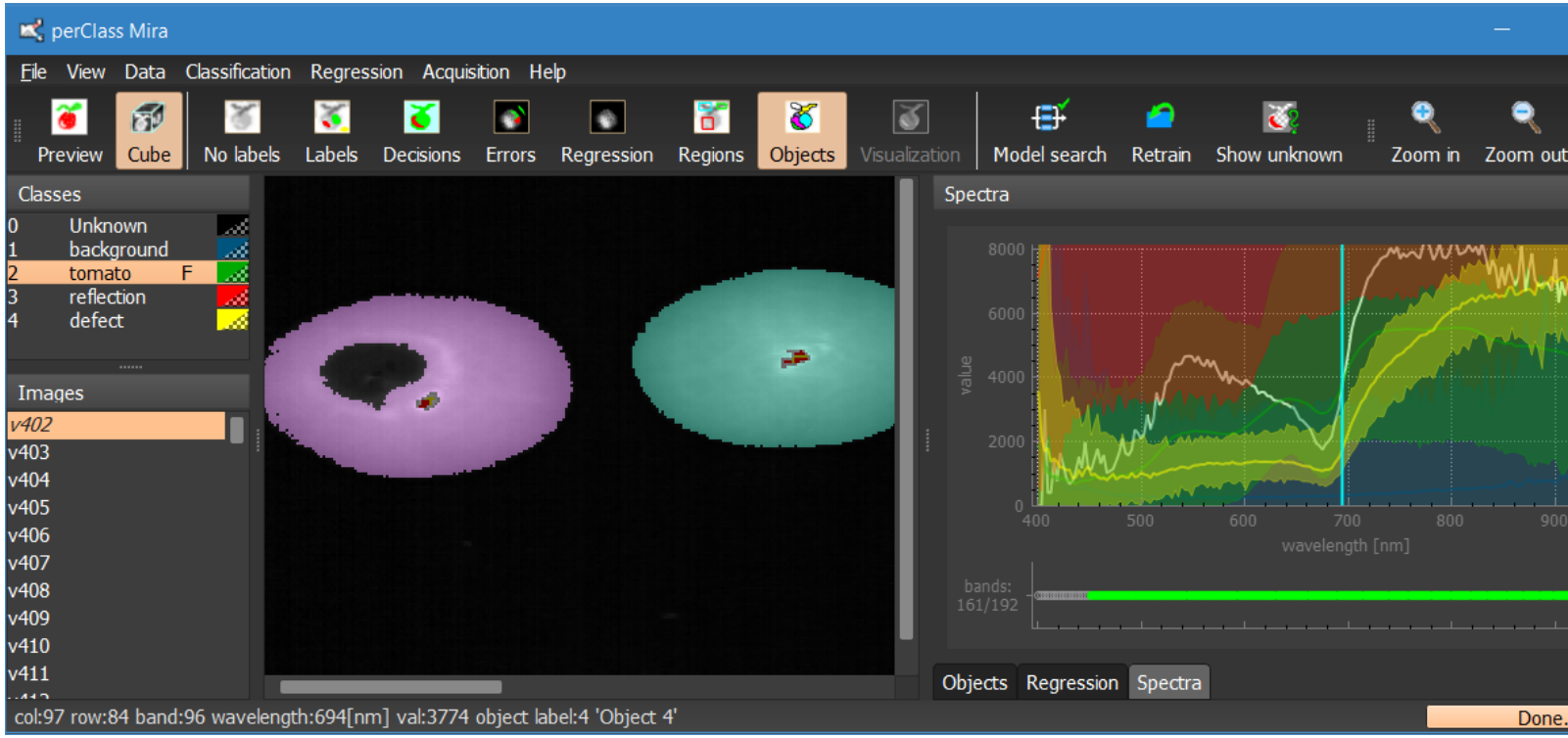
Object quality estimation work-flow

1. **Build pixel classifier**
2. Segment objects of interest
3. Annotate objects with numerical characteristics
4. Train regression model
5. Apply to new objects



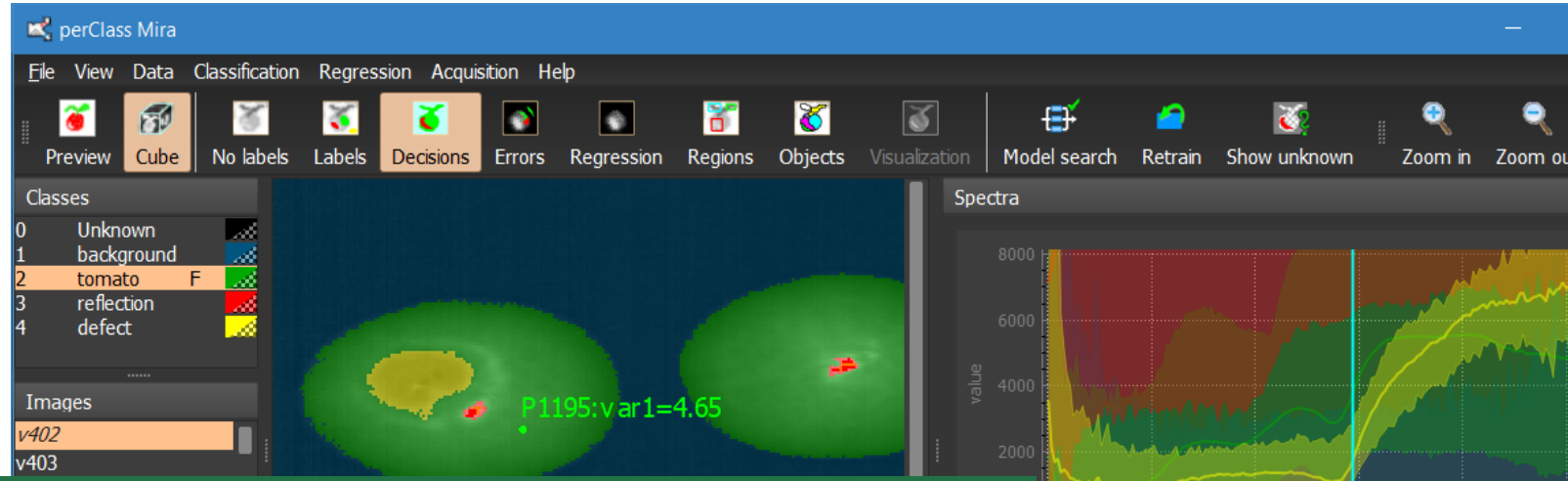
Object quality estimation work-flow

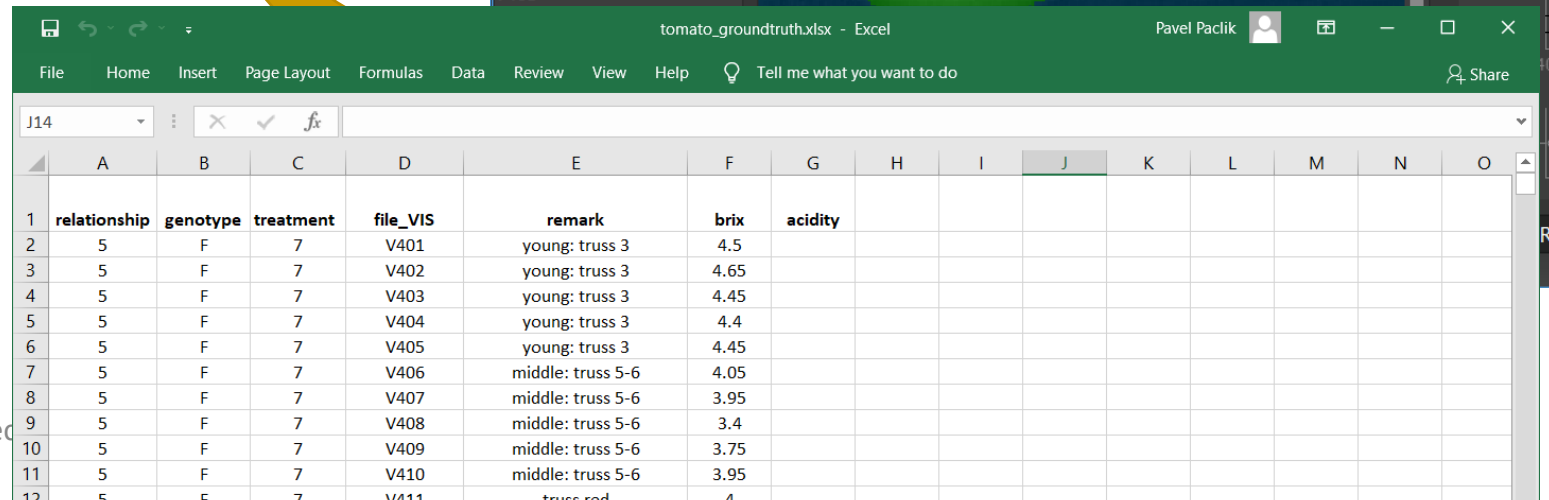
1. **Build pixel classifier**
2. **Segment objects of interest**
3. Annotate objects with numerical characteristics
4. Train regression model
5. Apply to new objects



Object quality estimation work-flow

1. **Build pixel classifier**
2. **Segment objects of interest**
3. **Annotate objects with numerical characteristics**
4. Train regression model
5. Apply to new objects

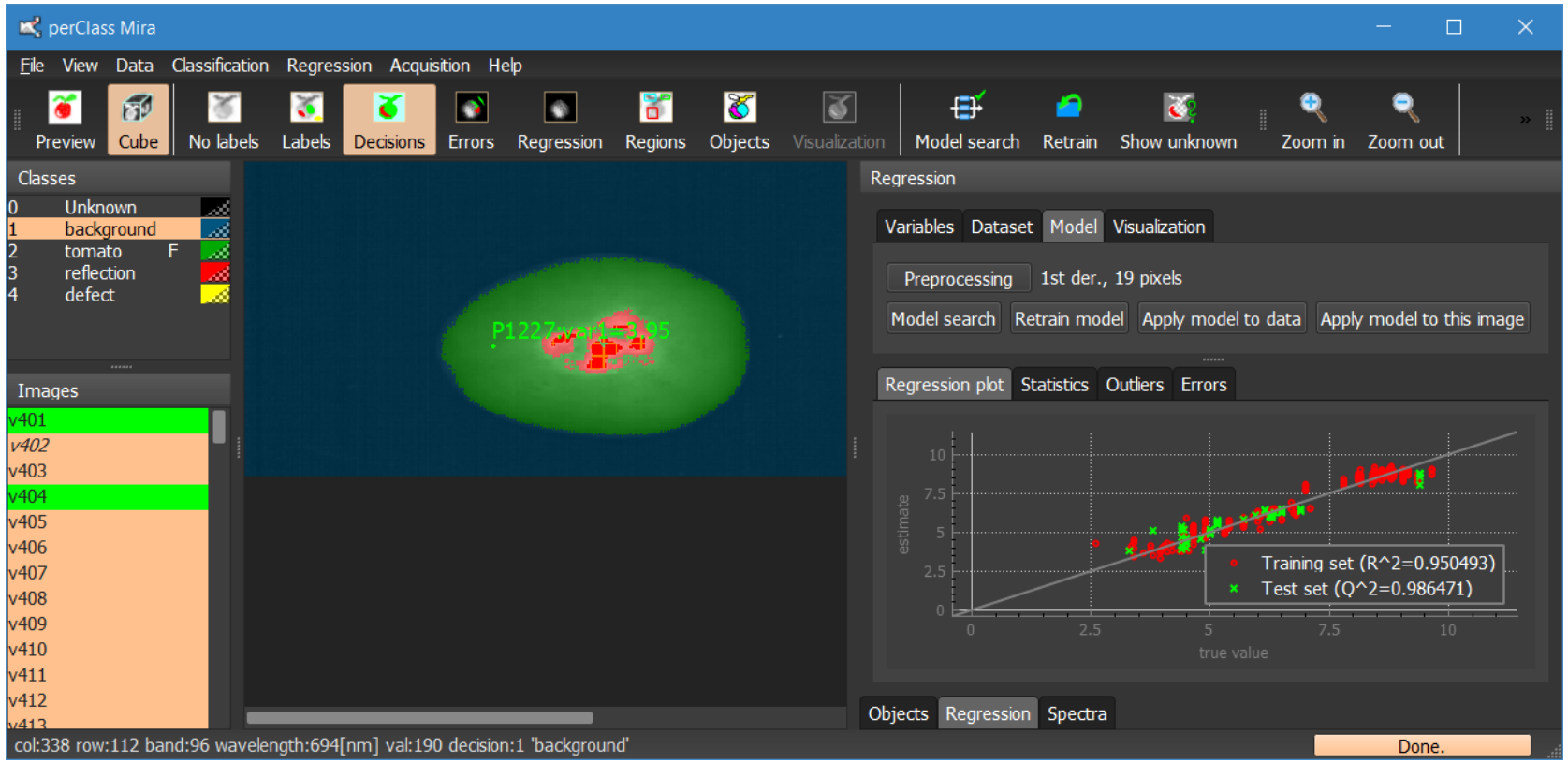




	A	B	C	D	E	F	G
1	relationship	genotype	treatment	file_VIS	remark	brix	acidity
2	5	F	7	V401	young: truss 3	4.5	
3	5	F	7	V402	young: truss 3	4.65	
4	5	F	7	V403	young: truss 3	4.45	
5	5	F	7	V404	young: truss 3	4.4	
6	5	F	7	V405	young: truss 3	4.45	
7	5	F	7	V406	middle: truss 5-6	4.05	
8	5	F	7	V407	middle: truss 5-6	3.95	
9	5	F	7	V408	middle: truss 5-6	3.4	
10	5	F	7	V409	middle: truss 5-6	3.75	
11	5	F	7	V410	middle: truss 5-6	3.95	

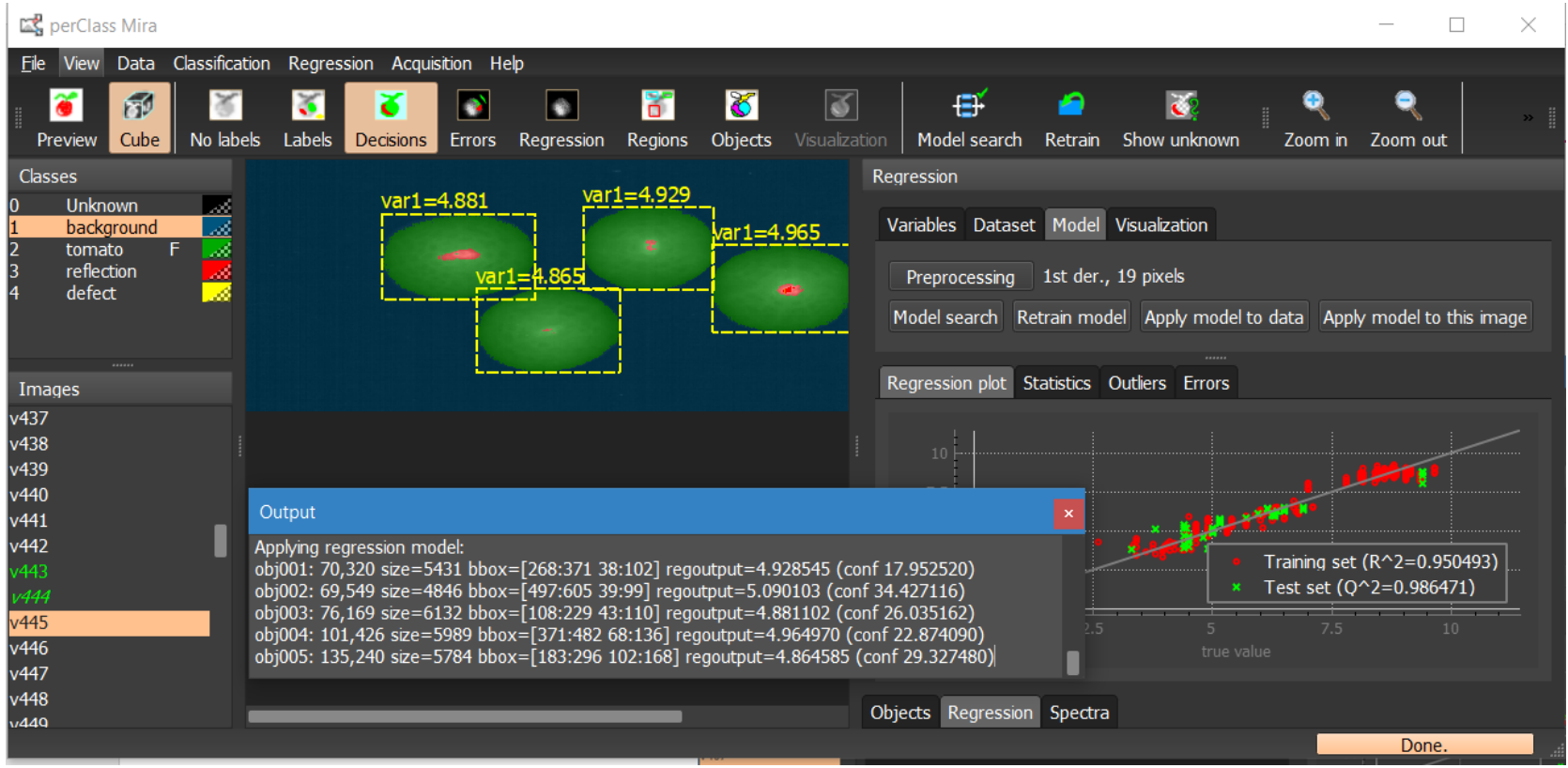
Object quality estimation work-flow

1. **Build pixel classifier**
2. **Segment objects of interest**
3. **Annotate objects with numerical characteristics**
4. **Train regression model**
5. Apply to new objects



Object quality estimation work-flow

1. Build pixel classifier
2. Segment objects of interest
3. Annotate objects with numerical characteristics
4. Train regression model
5. Apply to new objects



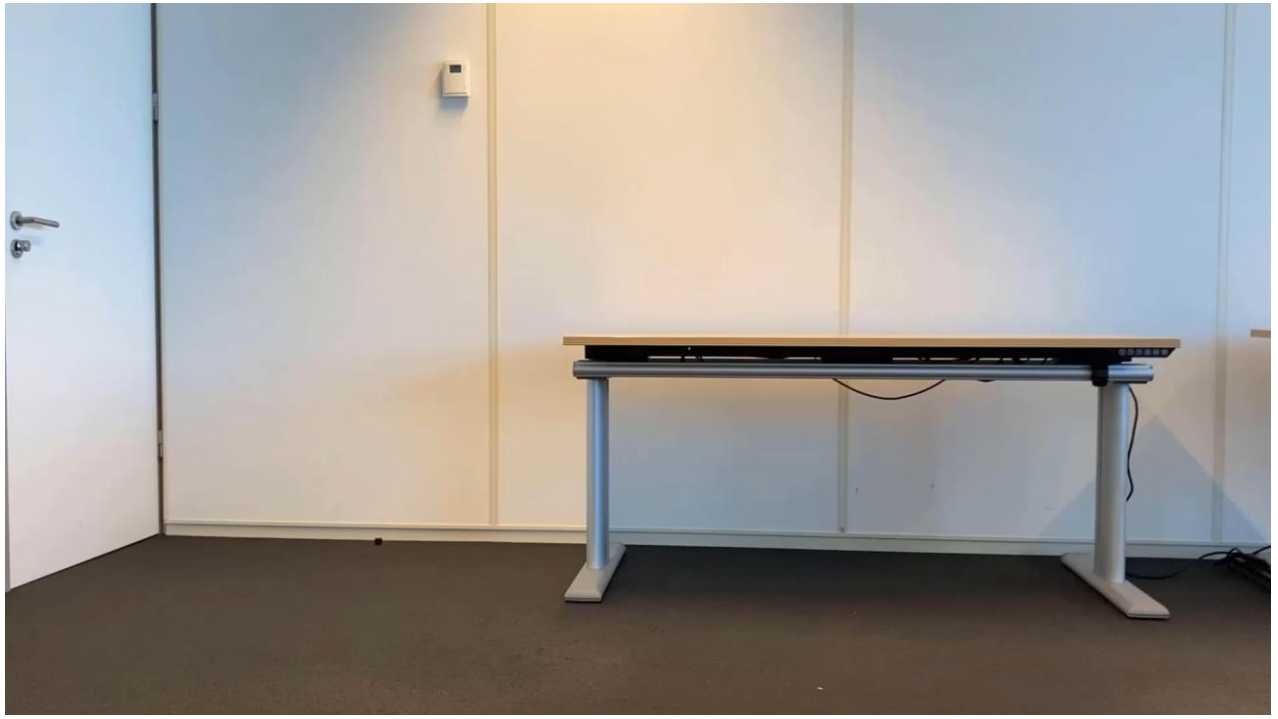
Practical challenges

1. You need to scan close to samples in the **production environment**
2. You need to scan **a lot of samples** generating very large data sets
3. You need to **build a robust model** and properly validate it
4. You need to **select spectral camera/range**
5. You need to **enable lab operators** to use the solution

perClass Mira Stage – a portable scanning solution

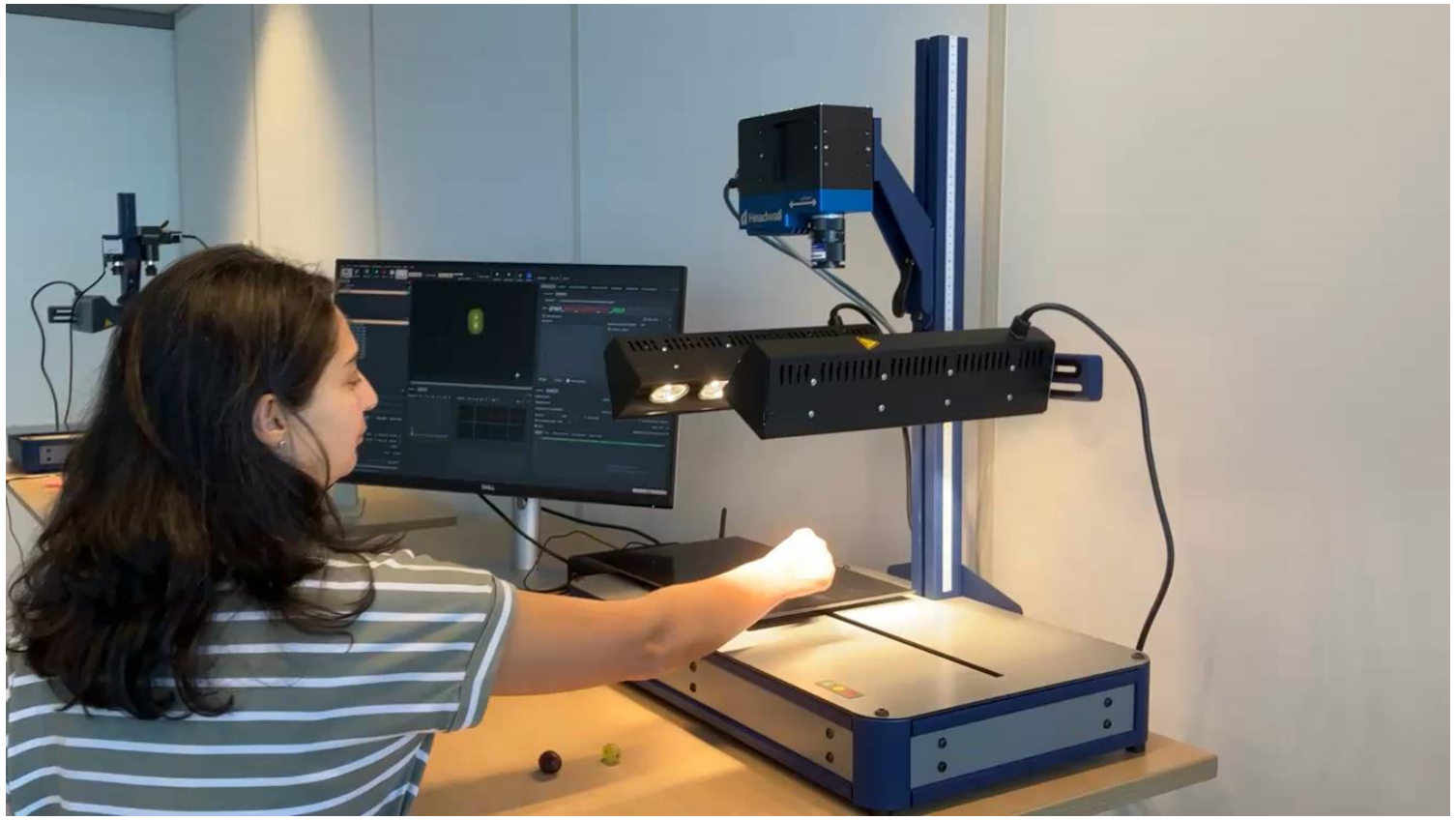
- Single rugged bag
- Can be check in on flights

- Mounting (3x speedup)

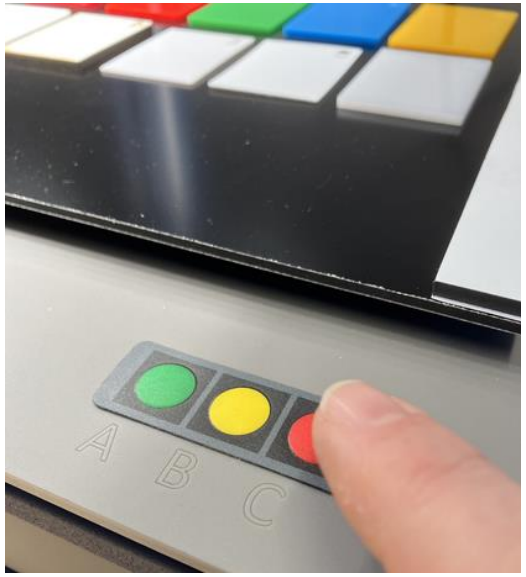


Fast scanning workflow

- Easy scanning workflow fully operated using stage buttons + mouse
- You can collect about 100 scans in 15 minutes

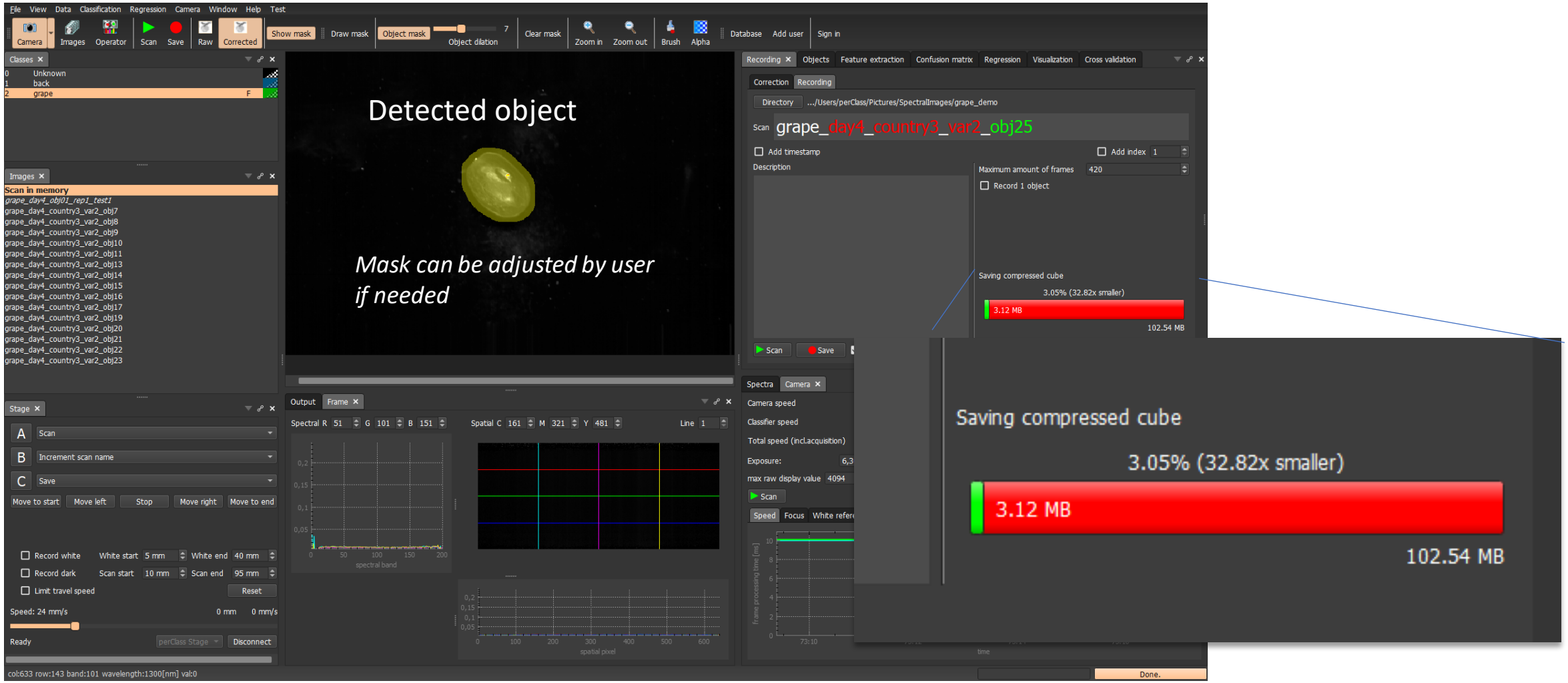


User-programmable buttons



Fast scanning workflow with data compression

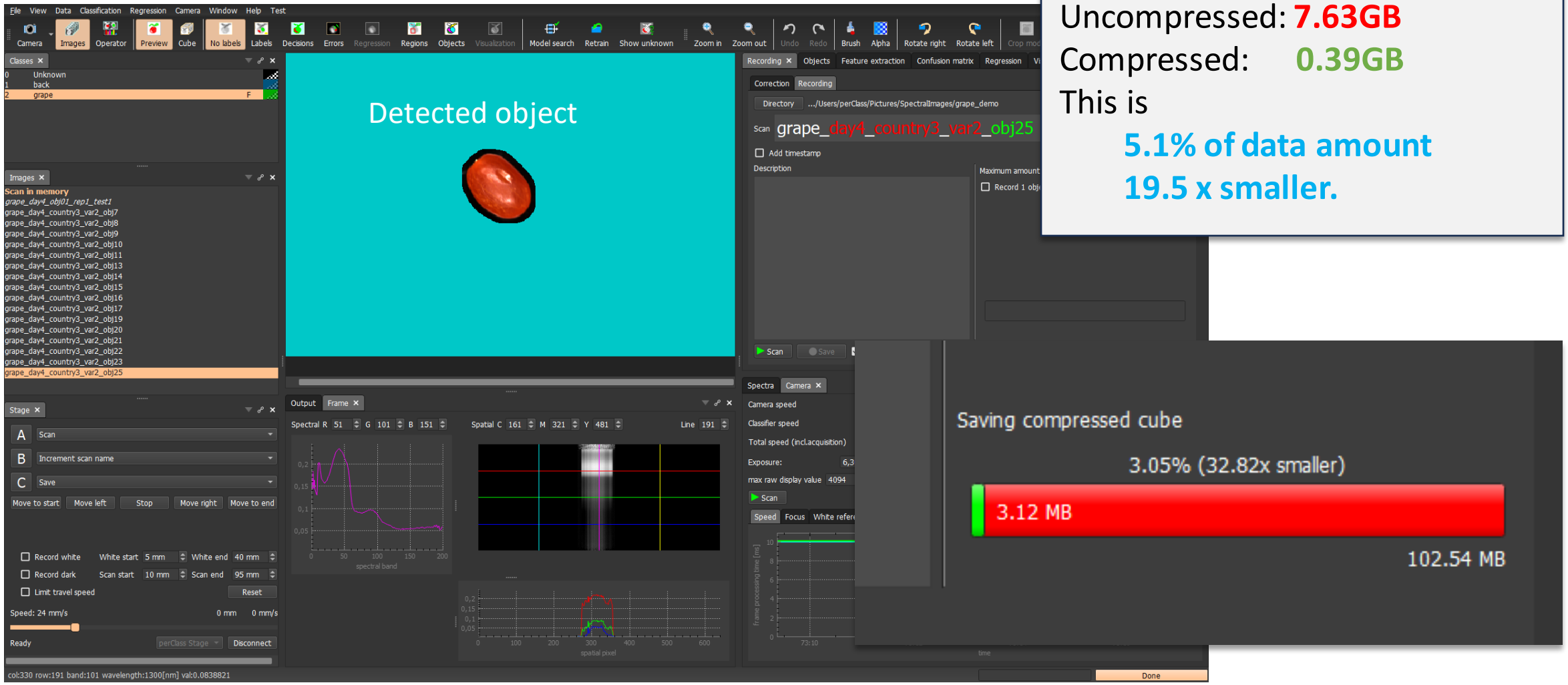
- Scan lossless compression saving only object data



Fast scanning workflow with data compression

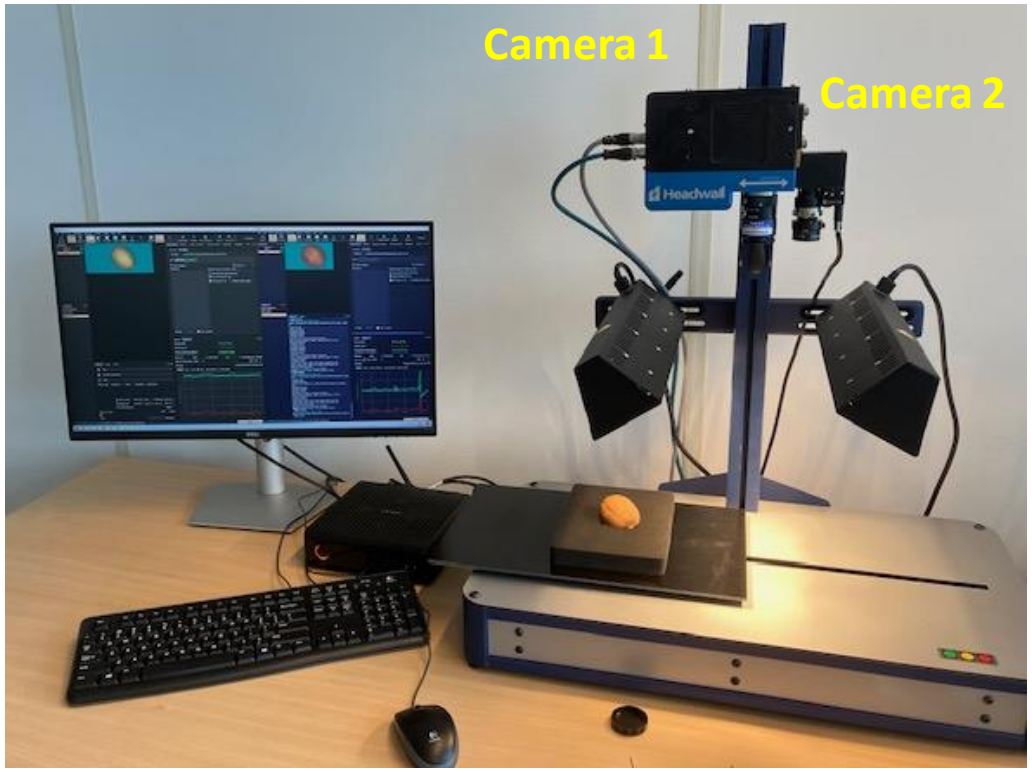
- Scan lossless compression saving only object data

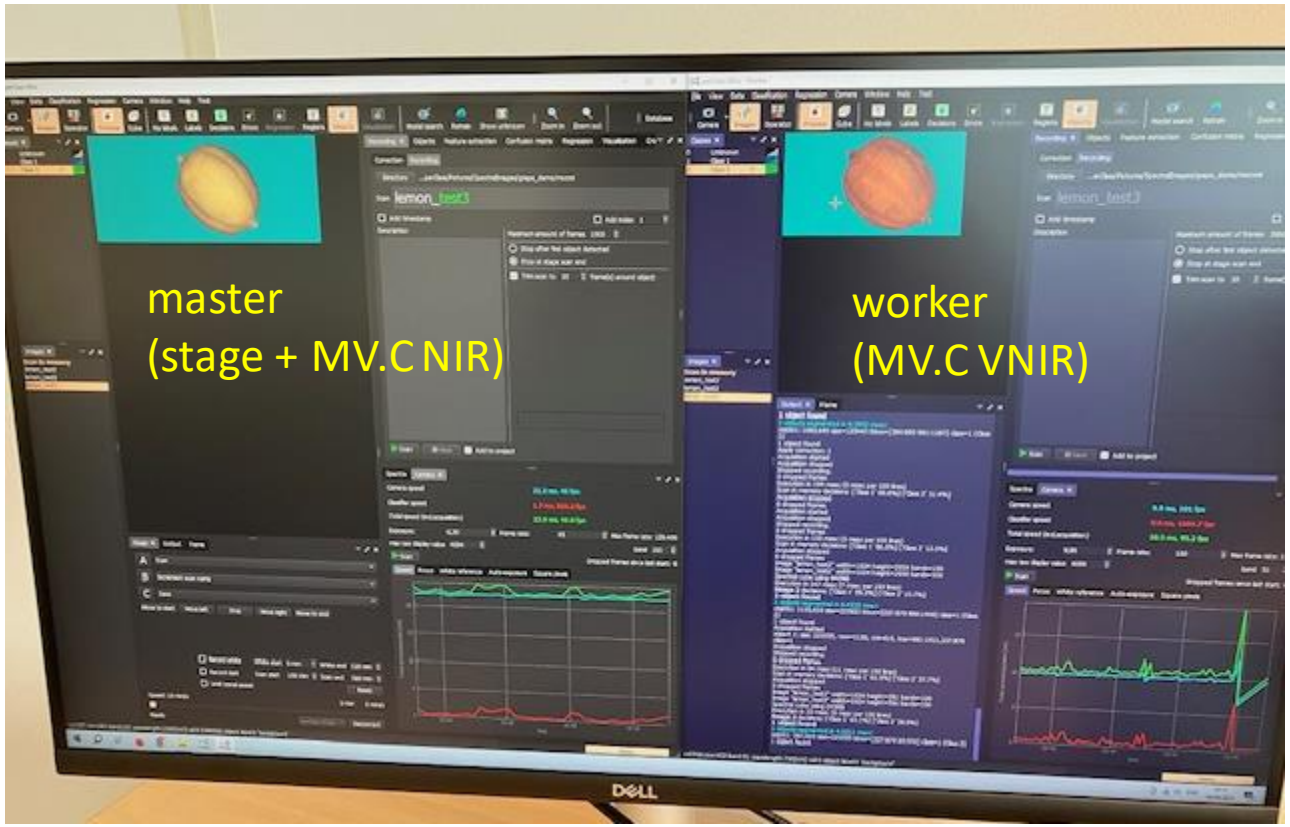
Example: One day of grape scans
Uncompressed: **7.63GB**
Compressed: **0.39GB**
This is
5.1% of data amount
19.5 x smaller.



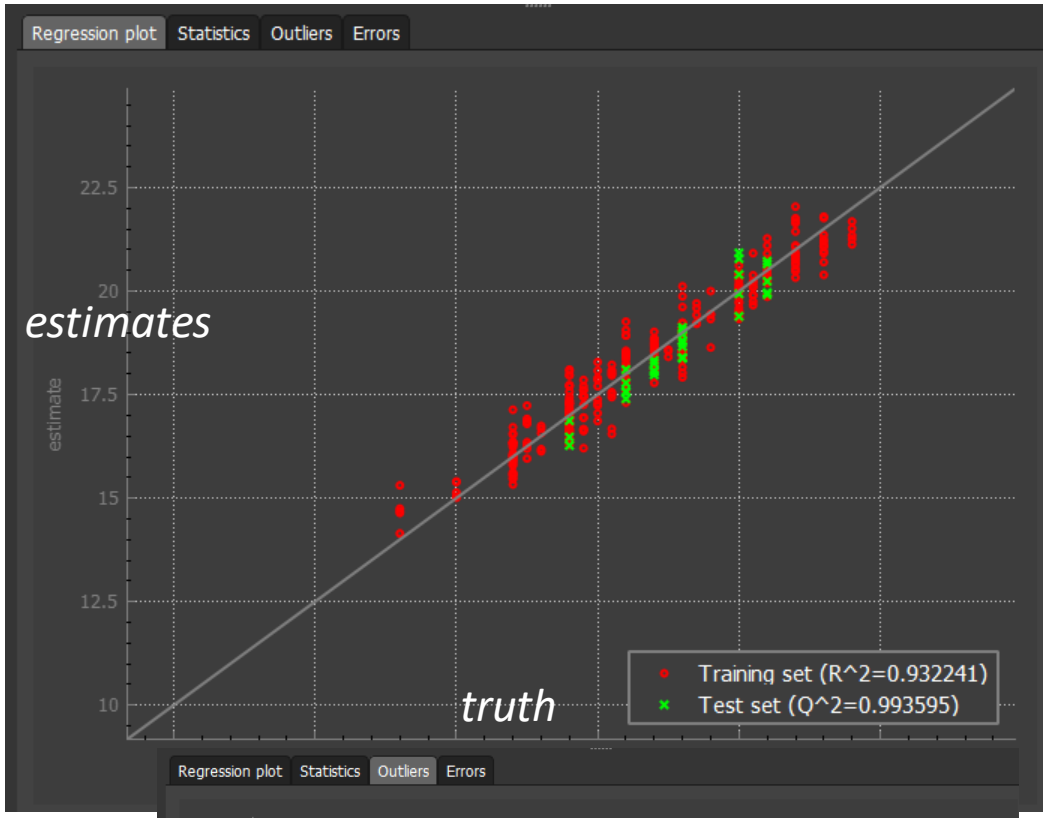
Multi-camera scanning

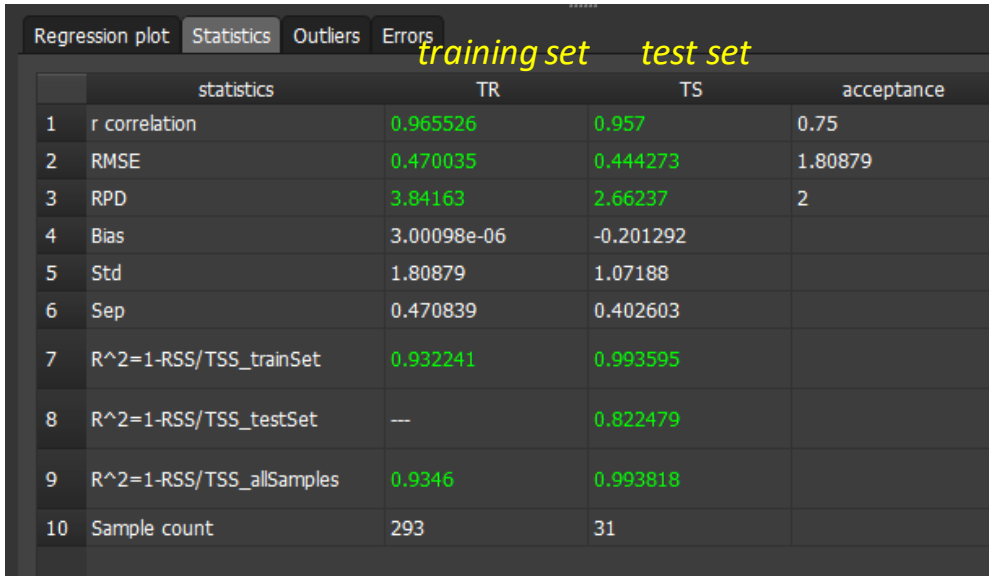
- Attaching multiple cameras on one stage
- perClass Mira *Master* instance controls stage + one camera
- *Worker* instance controls other camera
- Same or different PCs



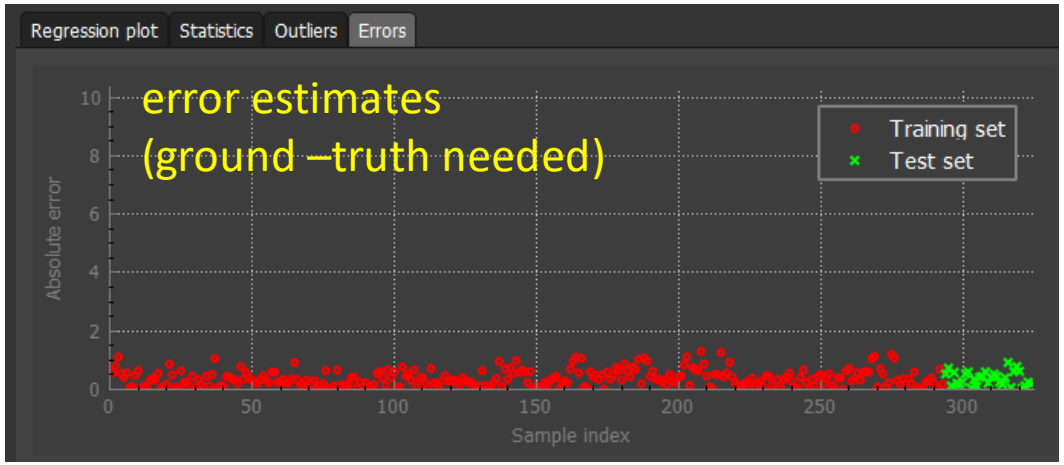


Building robust models

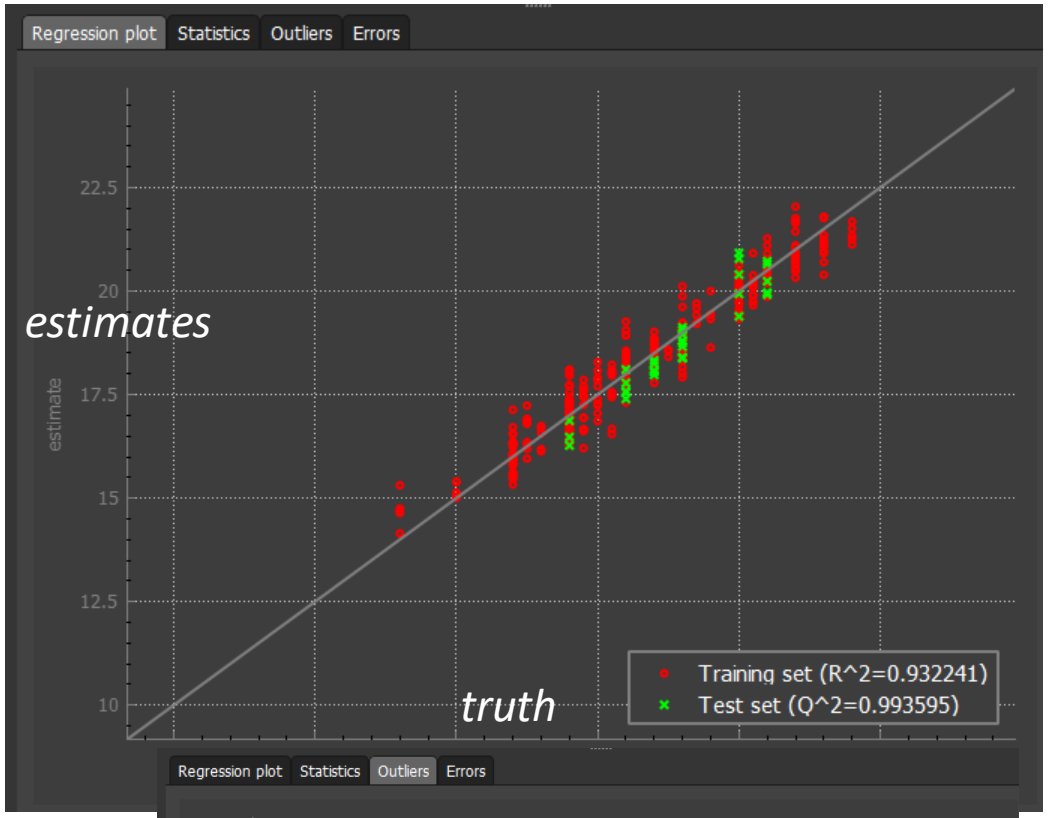


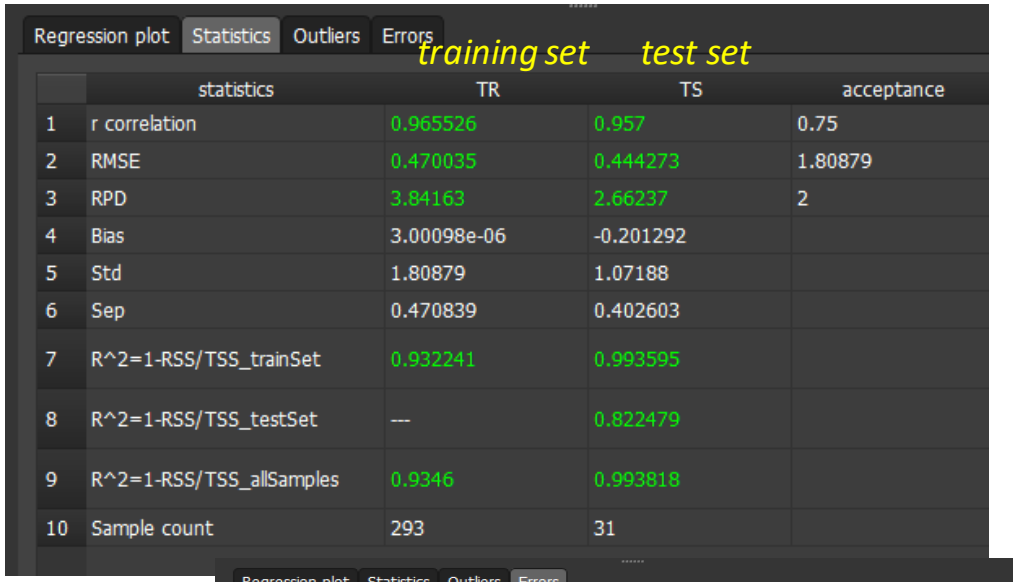


	statistics	TR	TS	acceptance
1	r correlation	0.965526	0.957	0.75
2	RMSE	0.470035	0.444273	1.80879
3	RPD	3.84163	2.66237	2
4	Bias	3.00098e-06	-0.201292	
5	Std	1.80879	1.07188	
6	Sep	0.470839	0.402603	
7	R^2=1-RSS/TSS_trainSet	0.932241	0.993595	
8	R^2=1-RSS/TSS_testSet	---	0.822479	
9	R^2=1-RSS/TSS_allSamples	0.9346	0.993818	
10	Sample count	293	31	



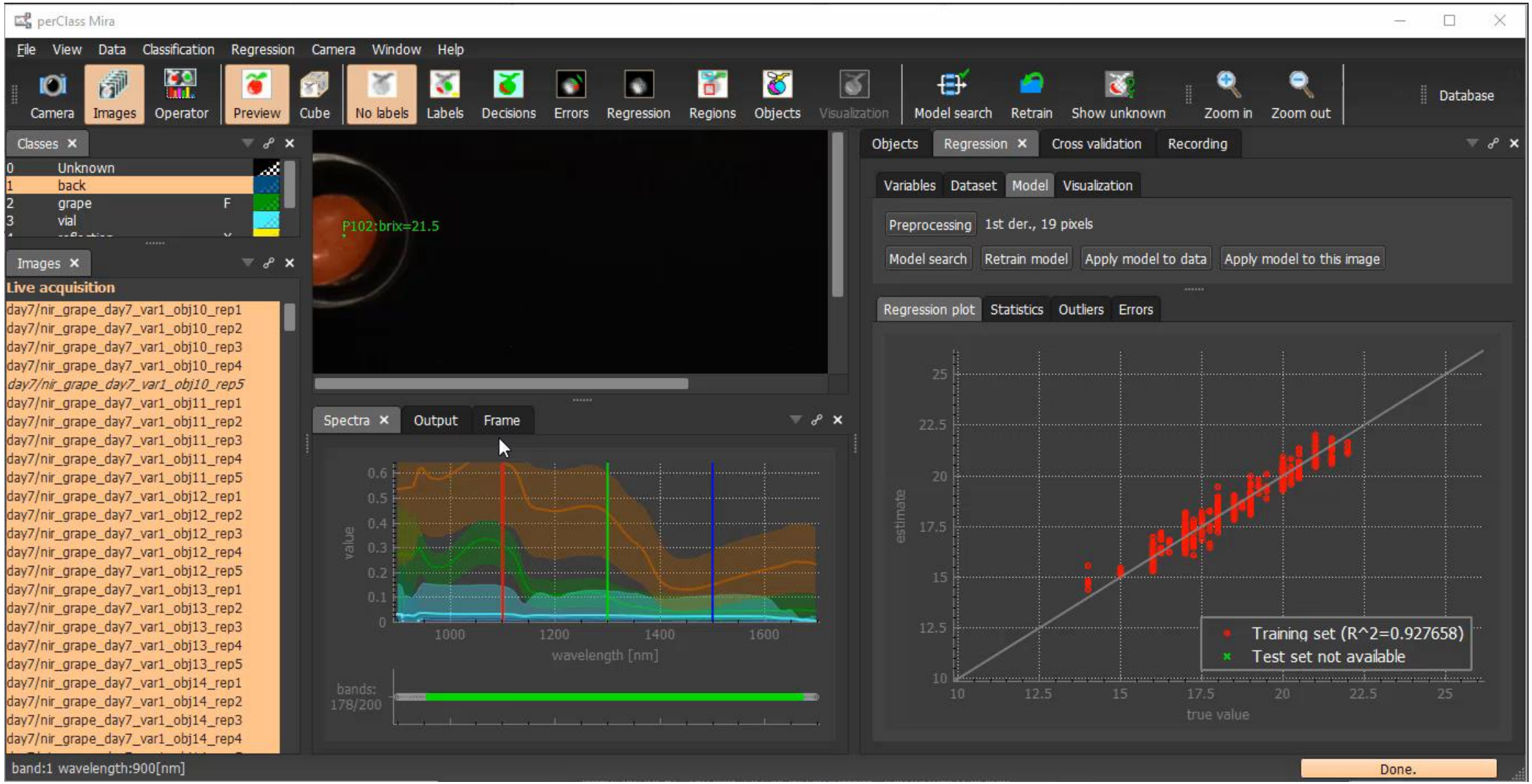
Building robust models





	statistics	TR	TS	acceptance
1	r correlation	0.965526	0.957	0.75
2	RMSE	0.470035	0.444273	1.80879
3	RPD	3.84163	2.66237	2
4	Bias	3.00098e-06	-0.201292	
5	Std	1.80879	1.07188	
6	Sep	0.470839	0.402603	
7	R^2=1-RSS/TSS_trainSet	0.932241	0.993595	
8	R^2=1-RSS/TSS_testSet	---	0.822479	
9	R^2=1-RSS/TSS_allSamples	0.9346	0.993818	
10	Sample count	293	31	

Advanced example: Cross-validation and use of replicas



perClass Mira Stage applicability in project work-flow

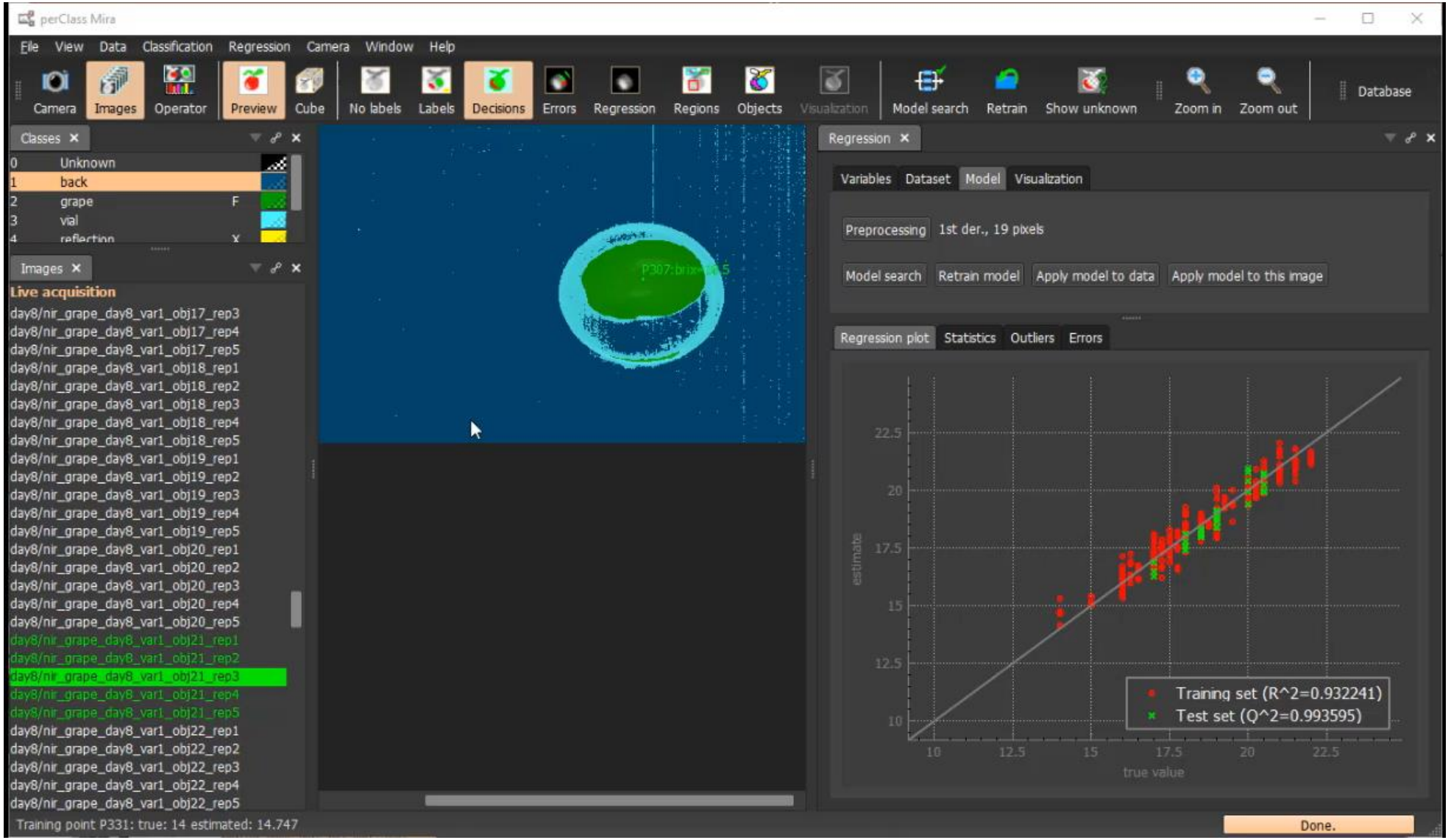
Quick scan
"Can it work?"

Feasibility study
"Is it good enough?"

Demonstrator
"Will it work?"

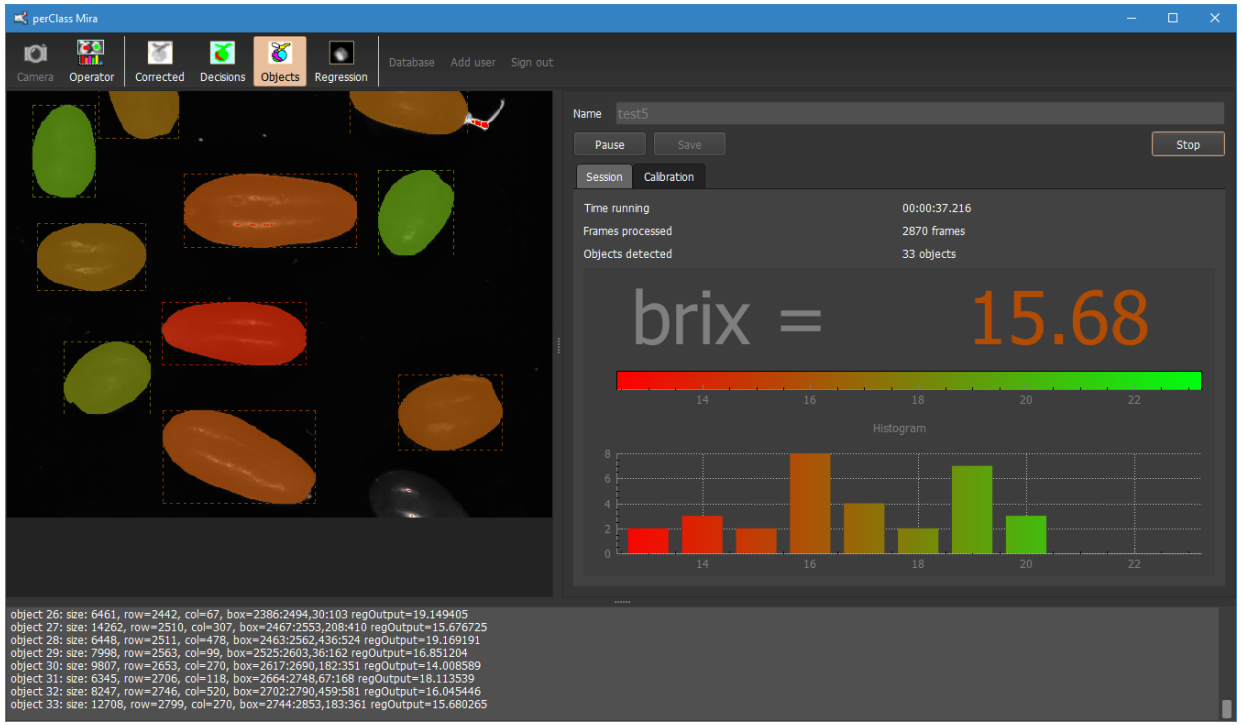
Integration
"It works."

Operator mode



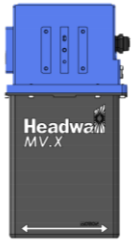
Operator mode

- Simplified interface
- User permissions and login
  - Developer / operator
- Database logging of actions and results
  - Sqlite (local)
  - MySQL / MariaDB (remote)



Supported cameras in perClass Mira

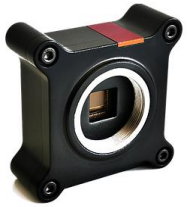
- Headwall MV.C (component) MV.X (processing) lines + Hyperspec legacy systems

- Specim FX10, FX17, SWIR, FX50

- Imec Mosaic (VNIR, SWIR)


- Silios



- Resonon

- Cubert Ultris

- Unispectral Monarch II

- Inno-spec RedEye

- HAIP BlackIndustry

Supported cameras in perClass Mira Stage

- Headwall MV.C (component) MV.X (processing) lines + Hyperspec legacy systems

- Specim FX10, FX17, SWIR, FX50

- Imec Mosaic (VNIR, SWIR)

- Silios

- Resonon

- Cubert Ultris

- Unispectral Monarch II

- Inno-spec RedEye

- HAIP BlackIndustry

Summary

- Spectral imaging enables non-destructive classification and quantification of samples

- It is now possible to do full end-to-end work-flow with a spectral camera in the loop
  - Without
    - Machine-learning / chemometric expertise
    - Programming
    - Low-level integration

- You can get started with a lab stage, camera and software in minutes
  - Solutions can be operated by non-experts in daily quality process

Contact

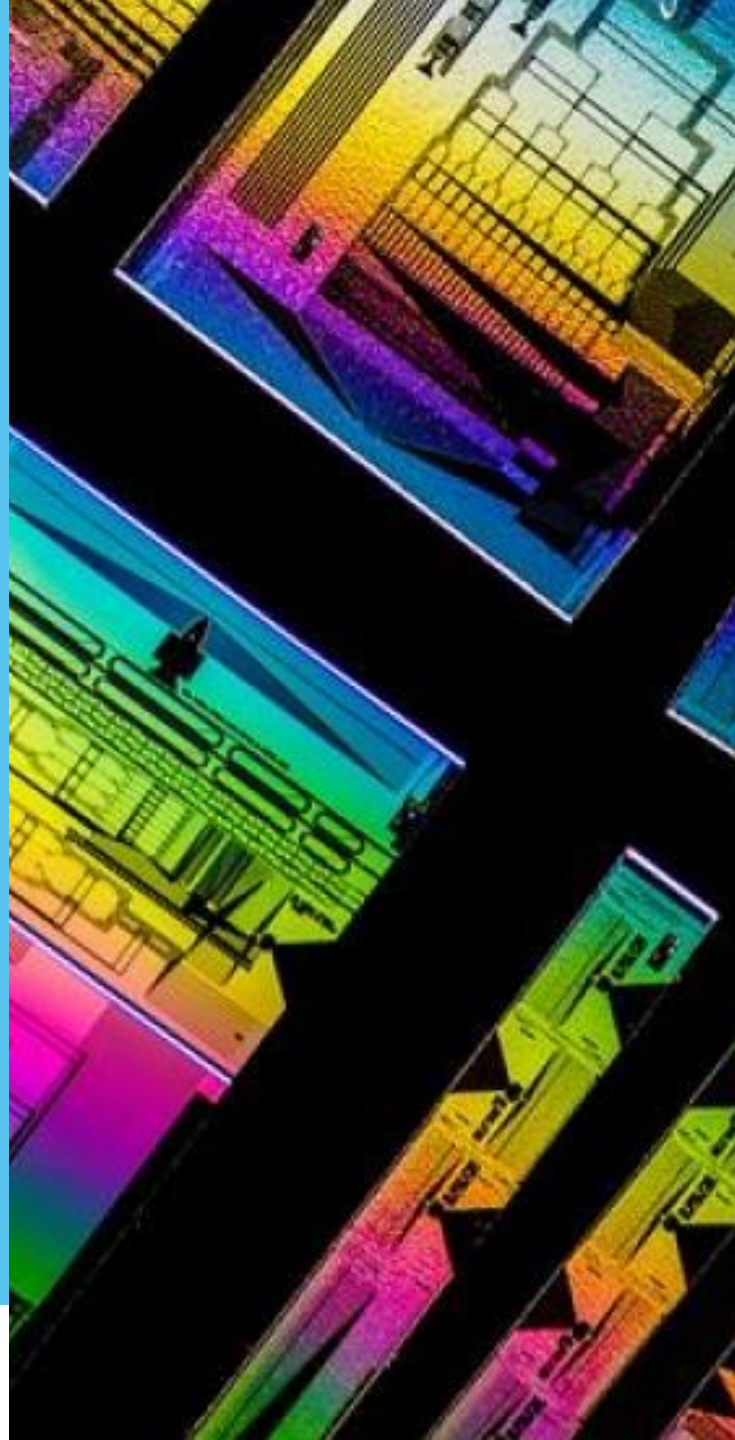
perClass BV
Molengraaffsingel 12
2629JD Delft
The Netherlands
http://perclass.com

email: pavel.paclik@perclass.com
phone: +31(0)648060368

Thank you!

Henk Reitsma - Greefa

Discussion



NEXT TECH FOOD FACTORIES

NXT GEN HIGHTECH

Dutch Photonics Event

GREEFA

perClass BV

OnePlanet Research Center

NEXT TECH FOOD FACTORIES

Volg NTFF op LinkedIn

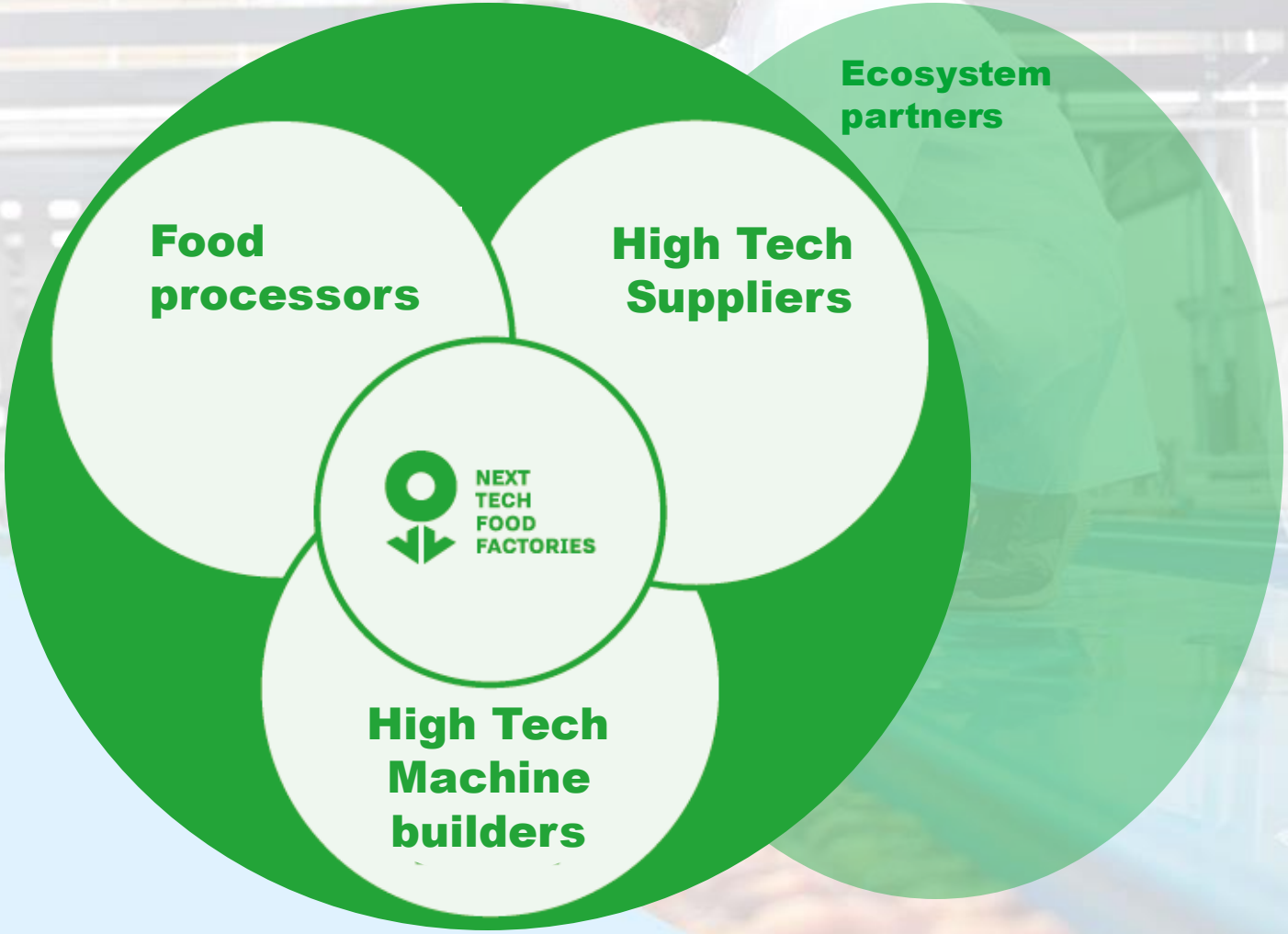
Next Tech Food Factories

Automation, digitalization, and robotics for a more sustainable, equitable, and healthier food system

Our mission

Contribute to addressing challenges for the food processing industry by
accelerating innovations in automation and digitalization
For economic, social, and ecological impact now and in the future.

Collaborate for a stronger ecosystem



Teamplayers

BRAINPORT EINDHOVEN

NEXT TECH FOOD FACTORIES

Business developer

Business developer

Program team

Programmanager

Senior projectmanager & internationalisation

Projectmanager

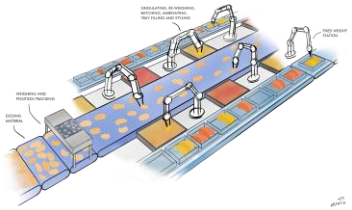
AgriFood Capital

NXTGEN HIGHTECH

NXTGEN HIGHTECH: Domain Agrifood, Innovation package Handsfree Food Processing

Four use cases – consortia:

1. “Dark Fruit Factory”
   Greefa, Fruitmasters & Fruit Tech Campus
2. “Ready to go (m)eat”
   Marel & One Planet Research
3. “Ready made meals”
   Van Wees Waalwijk & Wageningen Research
4. “Local Tea Production”
   Local Tea Global Impact, Van Wees Waalwijk & Wageningen Research



NEXT TECH FOOD FACTORIES

Shaping the current and future possibilities of photonics together!

LinkedIn Lisanne

Work together on a follow-up?
Contact Lisanne van Oosterhoud
l.vanoosterhoud@brainportdevelopment.nl
Or take a look at www.nexttechfoodfactories.nl

Next Tech Food Factories

NEXT TECH FOOD FACTORIES

Want to know more?
www.nexttechfoodfactories.nl
Or contact Lisanne van Oosterhoud via
l.vanoosterhoud@brainportdevelopment.nl

Projecten

NXT GEN HIGHTECH

high five
for digital and green food processing

EDIH ZUID NL European Digital Innovation Hub

Food scalEUp

Next Tech Food Factories
is een initiatief van

AgriFood Capital

BRAINPORT EINDHOVEN

Met support van

Provincie Noord-Brabant

Co-funded by the European Union

Volg NTFF op LinkedIn

Betrokken partijen

FME POWERED BY DUTCH TECHNOLOGY

FFA FOOD FOR ANALYTICS

marel

WAGENINGEN UNIVERSITY & RESEARCH

LOCAL TER

rbk group

Van Wees Machines Waalwijk Services

fruit tech campus

MARIËN MEESTERBAKKERS

OnePlanet Research Center

Fruit Masters.

GREEFA

Jaarevent NXTGEN domein Agrifood

Hier aanmelden

Datum: 6 oktober 12.00-18.00

Locatie: BIC

Doelgroep: partners, stakeholders, breed ecosysteem

Programma

12.00-12.45 | Inloop buffet
13.00-13.35 | Start programma
13.35-14.20 | Inspirerende keynote aan het woord:
Peter Zinn (TBC) over cybersecurity in Agrifood
14.40-16.20 | Breakout sessie thema's

- Toekomstbestendige arbeidsmarkt / Human capital
- Internationalisering
- Data interoperabiliteit en Connectiviteit
- Cybersecurity
- Smart Industry
- Rondleiding in de BIC
- Duurzame/circulaire technologie

16.20-16.35 | Wrap-up
16.35-18.00 | Borrel

NXT GEN HIGHTECH