AI-Autonomous Robots for Agriculture – Weeding with Laser

WeLASER Summer School

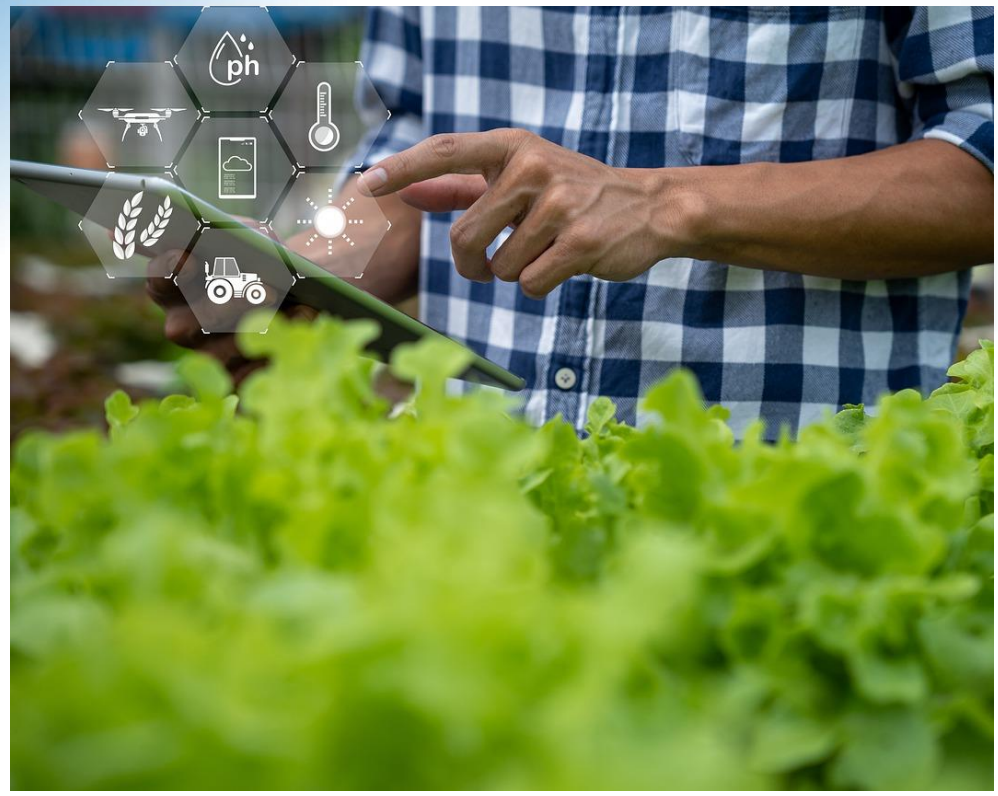

Bild von Chaiyan Anuwatmongkolchai auf Pixabay

AI algorithms for weeding with laser

M. Wollweber, H. Sandmann

11.7.2023

Funded by the Horizon 2020 programme of the European Union

CSIC Consejo Superior de Investigaciones Científicas · FUTONICS · LZH Laser Zentrum Hannover e.V. · University of Copenhagen · AGREENCULTURE Smart robots for smart farming · COAG · Alma Mater Studiorum Università di Bologna · IETU Instytut Ekologii Terenów Uprzemysłowionych · Ghent University · van den borne aardappelen

Applications of AI in Agriculture

Source: www.wipro.com/holmes/towards-future-farming-how-artificial-intelligence-is-transforming-the-agriculture-industry/

WeLASER – a use case scenario

- **WeLASER aims to merge current technologies to build and push close to the market a precision weeding system based on high power laser sources and autonomous vehicles**
- **main objective:**
  - ❑ of eliminating the use of herbicides and their health/environmental adverse effects
  - ❑ Simultaneously improving productivity and competitiveness

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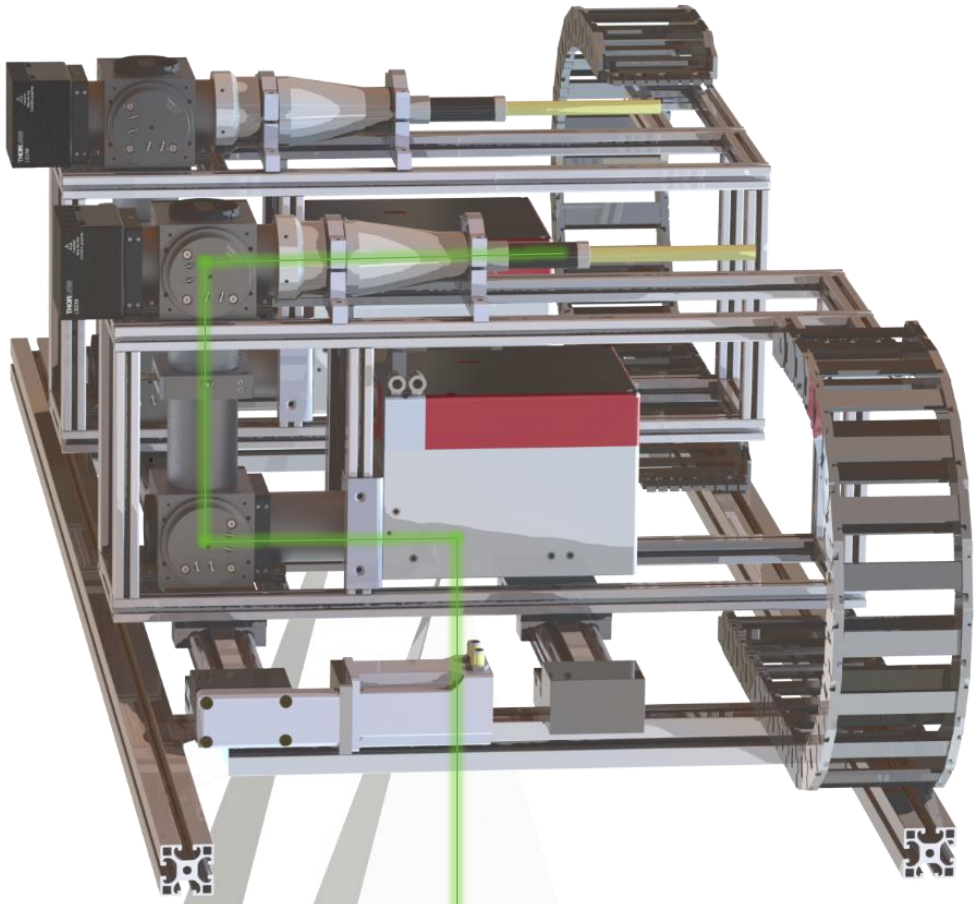
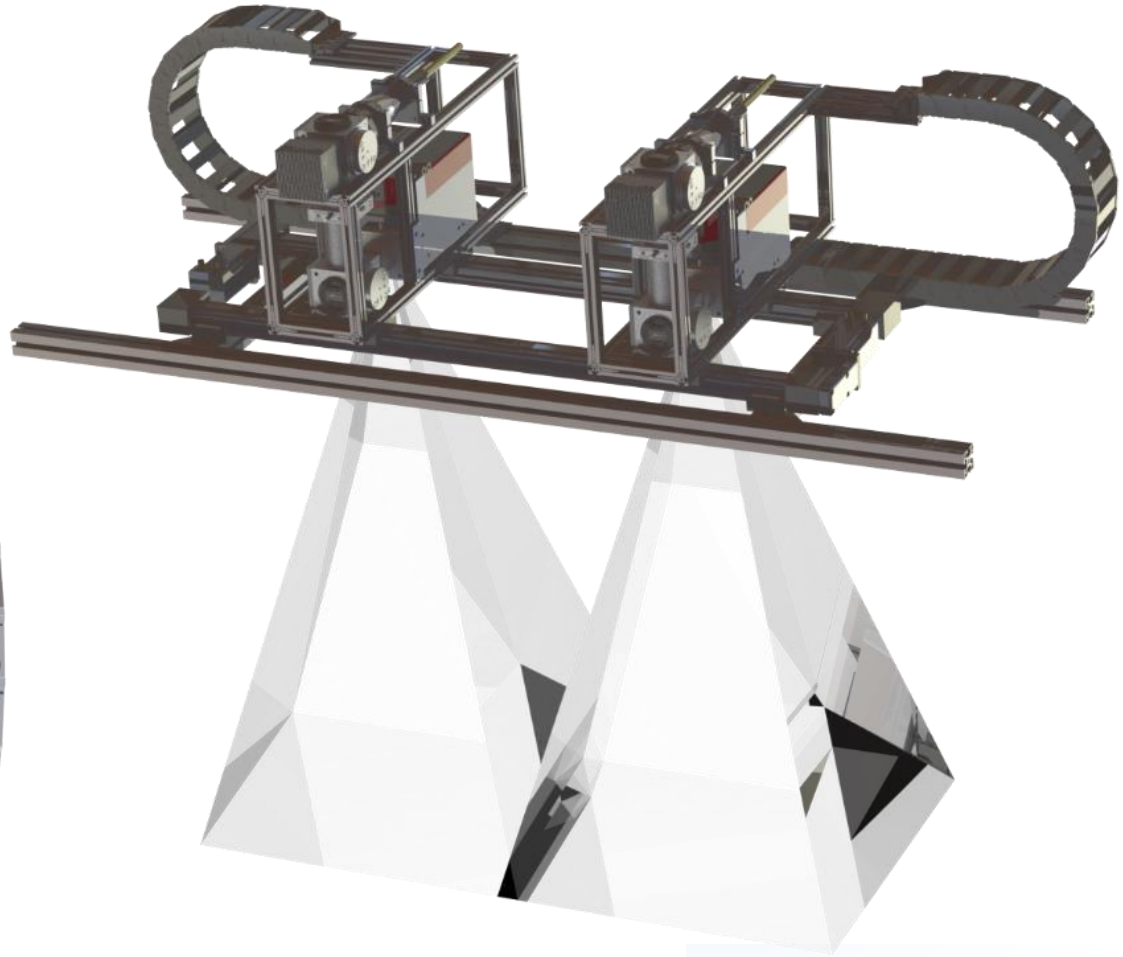
Laser-based Weeding Tool

- **Robot with Implement**
- **Weeding Scanner**





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WeLASER – System breakdown

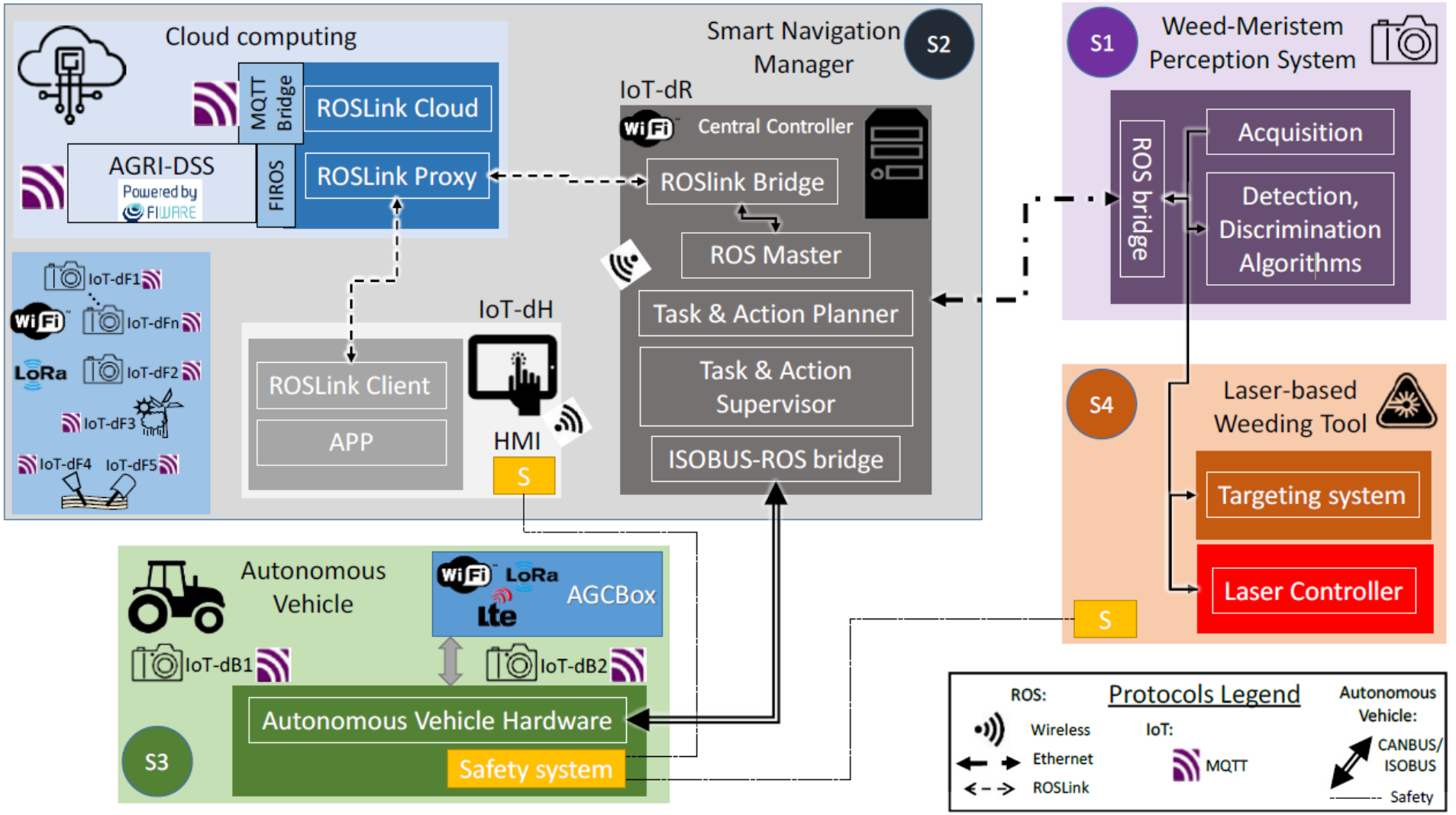


Fig. 2.13. WeLASER system architecture: communication interfaces and protocols

WeLASER – System breakdown

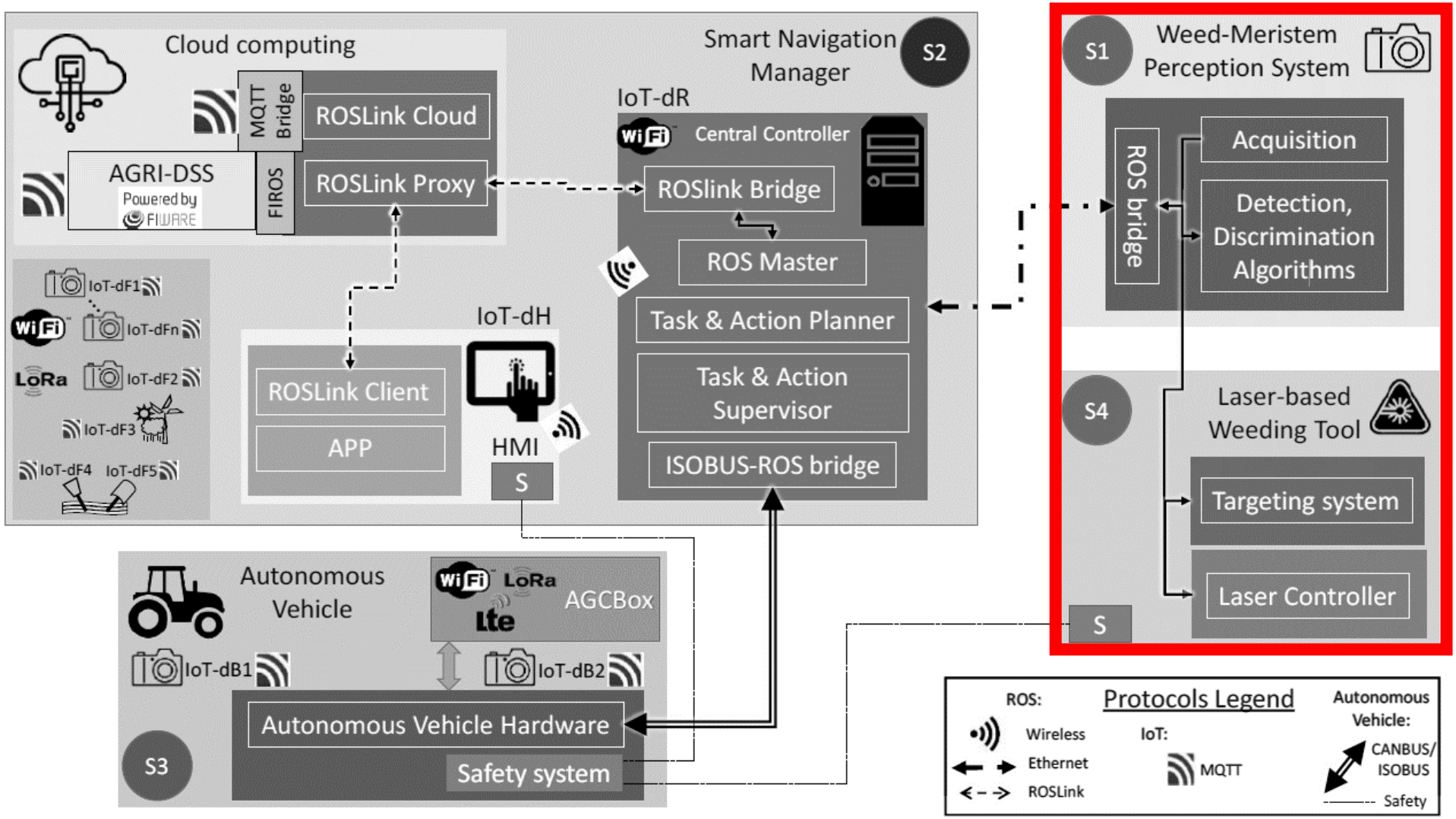
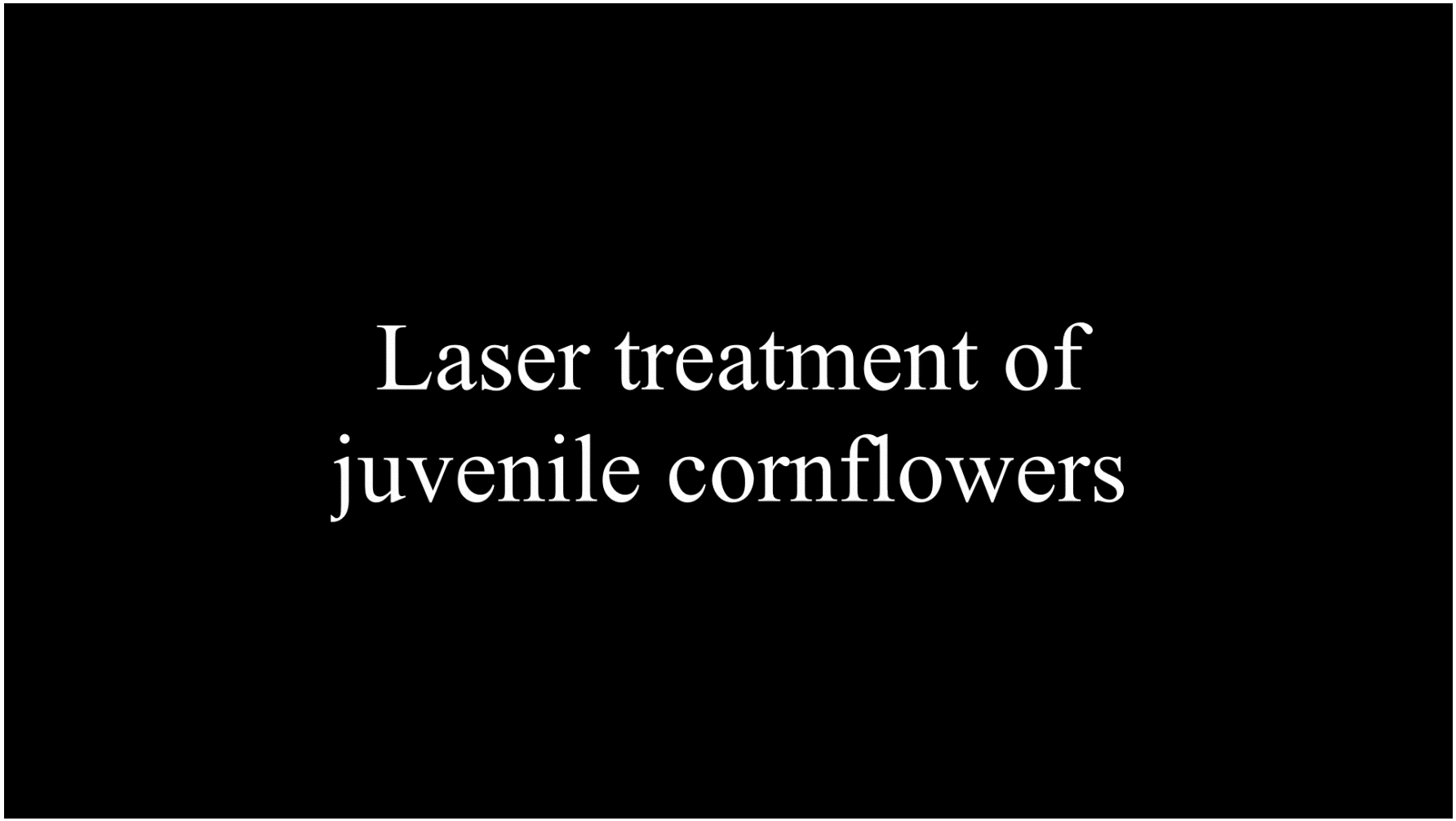


Fig. 2.13. WeLASER system architecture: communication interfaces and protocols

Laser treatment of plants – follow-up



NUBELA (2021)

Automatic control of laser weeding

- **Laser weeding process**
  - ❑ Plant recognition
  - ❑ Classification as „crop“ vs. „weed“
  - ❑ Find impact point (apical meristem, stem)
  - ❑ Target position to laser targeting system
  - ❑ Track target
  - ❑ Apply (lethal) dose
  - ❑ Go to next target

Automatic control of laser weeding

- **Laser weeding process**
  - ❑ Plant recognition
  - ❑ Identify weeds to treat
  - ❑ Find impact point (apical meristem, stem)
  - ❑ Target position to laser targeting system
  - ❑ Track target
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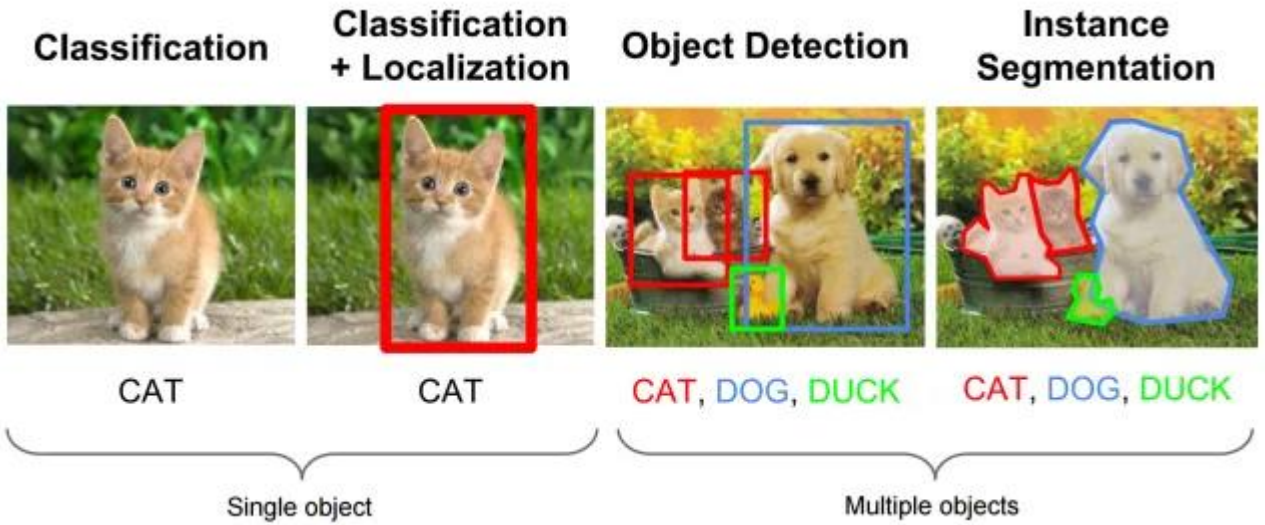
- **AI job?**
  - ➢ Object detection
  - ➢ Classification
  - ➢ Object detection/classification
  - ➢ -
  - ➢ (Object tracking)
  - ➢ -
  - ➢ -

Object detection in AI



- **Object Localization**

  A bounding box or enclosing region is determined in the tightest possible manner in order to locate the exact position of the object in the image.

- **Image Classification**

  The localized object is fed to a classifier which labels the object.

- **Semantic Segmentation**

  Each pixel in the given image is linked to a particular class label. These segments are then used to find the interactions / relations between various objects.

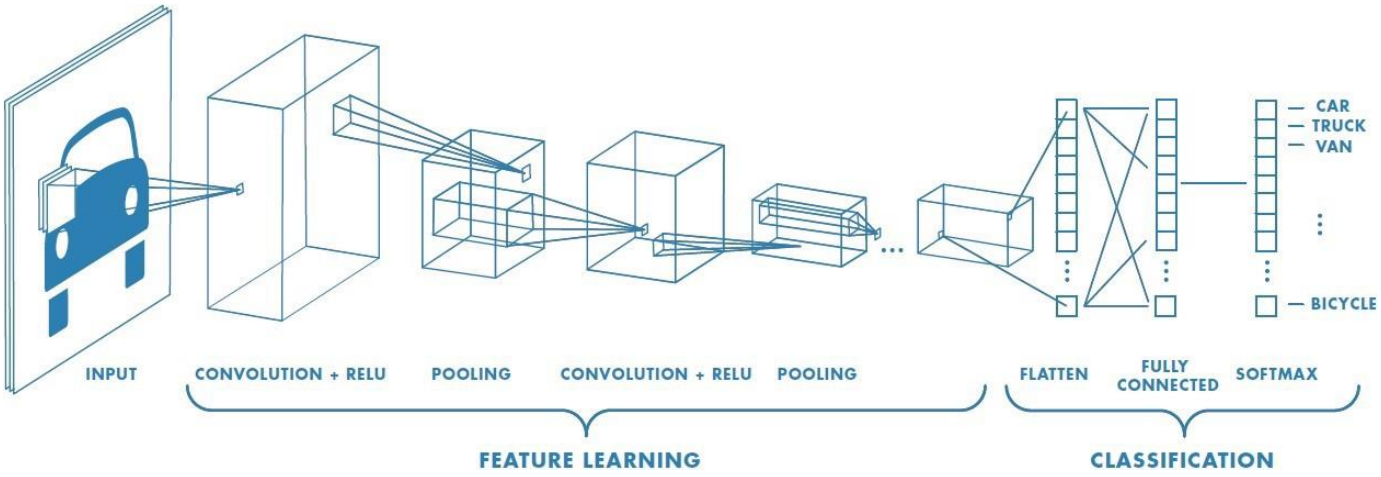
- **Instance Segmentation**

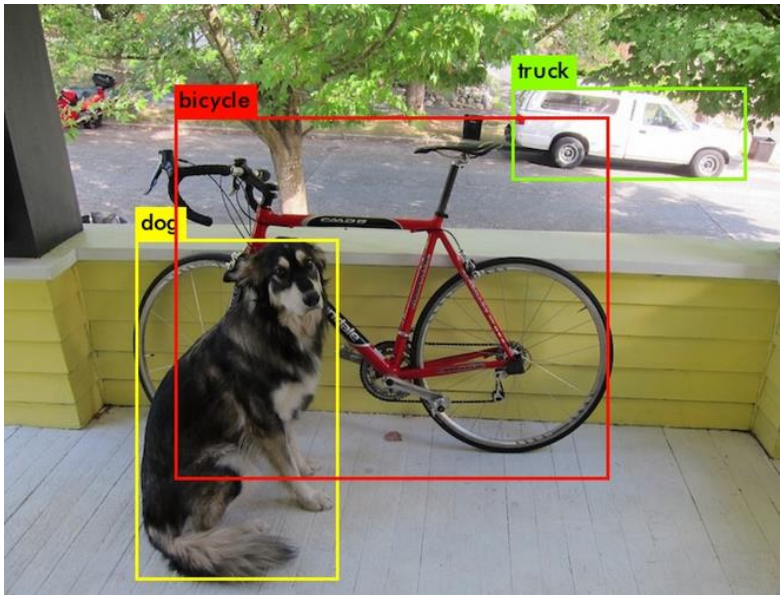
  Associate a class label to each pixel. Similar to semantic segmentation, except that it treats multiple objects of the same class as individual objects / separate entities.

Adapted from https://medium.com/swlh/object-detection-and-instance-segmentation-a-detailed-overview-94ca109274f2

WeLASER Perception System - Principle

- **Perception System**
  - ❑ Plant recognition with artificial intelligence and neural networks





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Bottleneck of agricultural AI application

- **Availability of high-quality data for training**
- **Agricultural image datasets require efforts and costs for acquisition and pre-processing**

Perception System - Principle

- **Perception System**
  - ❑ Plant recognition with artificial intelligence and neural networks
  - ❑ In addition to existing plant databases, new specific training data is acquired

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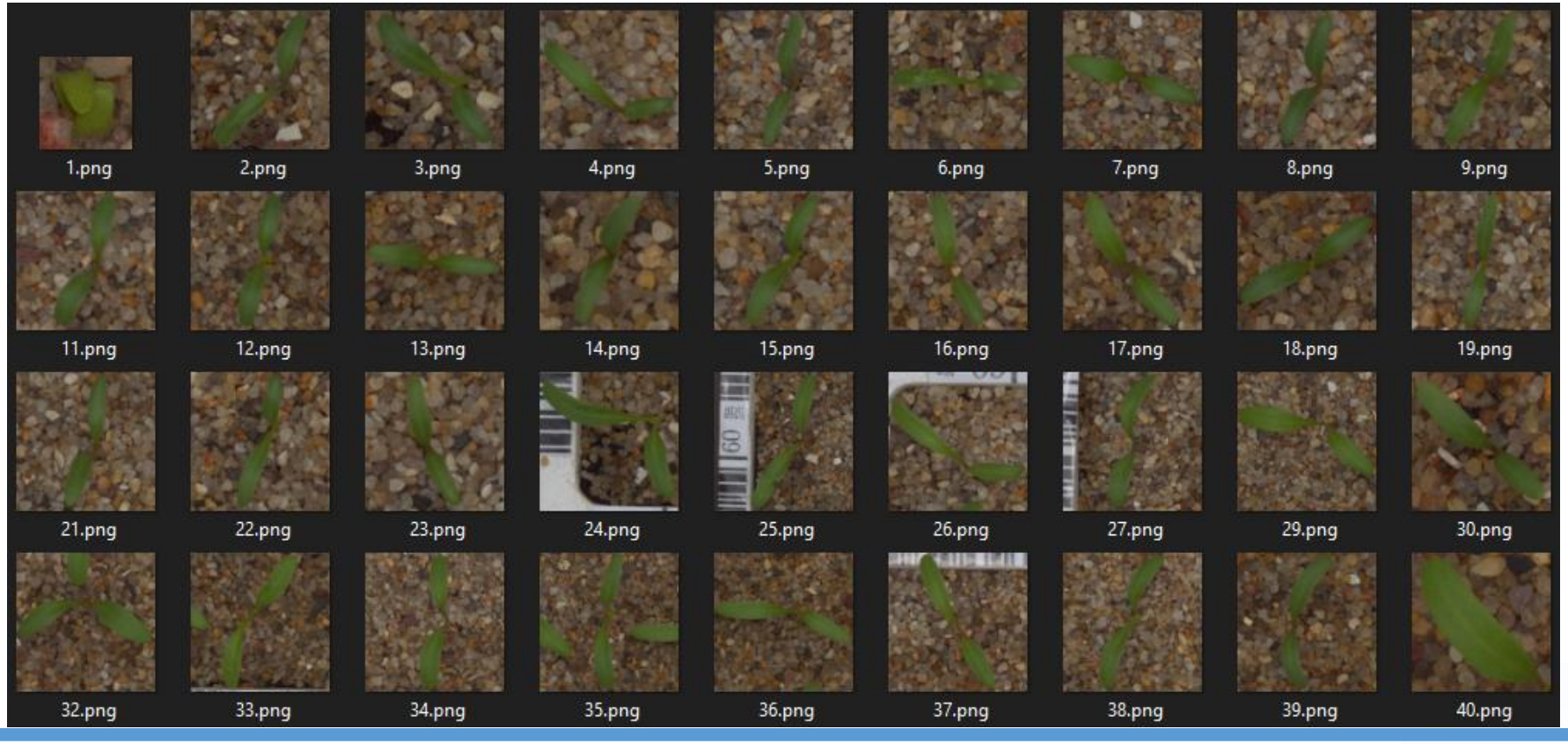

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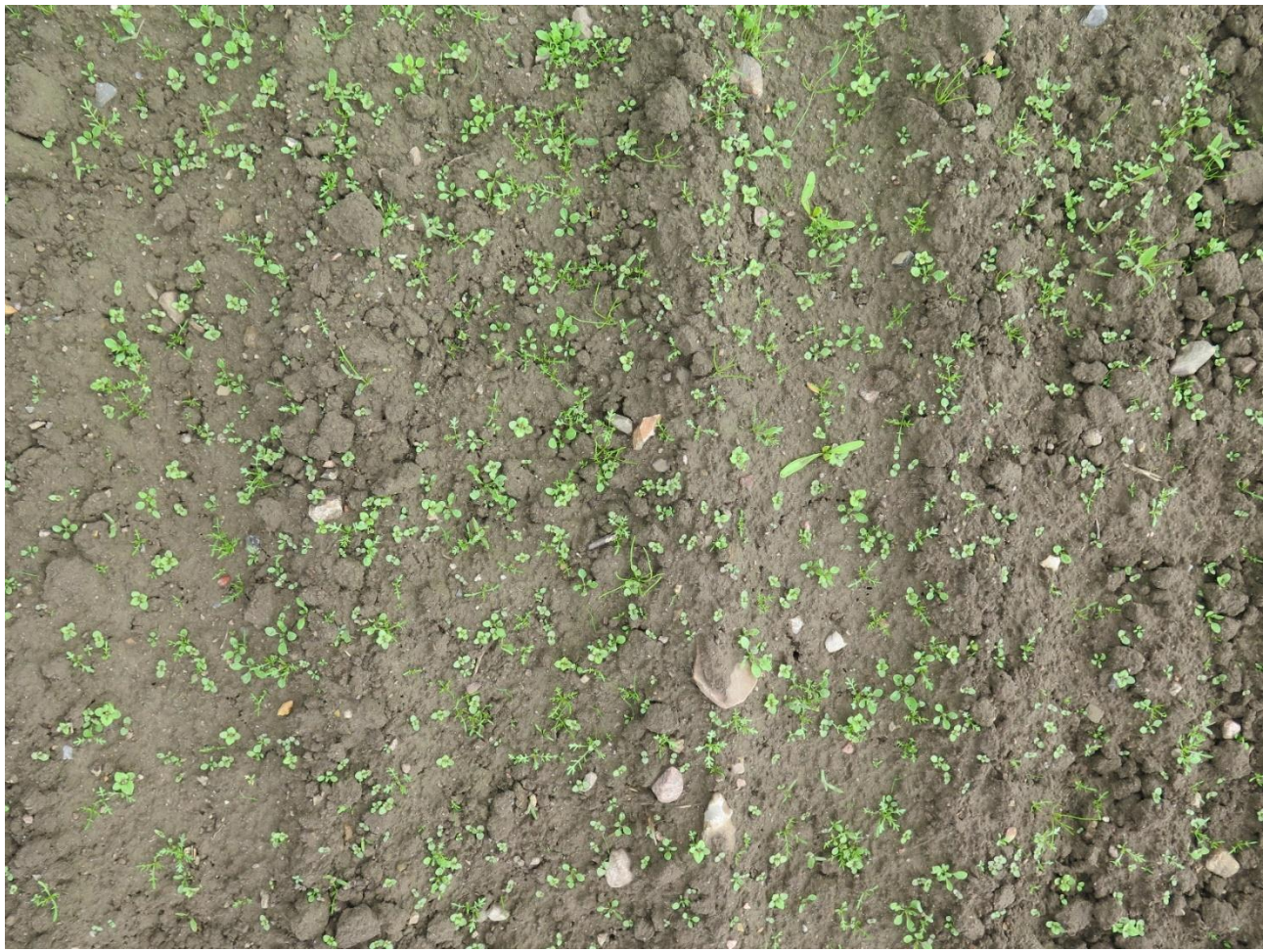
Perception System – Labelling Procedure

- **Own Dataset with labelled images has to be acquired**
- **How to get large labelled images?**



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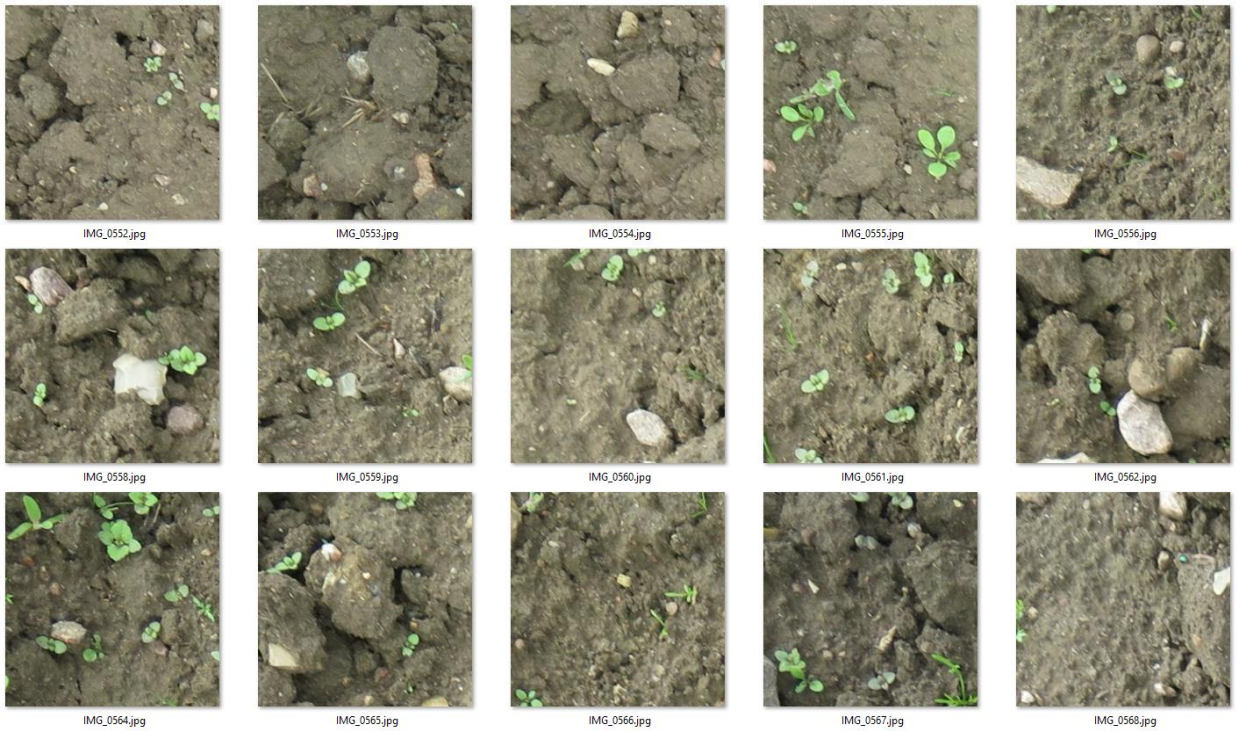

Perception System – Labelling Procedure

- **Own Dataset with labelled images has to be acquired**
- **How to get large labelled images?**
  - ❑ Split large unlabelled images
  - ❑ Label 416x416 px images

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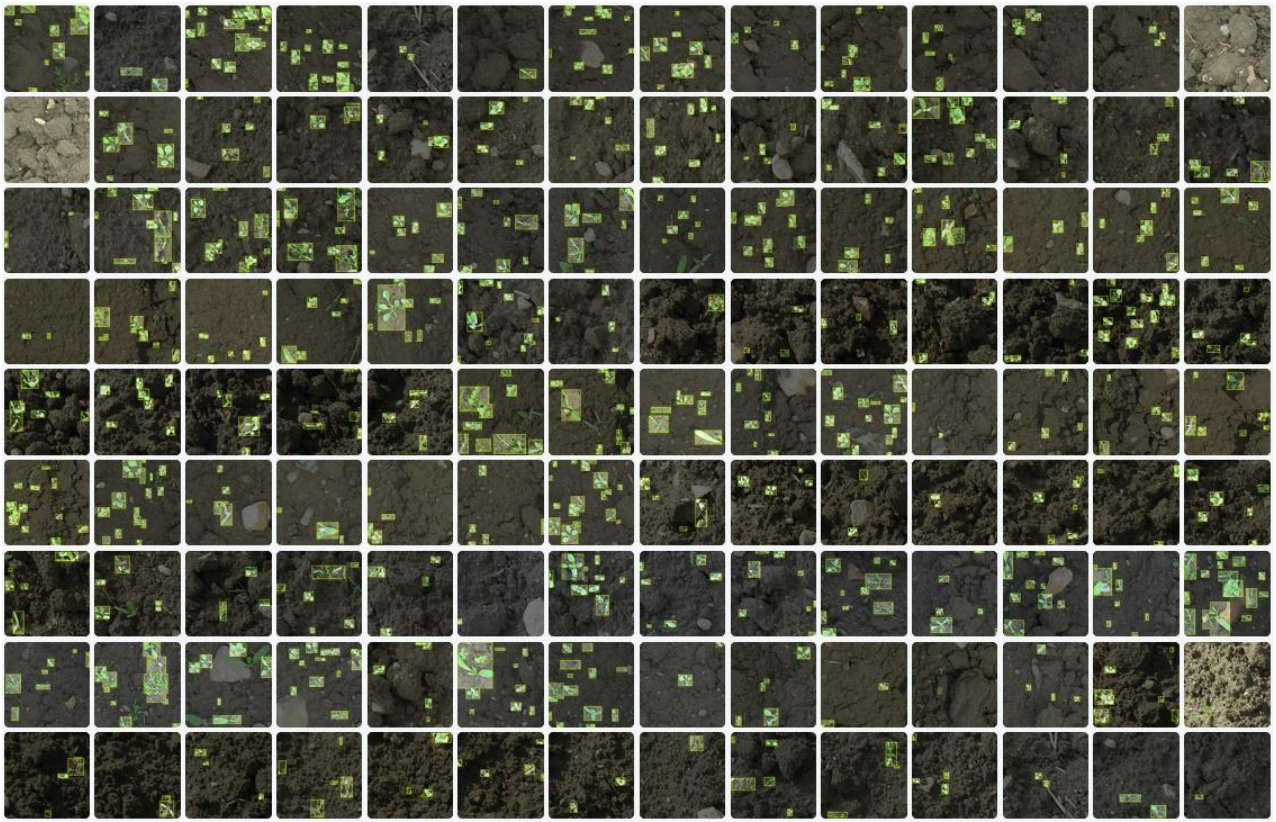

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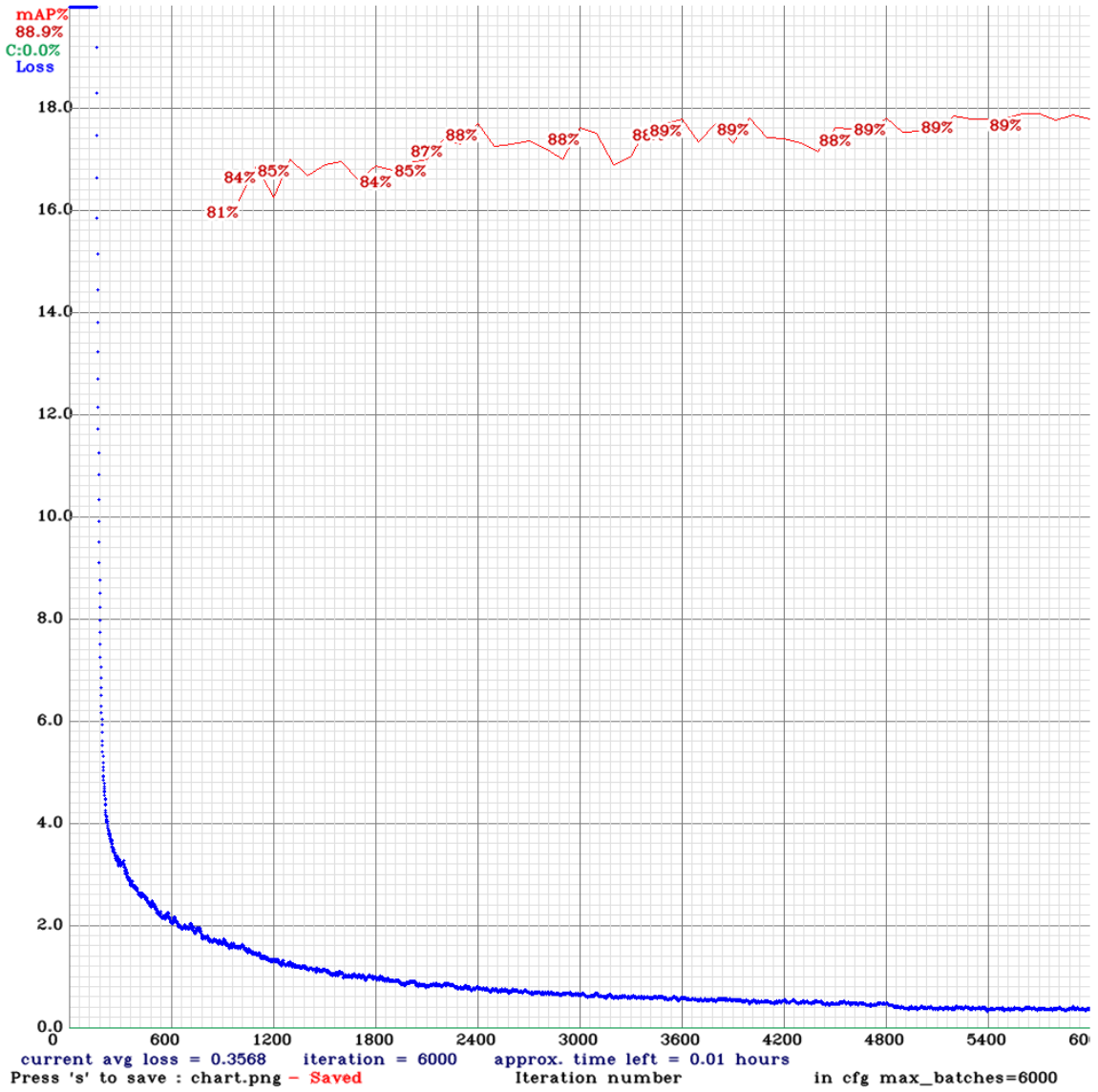
  - ❑ 3x Data Augmentation
  - ❑ Train full-scale 416 model



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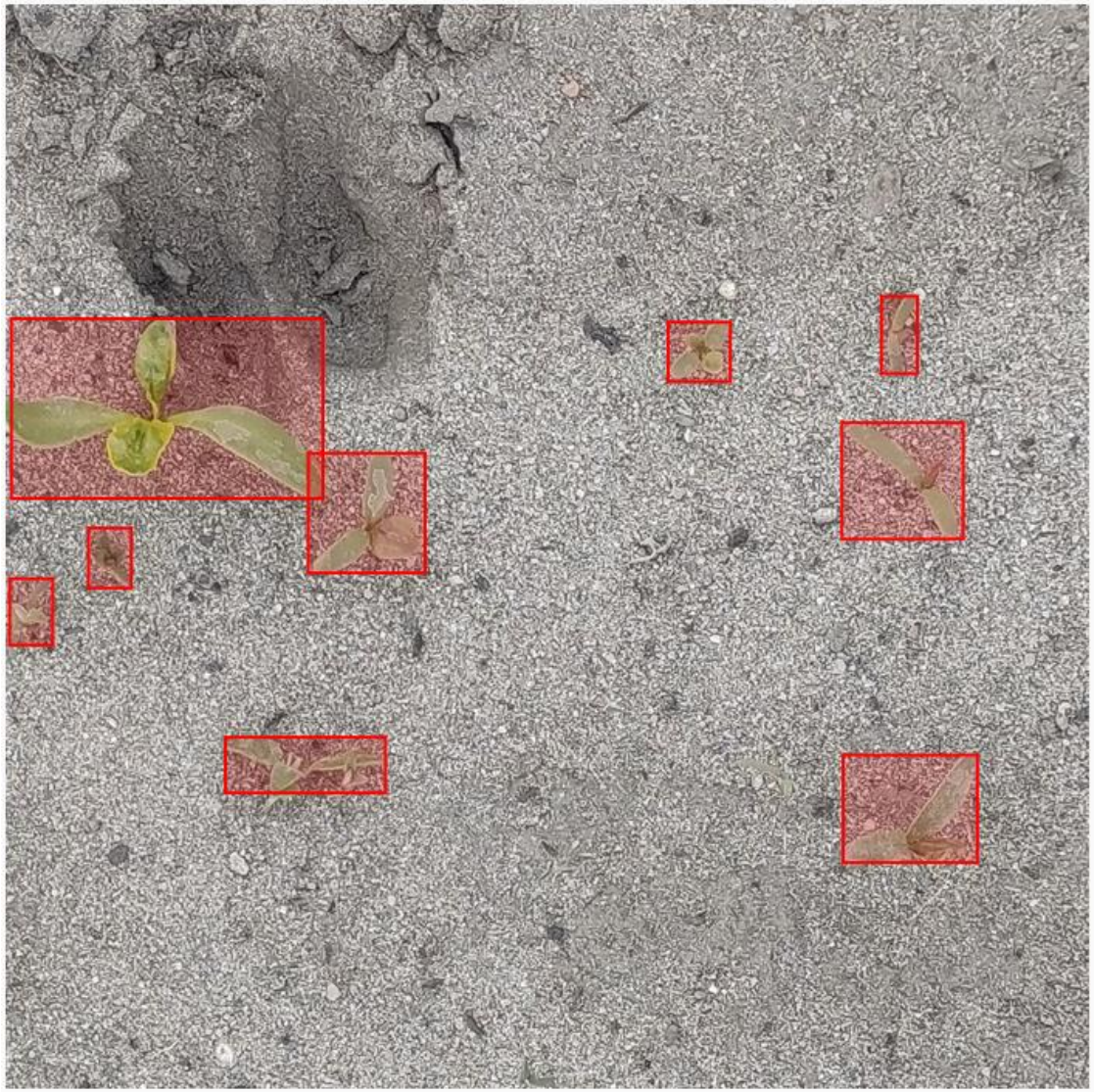
  - ❑ Apply on 1024x1024 images from German dataset
  - ❑ Improve labels by hand



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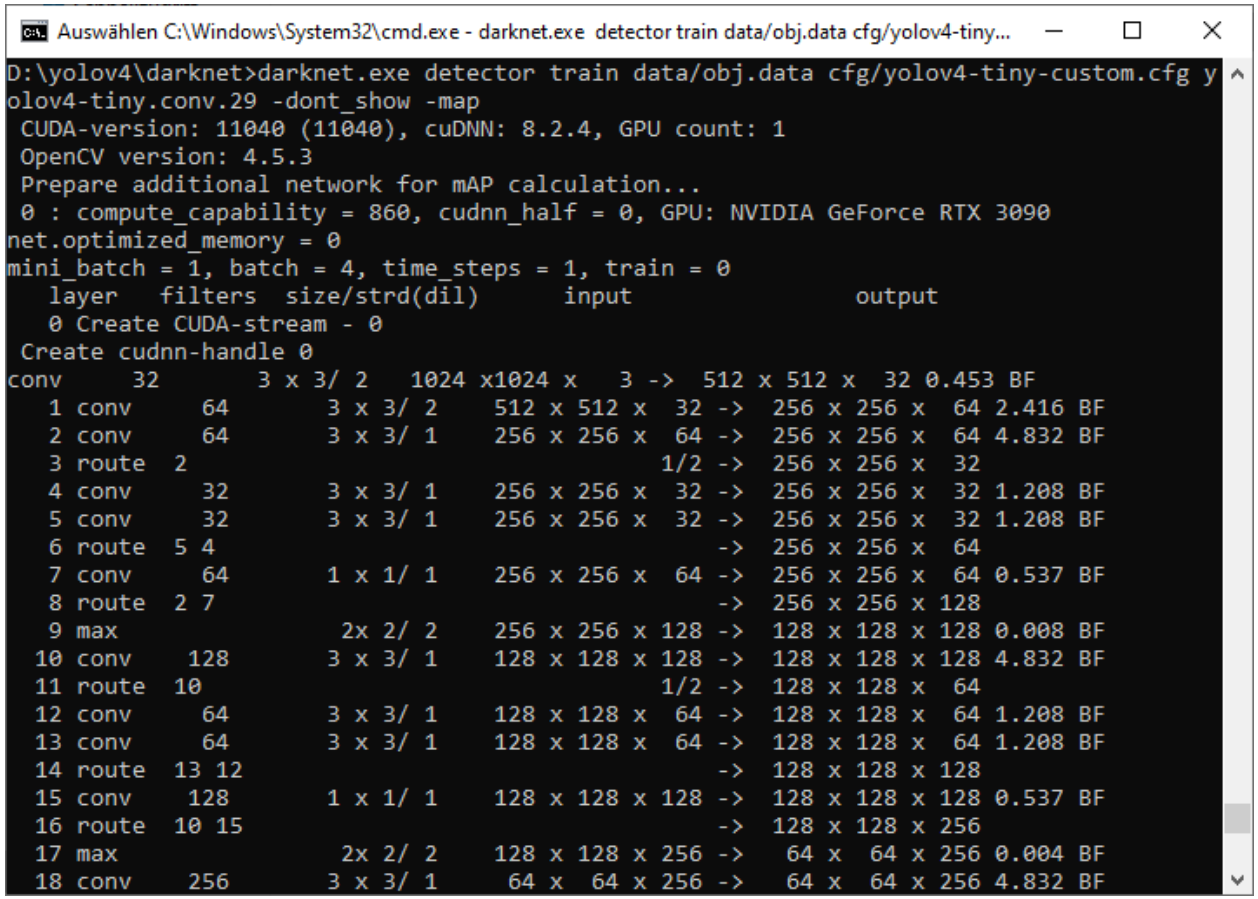
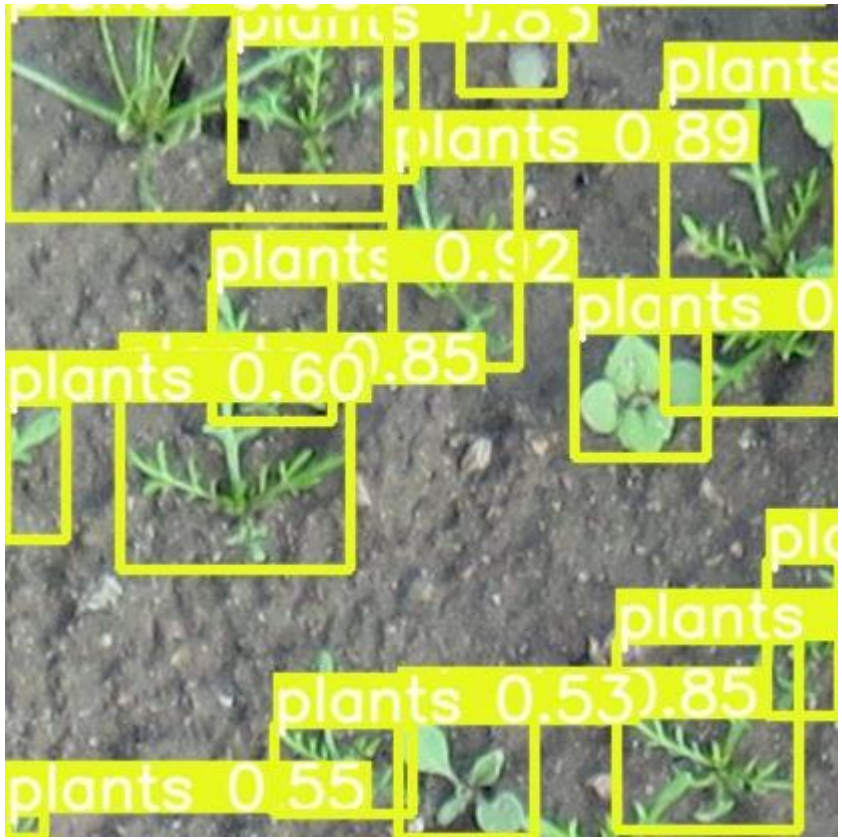
  - ❑ Improve labels by hand
  - ❑ Retrain with new data



Perception System – Detection Evaluation

- **Test on unknown images from cropped DK dataset**



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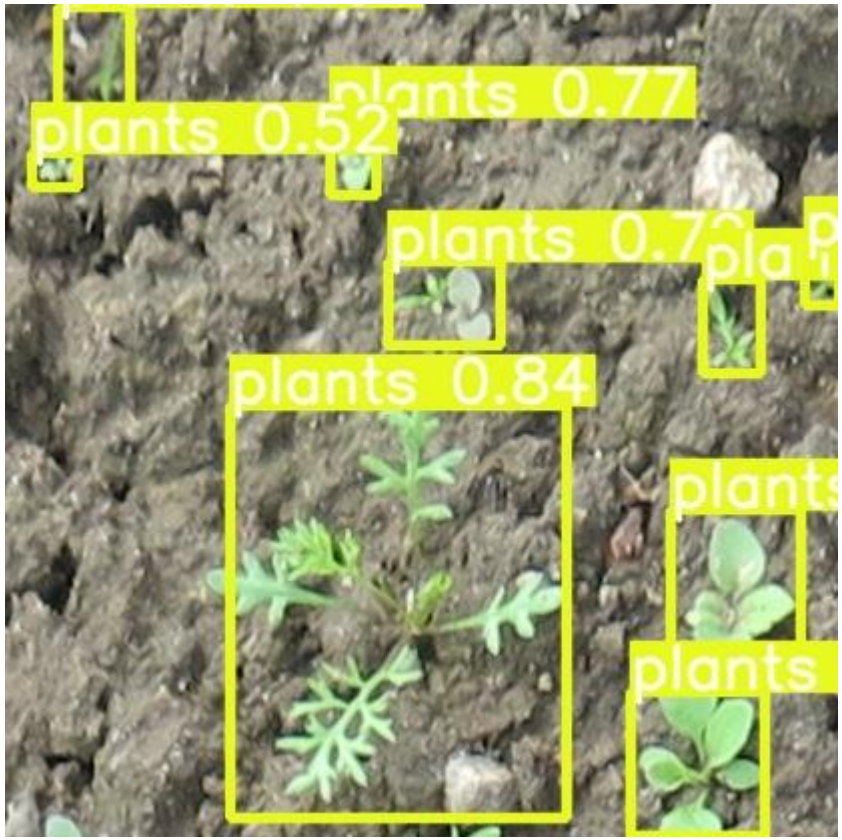

Perception System – Detection Evaluation

- **Test on unknown images from cropped DK dataset**

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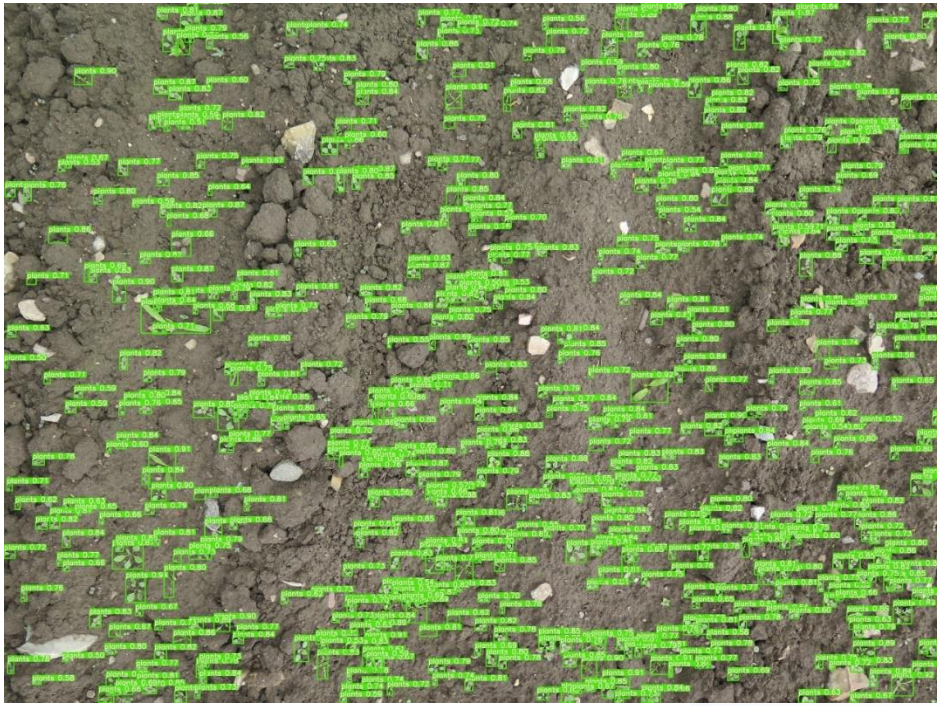
Perception System – Detection Evaluation

- Test on unknown images from cropped DK dataset
- Test on unknown images from full DK dataset



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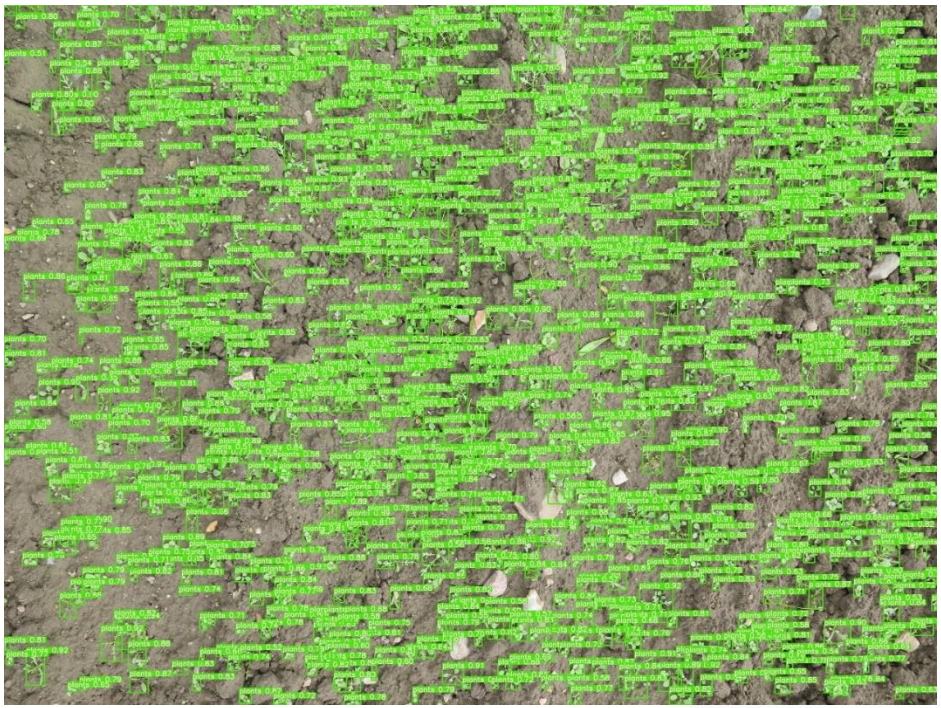
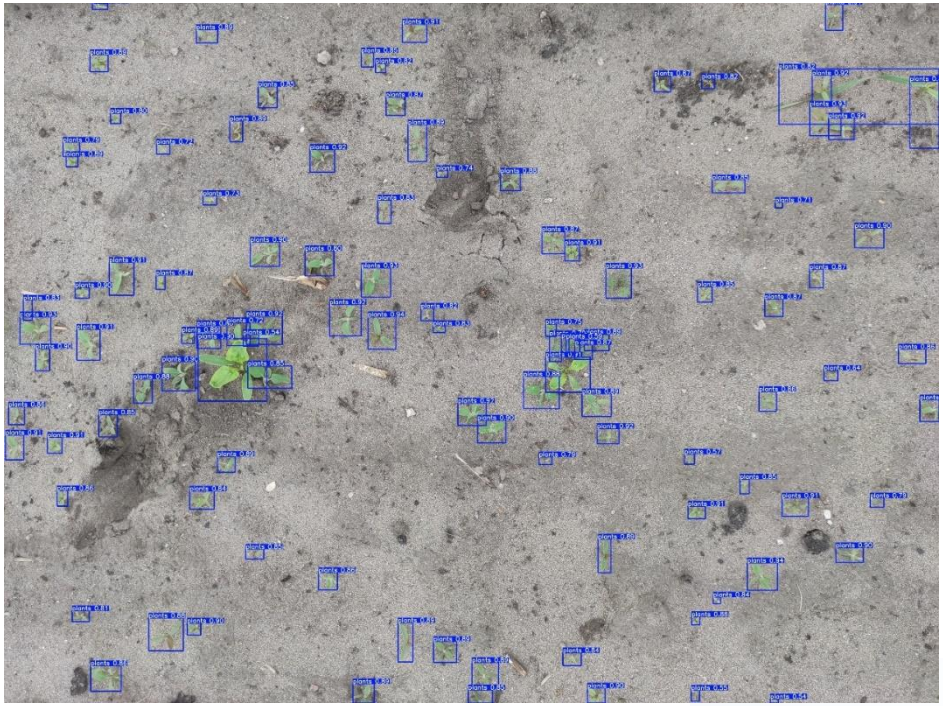


Perception System – Detection Evaluation

- Test on unknown images from cropped DK dataset
- Test on unknown images from full DK dataset
- Test on unknown images from DE dataset



Perception System – Detection Evaluation

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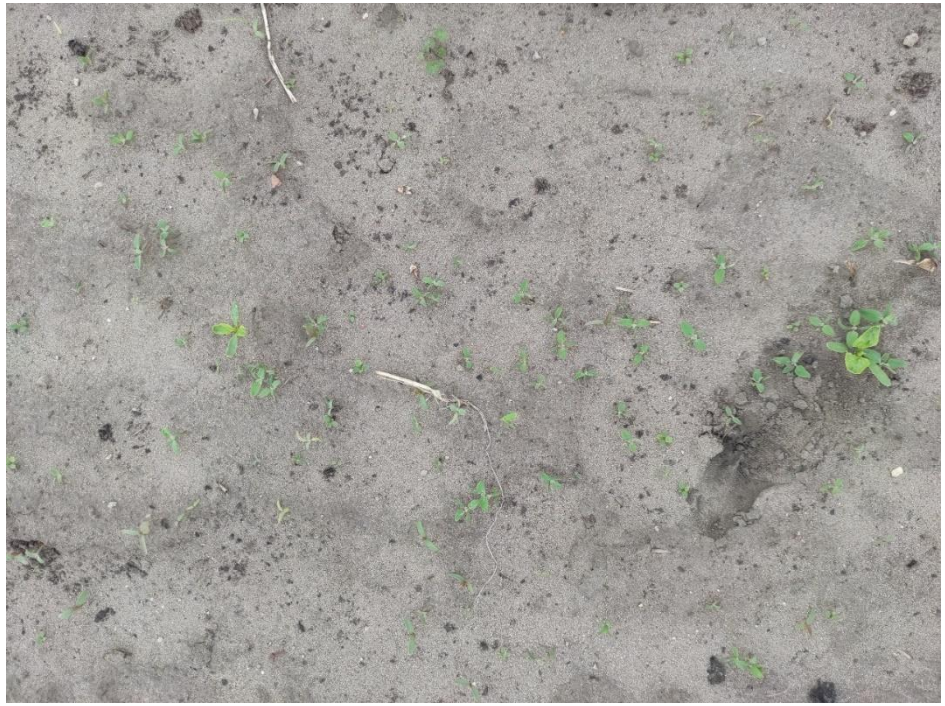

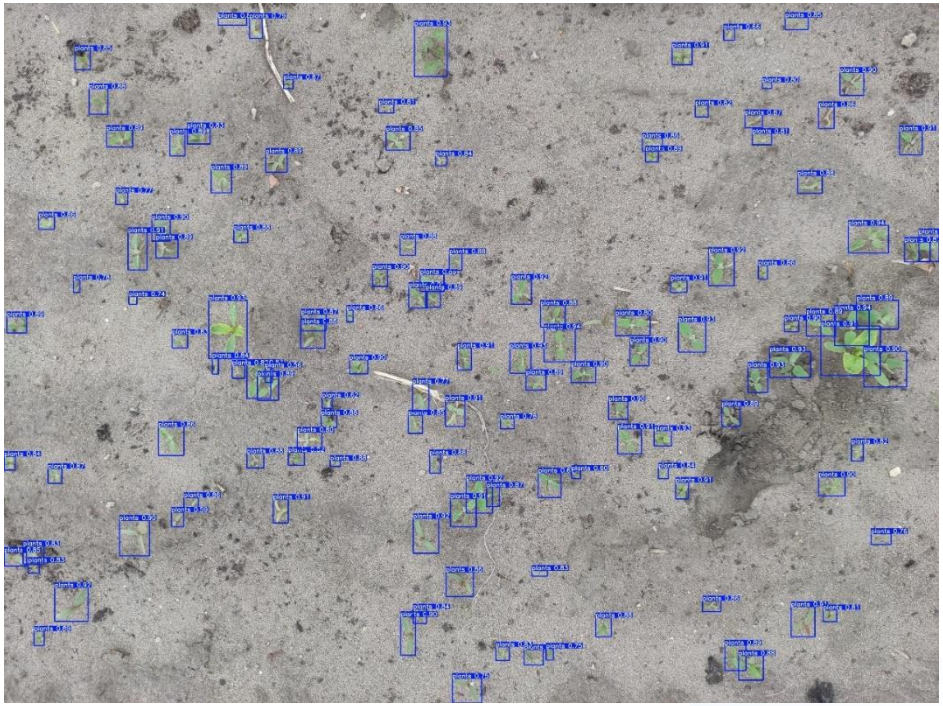

Perception System – Detection Evaluation

- Test on unknown images from cropped DK dataset
- Test on unknown images from full DK dataset
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- Test on unknown images from different field

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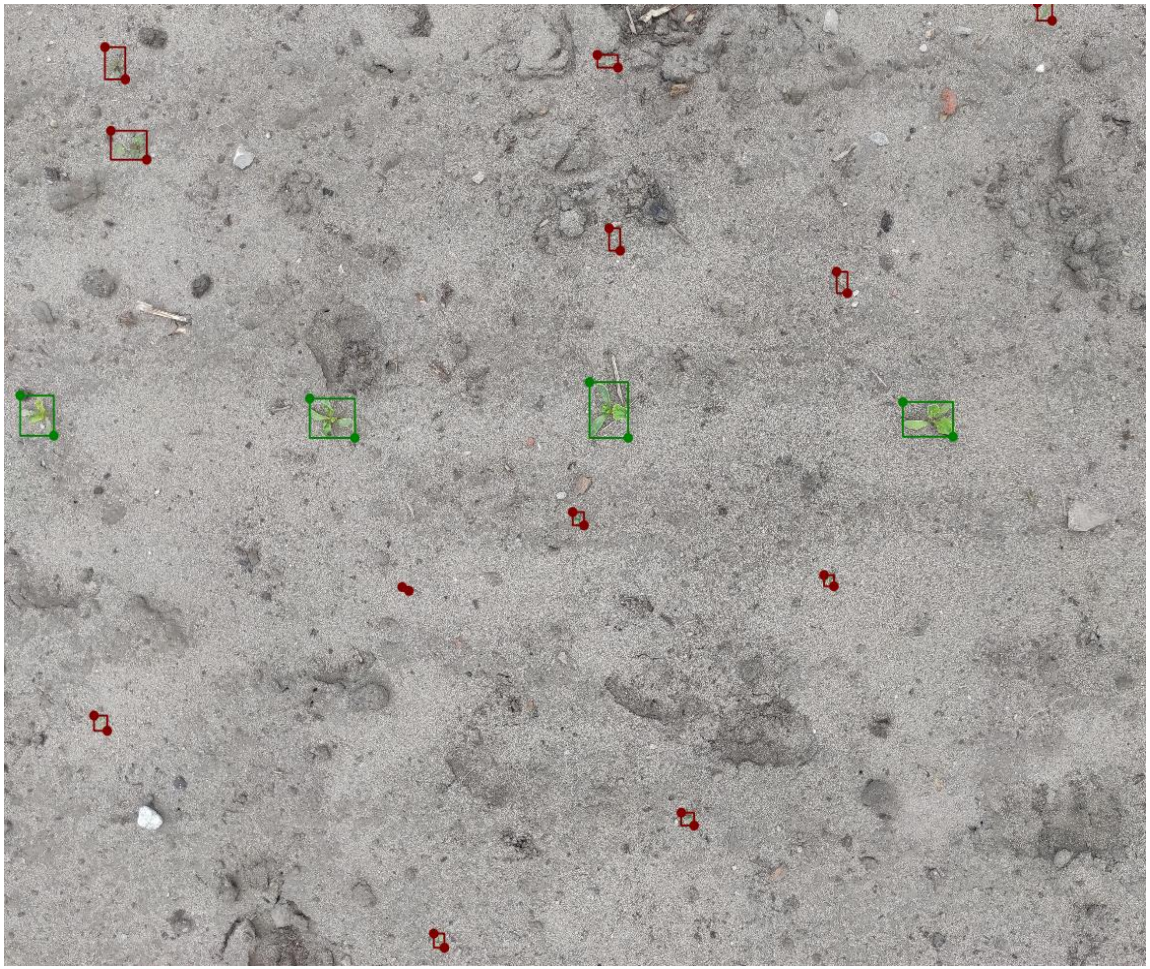
Perception System – Detection Evaluation

- **Crop/Weeds Distinctions**
  - ❑ Using YoloR CNN
  - ❑ 30 ms per „Full HD“ image
  - ❑ ~95% precision
  - ❑ Flexible future class count



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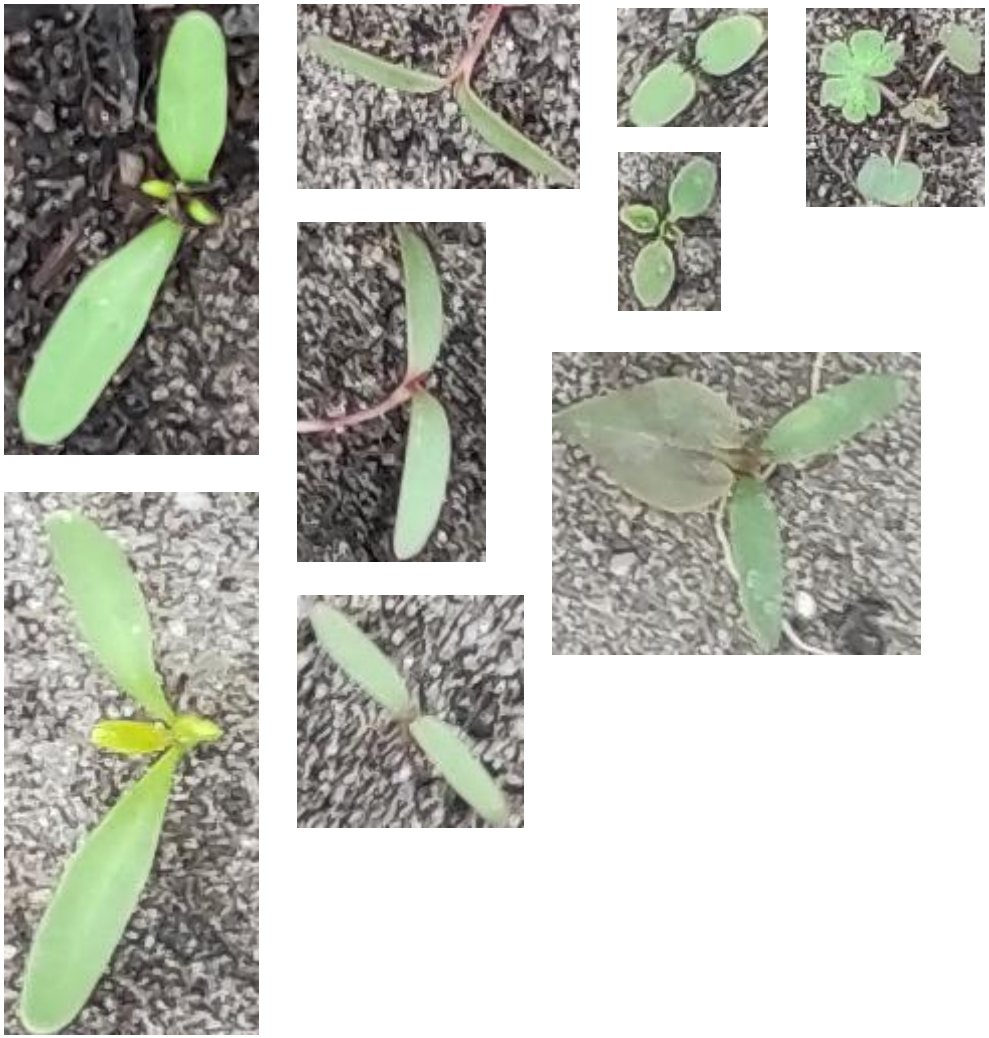
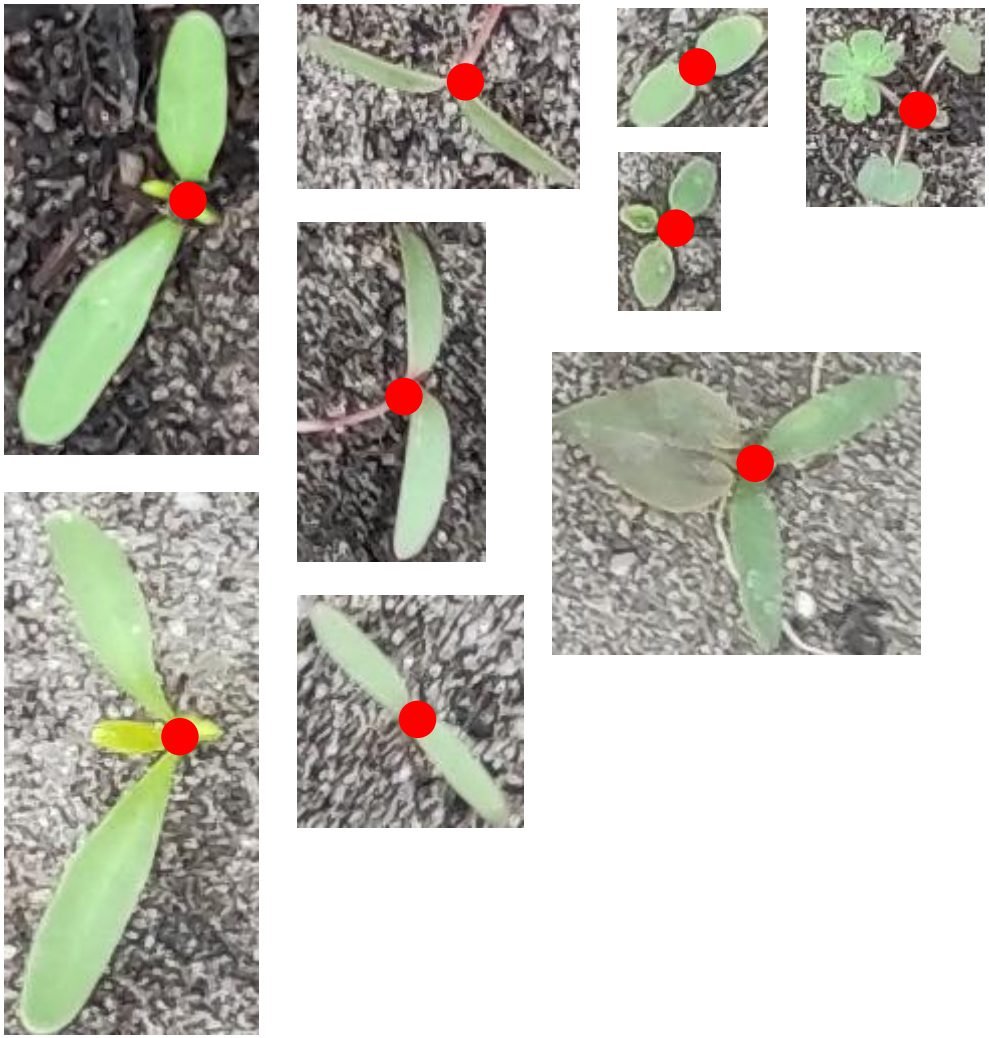
Perception System – Detection Evaluation

- **Meristem Detection**
  - ❑ Top-Down Method:
    - ❖ Cut out plants from large picture



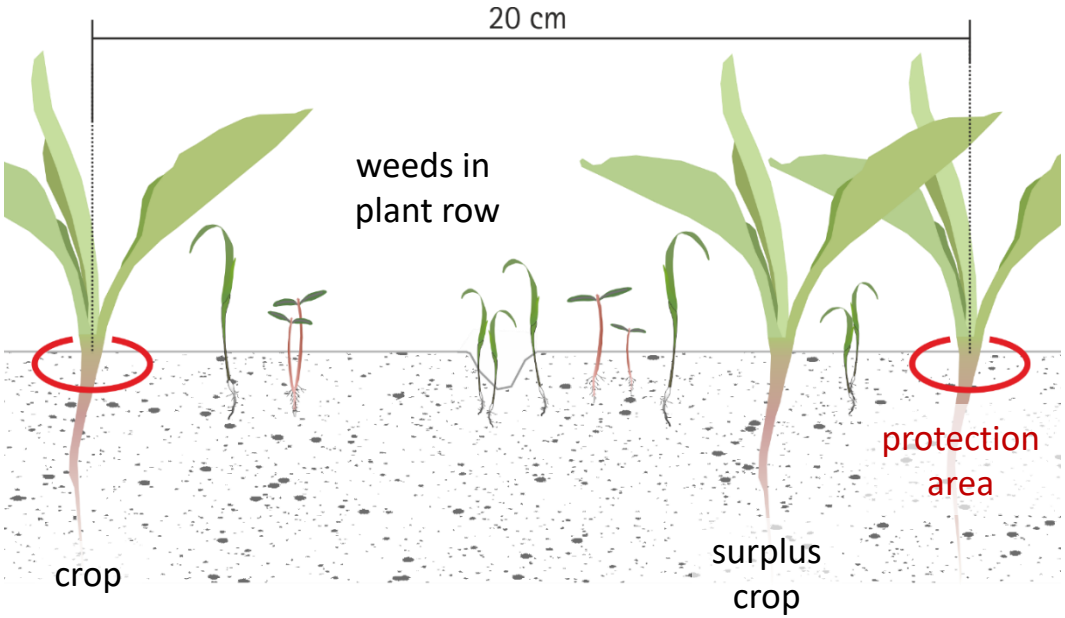
Perception System – Detection Evaluation

- **Meristem Detection**
  - ❑ Top-Down Method:
    - ❖ Cut out plants from large picture
    - ❖ Small convolutional neural network to predict impact point
    - ❖ ~80% precision
    - ❖ Total computation time of 50 ms per large image



Laser weeding: Innovative plant protection

- **Characteristics**
  - ❑ Precise single plant treatment
  - ❑ AI target classification and localization
  - ❑ Mechanism: thermal effect
  - ❑ Efficient for young plants up to BBCH14
  - ❑ Compatible to conservation soil cultivation
  - ❑ Low-wear technology
  - ❑ Precision + selectivity → enabling technology for weed management allowing for maximal biodiversity



Graphics: C. Marx LZH

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Thank you for your attention

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