SmartHort 2019, 6-7 March

Stratford-upon-Avon, Warwickshire , UK

Innovation in disease detection

Gerrit Polder

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Outline

- Introduction
- Spectral Imaging trends
- Spectral Imaging at WUR
- Applications

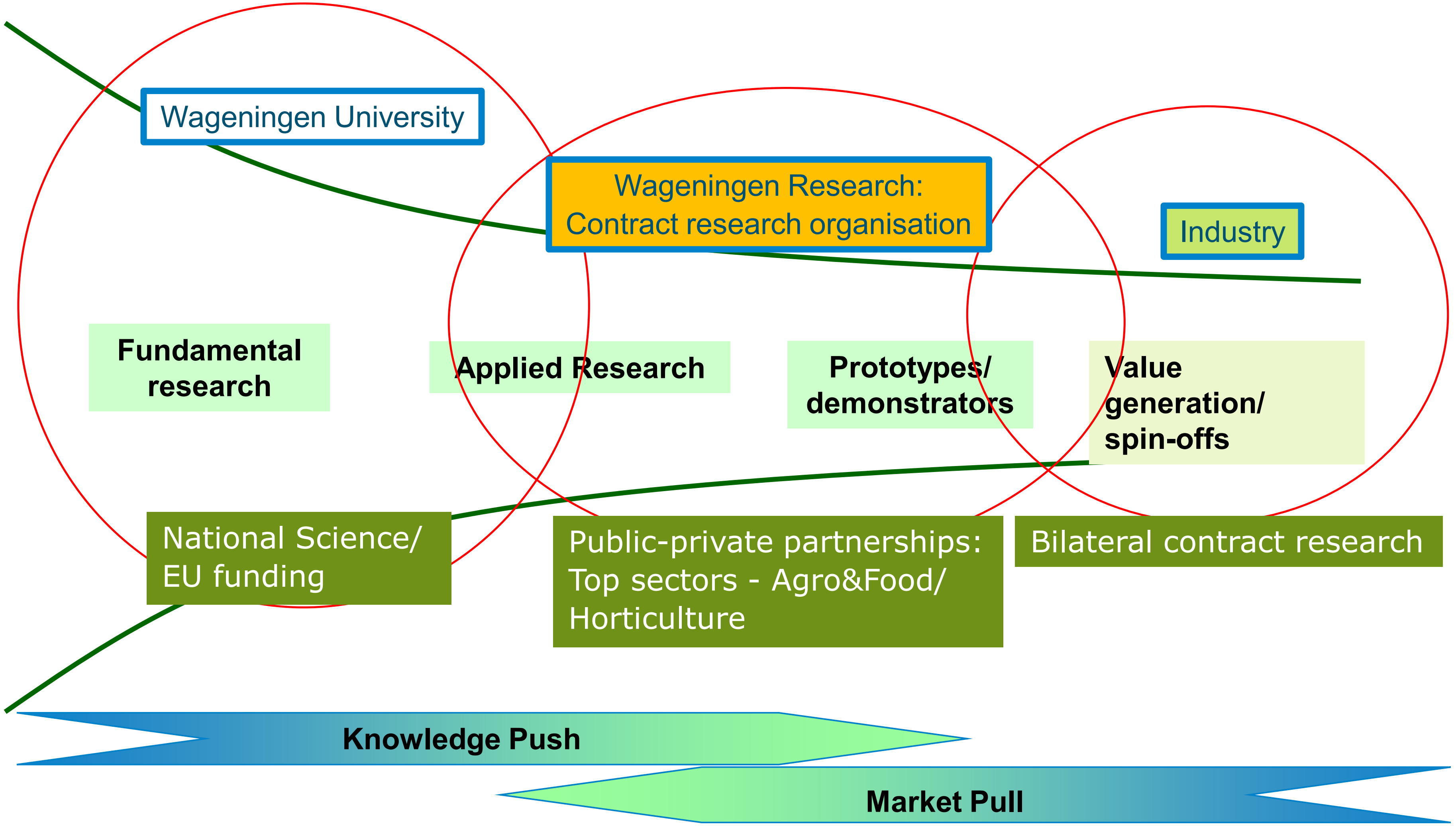
- Tomato compounds
- Tomato maturity
- Crop status
- *Botrytis* in Cyclamen
- Tulip Breaking Virus
- Seed Potatoes
- Optima

Wageningen University & Research

- A university plus R&D organisation for innovation in the agrifood sector.
- Working with industry, governmental authorities and other knowledge institutes

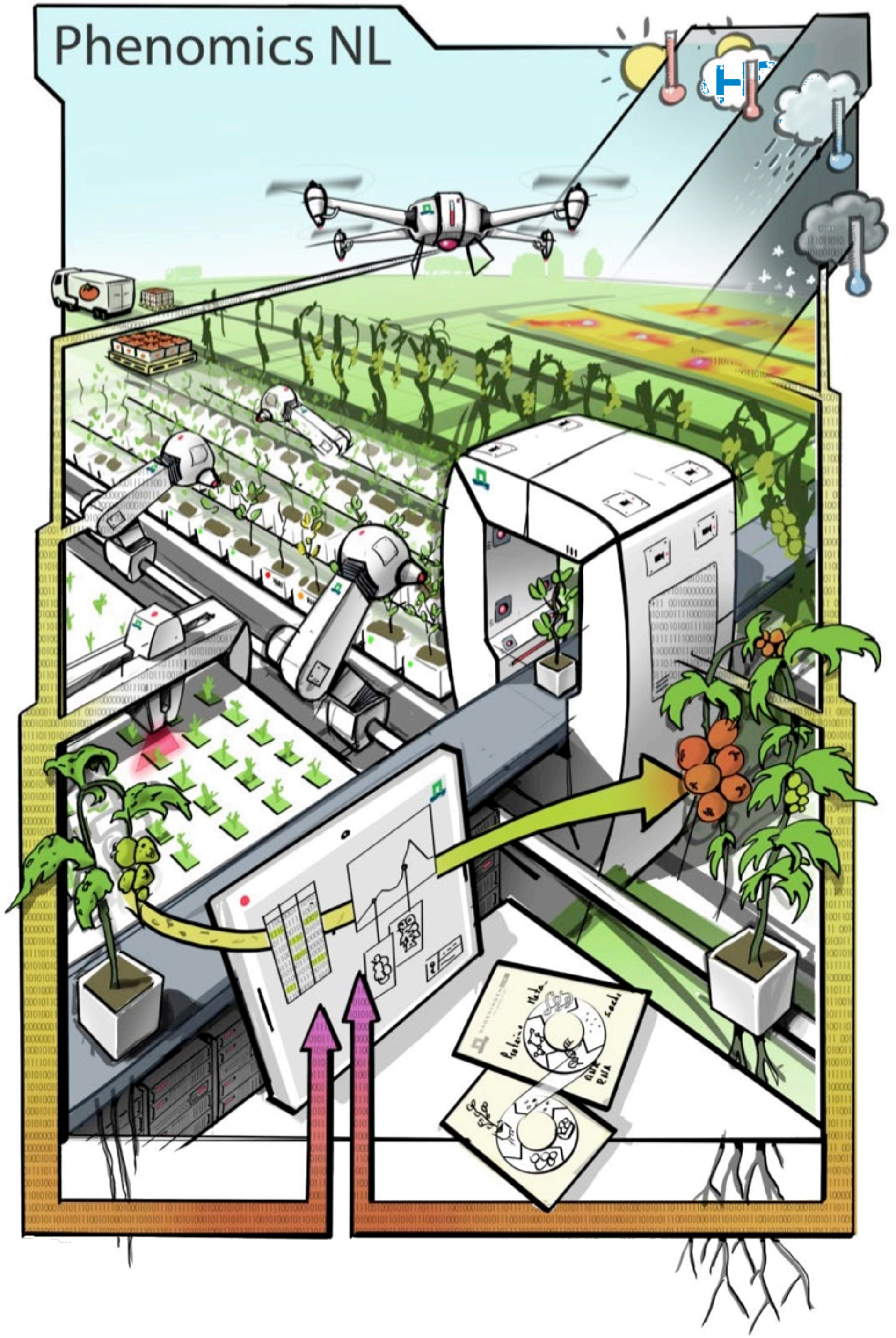
- 6.500 employees
- 12.000 students
- 100 countries

WUR – Way of working



Imaging for plant phenotyping

- Imaging devices for sensing:
- Plant -> sensor
- Sensor -> plant (greenhouse)
- Sensors on drones
- Sensors in the field
- Disease detection
- Multispectral imaging
- Hyperspectral imaging



Recently hyperspectral draws quite some attention

Recently hyperspectral draws quite some attention

VTT's hyperspectral imaging technology ranked as one of the top 10 information and communication technologies by Frost & Sullivan

15/06/2018

Frost & Sullivan, global market research and consulting company, has ranked VTT's hyperspectral imaging technology as one of the "companies to watch" in their recent report on 2018 Top Information and Communication Technologies. For the report, Frost & Sullivan scanned through more than 1000 technologies, out of which they selected the top 50 and then narrowed those down

In the media

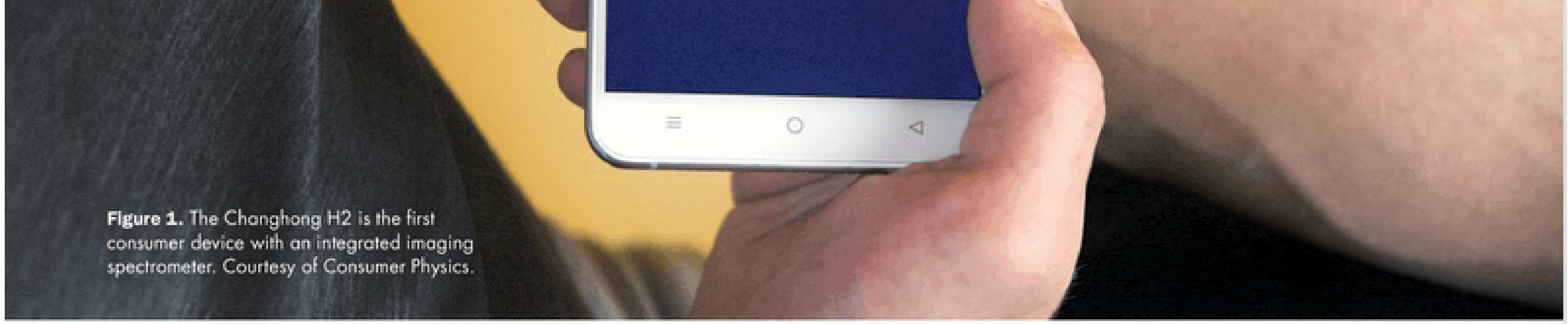


Figure 1. The Changhong H2 is the first consumer device with an integrated imaging spectrometer. Courtesy of Consumer Physics.

Smartphone Spectroscopy
Takes the Lab to the People

The revolutionary power of smartphone spectroscopy is boosting biological and medical applications, and making point of care more effective.

BY FAROOQ AHMED, SCIENCE WRITER

By 2020, the number of smartphone users in the world is expected to reach almost 2.9 billion — nearly doubling in six years from about 1.6 billion in 2014. Technology companies and researchers have been directly and indirectly imbuing smartphones with additional capabilities, including spectroscopy for biological and medical applications, among other uses (Figure 1).

The result is reminiscent of something from "Star Trek," the seminal 1960s television series that delivered futuristic inventions and Capt. James T. Kirk's roguish smile into American homes on a weekly basis. Among the show's memorable gadgets were the communicator, which inspired the design of the clamshell cellphone, and the tricorder, a portable, Swiss Army knifelike gadget that allowed the crew of the USS Enterprise to diagnose medical conditions in seconds with the flash of a hand-held probe across a patient's body. Despite decades of attempts, no one device has completely replicated the original tricorder's capabilities.

Portable analysis

Progress for consumer-oriented devices is being made. According to Brian Cunningham, professor of electrical and computer engineering at the University of Illinois at Urbana-Champaign, "The 'Star Trek' tricorder was absolutely a touchstone as we developed our device — the TRI Analyzer." His group is one of several across the world exploiting the convergence of smartphone computing and spectroscopy.

The TRI Analyzer is a 3D-printed cradle that physically attaches to a smartphone and uses the phone's internal camera as a visible-light spectrometer (Figure 2). "Cellphones today are very well-engineered," Cunningham said. "And their hardware and software are very well-integrated."

This point-of-care device detects the photon emission spectrum of liquids that are used in three common biological diagnostic tests: an enzyme-linked immuno-

In the media

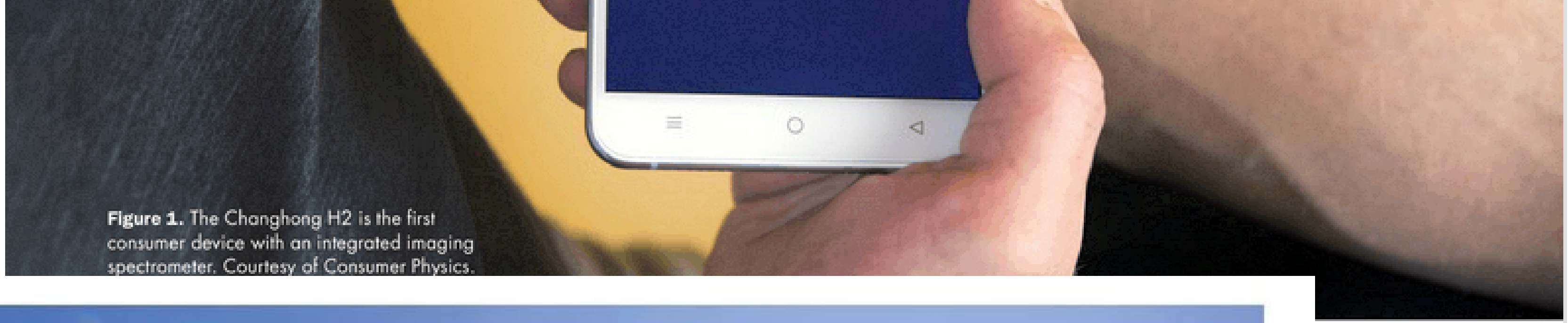


Figure 1. The Changhong H2 is the first consumer device with an integrated imaging spectrometer. Courtesy of Consumer Physics.

Figure 7. The Changhong H2 can be used for several health-related analyses **(a)** and can detect the freshness and sweetness of fruits such as strawberries **(b)**.

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Low cost

ACE AWARDS 2016 ANNUAL CREATIVITY IN ELECTRONICS WINNER

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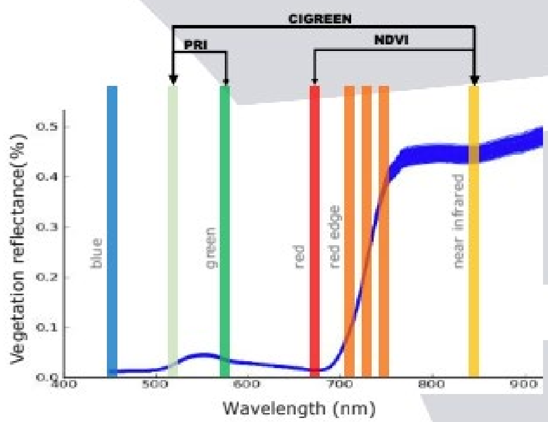
Hyper/multispectral imaging at WUR

SPECIM IQ

reddot award 2018
winner



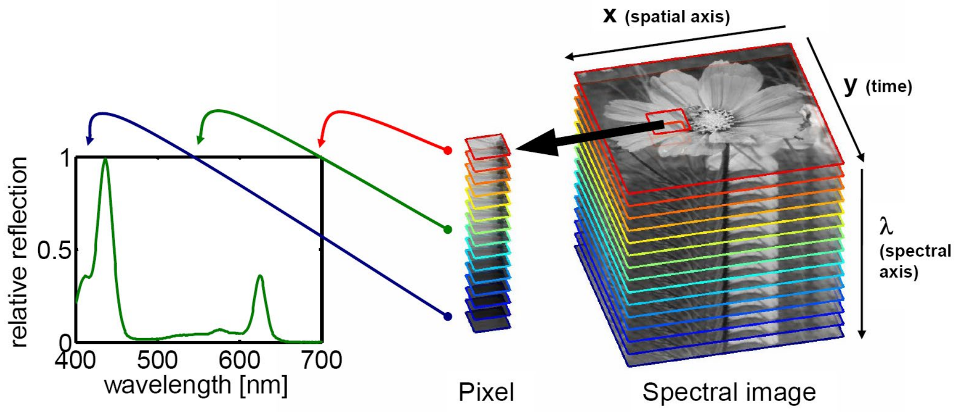
Standard set of bands

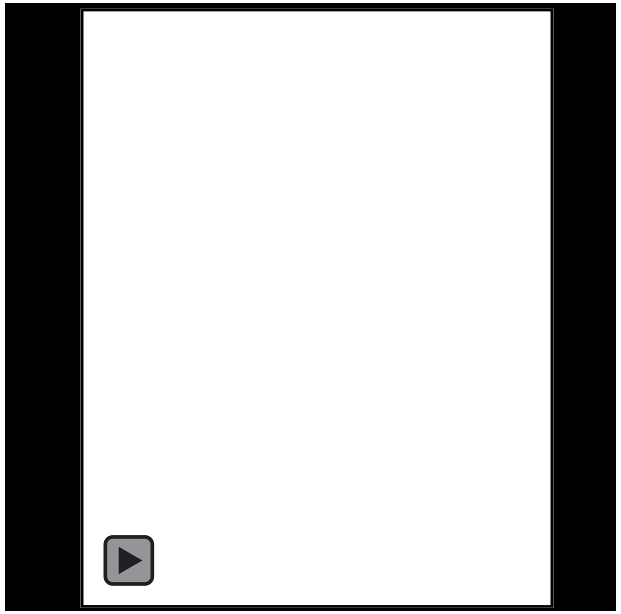
Airphen + FLIR Tau 2

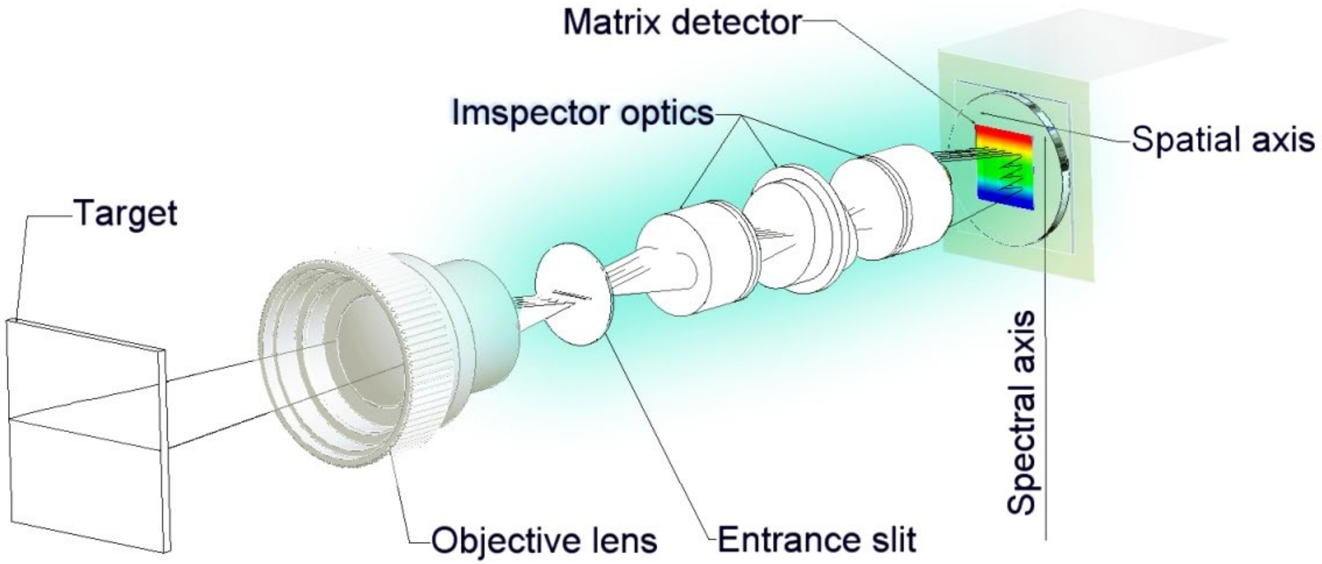
https://youtu.be/cB1blIlIvls

Pushbroom spectrograph

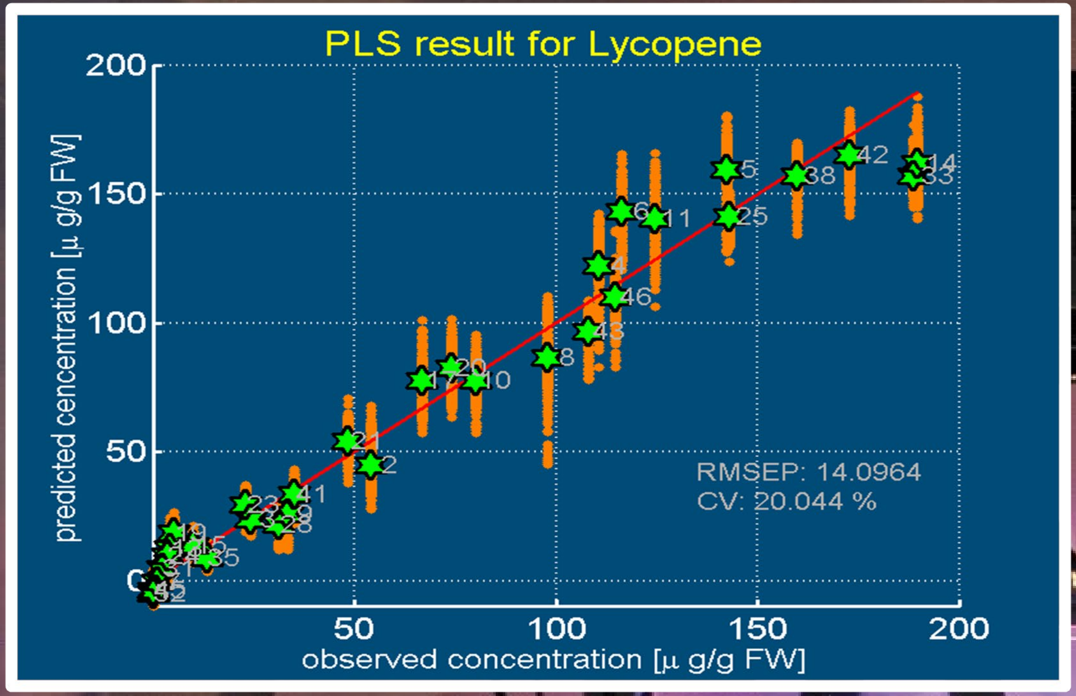
- Slit-spectrometer collects a “wall” of data: pushbroom allows acquisition of a complete data cube.



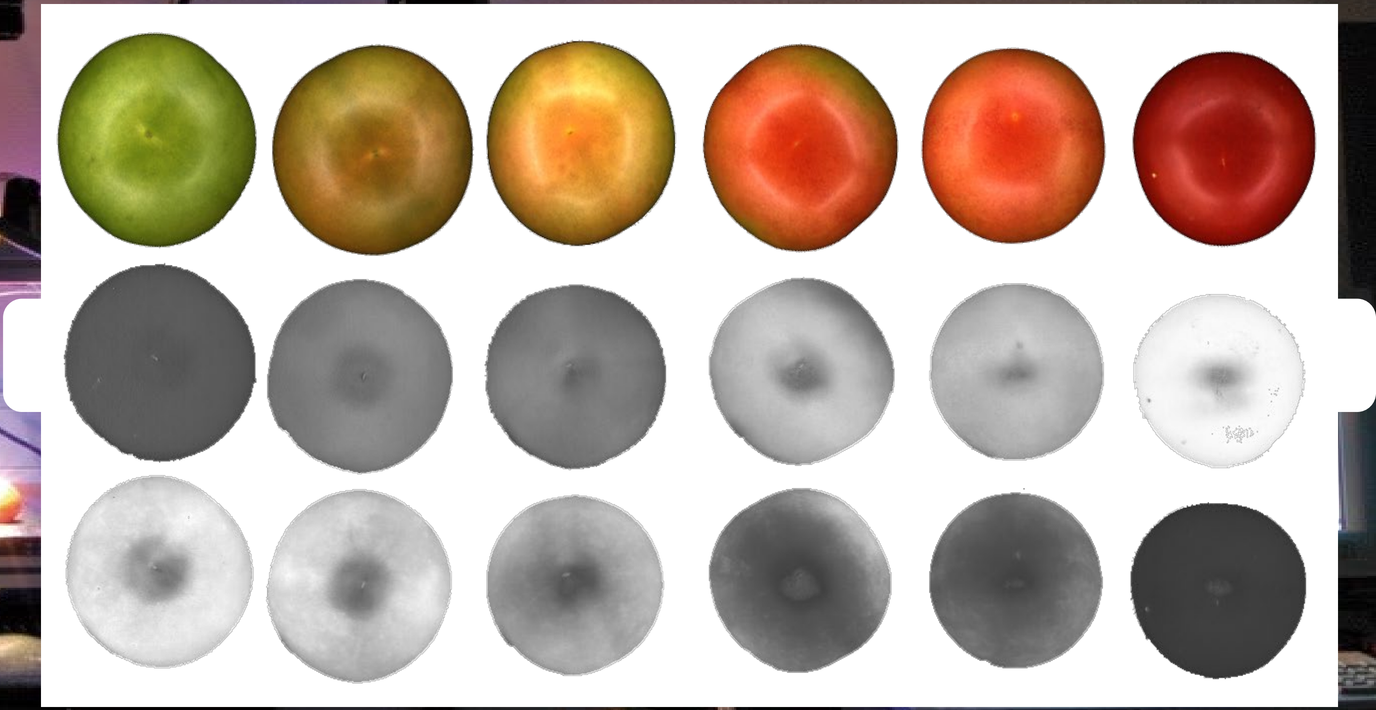




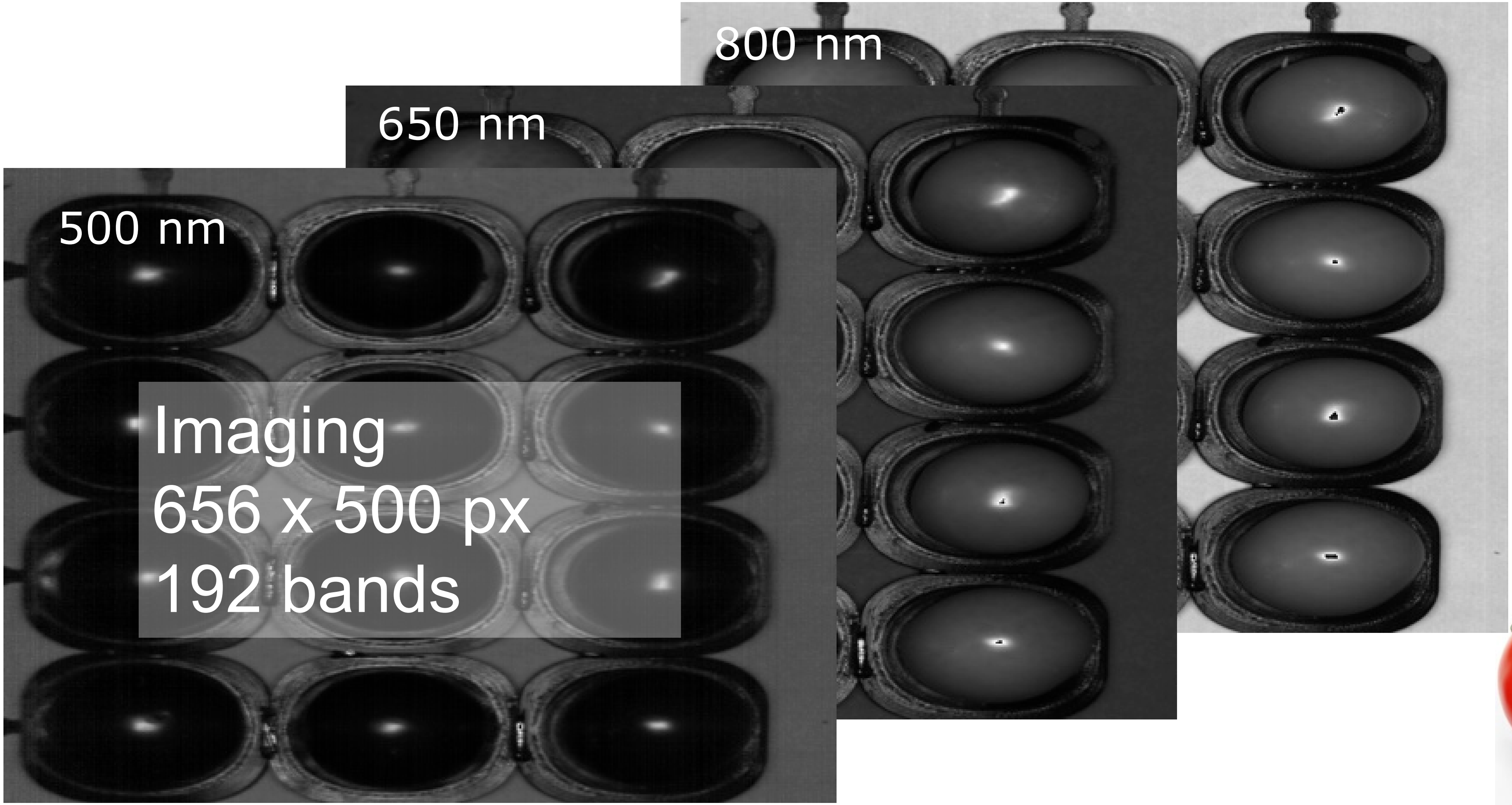
Application examples



Predicting biochemicals or diseases in a spatial preserving way



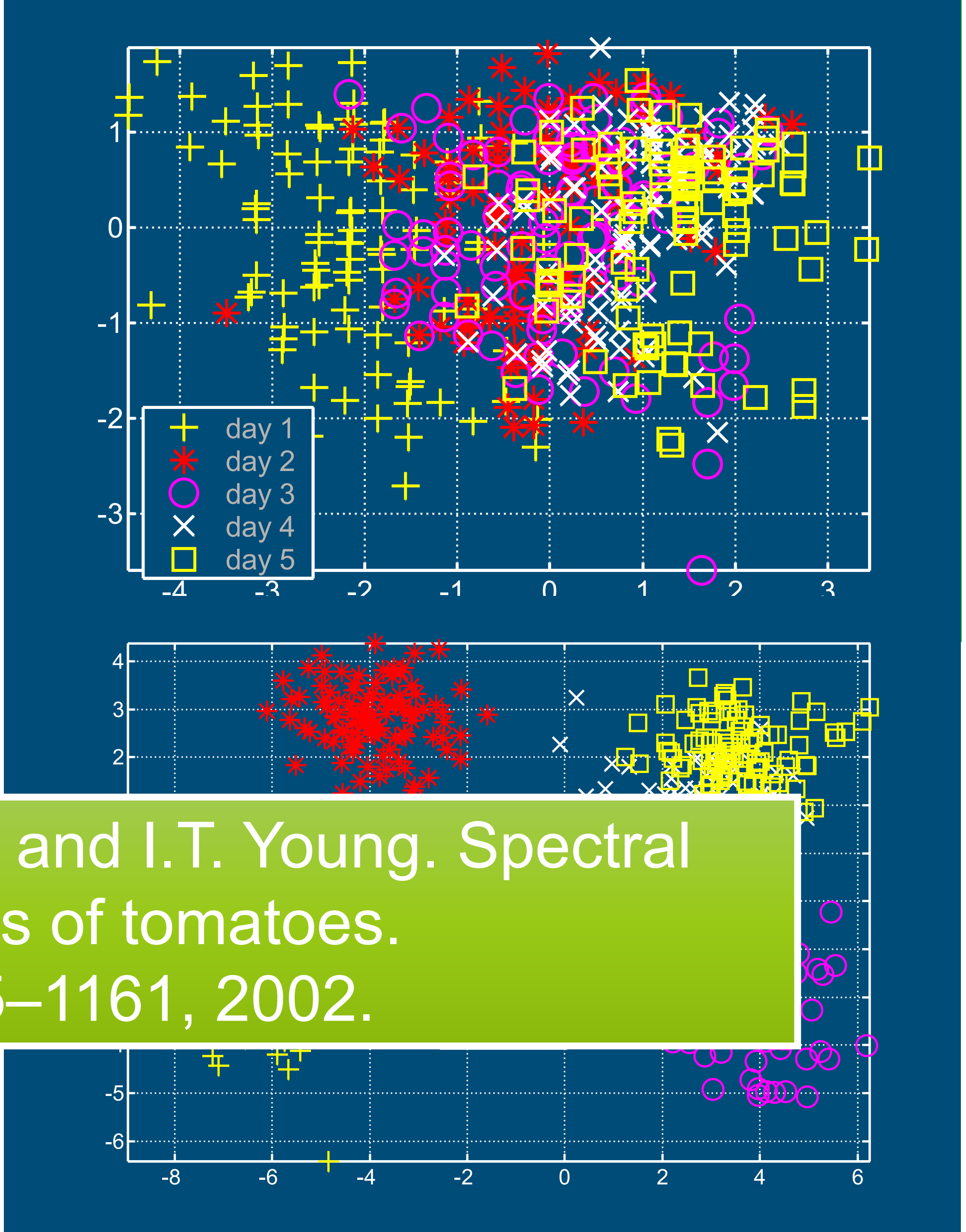
Tomato hyperspectral reflection



Imaging
656 x 500 px
192 bands

Ripening of tomatoes

- Scatter plot of feature analysis of the RGB and spectral images.
- Classes 1-5 represent the ripeness stages of a tomato during the five days after harvest respectively



G. Polder, G.W.A.M. van der Heijden, and I.T. Young. Spectral image analysis for measuring ripeness of tomatoes. Transactions of the ASAE, 45(4):1155–1161, 2002.

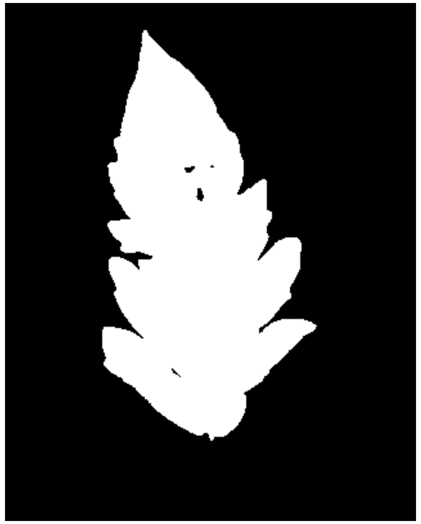
Monitoring crop status

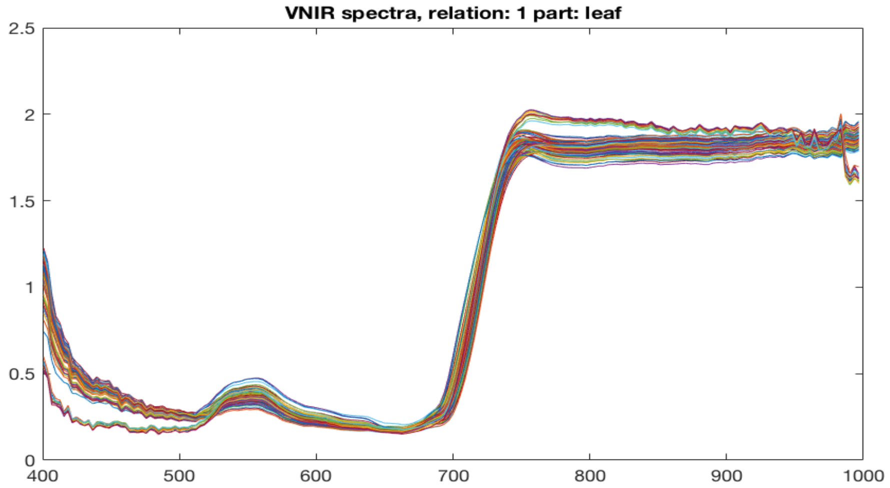
- Crop growers need information on status of the leaves before they are removed during crop cultivation.
- Currently this can only be done using leaf samples send to an external laboratory.
- Can hyperspectral imaging be used for measuring leaf and fruit compounds non-destructively?

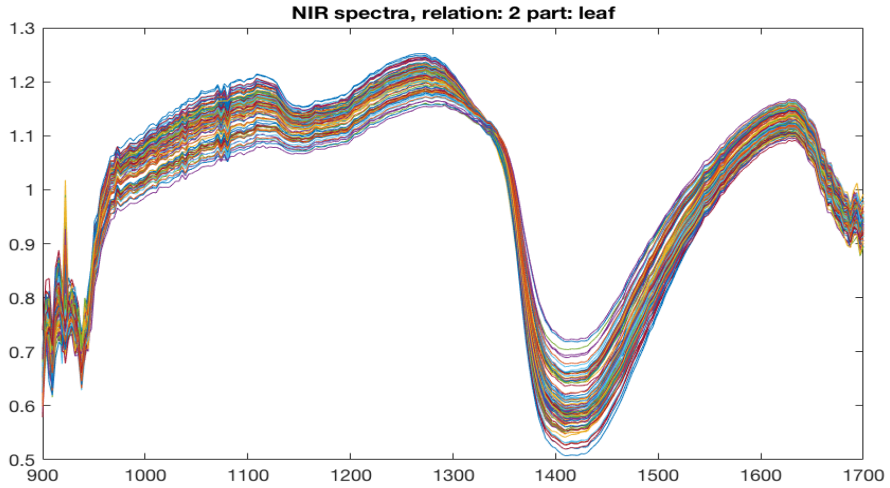
Monitoring crop status

Setup:

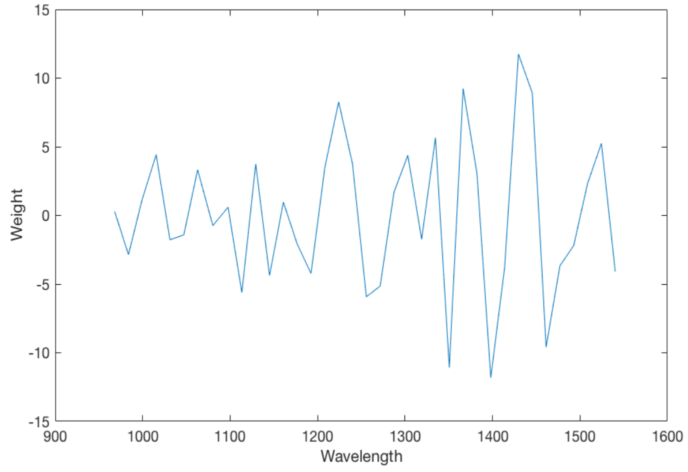
- VNIR HSI, Specim V10e, 400-1000nm
- NIR HSI, Specim N17, 900-1700nm
- 412 leaf samples
- 200 fruits
- Supervised foreground/background segmentation
- Average spectrum per sample
- Reference measures
- Partial Least Square (PLS) regression, using leave one out cross validation.

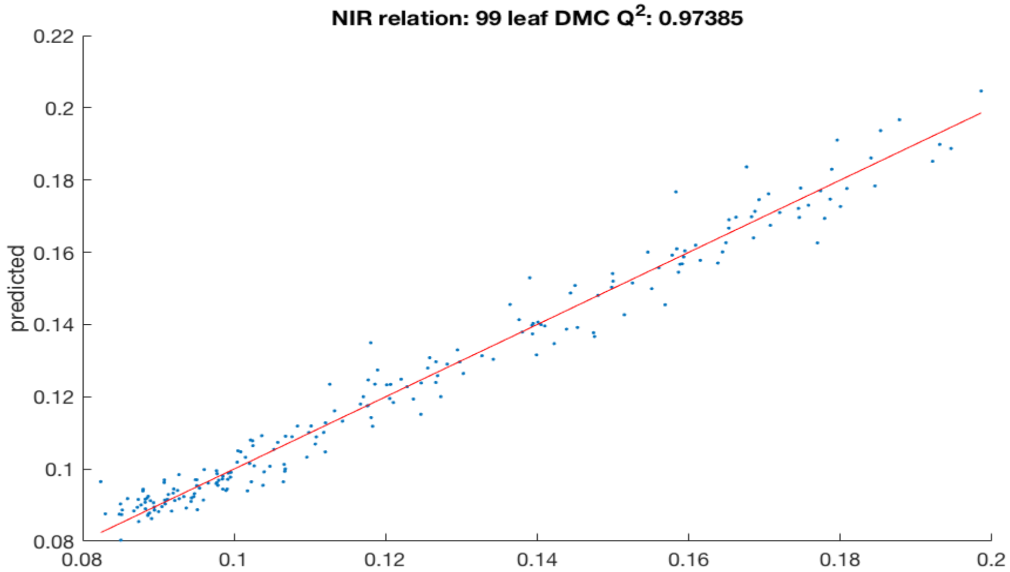


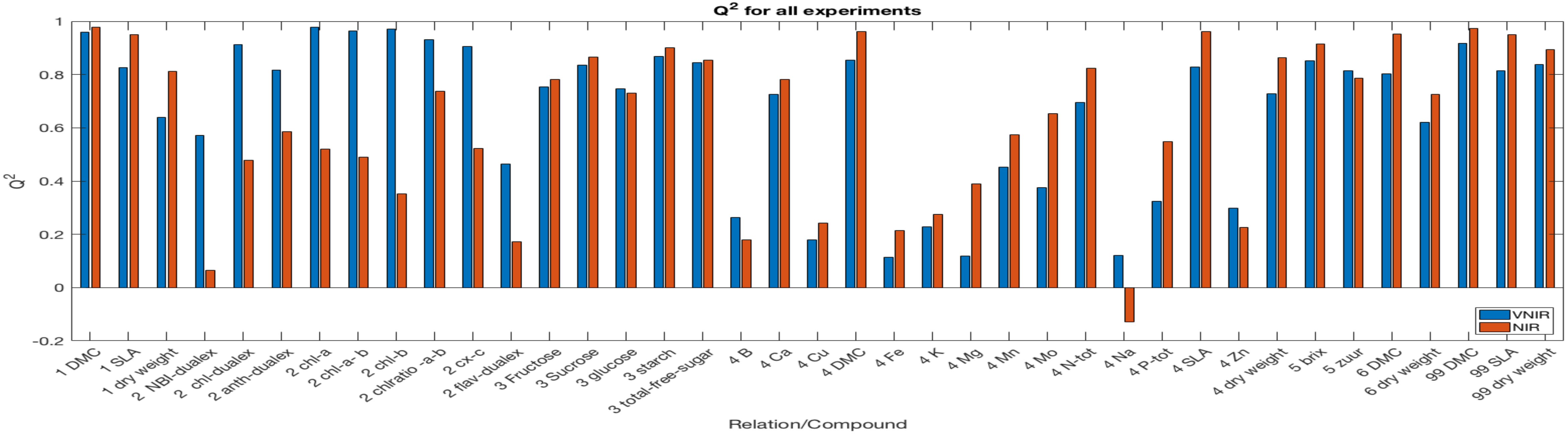




Monitoring crop status







Detection of *Botrytis* in the greenhouse

- Cyclamens are particularly susceptible to grey mould caused by Botrytis cinerea. This causes a grey fuzzy mould on infected plant parts, and also attacks the stalks of developing leaves and flowers, causing them to collapse.

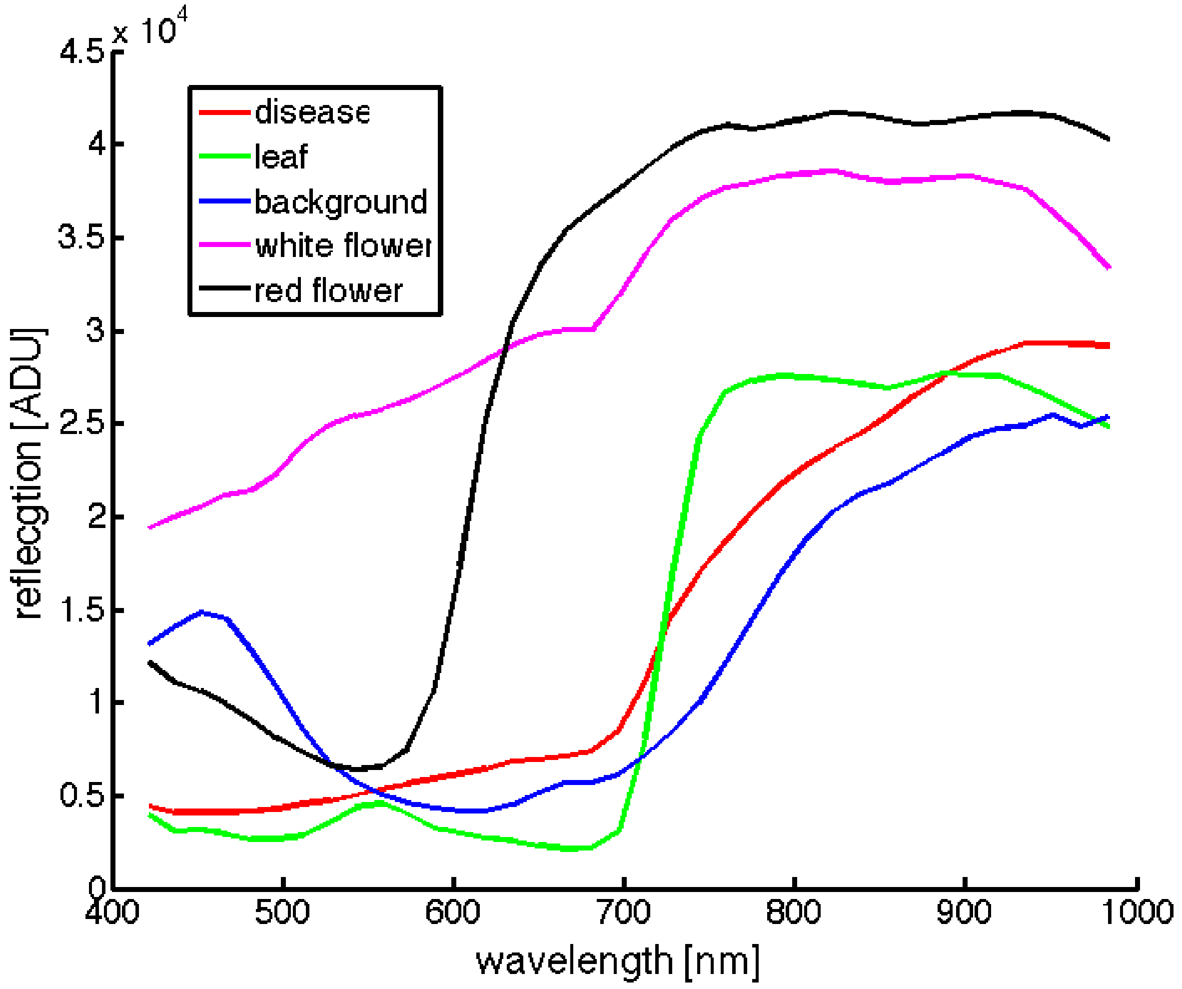
- LAB experiment
- 72 Cyclamen plants
  - Healthy (18)
  - Infected (18)
  - Diseased (18)
  - Heavy diseased (18)
- Hyperspectral recordings, (400-1000nm)
- Originally 193 bands, reduced to 37 bands, 15 nm bandwidth.

Detection of *Botrytis* in the greenhouse

1. Healthy
2. Infected
3. Diseased
4. Heavily diseased

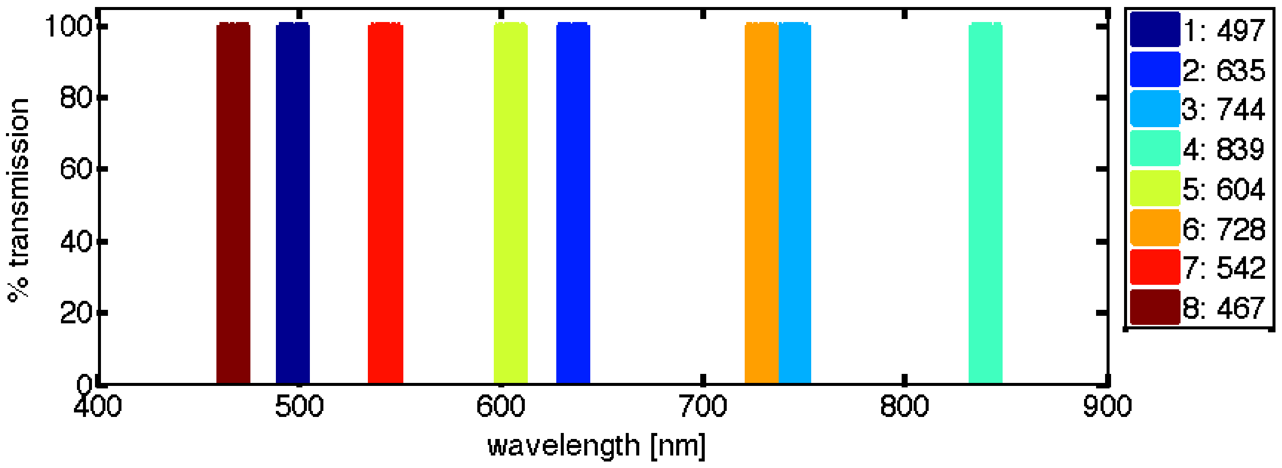
Detection of *Botrytis* in the greenhouse

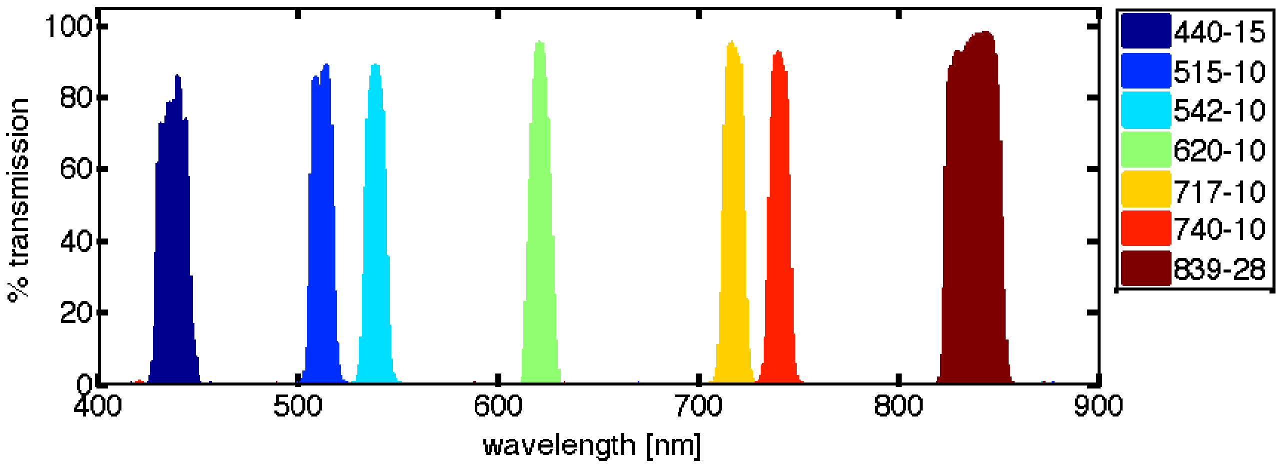
- Classification
- In the plant images mainly five regions with different spectral signatures are present:
  - blue background
  - white flower
  - red flower
  - leaf
  - diseased area



Detection of *Botrytis* in the greenhouse

- Feature selection
- Search algorithm to find 8 most discriminating wavelength bands

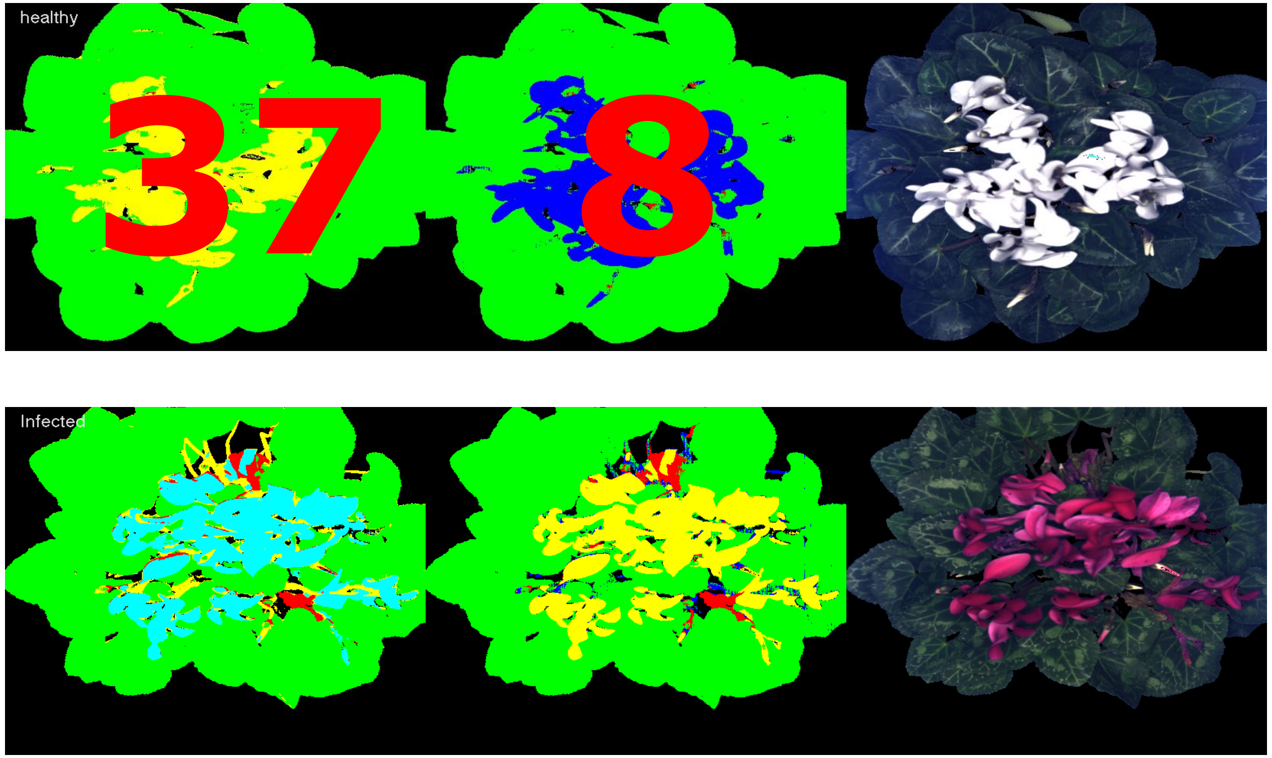


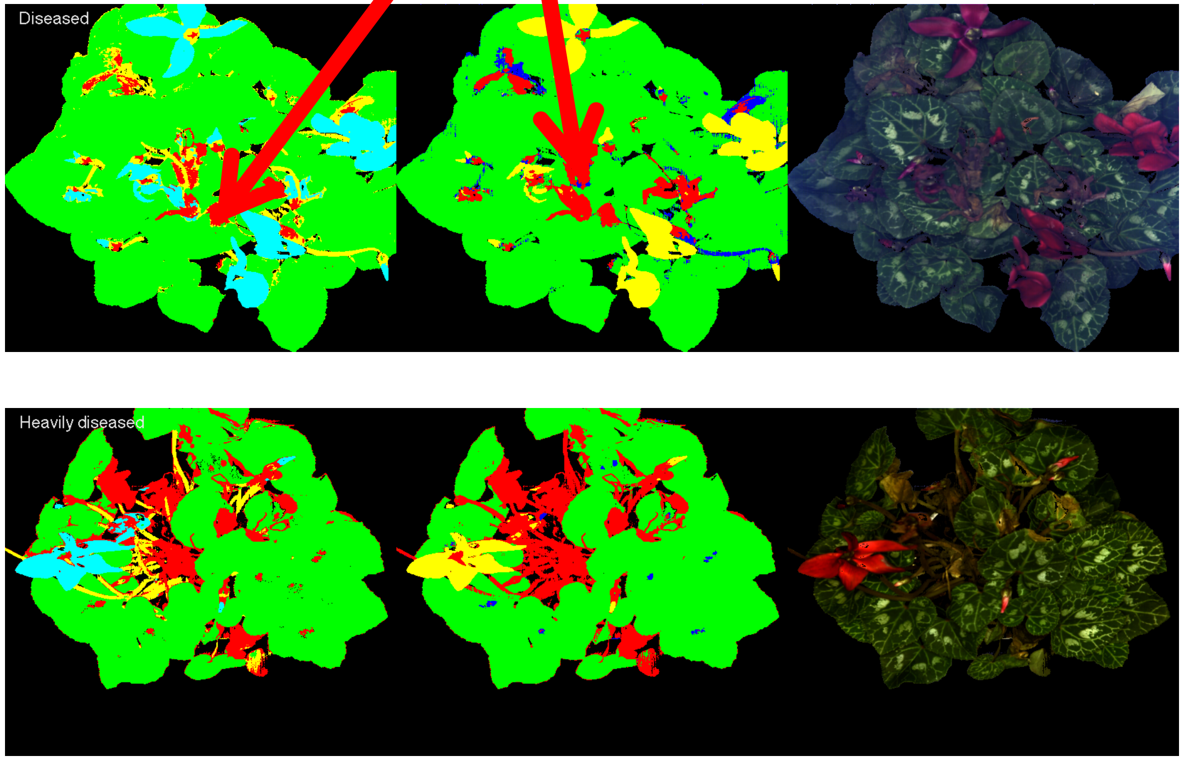


Detection of *Botrytis* in the greenhouse

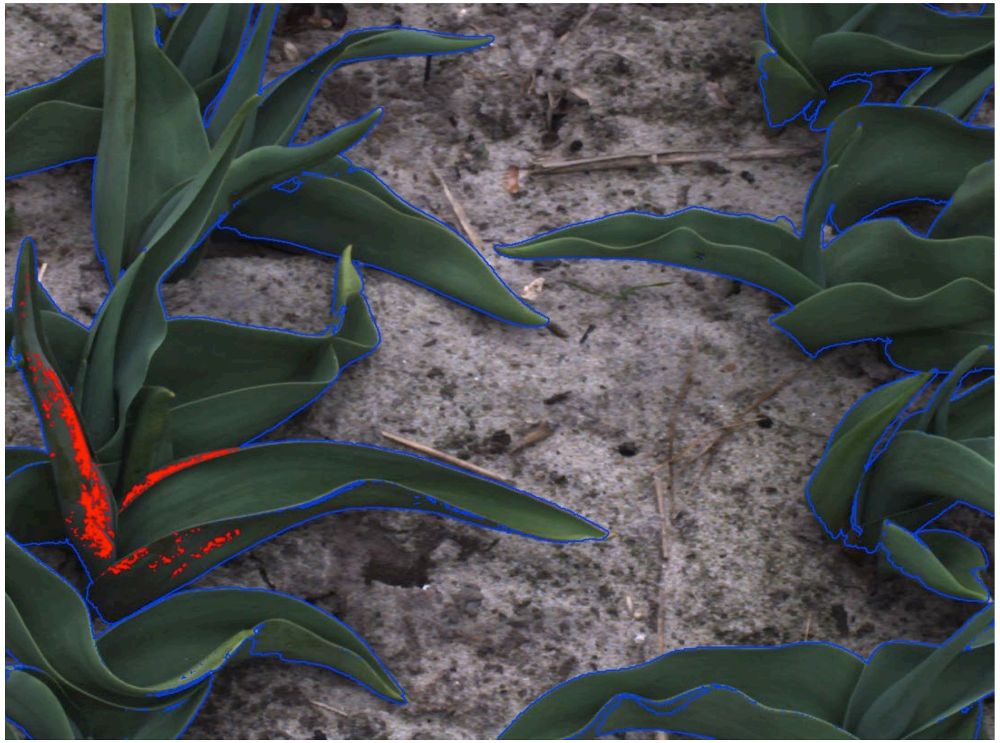
- Classification results for 37/8 bands

Diseased





G. Polder , G. W. A. M. van der Heijden, J. van Doorn, J. G. P. W. Clevers, R. van der Schoor and A. H. M. C. Baltissen, 2010. Detection of the tulip breaking virus (TBV) in tulips using optical sensors. *Precision Agriculture*, vol. 11 (4), pp. 397-412.

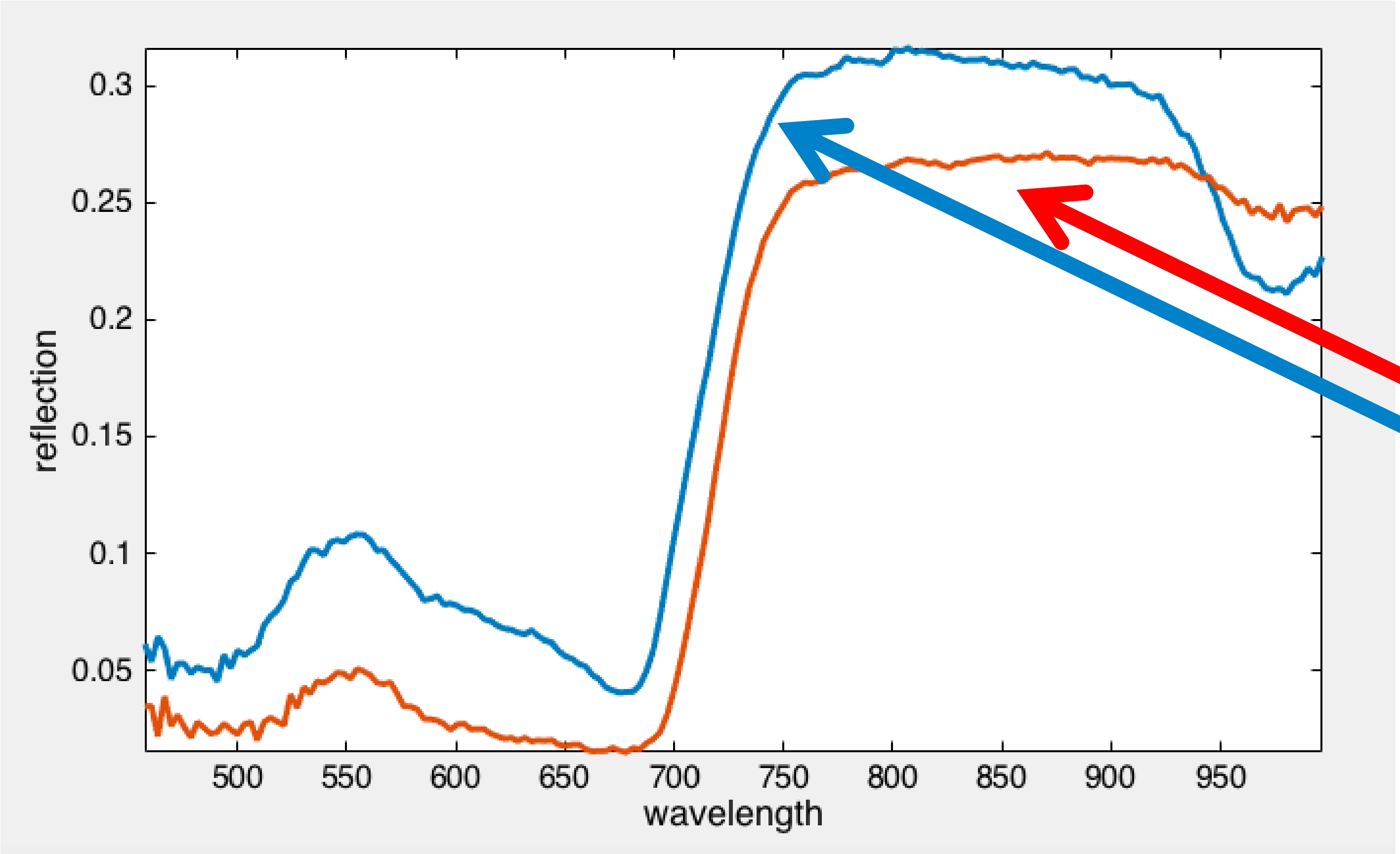


Detection of tulip breaking virus in the open field

In field detection of tulip breaking virus

- https://youtu.be/Ns6OyGZ6BaQ

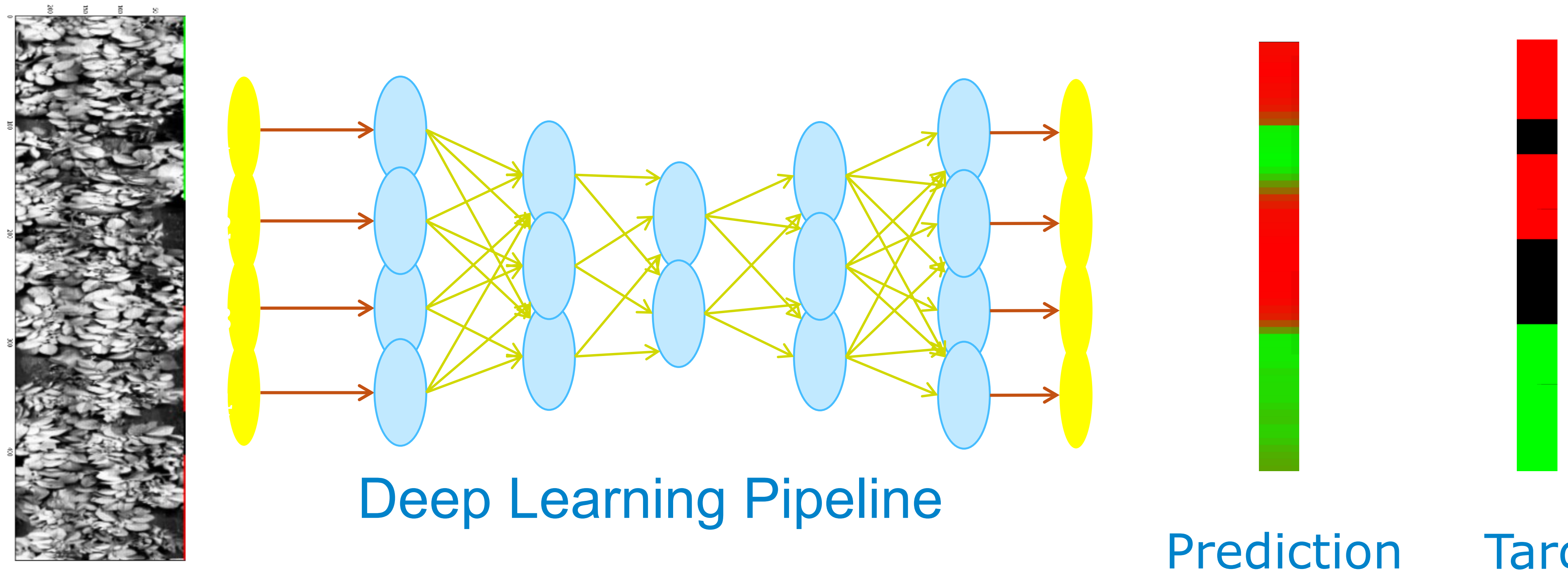
Distinction between stem and leaf



Distinction between stem and leaf

Based on a few images a classifier is built to distinguish between stem and leaf, in order to find diseases in the stem or leaf respectively.

Disease detection in seed potatoes

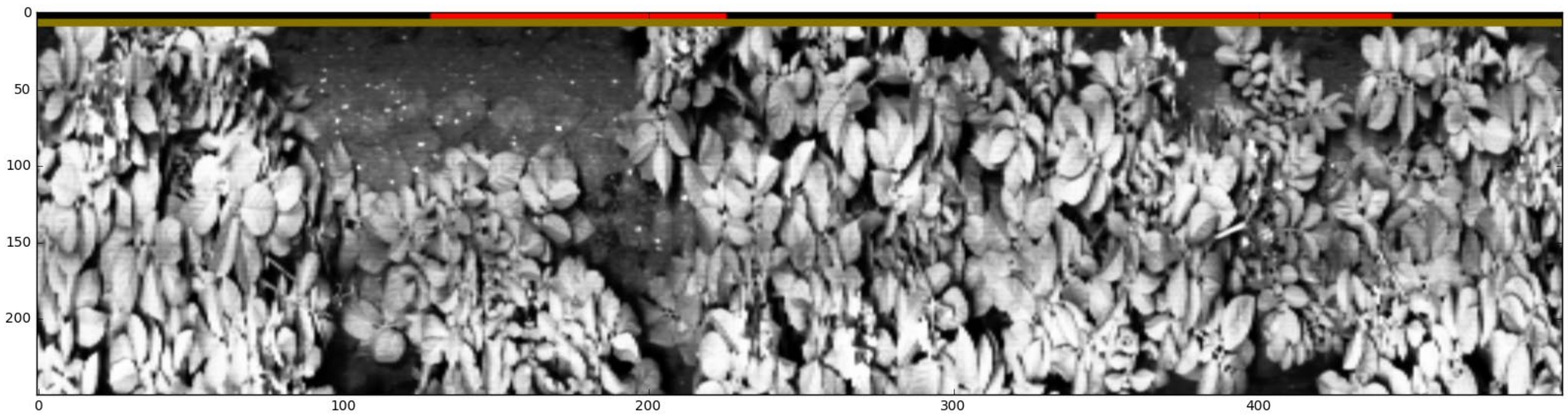


Deep Learning Pipeline

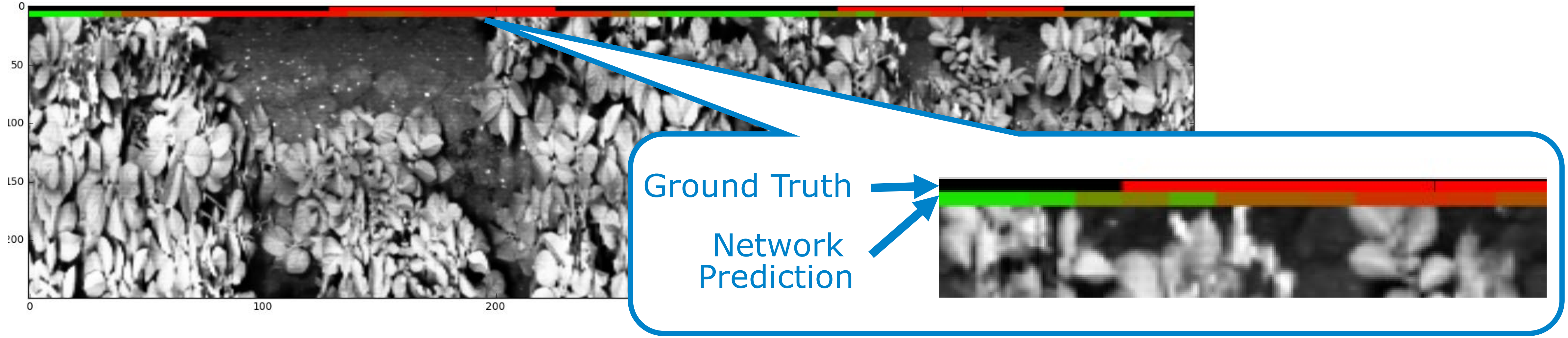
Prediction Target

- Fully convolutional neural network converted to predict a 1D “image” instead.
- Basic principle is the same, network structure is a bit different.

Disease detection in seed potatoes

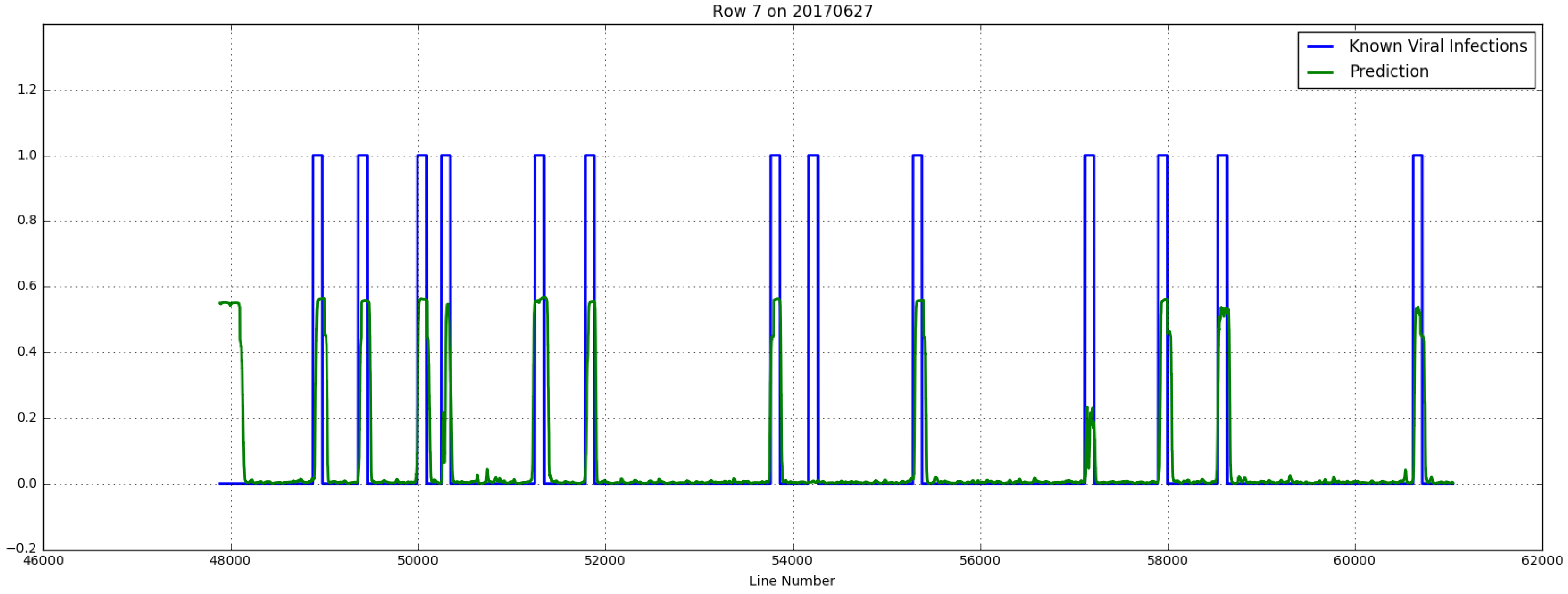


Test image at start and end of training



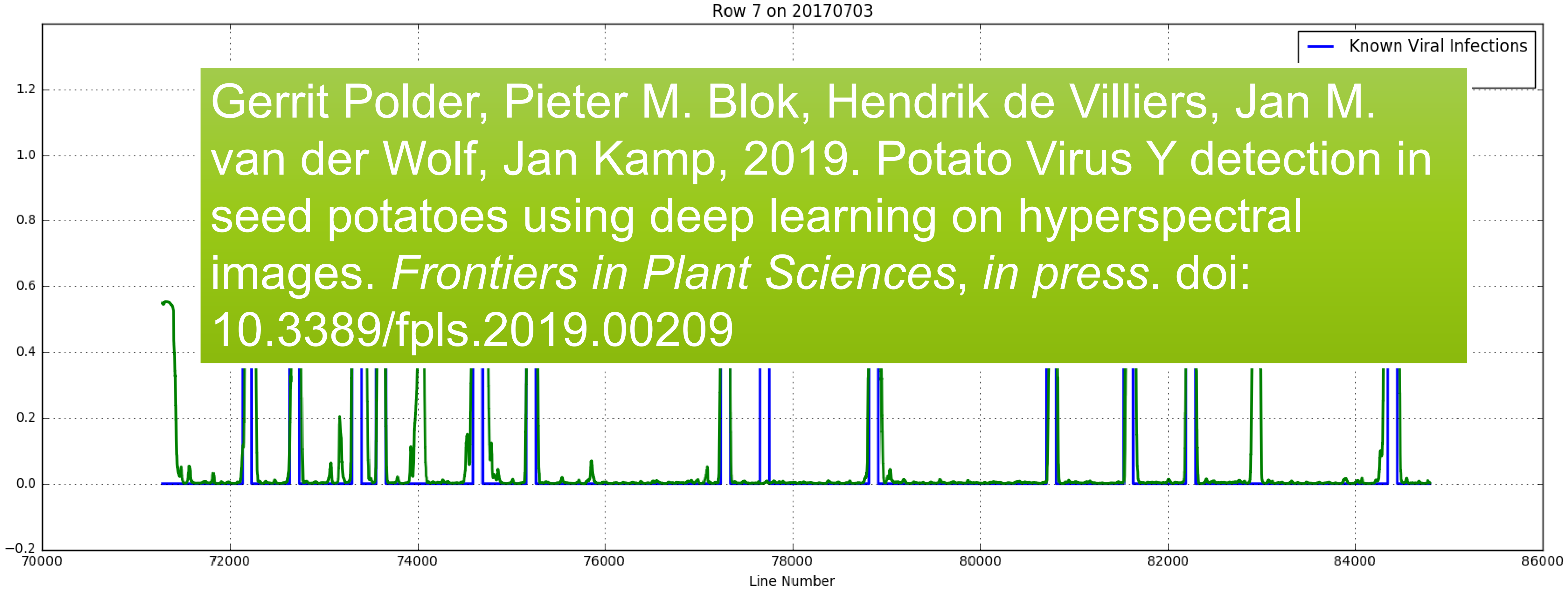
Disease detection in seed potatoes

- Results: Row 7 (Vermont) 27/6/2017



Disease detection in seed potatoes

- Results: Row 7 (Vermont) 3/7/2017



Gerrit Polder, Pieter M. Blok, Hendrik de Villiers, Jan M. van der Wolf, Jan Kamp, 2019. Potato Virus Y detection in seed potatoes using deep learning on hyperspectral images. *Frontiers in Plant Sciences*, *in press*. doi: 10.3389/fpls.2019.00209

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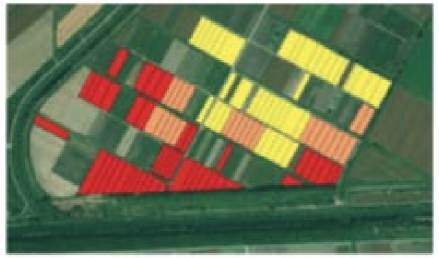
OPTimised Integrated Pest MAnagement

1 Optimise early disease detection method and disease prediction models

Crop

Disease detector



Precise prediction of when, where and how much the disease will be present in the field

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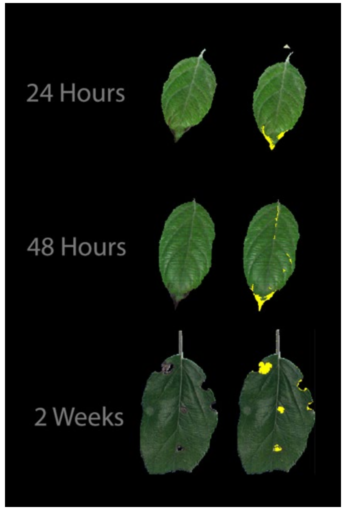
OPTimised Integrated Pest MAnagement

Objectives Work Package 2:

- develop a Decision Support System (DSS) for disease control scheduling;
- develop advanced detection systems for in-field localization and monitoring of the selected diseases in the use-case crops;
- use pattern recognition through artificial intelligence/deep learning to detect, segment and quantify plant diseases.



Summer School on Image Analysis for Plant Phenotyping

MARVIN

Organised byWageningen Academy,
Wageningen Agro Food Robotics

Date Mon 8 July 2018 until Fri 12 July 2019

Duration 5 days

Setup Campus WUR

Venue Wageningen

WAGENINGEN SUMMER SCHOOL

Acknowledgements

Gerie van der Heijden, Joop van Doorn, Ton Baltissen, Erik Pekkeriet, Hans Jansen, Rick van de Zedde, Gert Kootstra, Gert-Jan Swinkels, Pieter Blok, Toon Tielen, Hendrik de Villiers, Jan Kamp, Jos Ruizendaal, Freek Daniels, Joseph Peller.

Questions

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