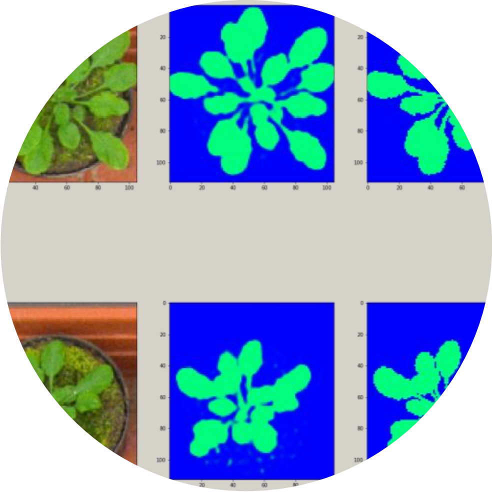
Role of Computer Vision and Machine Learning in protected cultivation

A selection of examples

18 May 2022, Aneesh Chauhan | Sr. Scientist, Computer vision and Robotics



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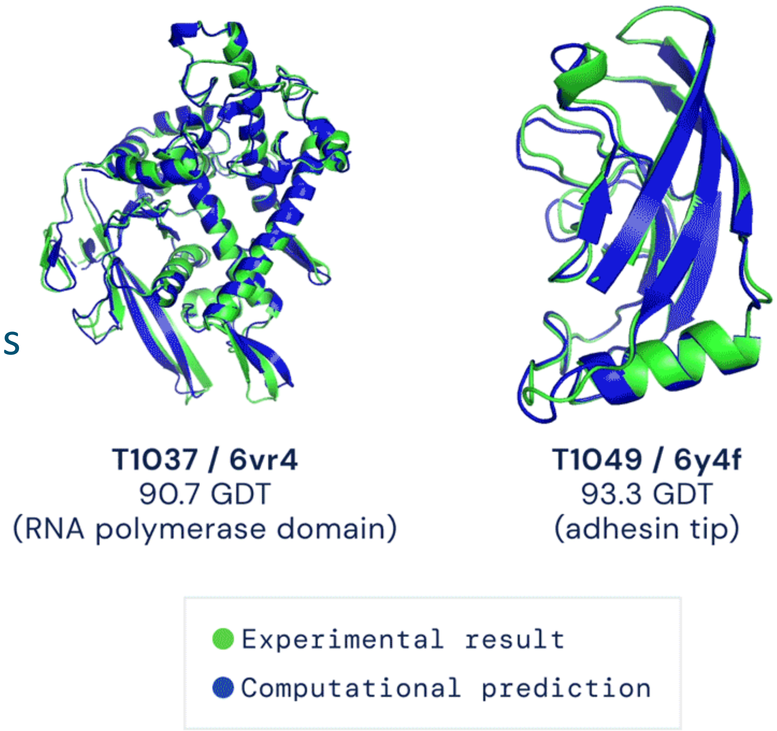
Protein folding problem

What a protein does largely depends on its unique 3D structure.

Figuring out what shapes proteins fold into is the **protein folding problem**, and has stood as a grand challenge in biology for the past 50 years



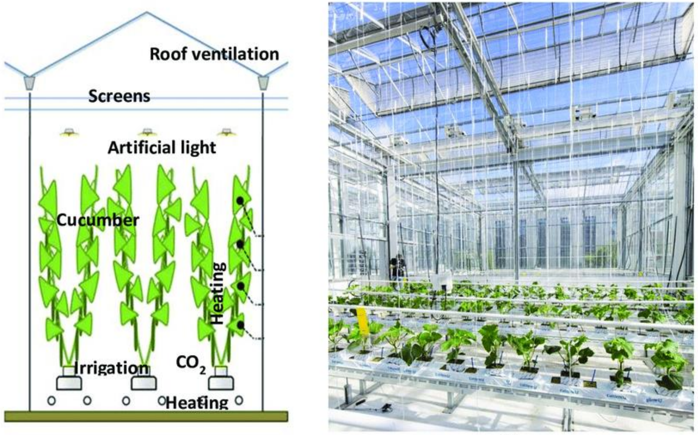
AlphaFold2: High Accuracy Protein Structure Prediction Using Deep Learning
https://deepmind.com/blog/article/alphafold-a-solution-to-a-50-year-old-grand-challenge-in-biology

Aneesh Chauhan

- Expertise Leader | Computer Vision and Robotics
  - Focus: Post-harvest Technology and AgroFood Robotics
- Education
  - B. Eng. Computer Science and Engineering (BAMU, India | 2001)
  - MSc. Autonomous Systems (Exeter University, UK, 2004)
  - PhD Informatics and Robotics (University of Aveiro, Portugal 2014)
- Experience
  - 2 decades of experience in Computer Vision, Machine Learning and Robotics
  - Robotic systems: Robotics arms, Humanoid robots, Drones
  - Applications: Service robotics, Industrial inspection, Agri-food

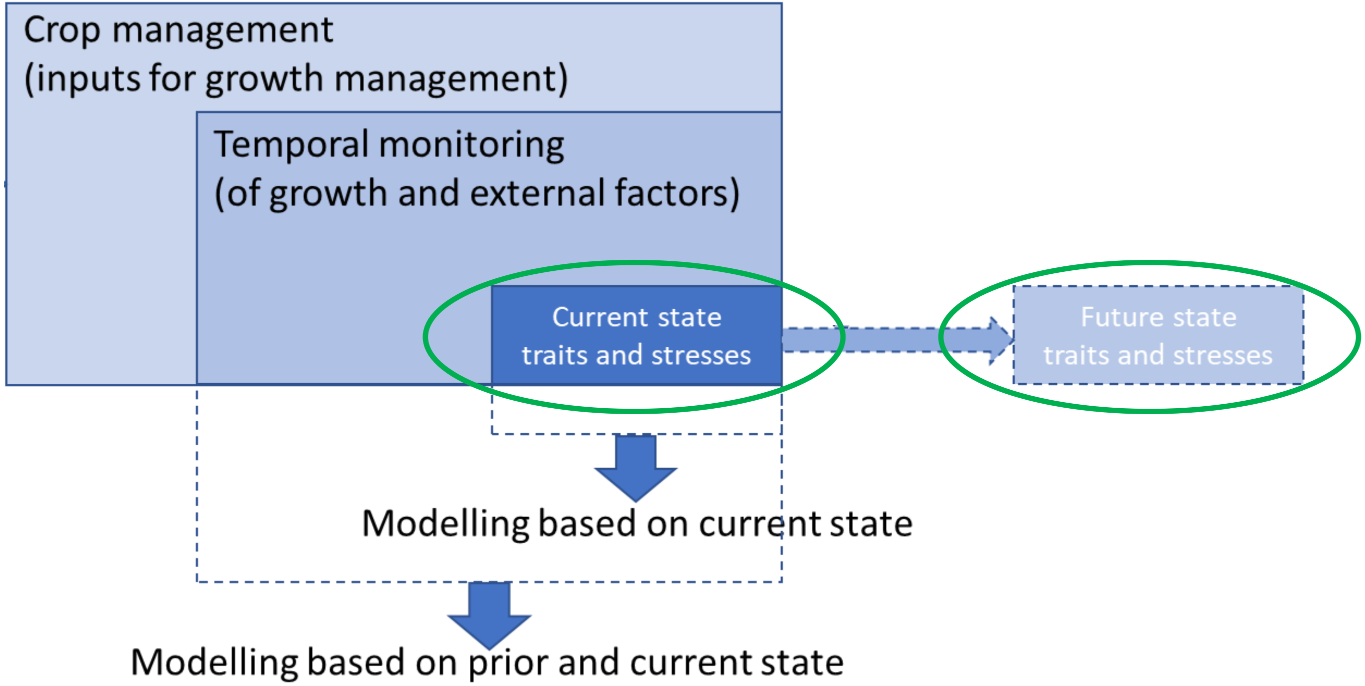
To model change

- Factors causing the change
  - Product biology
  - Input variables
  - Climate variables
  - Diversity of varieties

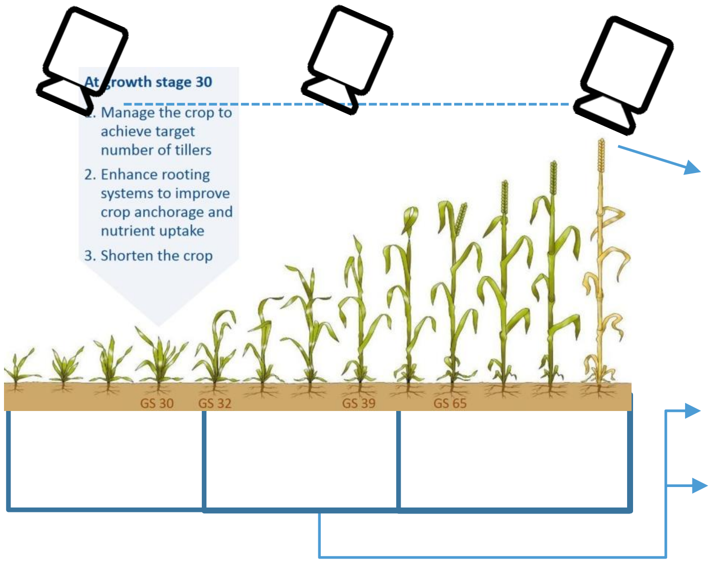


(a) (b)

Towards closed-loop cultivation



What shall we model?



A. Crop current state modelling to retrieve
- Relevant crop traits [depends per crop]
- Relevant stresses

B. Crop current state modelling based on prior state knowledge
- Relevant crop traits
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C. Future state modelling based on prior state knowledge
- Relevant crop traits
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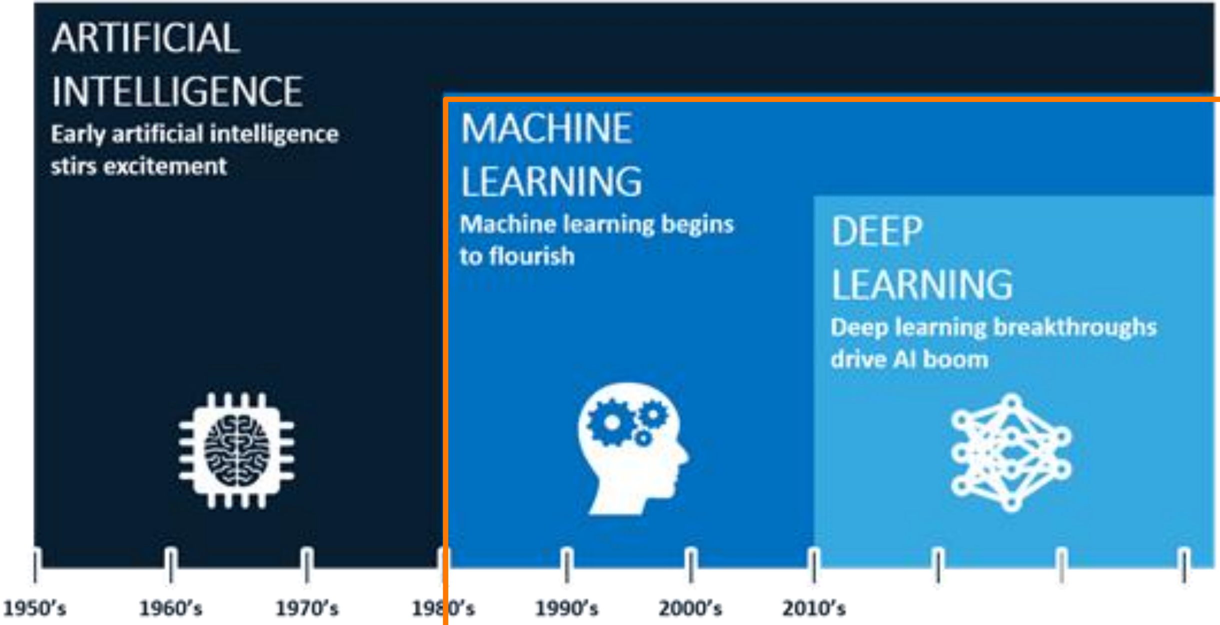
https://www.agricentre.basf.co.uk/Pictures/agricentre_pictures/pgr_2_pictures/pgr_growth_stage_pictures/pgr_growth_stage_one_850x478.jpg

Machine learning in AI ecosystem



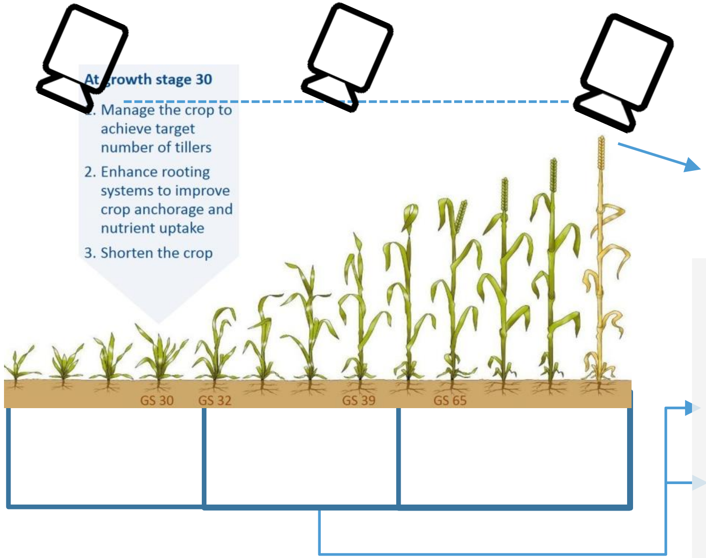
AI: Intelligence demonstrated by machines rather than humans or animals.

ML: Giving computers the skills to learn without explicit programming

~~**DL:** Is an ML subset, examining algorithms that learn and improve on their own.~~

Image source: https://www.usoft.com/blog/difference-between-ai-ml-and-deep-learning

What shall we model?



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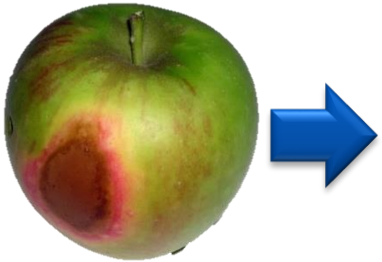
Supervised learning

- Dataset is available such that we know what the expected output should be
- There is relation between the data and expected output
- Feedback from incorrect prediction can be used to improve learning
- Two types:
  - Classification – Discrete decision
  - Regression – Continuous value output

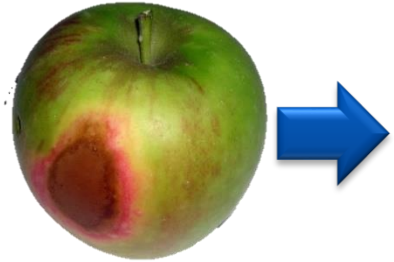
A classification problem



Healthy? /

Damaged?

Regression problem



Degree of damage?

Finding patterns in raw data is hard!

What we see

What machine "sees"

101001100010101011111100101
110100011001110001111100100
110110010010101110010101010
101011110011110001011000111
100001100110101001100010101
011111100101110100011001110
001111100100110110010010101
110010101010101011110011110
001011000111100000110011010

... and so on

Phalaenopsis root quality assessment

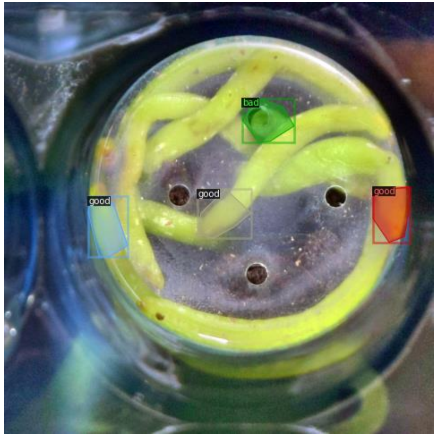
Floricultura and Anthura

- The **goal** of the project is to build objective quality assessment tool for the roots (Phalaenopsis plant).
- **Quality** is defined by the number of good and bad root tips

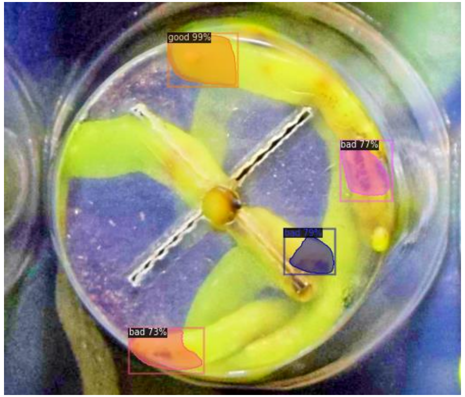
Root quality assessment

- Data collection: ~3k images collected
- Data annotation: Good & Bad root tip ~350 images annotated
- Problem definition: Detect the root tips and classify them as Good or Bad
- Choice of deep network: Mask-RCNN

Sample annotation



Network Output



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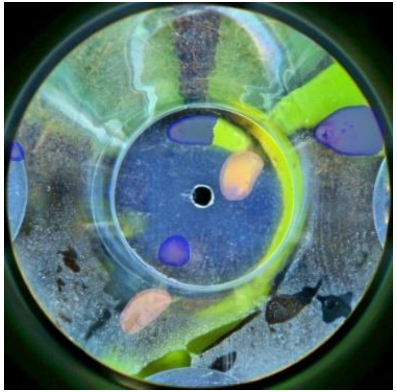
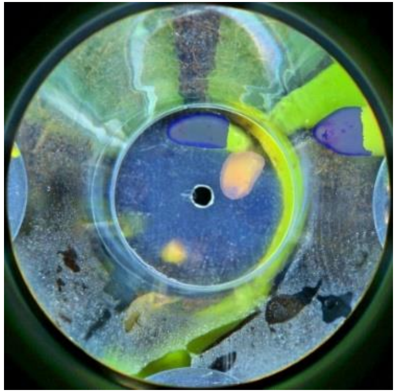
Root quality assessment

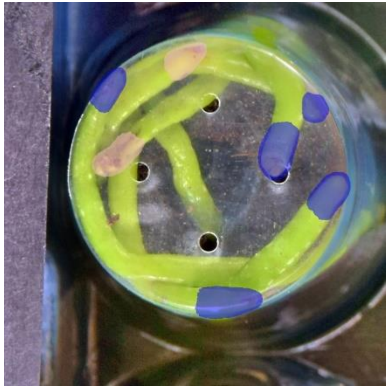
Detection



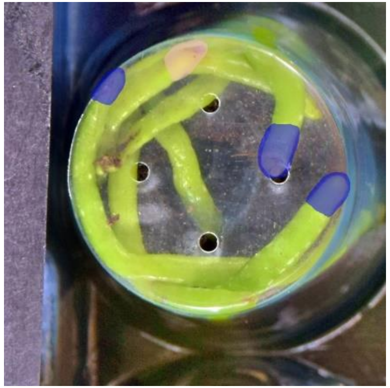
Ground truth



Detection



Ground truth



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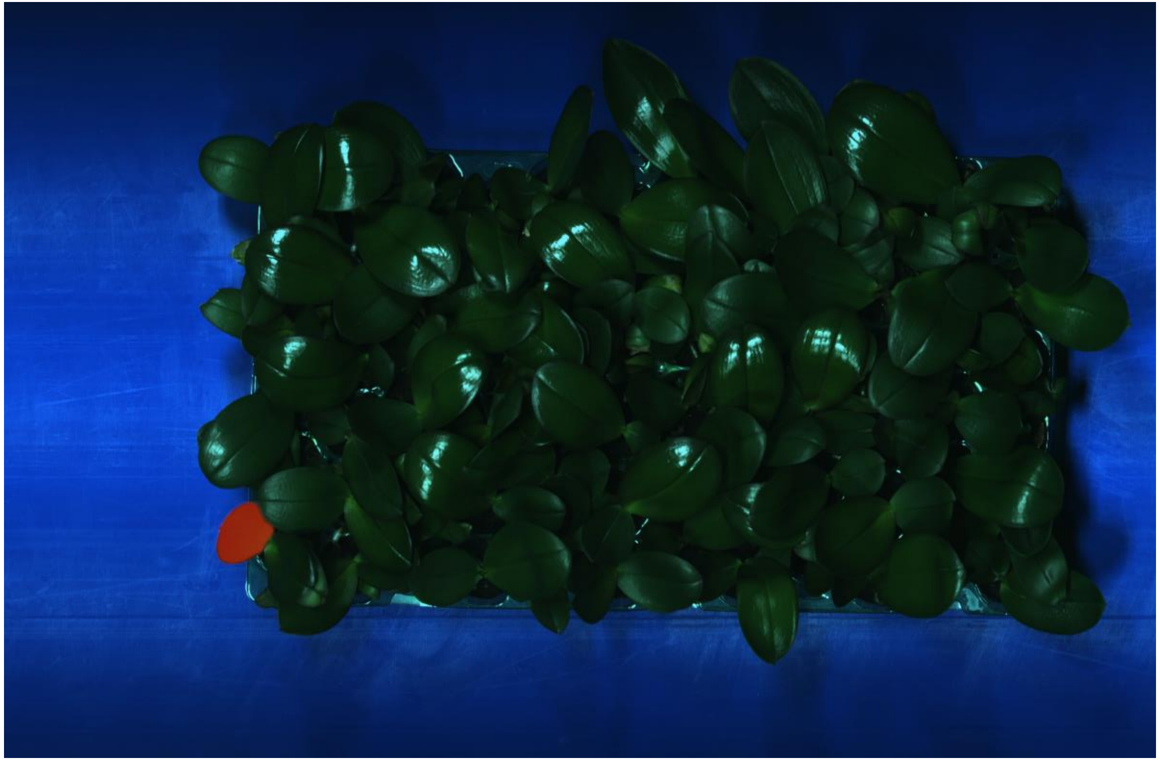
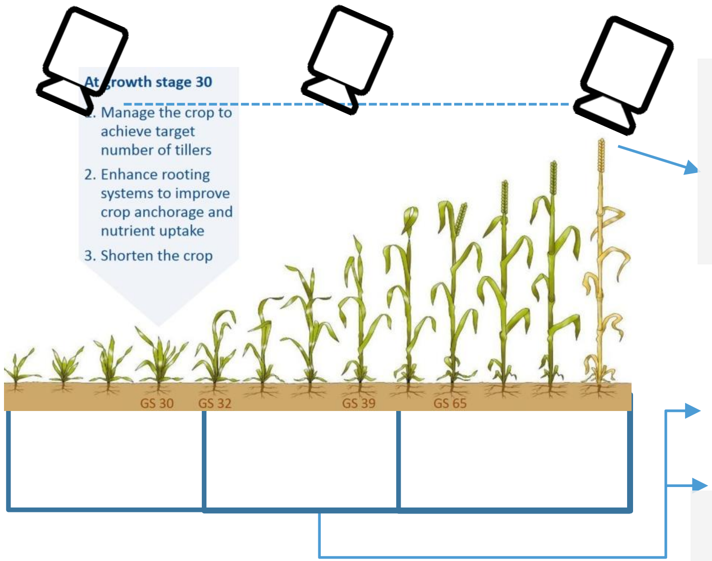
Plant phenotyping

- How many plants do you see?
- How many leaves do you see?
- Where exactly is each leaf?



Temporal analysis

What shall we model?



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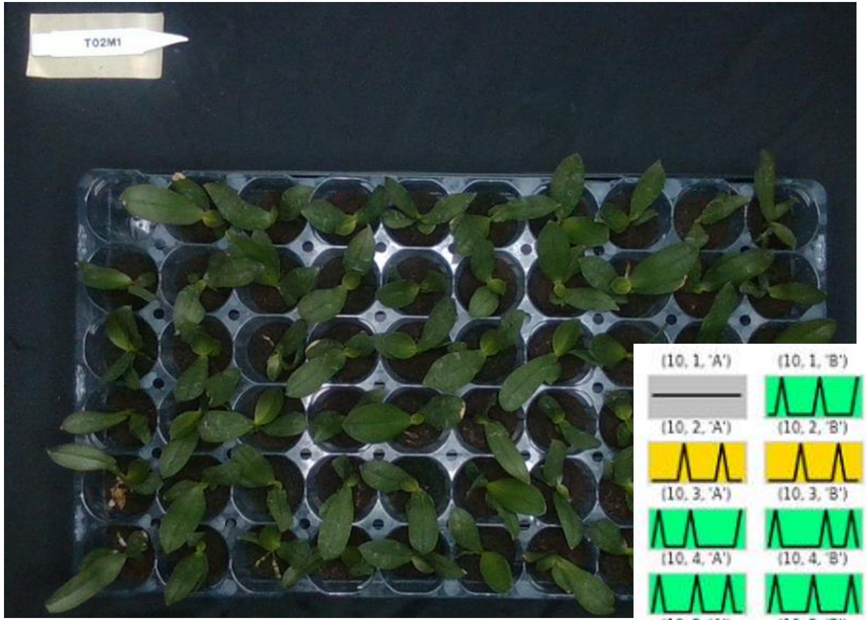
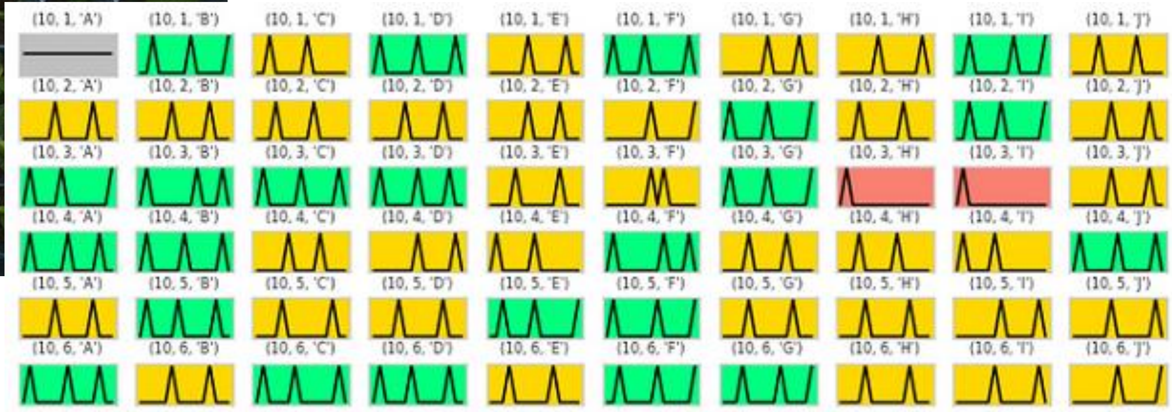
Detecting new leaves under occlusion

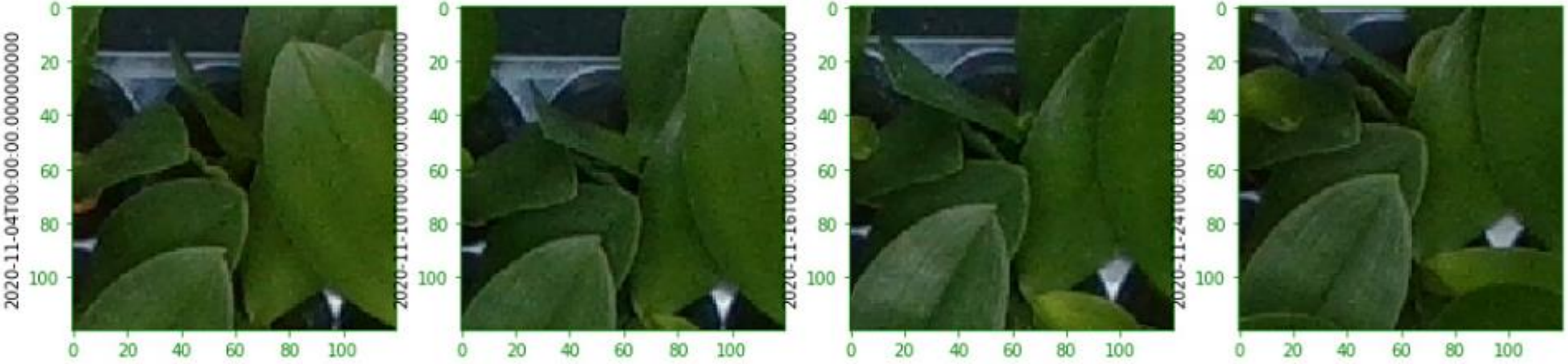
Floricultura and Anthura





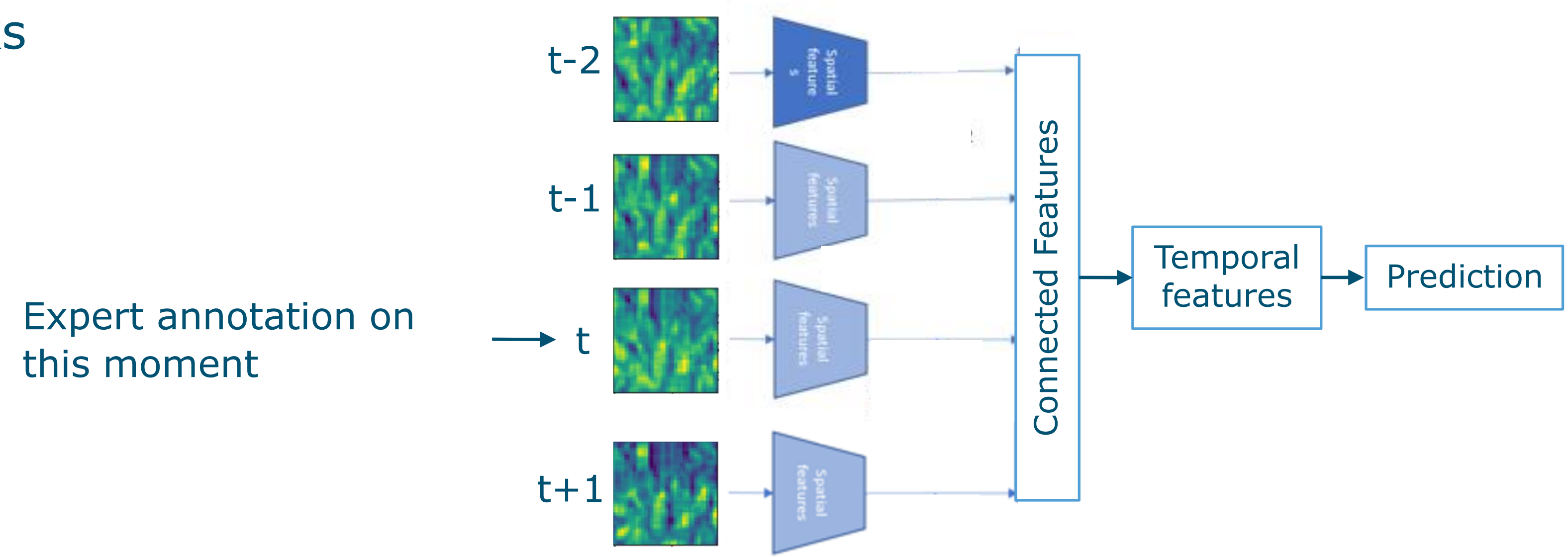
Where is the new leaf?

```
14
(2, 1, 'F')
New leaf ground truth:  [1]
New leaf prediction:  [1]
```



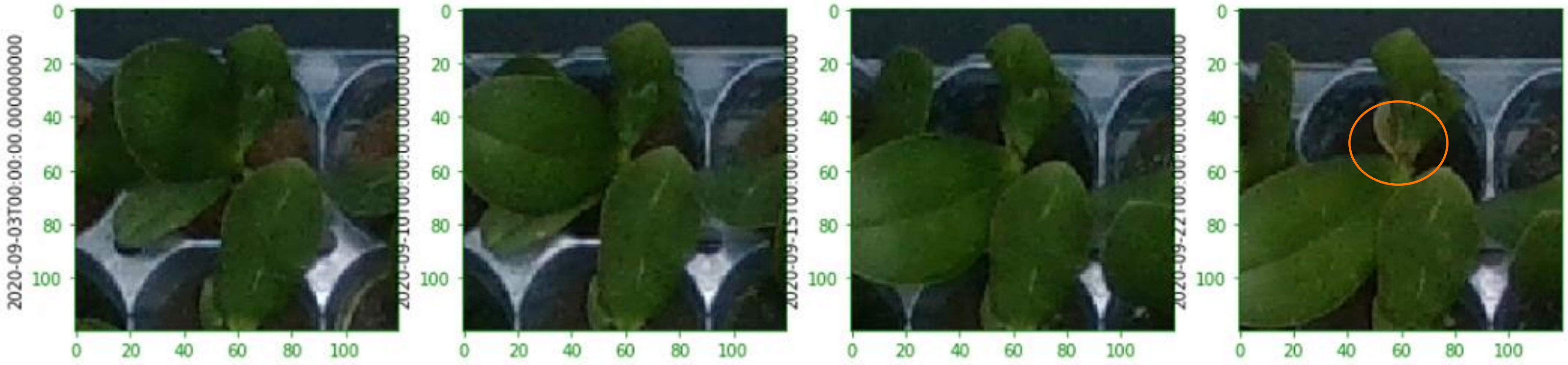
Network architecture (Prediction a week later)

- Accounts for history of 4 weeks



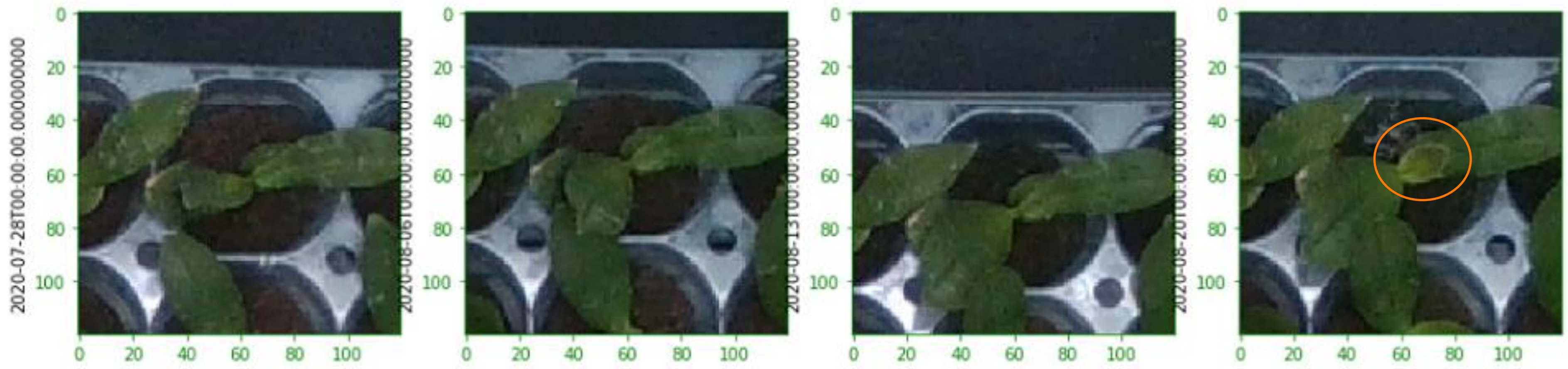
Example 2: Successful predictions

```
5
(17, 1, 'D')
New leaf ground truth:  [1]
New leaf prediction:  [1]
```



Example 3: Successful prediction

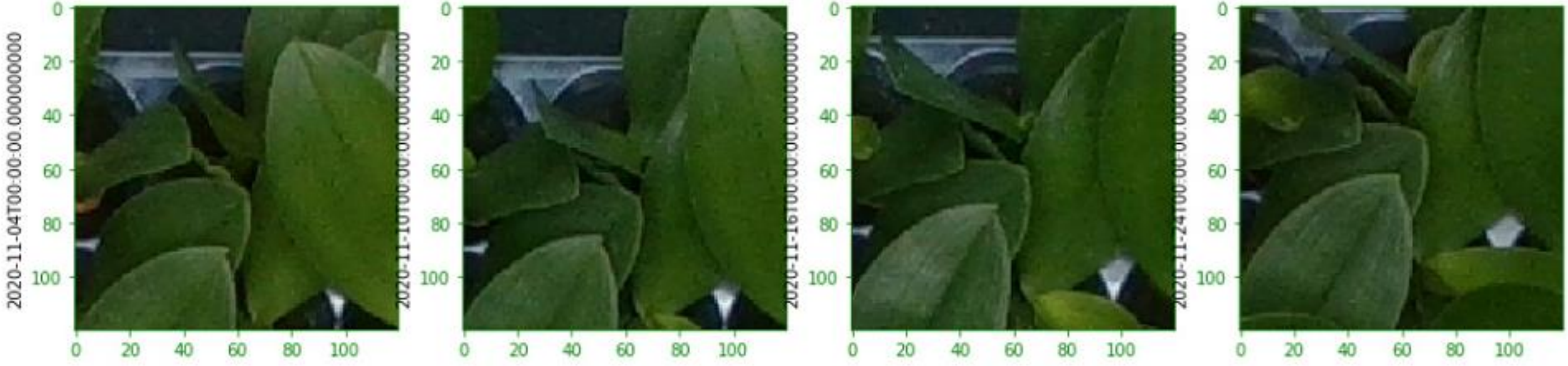
```
(2, 1, 'F')
New leaf ground truth:  [1]
New leaf prediction:  [1]
```



Example 4: Correct prediction

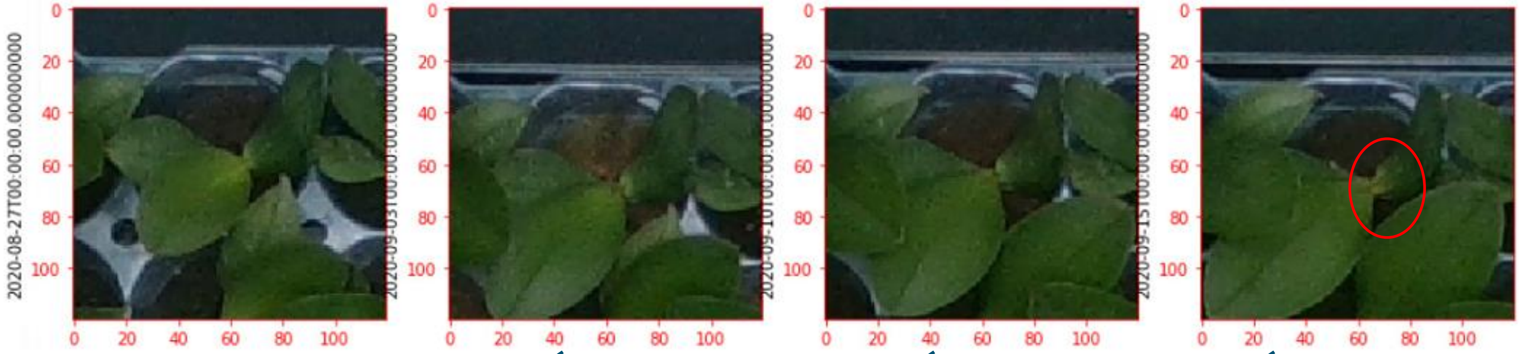
Where is the new leaf?
- Hard to intuitively understand the model result
- Likely the model captured some temporal trend

```
14
(2, 1, 'F')
New leaf ground truth:  [1]
New leaf prediction:  [1]
```

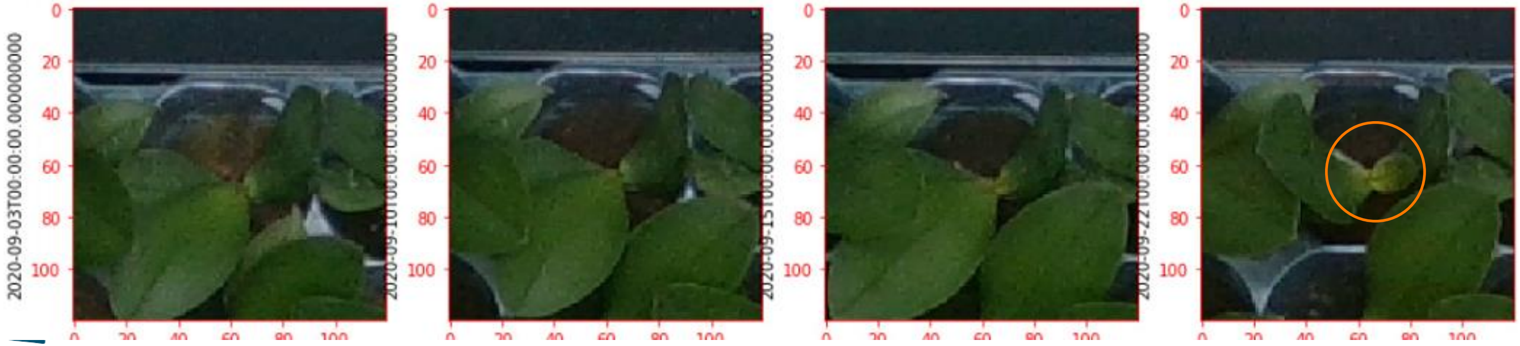


Example 1 cont.
Correct prediction one week later

```
4
(2, 1, 'D')
New leaf ground truth:  [1]
New leaf prediction:   [0]
```

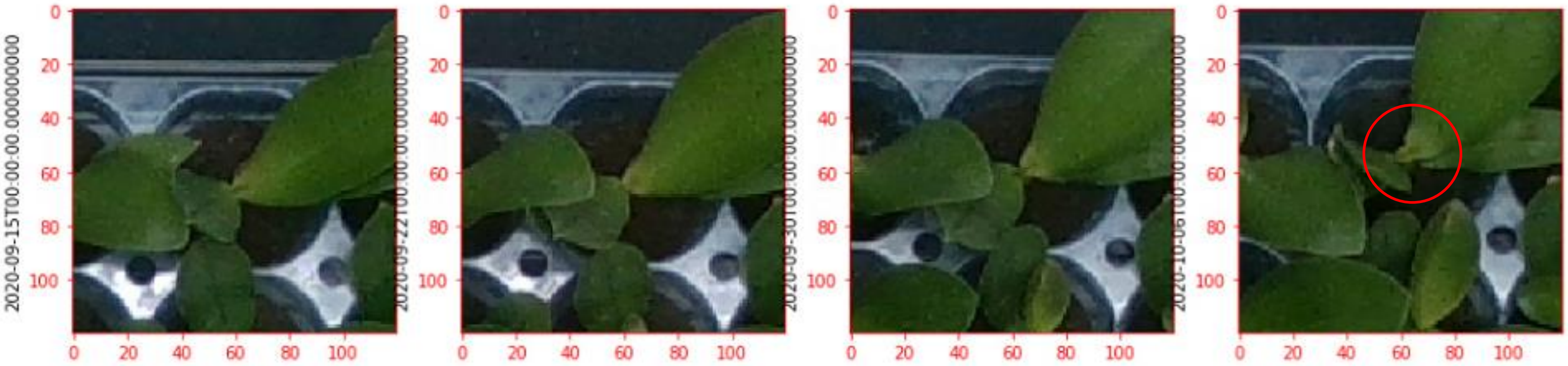



```
5
(2, 1, 'D')
New leaf ground truth:  [0]
New leaf prediction:   [1]
```

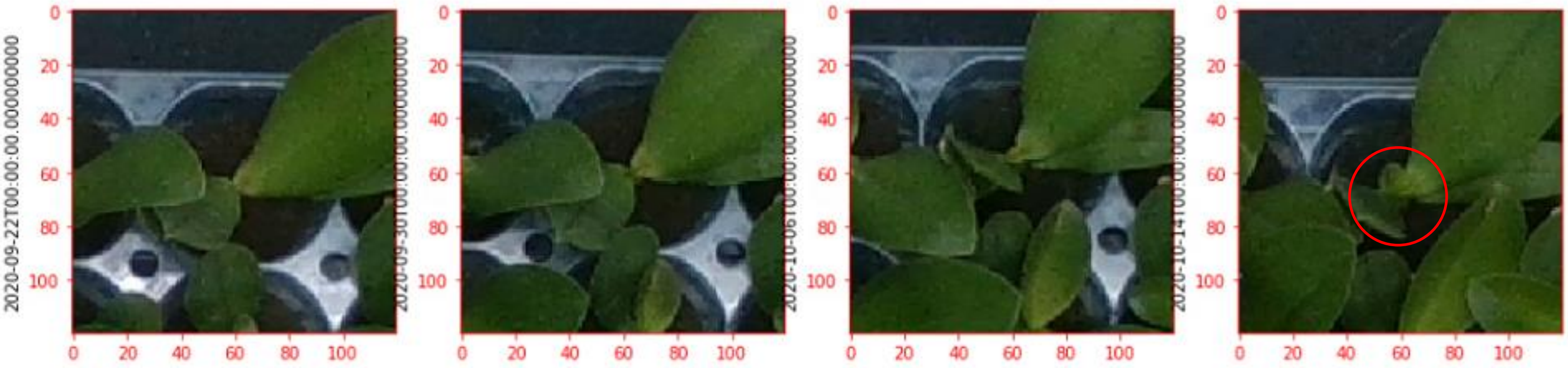


Example 2: Correct prediction one week earlier

```
7
(2, 1, 'F')
New leaf ground truth:  [0]
New leaf prediction:  [1]
```



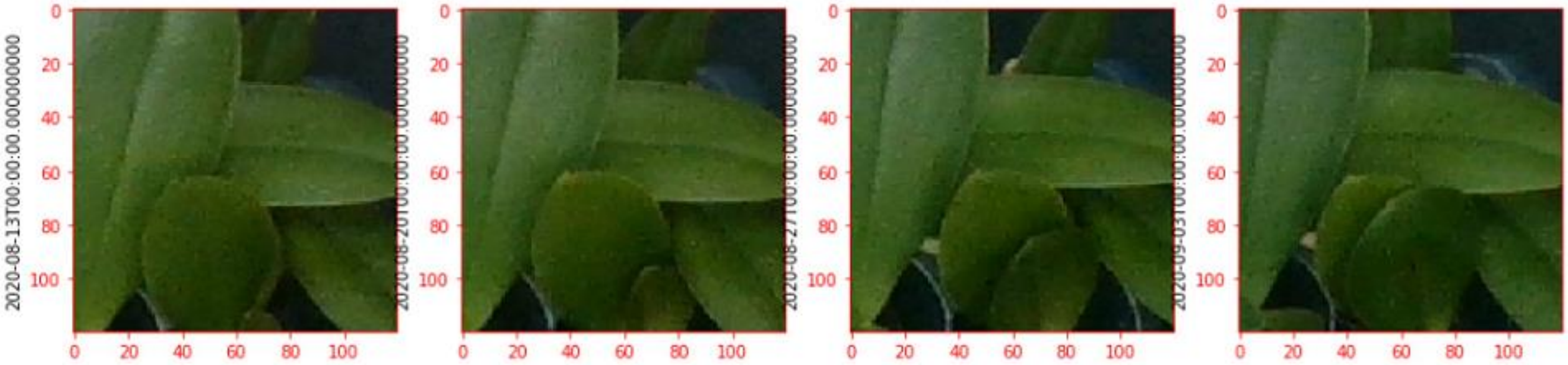

```
8
(2, 1, 'F')
New leaf ground truth:  [1]
New leaf prediction:  [0]
```



Example 5: Failed prediction

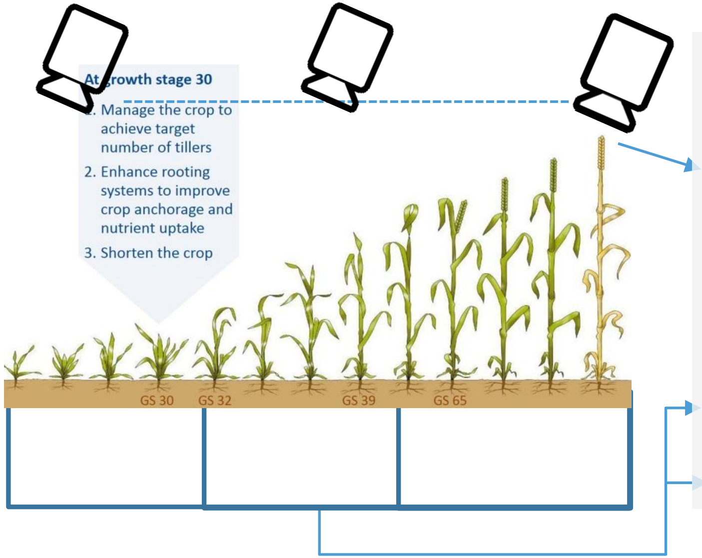
- Plant is occluded from neighbouring plant leaves for 4 weeks

```
2
(28, 1, 'J')
New leaf ground truth:  [0]
New leaf prediction:  [1]
```



Explainable AI

What shall we model?



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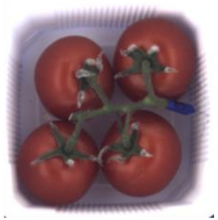
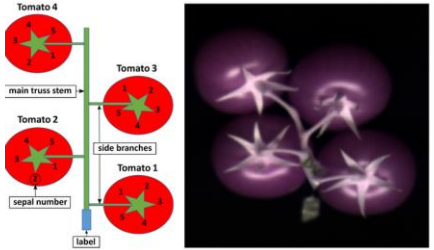
Explainable AI: Predicting sensitivity of tomato sepals to future fungal infections

Prominent growers/DOOR partner



Day 1

Day 5



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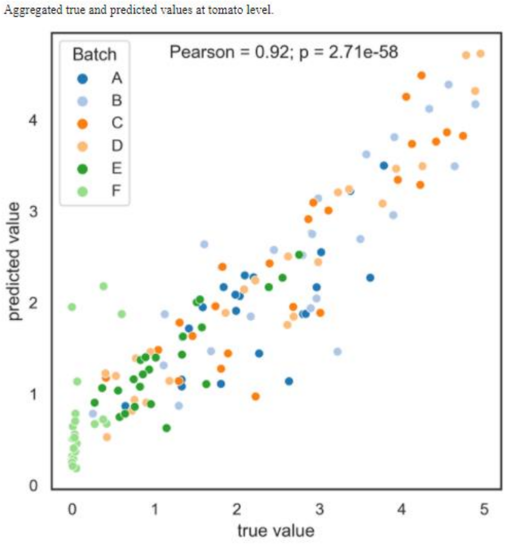

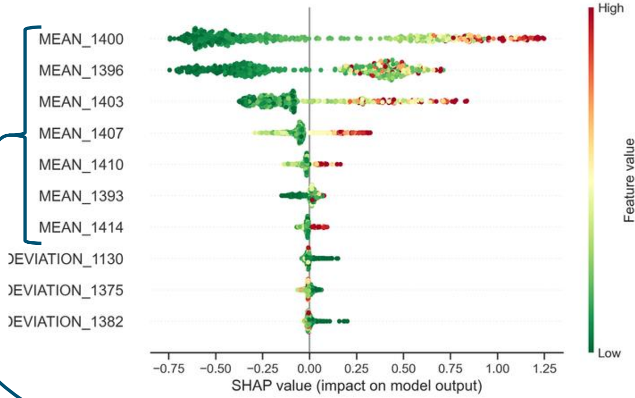

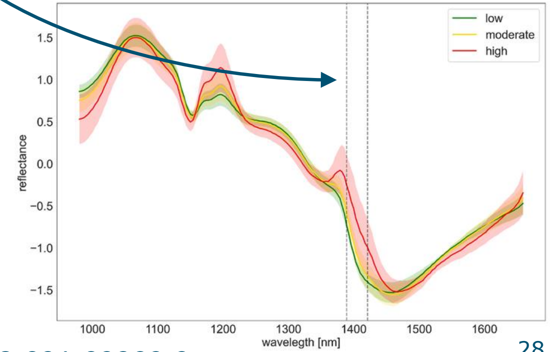

https://www.nature.com/articles/s41598-021-02302-2

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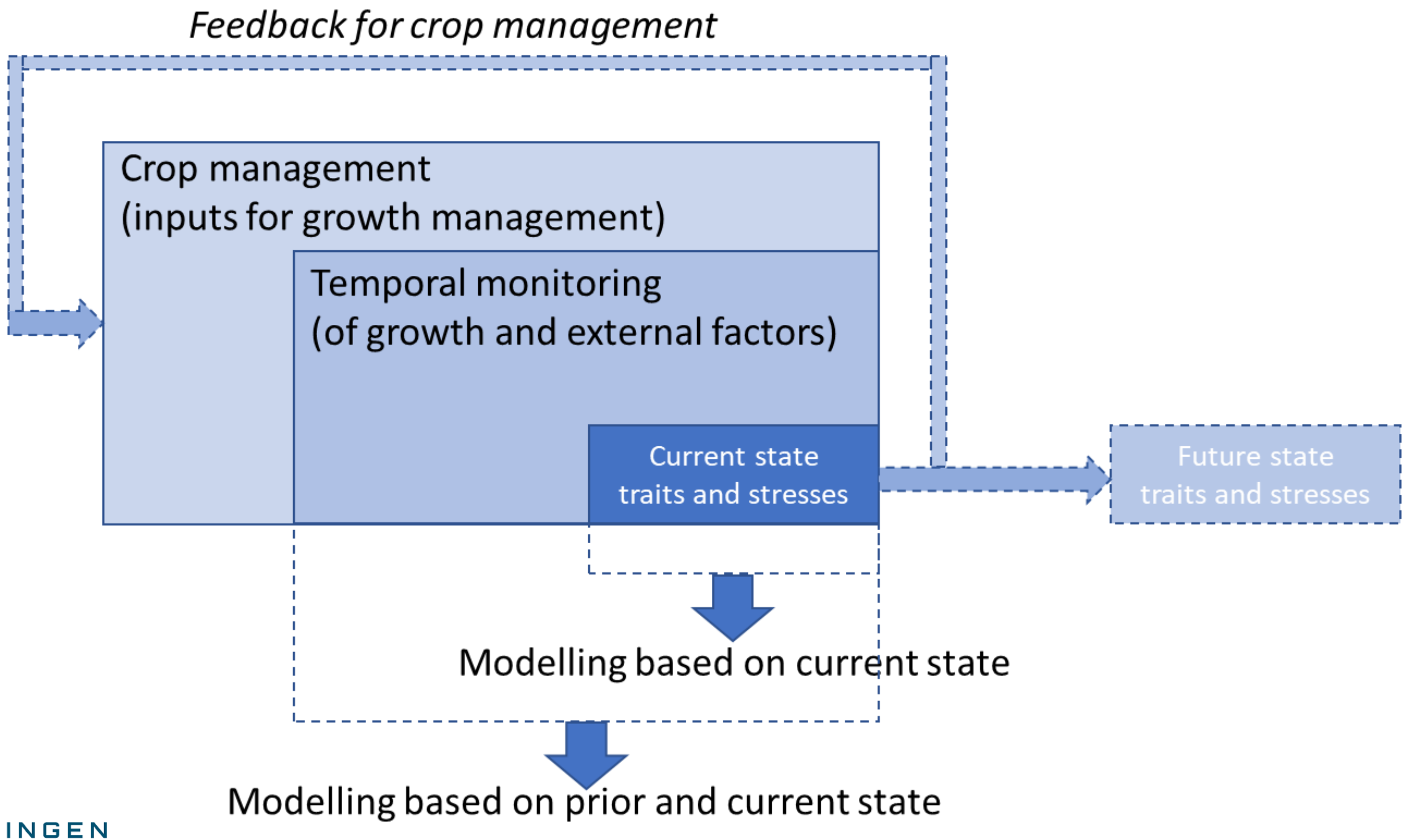
Major challenges of the day

- Be aware of the bias in our data
  - Making decisions based on biased data (data is not representative of the problem)
- Interpretation of models
  - Life used to be simple and explainable with models with less parameters
- Responsibility: Who is to blame when things go wrong?
- Combining existing “knowledge-driven” models with data-driven models

Summary

- This session was to encourage you to see the potential of advances in computer vision and machine learning
- We looked at some examples of deep learning in protected cultivation
- These technologies are disrupting WUR domains, and solving real world business and social problems
- Let's not throw the caution out of the way – Be aware of pitfalls of the technology

Closed-loop protected cultivation



Acknowledgements

AgroFood Robotics team
www.wur.nl/agrofoodrobotics

And multiple WUR and external partners

PPS Exploitation of high-tech plant phenotyping tools for breeding companies and growers.

Partners: Floricultura and Anthura

PPS Humistatus, partners: Prominent growers/DOOR
EU Horizon project Antares, partner BioSense Institute, Serbia

How would you use these technologies and solve your challenges?

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E: aneesh.chauhan@wur.nl
W: https://tinyurl.com/wfbr-computer-vision-and-robot

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