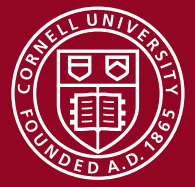
Cornell AgriTech

New York State Agricultural Experiment Station



Cornell CALS

College of Agriculture
and Life Sciences

Robotics and AI-Enabled High-Throughput Phenotyping for Grapevine Disease Resistance and Breeding

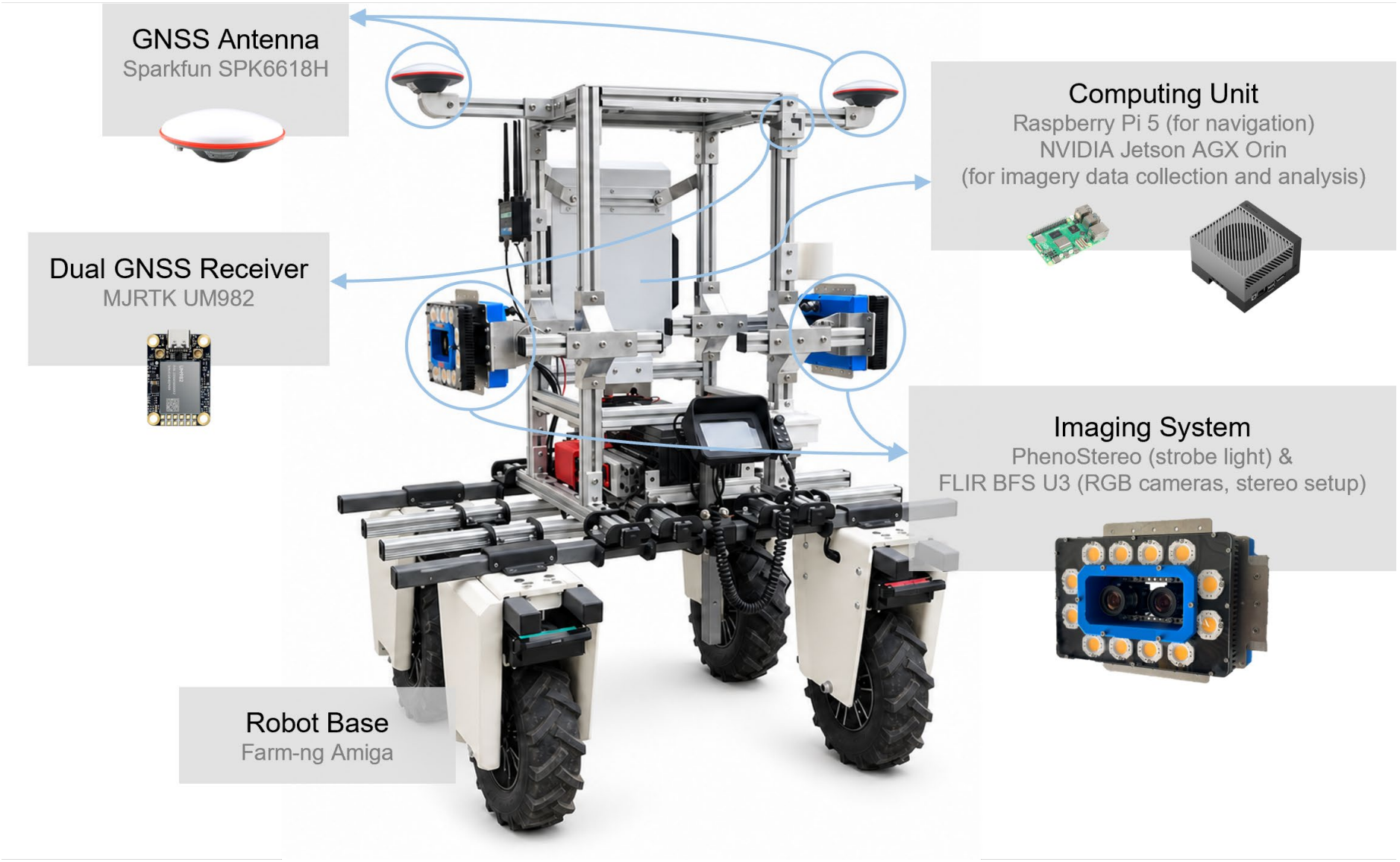
***Yiyuan Lin* 林翊源**
School of Electrical and Computer Engineering
Cornell University

Oct 13, 2026
PPBMB 2026 Retreat

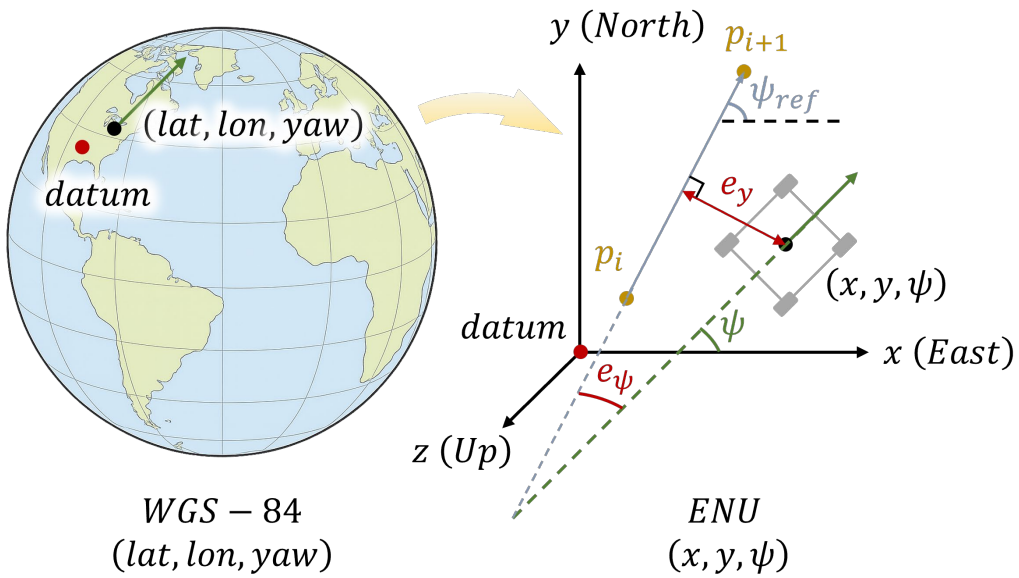
Why study plant disease?

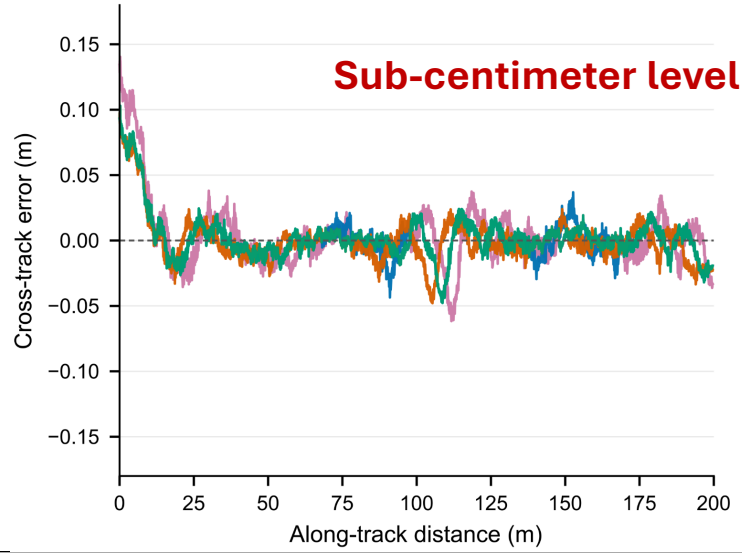


PhytoPatholoBot v2 (PPBv2)



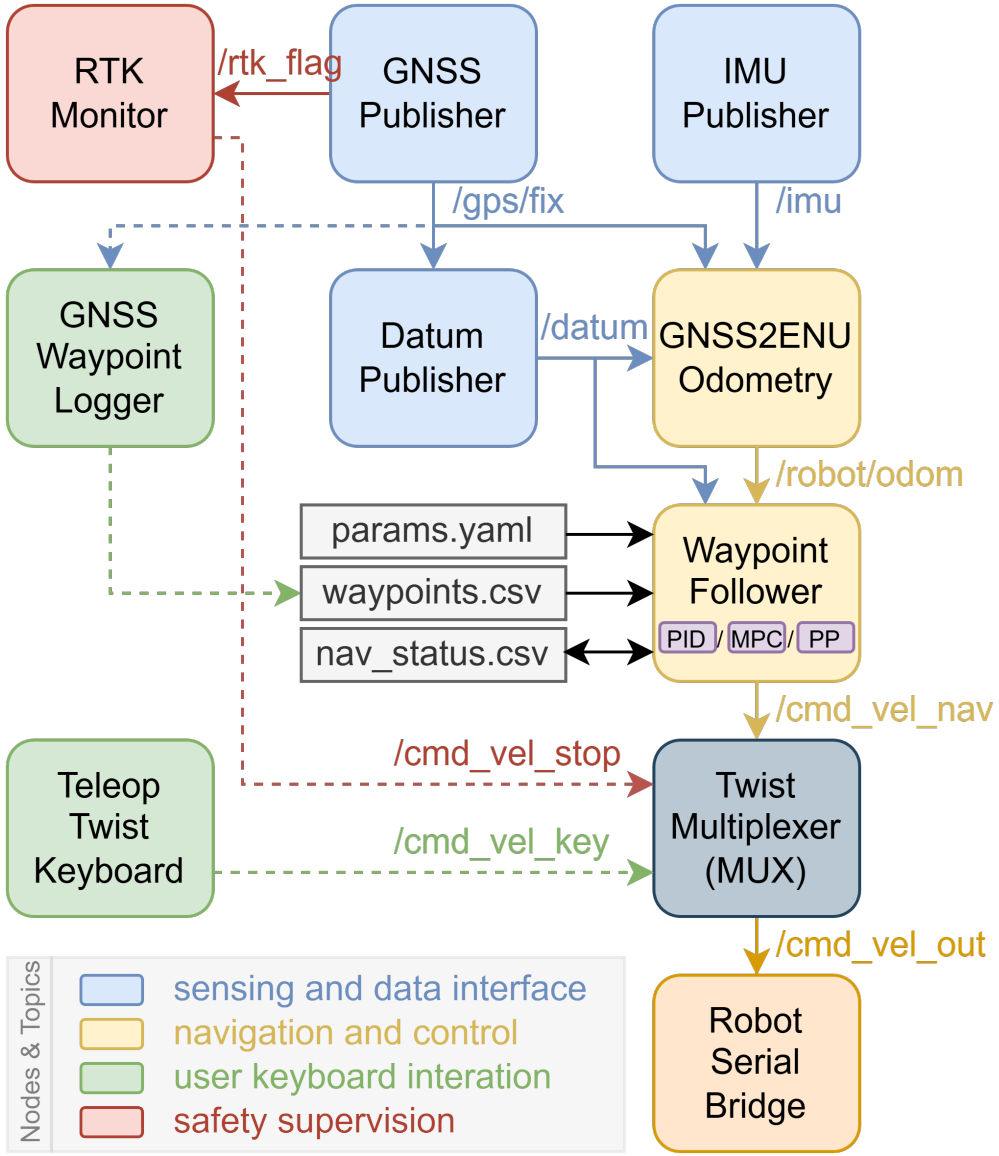
PPBv2 Navigation





Sub-centimeter level navigation

±5cm navigation error in the field



PPBv2 Imaging System and Sample Data



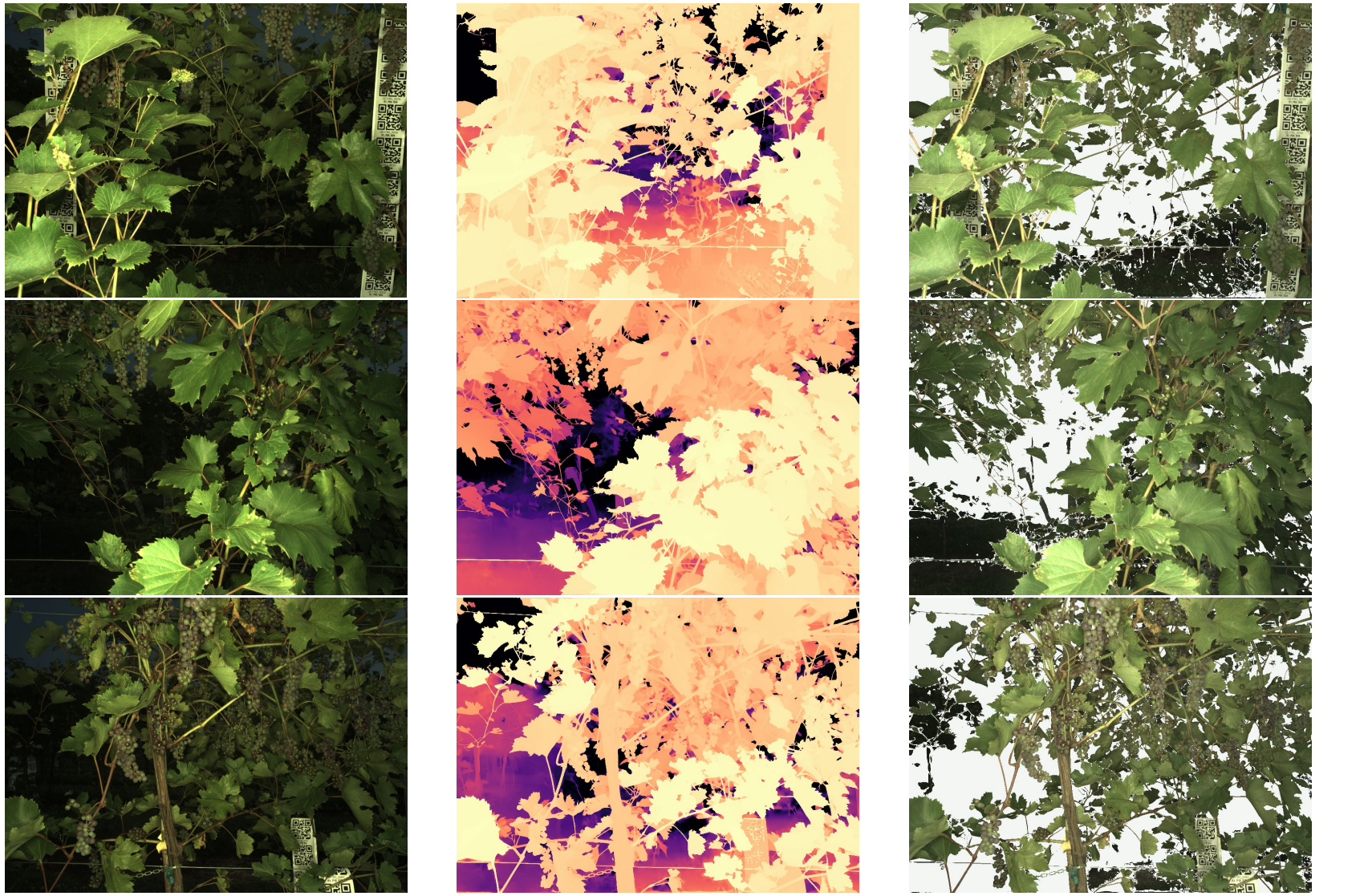
Imaging System
(Strobe light + RGB cameras)



image (L) image (R)

Foundation Stereo

image | Reconstructed Depth | Reconstructed Point Cloud (0-3m)

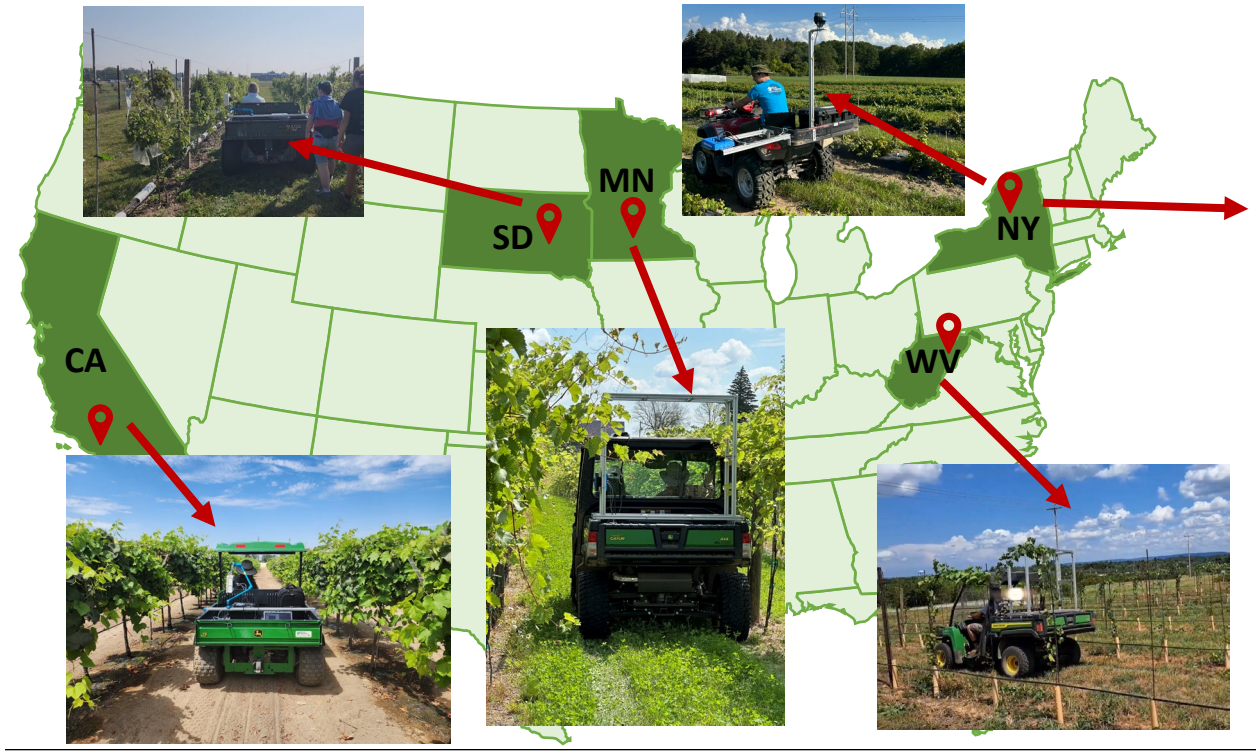


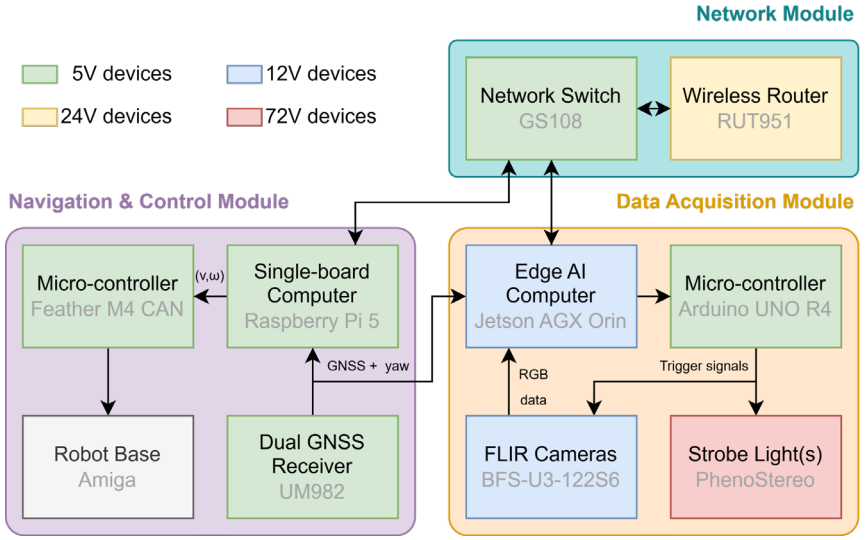
CAIR Cyber-Agricultural Intelligence and Robotics Laboratory

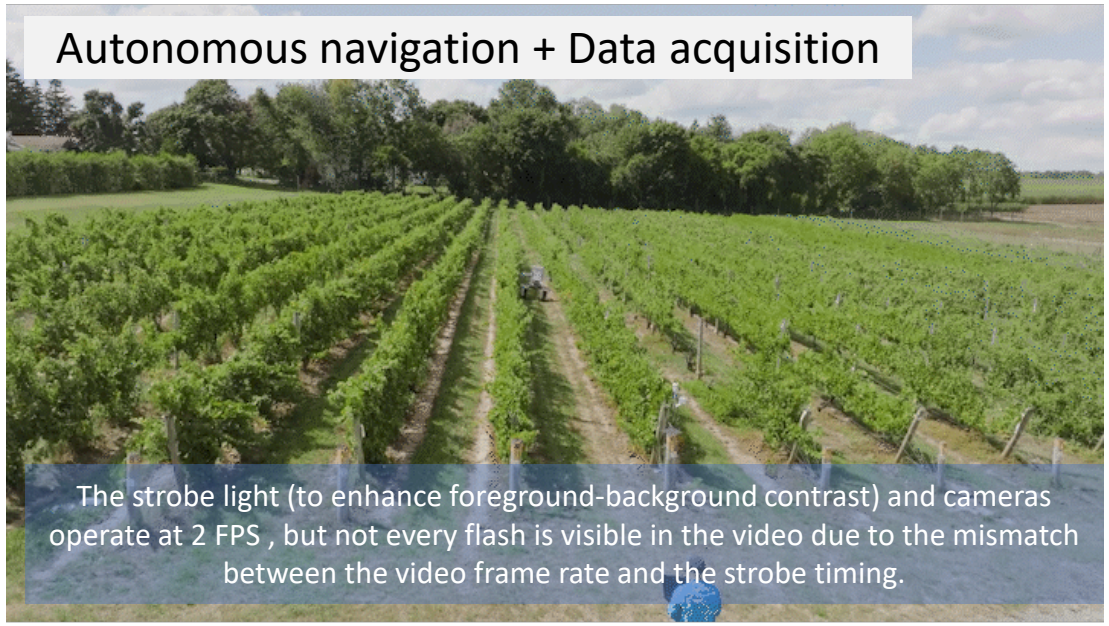
Bowen Wen, Matthew Trepte, Joseph Aribido, Jan Kautz, Orazio Gallo, Stan Birchfield.
“FoundationStereo: Zero-Shot Stereo Matching”, CVPR 2025

Weekly PPBv2 deployment

- PPBv2 robots based autonomous system
- ATV-based system
  (shared data acquisition module)







Data Distribution of Grape Disease Phenotyping

- The imaging system can control data distribution on the sensor side, but not the domain shift on the plant side…



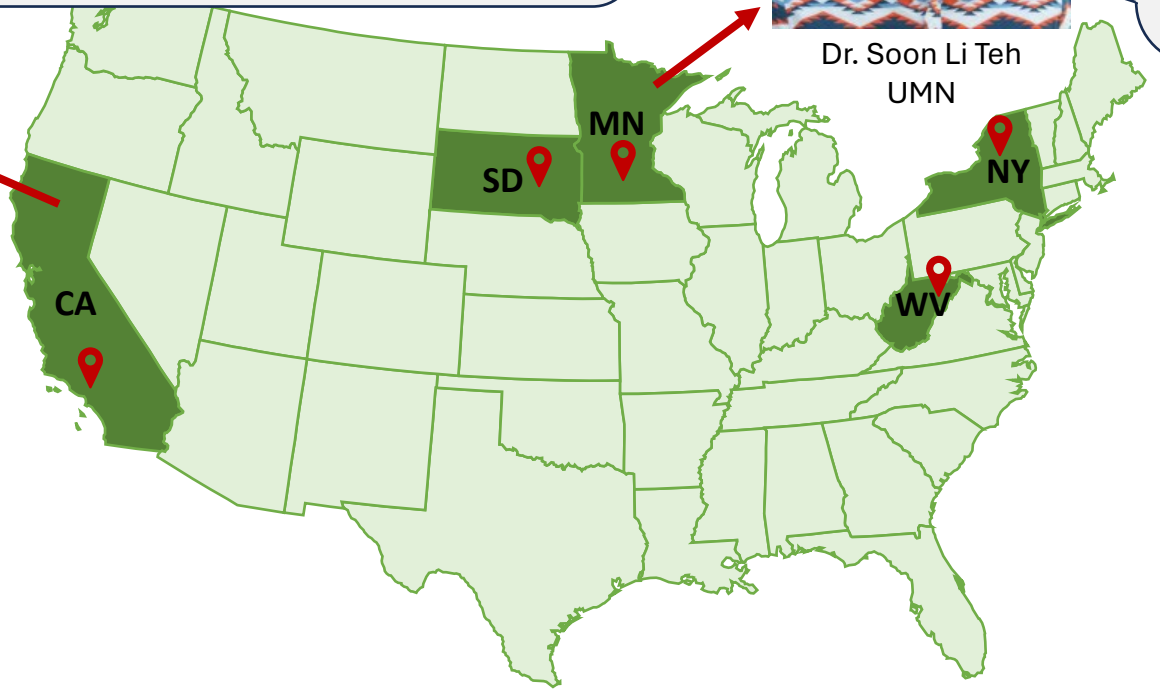
Dr. Summaira Riaz
USDA-ARS

Can you train an AI model to identify powdery mildew (PM) for me? They are **dense, yellow powdery patches with high visual contrast**.



Dr. Soon Li Teh
UMN

I also want a PM model, but the symptom in Minnesota doesn't look like that in CA…They are **sparse, scattered, gray-white powdery spots with diffuse, low-contrast boundaries**.





PM sample in California



PM sample in Minnesota

Challenges in Powdery Mildew Segmentation

- Data Annotation
  - Domain knowledge required
  - Time and energy consuming

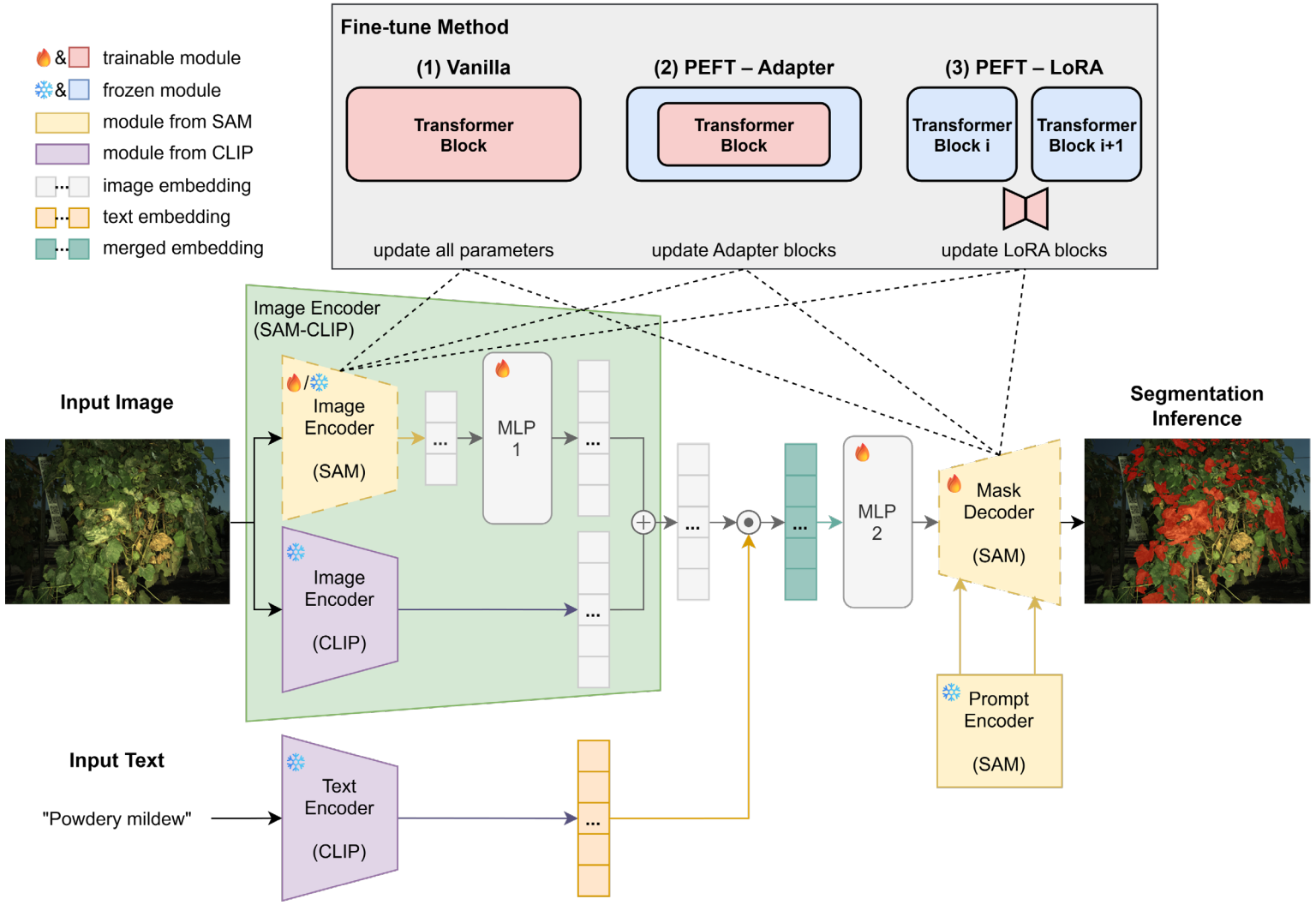
Small annotated image dataset

- Appearance Variation
  - Irregular shape
  - Various color

Hard to model the irregular visual features in a unified manner

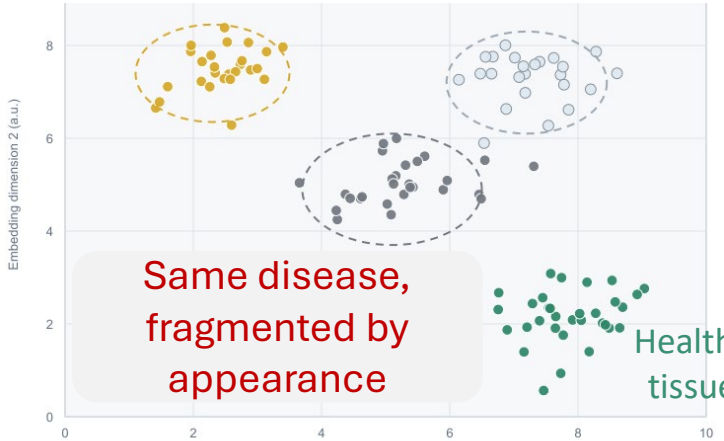


SAM-CLIP Model for Disease Segmentation



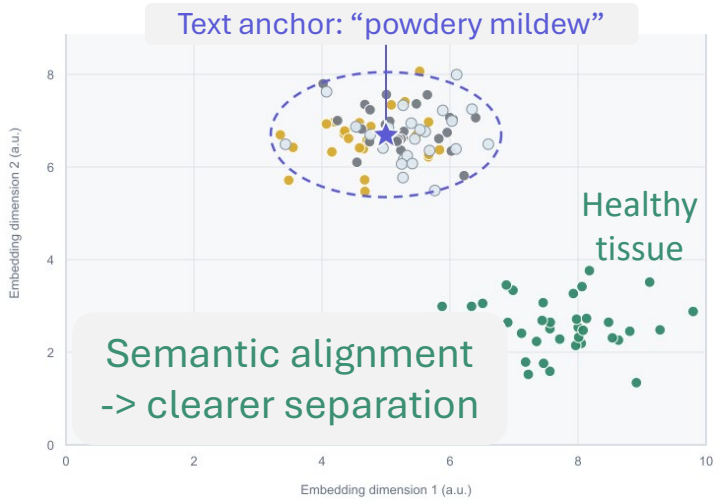
Before text regulation (image only)

Appearance-driven PM subclusters

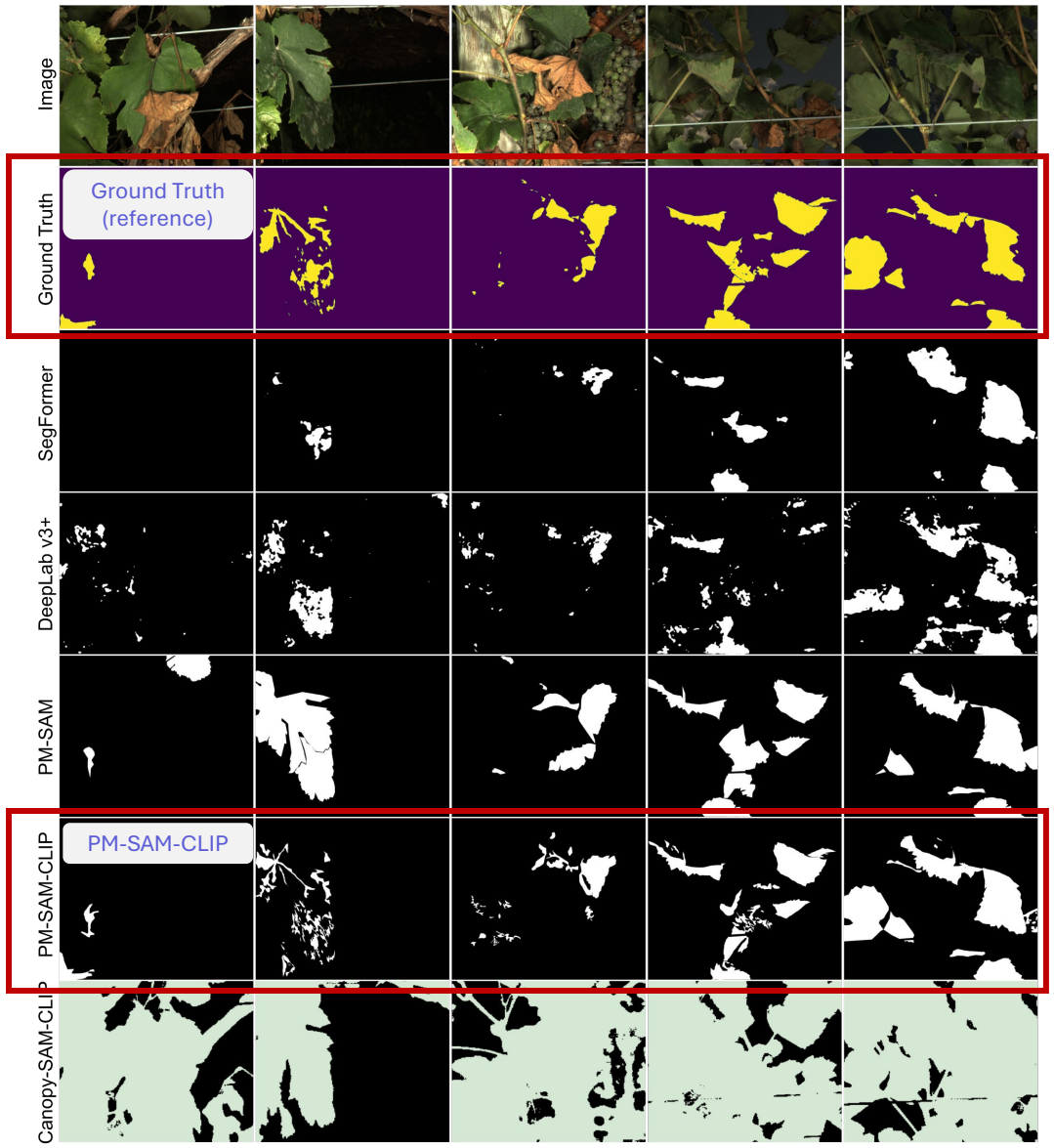


After text regulation (image+text)

Text-aligned semantic PM clusters



SAM-CLIP Model Performance

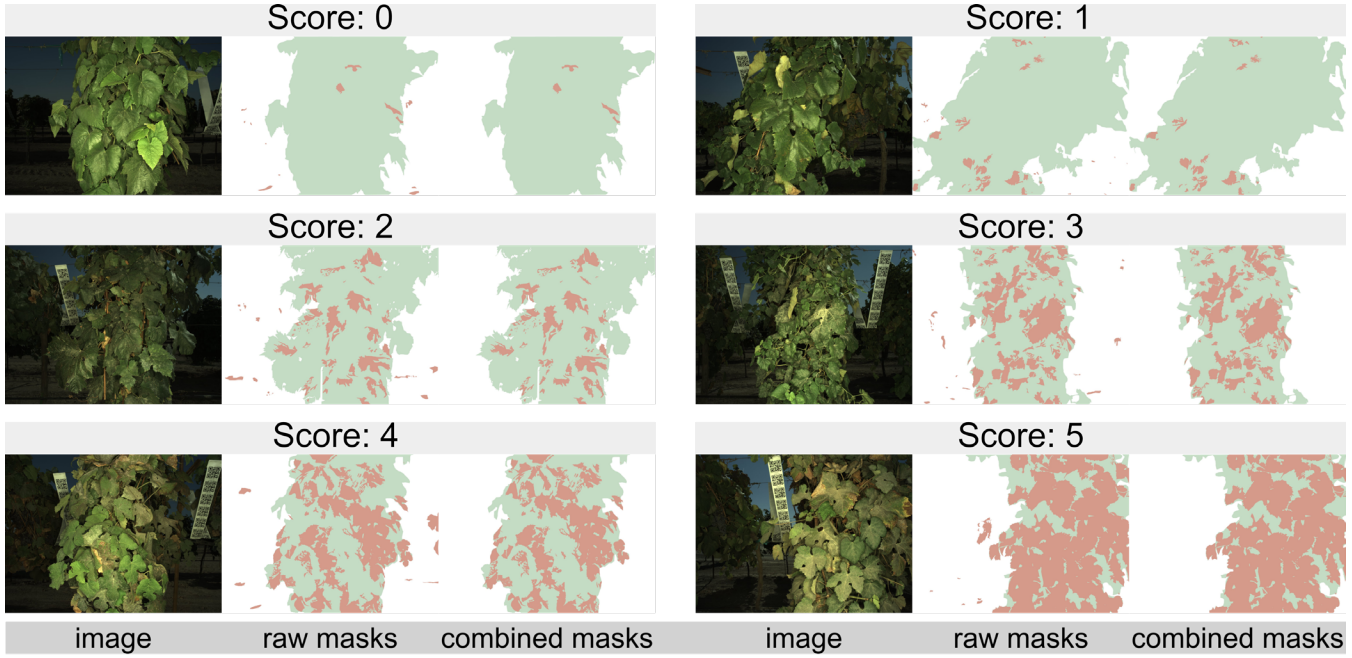


Model performance of SAM-CLIP and baseline

Model	Dataset	$mIoU^I$	$mIoU^D$	IoU^{C5}	IoU^{C10}	IoU^{C15}
PM-SAM-CLIP	PM_NY_2019	59.63	64.12	21.51	26.40	30.25
PM-SAM	PM_NY_2019	46.69	50.11	3.46	6.45	14.03
DeepLab v3+	PM_NY_2019	25.89	29.12	0.00	0.44	0.63
SegFormer	PM_NY_2019	21.41	25.54	0.00	0.00	0.00
Canopy-SAM-CLIP	Canopy_NY_2020	95.59	97.15	65.70	77.95	83.02

Human Scouting: 0-5 score

Robot Scouting: % -> 0-5 score



Requests Never Stop...



Dr. Medeline Oravec
Cornell

Can you build a model for **downy mildew** (DM)? We can annotate some DM for you.

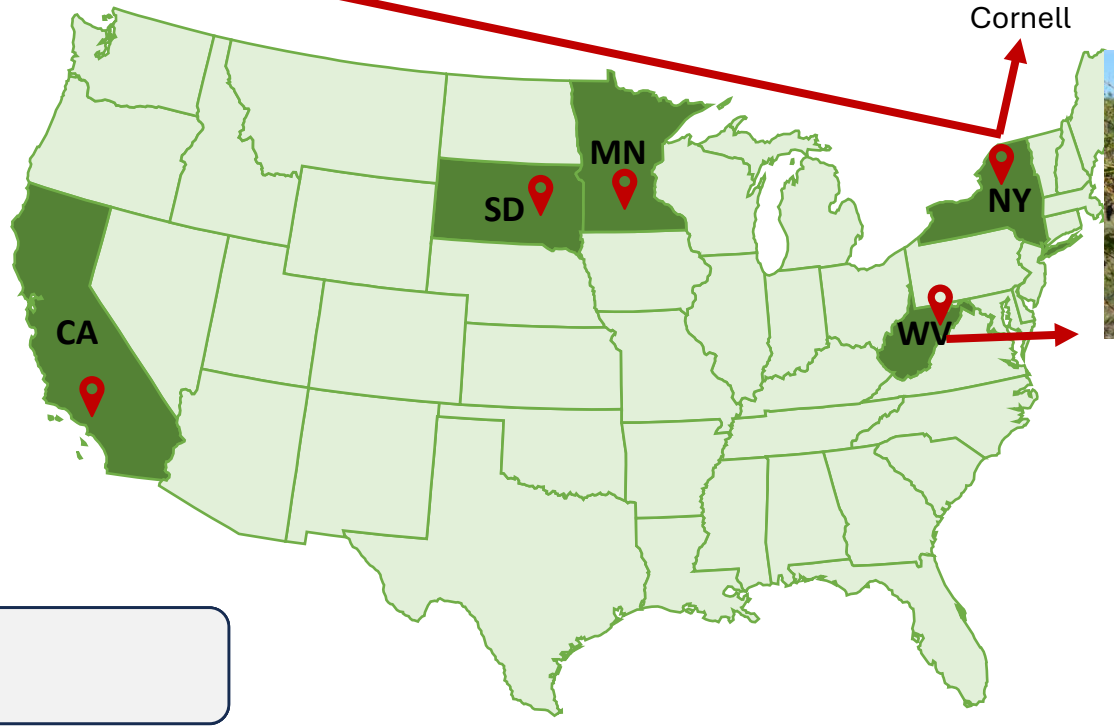


Dr. Katie Gold
Cornell

I am a plant pathologist, I want to study **all these diseases** in my vineyard. And faster is better!



Downy mildew sample



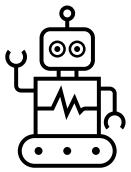


Dr. Surya Sapkota
USDA-ARS

Can you build a model for **black rot** (BR)? We can also annotate some BR.



Black rot sample



Wait...

Disjoint Single-Class Supervision

- Single-Class annotation datasets

Hierarchical overlap:
Downy Mildew and Powdery Mildew are on Canopy

Image



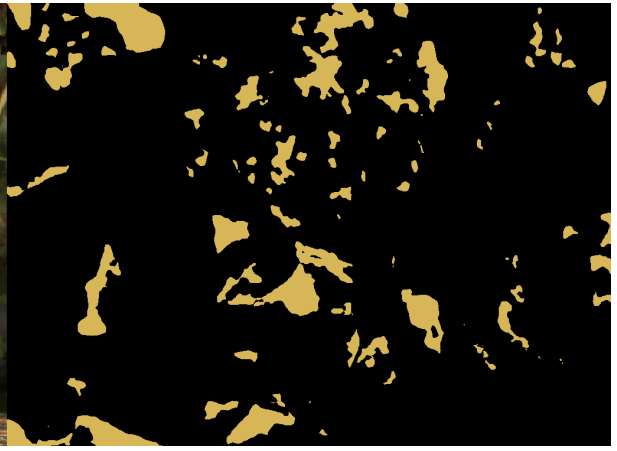
Mask - Canopy (C)



Image



Mask - Downy Mildew (D)



Image



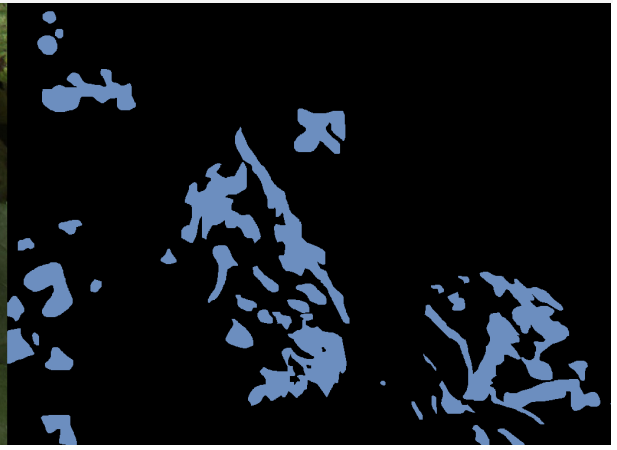
Mask - Berry (B)



Image



Mask - Powdery Mildew (P)



Real-Time Edge Deployment Constraints

* Pictures are generated by ChatGPT 5.2



Keep high resolution input
for small disease lesion detection



Robotic Precision Spraying*



Grower Decision Making*

Onboard Computing

Embedded GPU constrain

Multi-Teacher Knowledge Distillation for Continual Segmentation

Canopy-SAM-CLIP

Berry-SAM-CLIP

DM-SAM-CLIP

PM-SAM-CLIP

Multi-Teacher

Knowledge Distillation



Class-Incremental Learning (Continual Learning)

The student model needs to be

1. **Light-weight for real-time**
2. **Multi-class segmentation**
3. **Future expansion**

Student Model

Single-Student



Dr. Katie Gold
Cornell

New disease!!?? I want to study **all these diseases** in my vineyard.

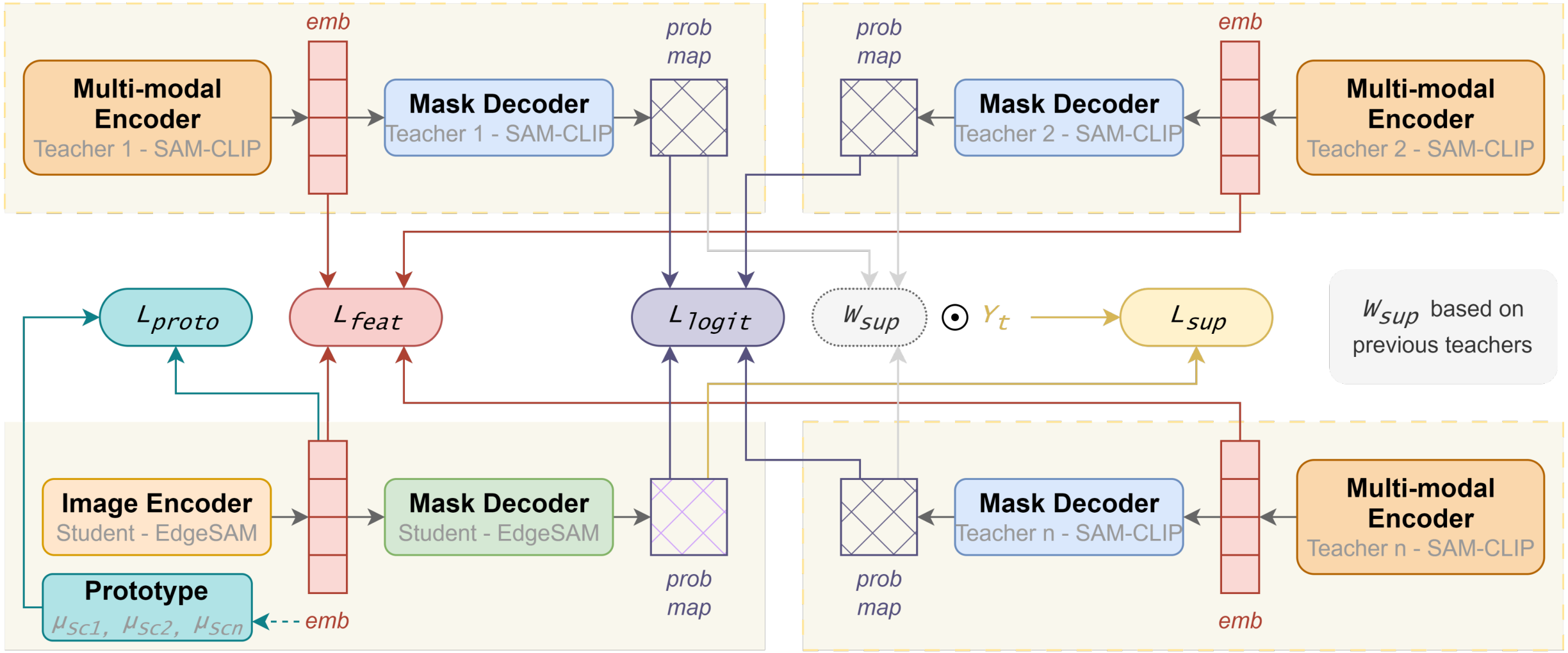
Our climate is different. We have new disease different with other sites.





Dr. Anne Fennell
SDSU

Sequential Teacher-to-Student Integration



Progressive Category Integration

Image







Image





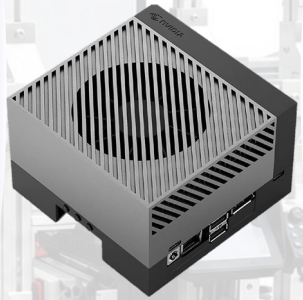


Real-Time Inference

Field Image Acquisition: **2** FPS

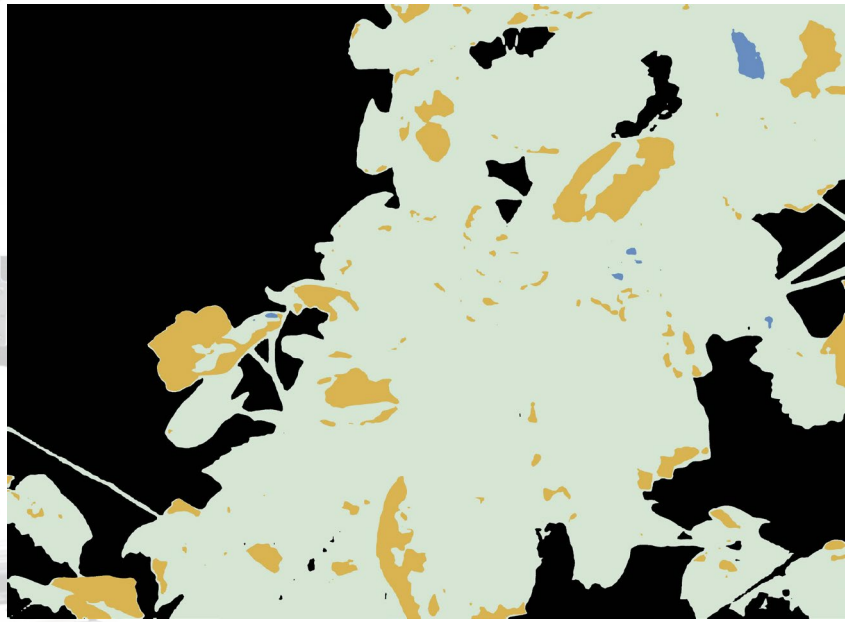


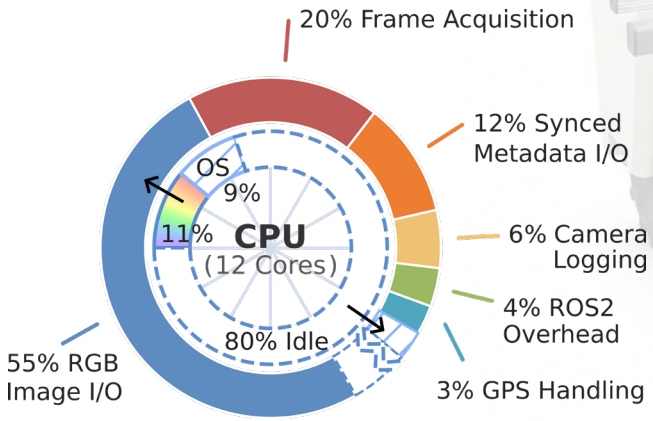
Student Model
EdgeSAM

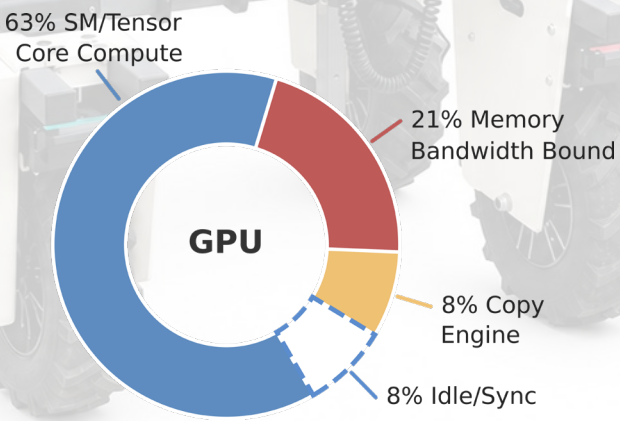


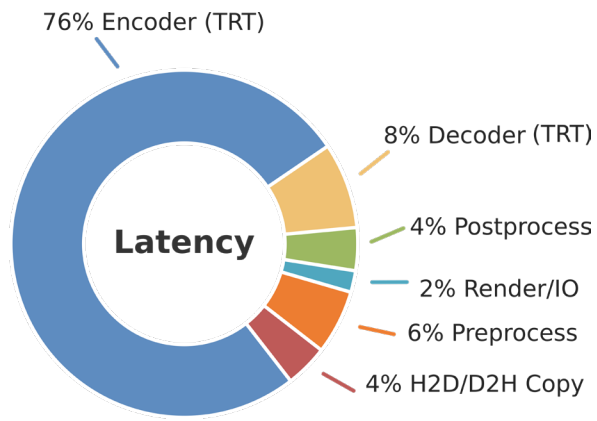
NVIDIA Jetson
Orin 64GB

Full Image (4096*3000) onboard Inference: **5.8** FPS
Patch (1024*750, batch=16) Inference: 93 FPS





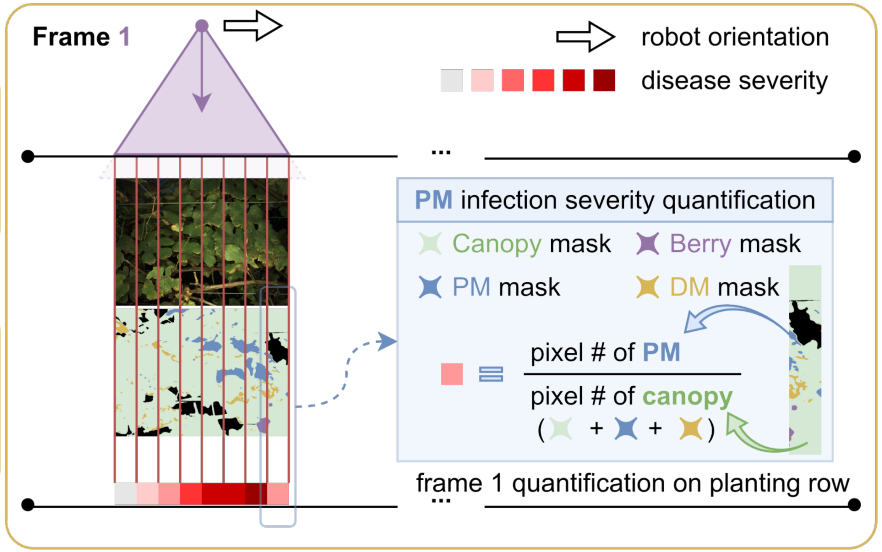


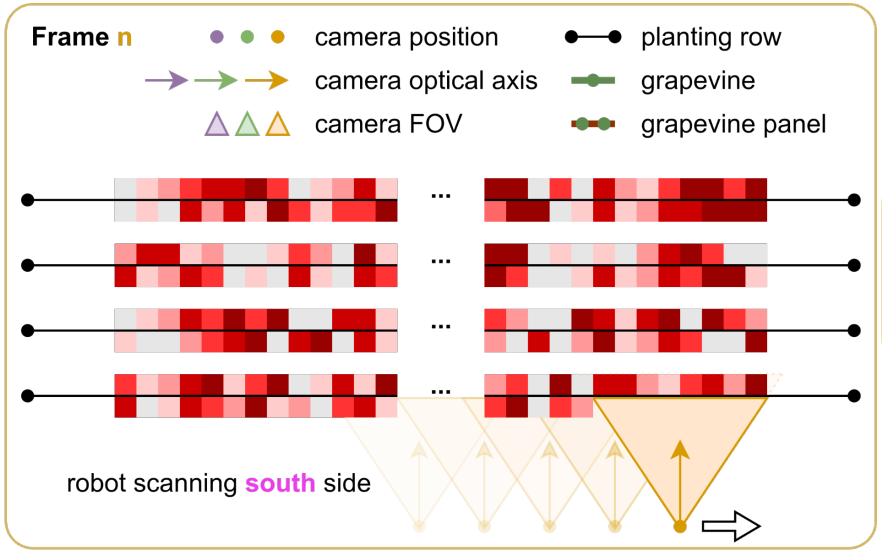


Geo-Referenced Data Mapping

row-based spatial discretization

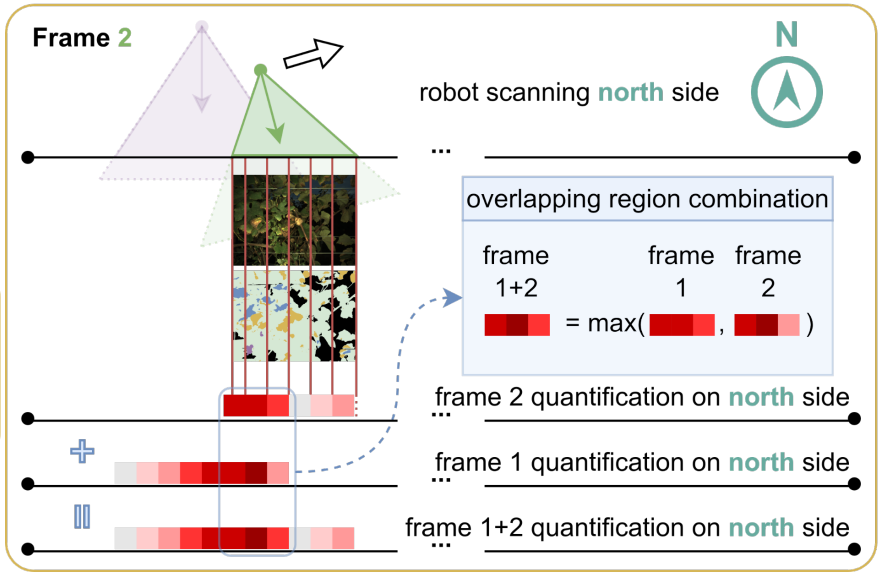
back-projection to image space

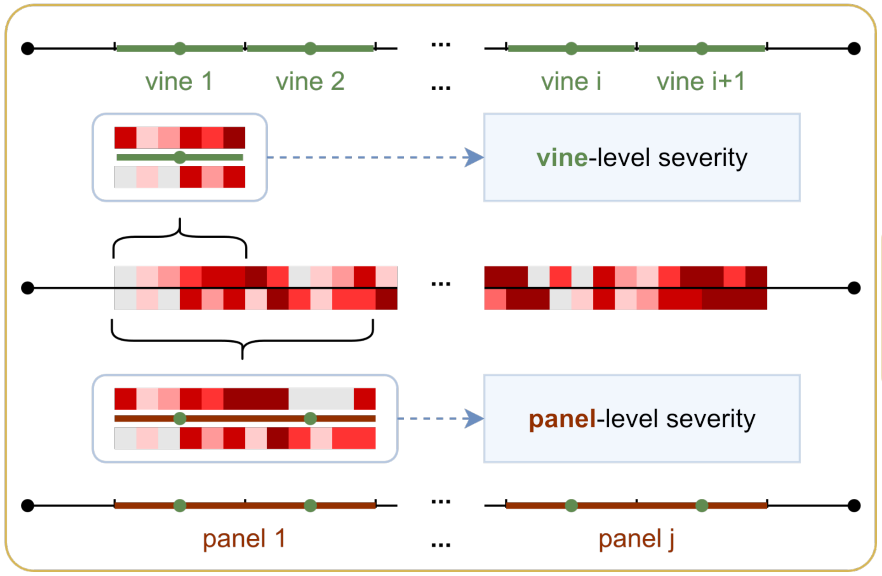




multi-view perception

local disease quantification





global spatial aggregation

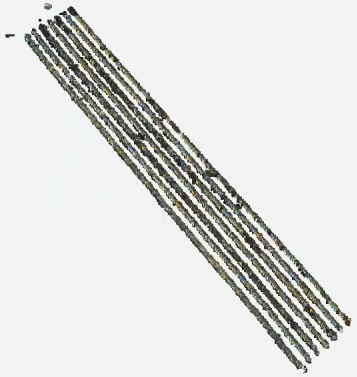
3D Reconstructed Point Clouds and Disease Map

FoundationStereo
➔ **Depth**

SuperPoint + LightGlue + PnP
➔ **relative camera poses**

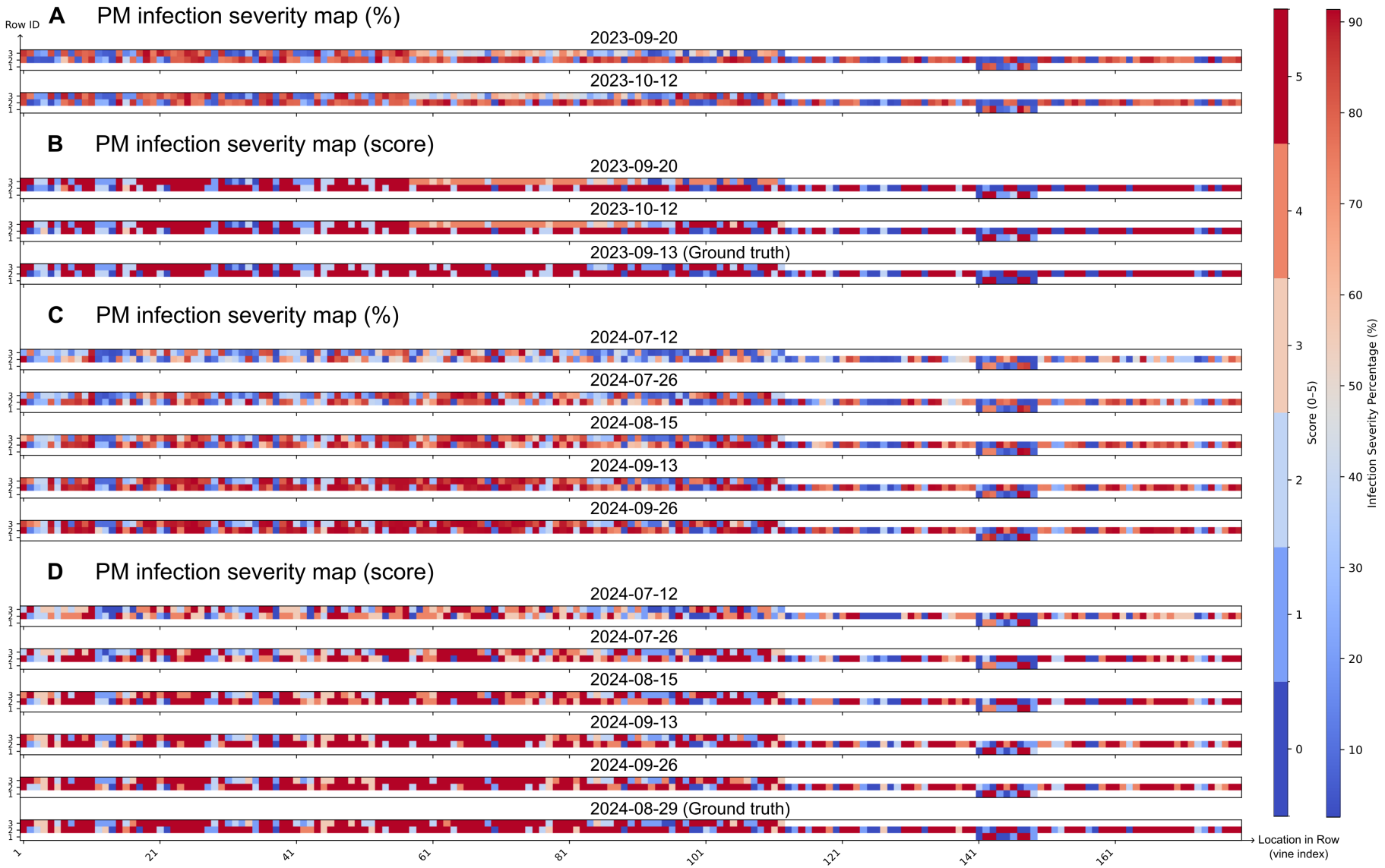
GNSS and approximate camera-to-vehicle extrinsics
➔ **global alignment**



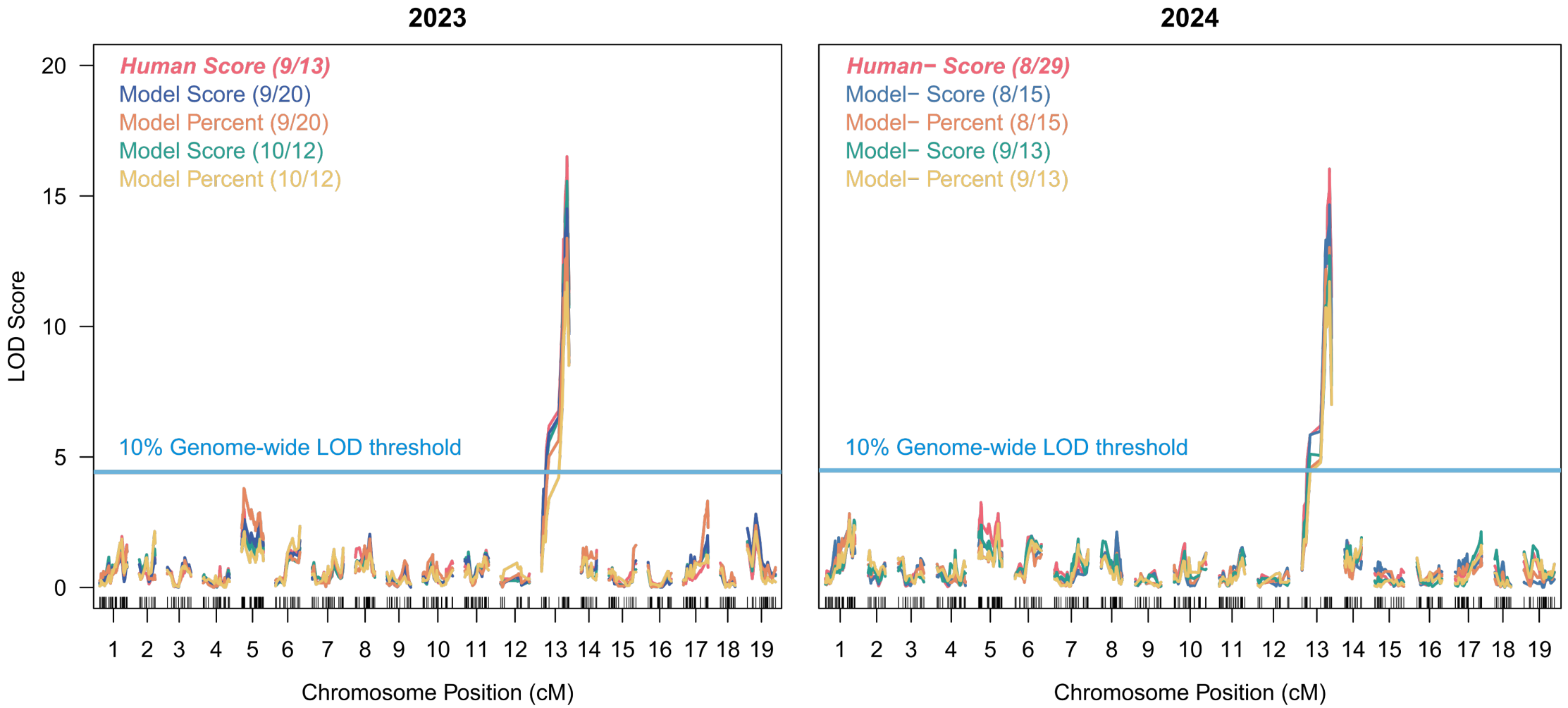


Spatio-Temporal Disease Map

- Frequency?
- Throughput?
- Precision?



Quantitative Trait Locus (QTL) Analysis on PM Resistance



PhytoPatholoBot Next Generation (PPB-NG)

GNSS Antenna
Sparkfun SPK6618H



Dual GNSS Receiver
MJRTK UM982



SWIR Power Control Unit
Specim PCU



Computer for Data Acquisition
Vecow ECX-3200 (M12)



Robot Base
Farm-ng Amiga

Computer for Navigation
Raspberry Pi 5



In-view White Reference (for Hyper-spectral cameras)

Hyper-spectral Cameras
Specim SWIR & Specim FX10e (VNIR)



Stabilization Mount
SOMAG RSM 400



Thermal Camera
FLIR A6701 (MWIR)

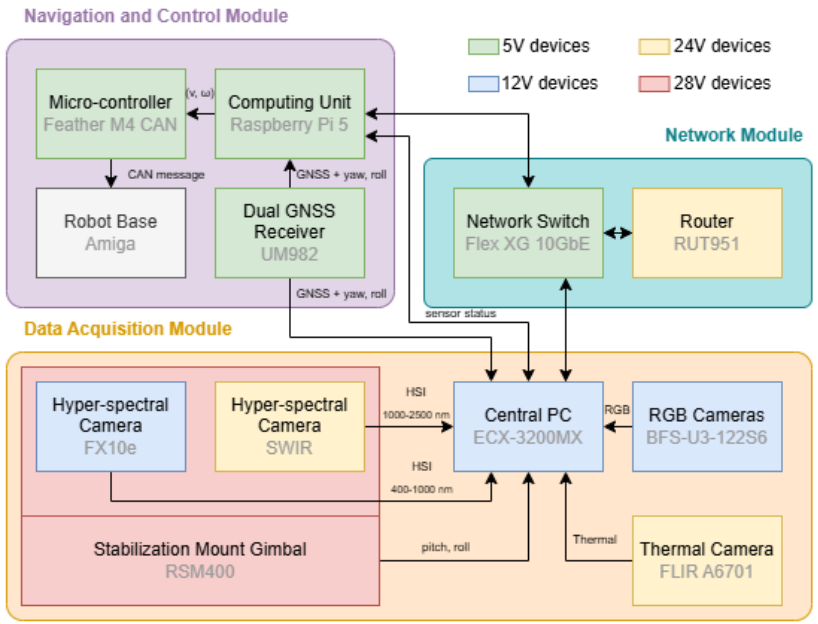


RGB Camera
FLIR BFS-U3-123S6

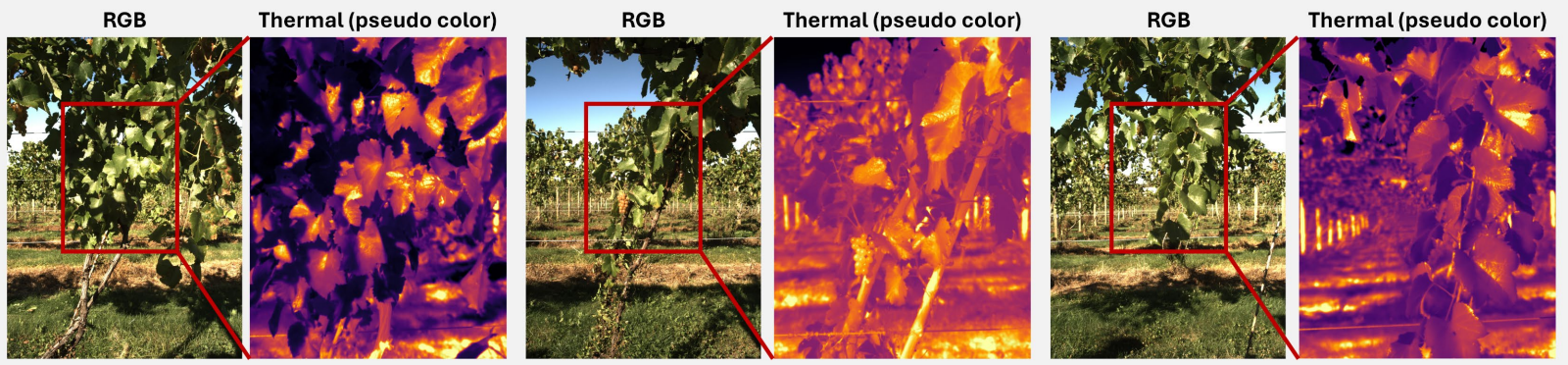




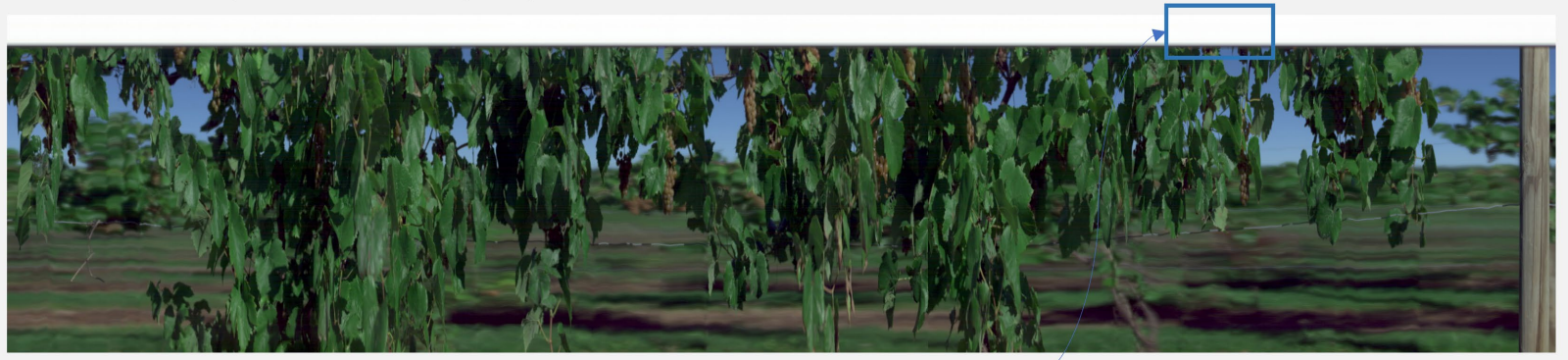
PPB-NG Modular Design Sample Data





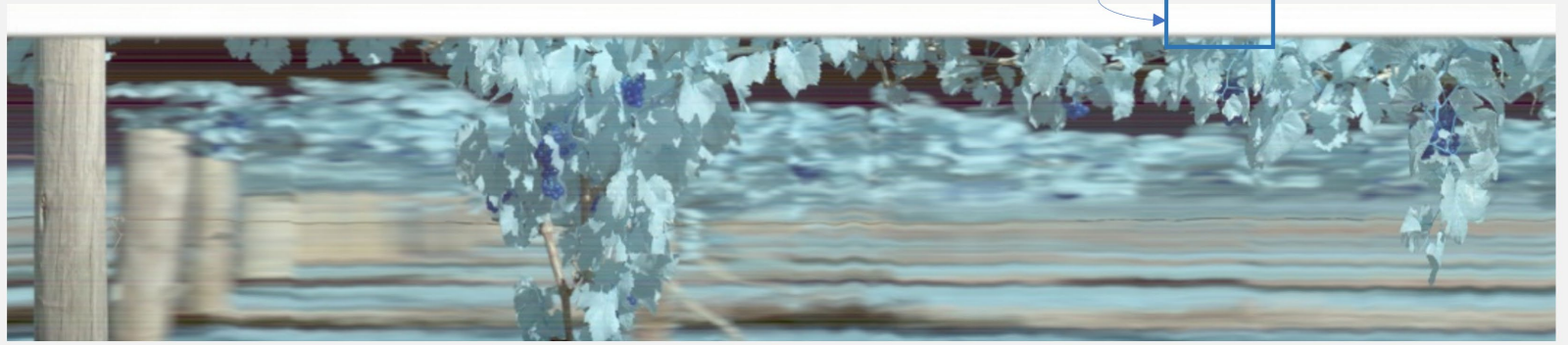


400-1000nm VIS-NIR (visible-band RGB composite)



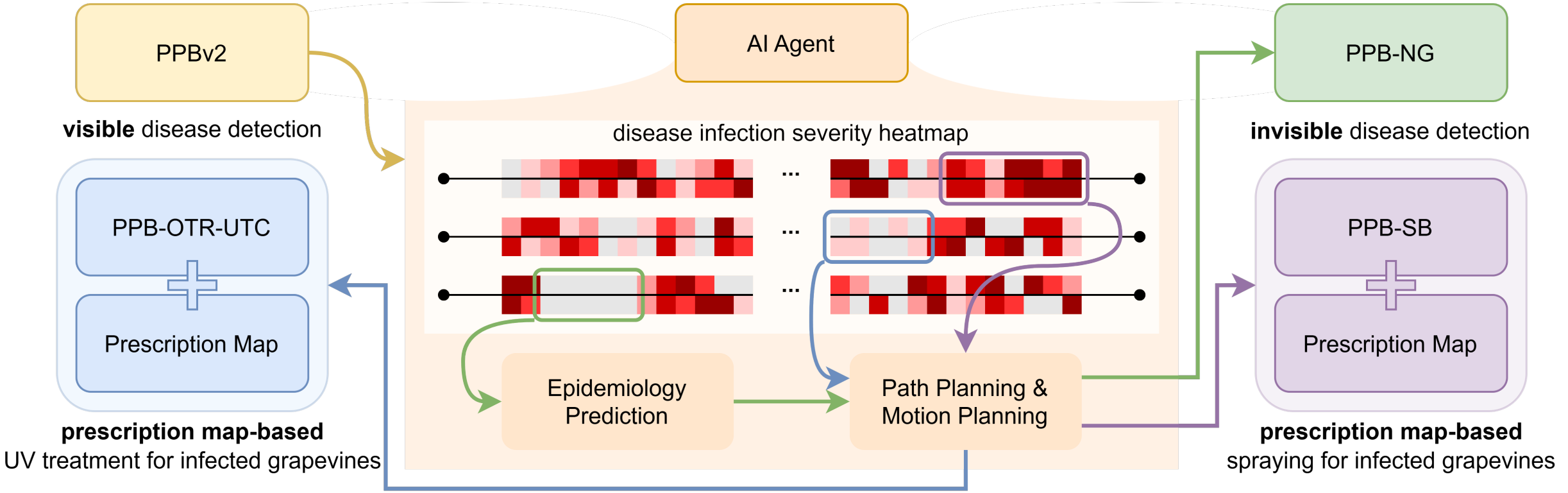
1000-2500nm SWIR (false-color composite)

In-view white reference



AI Agent Orchestrated Field Robotic Swarm

- Shared dynamic field state enables 1) concurrent sensing, 2) selective inspection, and 3) targeted intervention.



Shared State • Capability-Based Coordination • Asynchronous Replanning

More Robot Applications

- Autonomous UV treatment

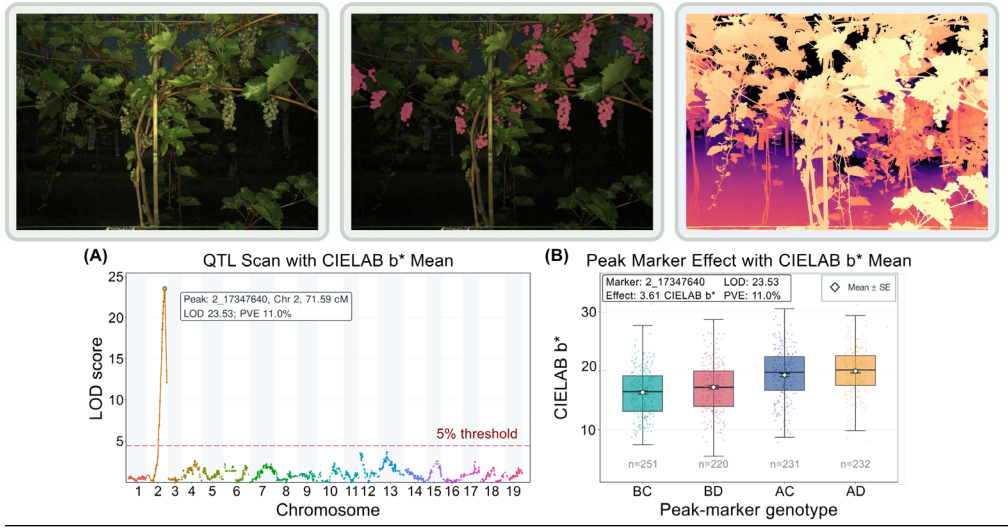


- Robot mowing

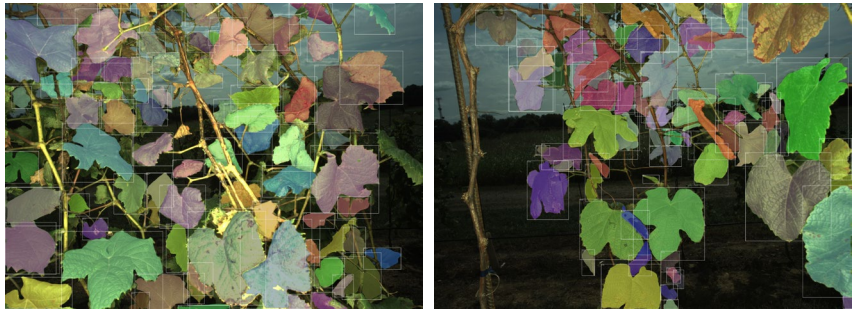




- Grape berry color QTL analysis



- Leaf instance segmentation for leaf size estimation



- Budbreak detection



Thanks for your attention!



Yiyuan Lin 林翊源

Center for Agricultural Intelligence and Robotics
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Personal Website: https://yiyuanlinxx.github.io/
CAIR Website: https://www.cair.cals.cornell.edu/

My Robots

About Me

CAIR