NPEC

FUTURE OF INOCULATION

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PROBLEM DEFINITION

Plant phenotyping is a critical component of agricultural research, involves observing and measuring plant traits to understand growth patterns, pathogen resistance, and other factors influencing crop performance. Traditional phenotyping methods are labor-intensive, time-consuming, and costly, limiting accessibility for many researchers.

CURRENT CHALLENGES

- Labour intensive process
- Scalability
- Integration of technologies

SOLUTION

Hades

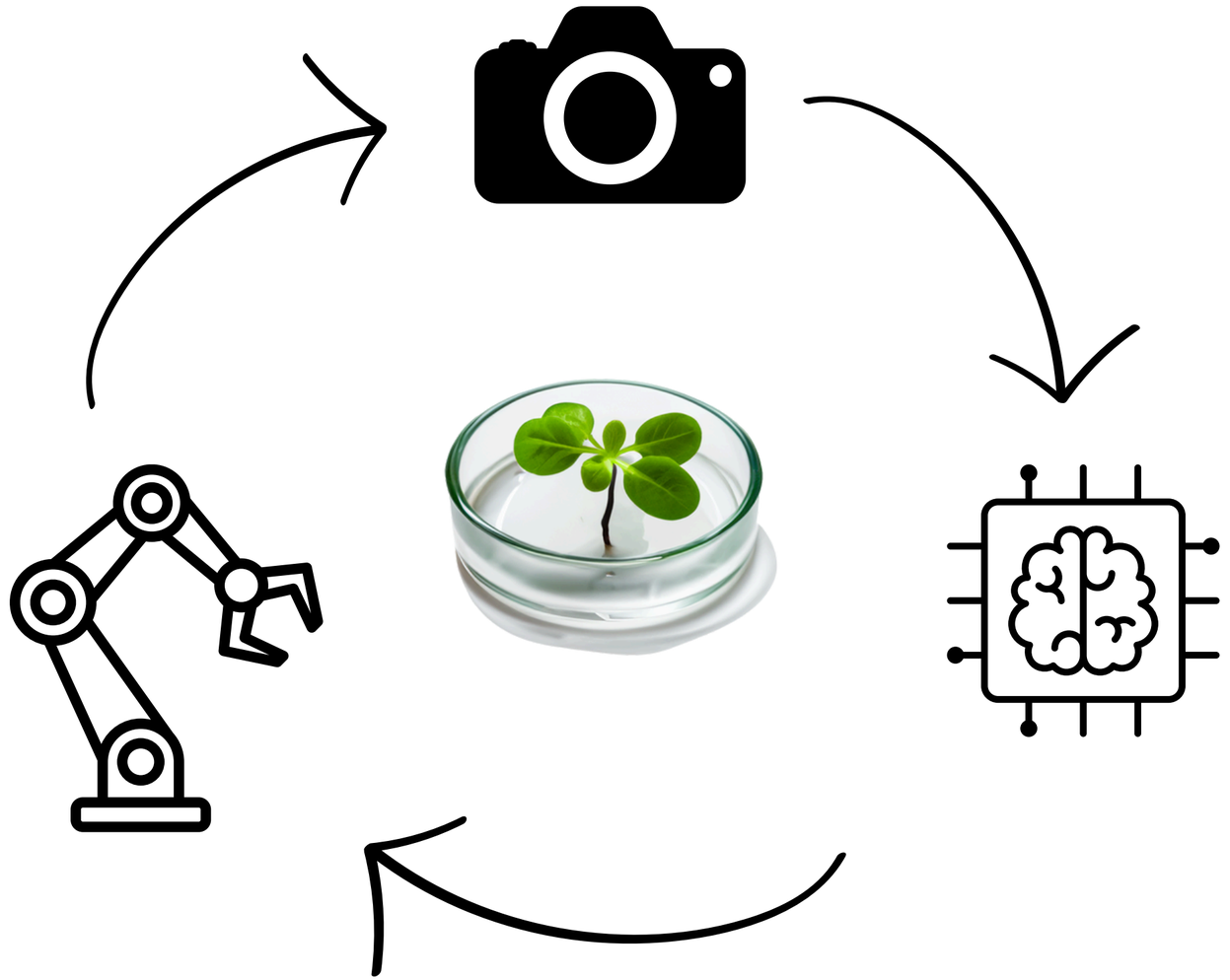
HADES is an automated system for studying plant root systems, allowing to assess root structure and interactions in controlled environments. It can handle up to **10,000 seedlings** on over **2,000 Petri dishes**, taking care of everything from filling the dishes, planting seeds, and cooling them for germination, to growing plants in a perfect environment. It can also automatically treat plant roots with helpful or harmful microbes. Using special imaging technology, HADES can study roots without damaging them, **capturing detailed pictures of their structure**.

AI & Computer vision

Computer vision and deep learning significantly enhance phenotyping by **automating** the analysis of complex plant traits, such as lengths of main roots and their tips locations, with high accuracy and efficiency. These technologies enable the processing of large datasets, providing insights into root structures and other functional dynamics that were previously labor-intensive to measure.

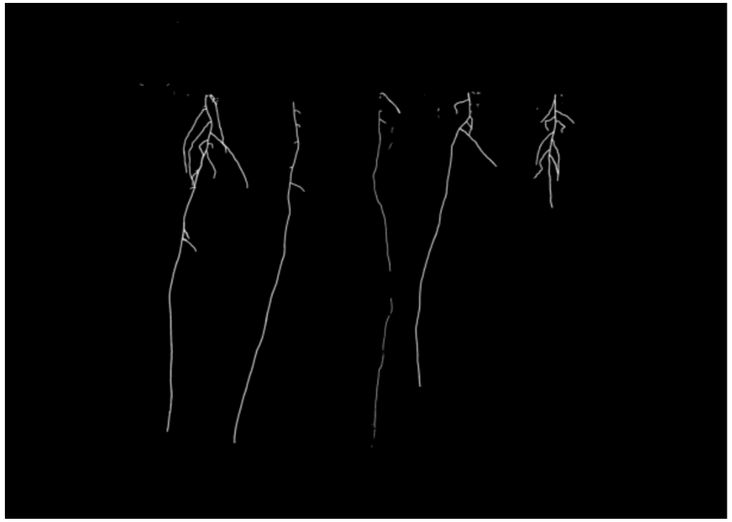
AUTONOMOUS INOCULATION

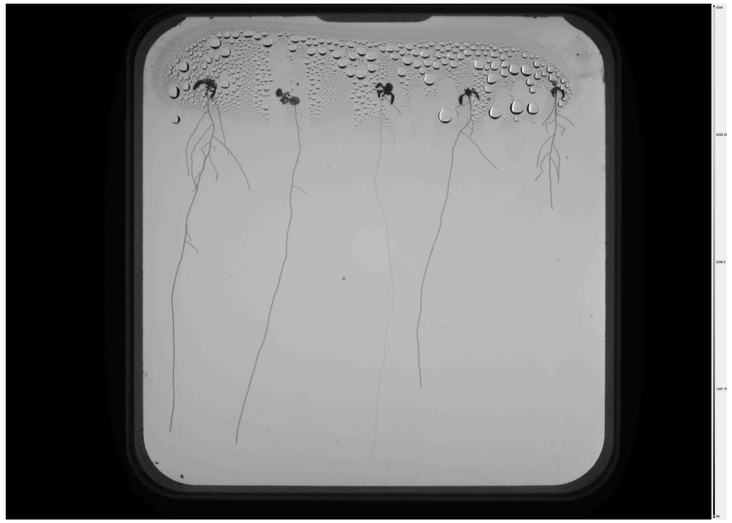
Thanks to technological advancements that HADES brings to the table, and advanced AI pipeline analyzing root structures, allows the automation of the inoculation process, delivering similar results with minimal human oversight.

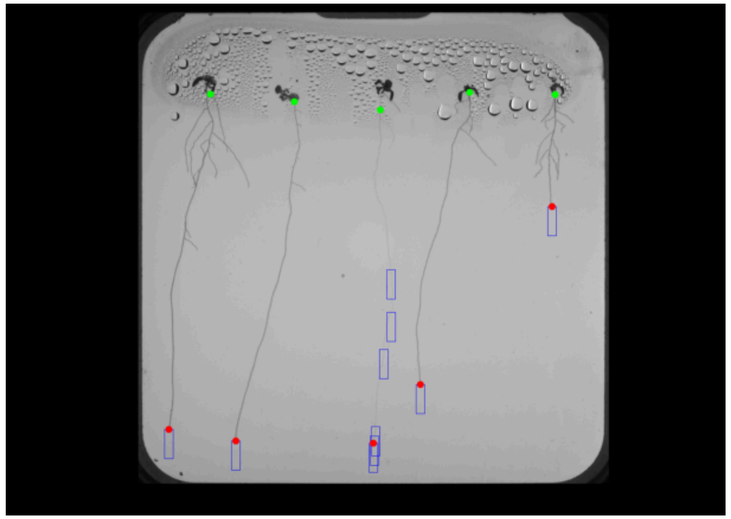


COMPUTER VISION PIPELINE

The image taken is fed to DL model that outputs a mask of all the roots. Then the analysis is done to extract root tip coordinates and lengths of main roots.

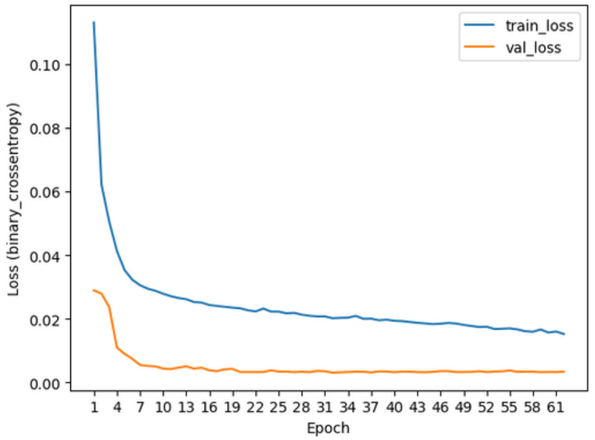




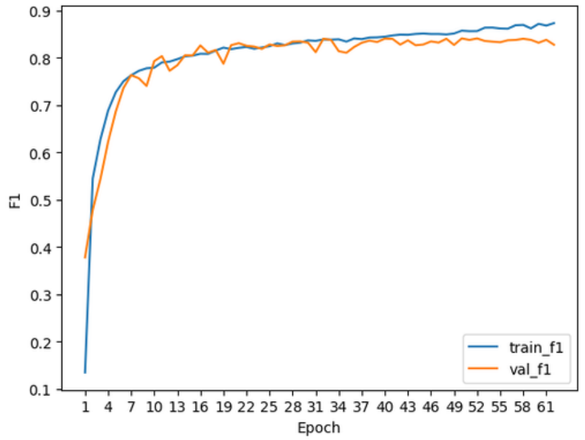


SEGMENTATION MODEL TRAINING

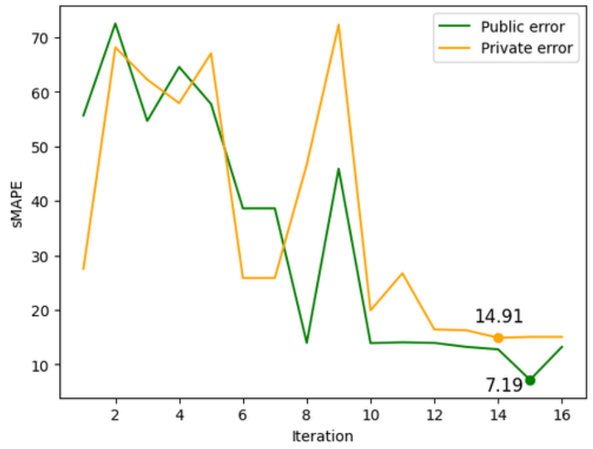
Training Loss



Training F1 Score



Prediction of main root length

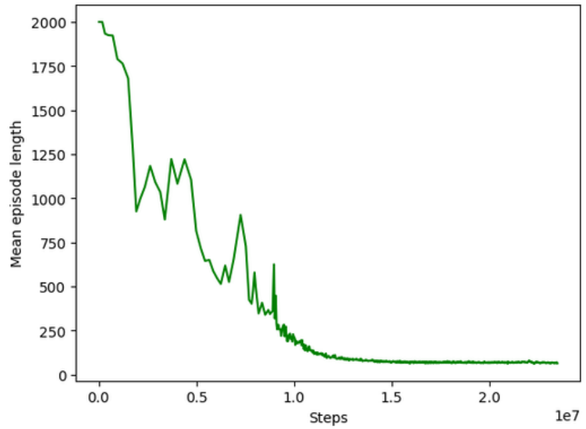


ROOT LENGTH PREDICTION

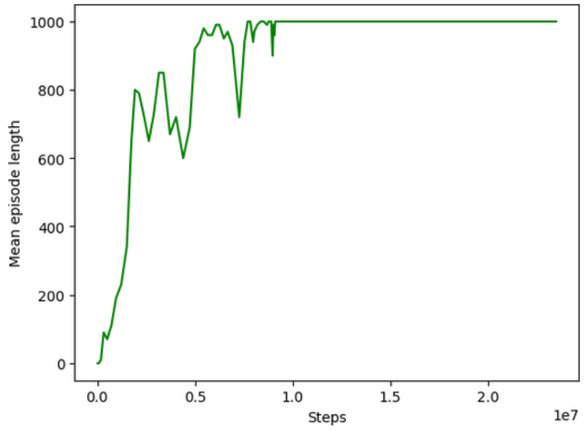
sMAPE - Symmetric mean absolute percentage error - The error was used to evaluate performance of computer vision pipeline that had a goal of measuring main roots lengths

OT-2 CONTROLLER TRAINING

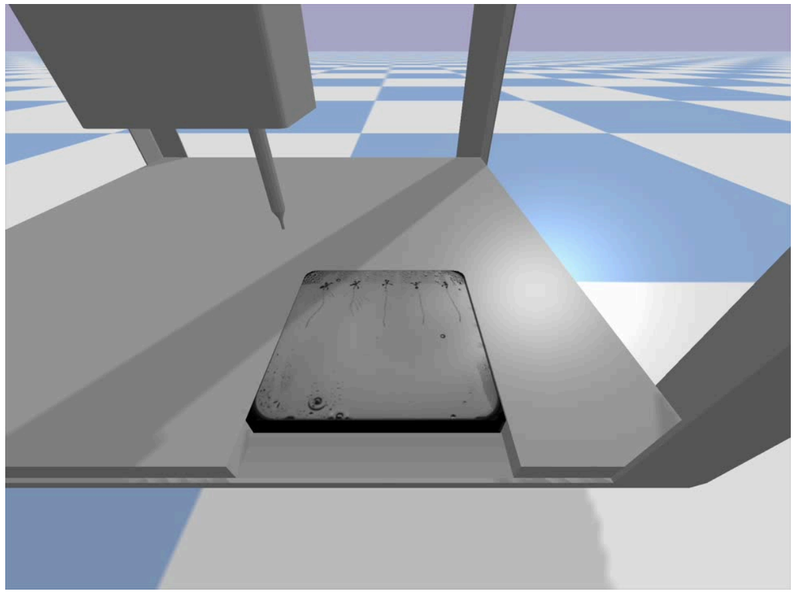
Mean episode length

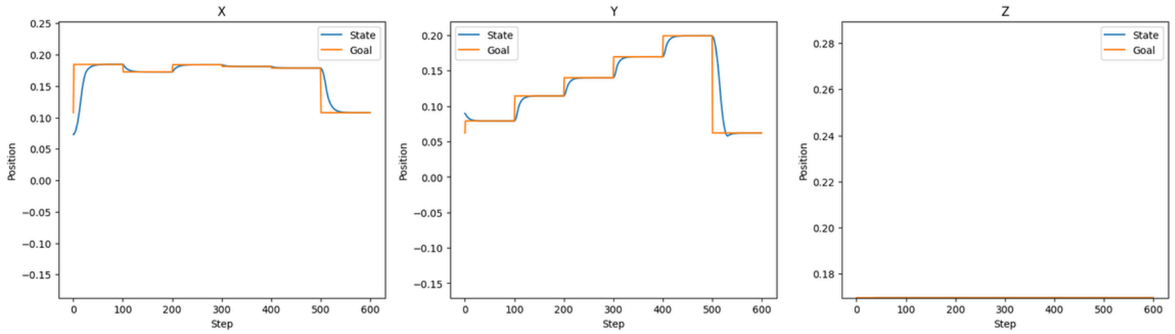


Mean episode reward

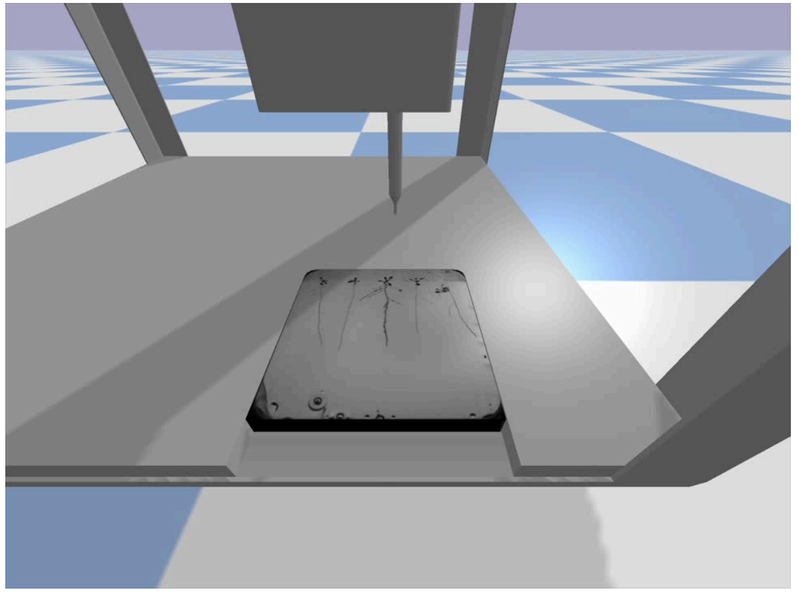


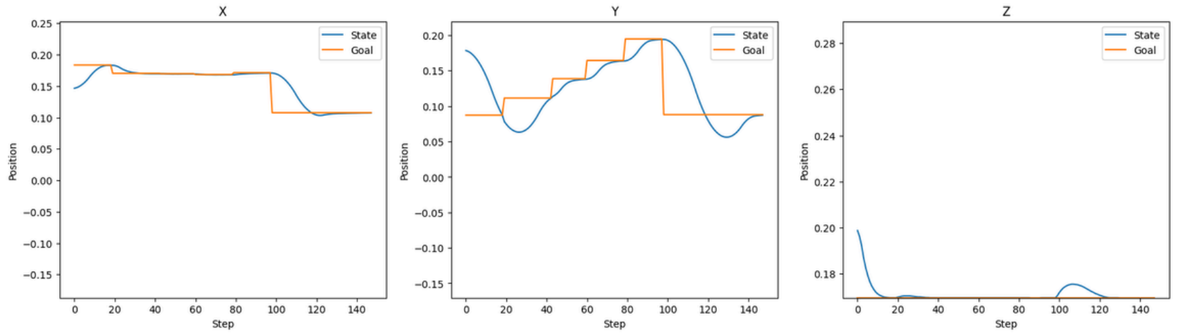
PD CONTROLLER





RL CONTROLLER

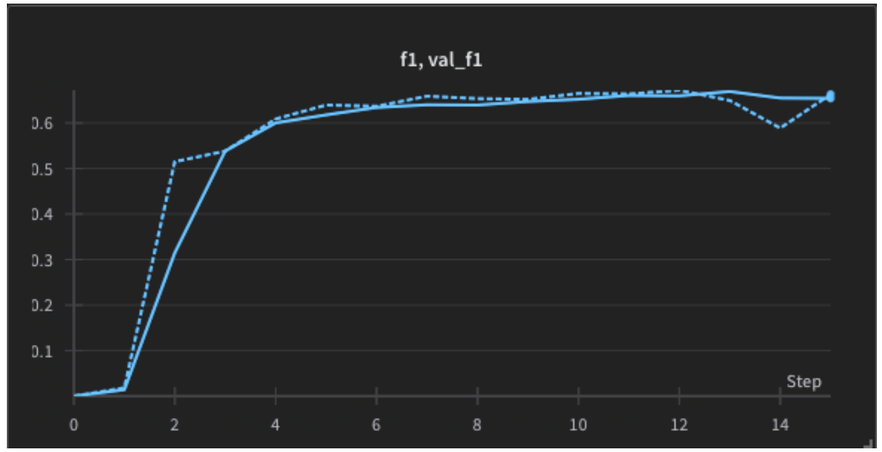




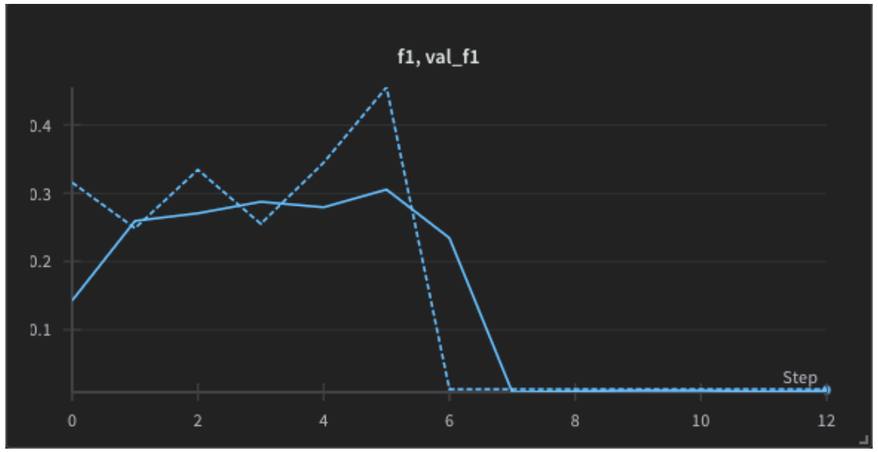
IMPORTANT ITERATIONS

All iterations ware done using simple U-NET model, early stopping and patch size of 256px

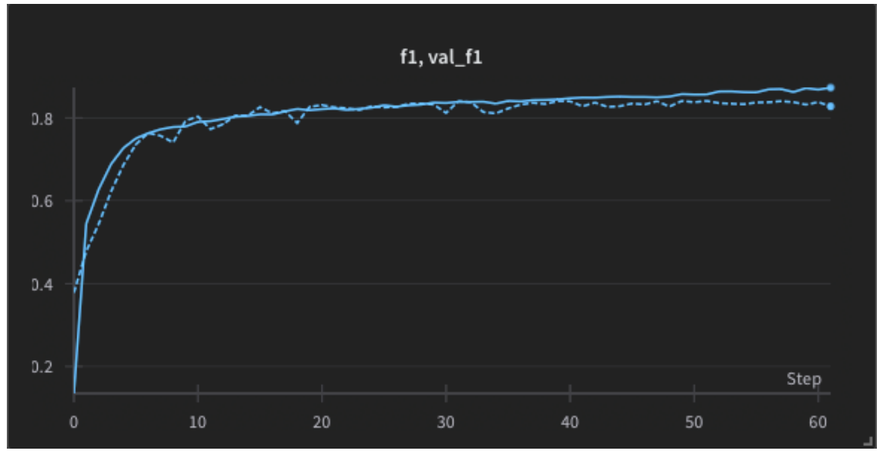
Class weights: Imbalanced, each class has the same weight
Learning rate: 0.005
Batch size: 64



Class weights: balanced
Learning rate: 0.005
Batch size: 128



Best run
Class weights: excluded from the run
Learning rate: 0.001
Batch size: 256



ASSUMPTIONS OF THE PIPELINE

- Roots don’t overlap
- There are exactly 5 seedling on a Petri dish
- The main root starts in the top part of a Petri dish and ends in the lowest point of the root structure

LIMITATIONS OF THE PIPELINE

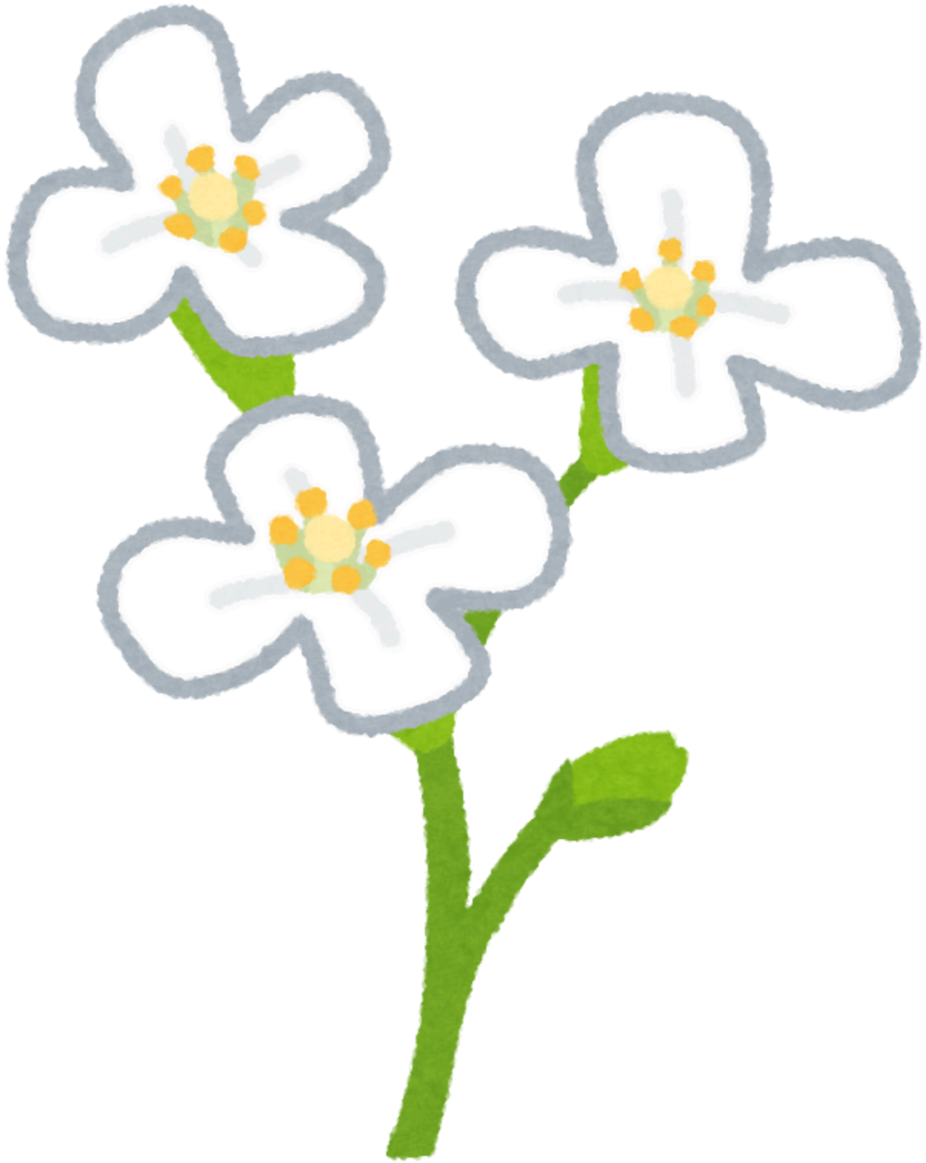
- Unfortunately the extraction of root tips requires a root in a particular place, if there is none but only a seed the OT-2 robot doesn’t have a location of the seed to inoculate.
- If the root is very thin it might cause a broken mask prediction, which would result in miscalculation of a root tip location

HOW DOES IT HELP?

Automation

Speed

Free up human resources



NEXT STEPS

- Train a model for seed extraction and implement it to the pipeline
- Test more edge cases and consult them with a professional biologist
- Try different types of seedlings and analyze the performance

SUMMARY

The project began with image labeling and evolved into a functional computer vision pipeline integrated with a simulated robot performing the desired tasks. Thanks to the client-provided images, we gained valuable insights and hands-on experience in turning an idea into a practical implementation. Looking ahead, the outcome of intencive work and determination resulted in making high-throughput phenotyping possible.

THANK YOU

REFERENCES

- Module 2—Plant-Microbe Interaction Phenotyping—Hades. (n.d.). NPEC. Retrieved 21 January 2025, from NPEC - https://www.npec.nl/phenotyping-modules/module-2-plant-microbe-interactions-phenotyping/hades/

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