東京大学
THE UNIVERSITY OF TOKYO

Utokyo Field Phenomics Lab

Virtual broccoli farmland by fusing close-range and aerial phenotyping

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01

Introduction

1. Introduction

Farmland monitoring

Conventional method

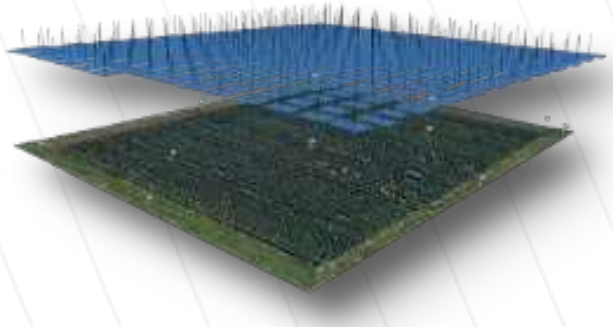
For agriculture activities, it is necessary to monitor the crop status

- Response to stress, like disease, pest, etc. in time.
- Decide the optimal harvest date

Limits: Time costly, labor intensive, low accuracy & efficiency

1. Introduction

Aerial survey



Drone-based phenotyping approach

Helps to collect image data for entire field in a few hours

(high efficiency)

The resolution is not enough for accurate organ-level analysis

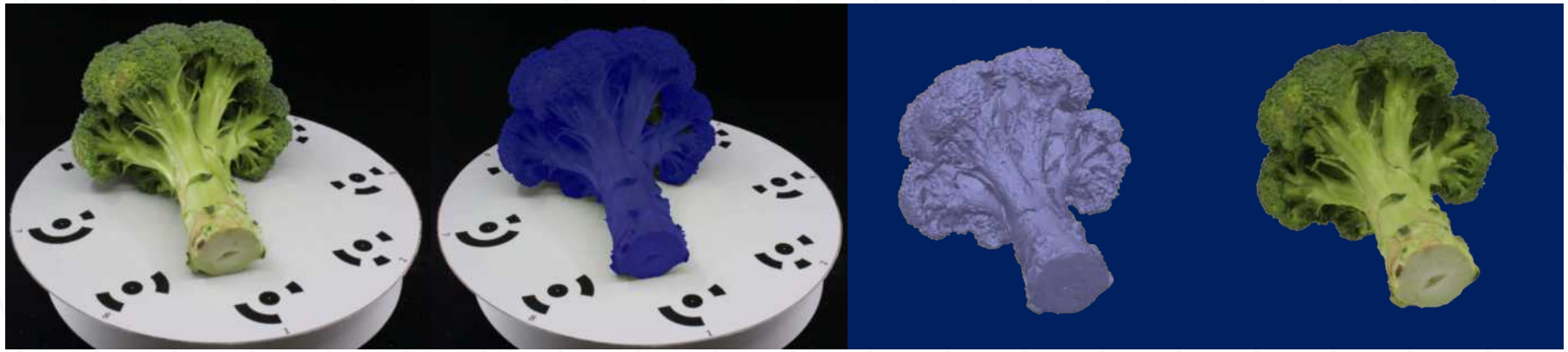
Leaf occlusion

(Low quality)

Poor organ structure

1. Introduction

Close-range survey



Close-range (indoor) reconstruction can obtain ultra high-quality crop models

- Need destructive sampling
- ~10min processing per plant
- Not suitable for surveying all plants in entire field

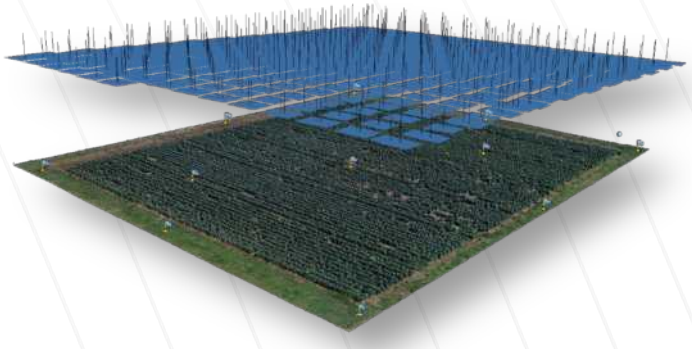
(Low efficiency)

1. Introduction

Research question

(high efficiency)

(Low quality)



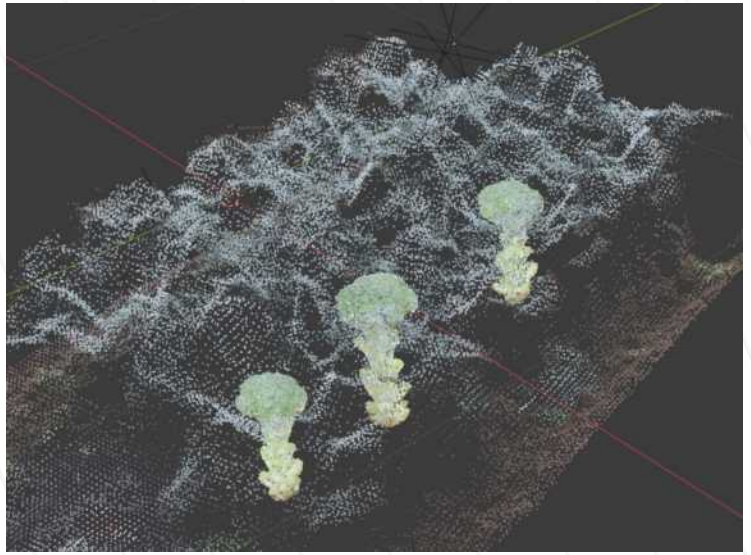
Aerial survey

(high quality)

(low efficiency)

Close-range survey

(high efficiency & quality)

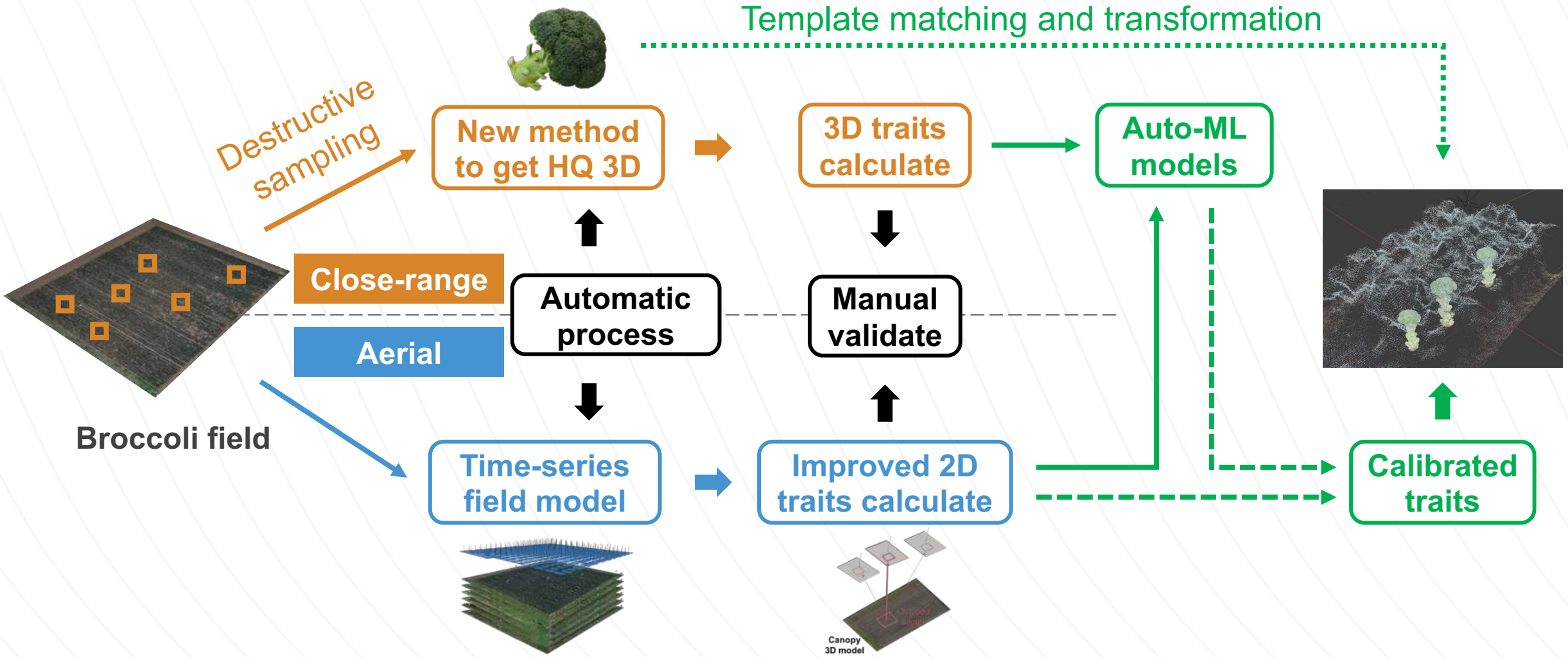


3D high quality crop models of entire field (virtual farmland)

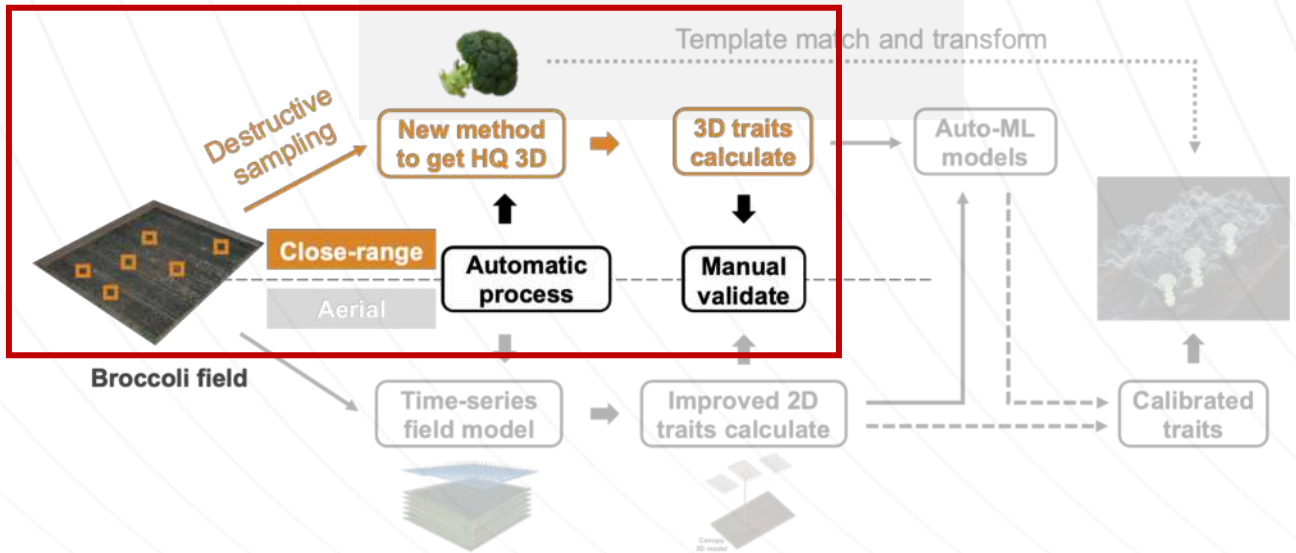
Predict yield, harvest date and income more accurately

1. Introduction

The proposed data-fusion workflow

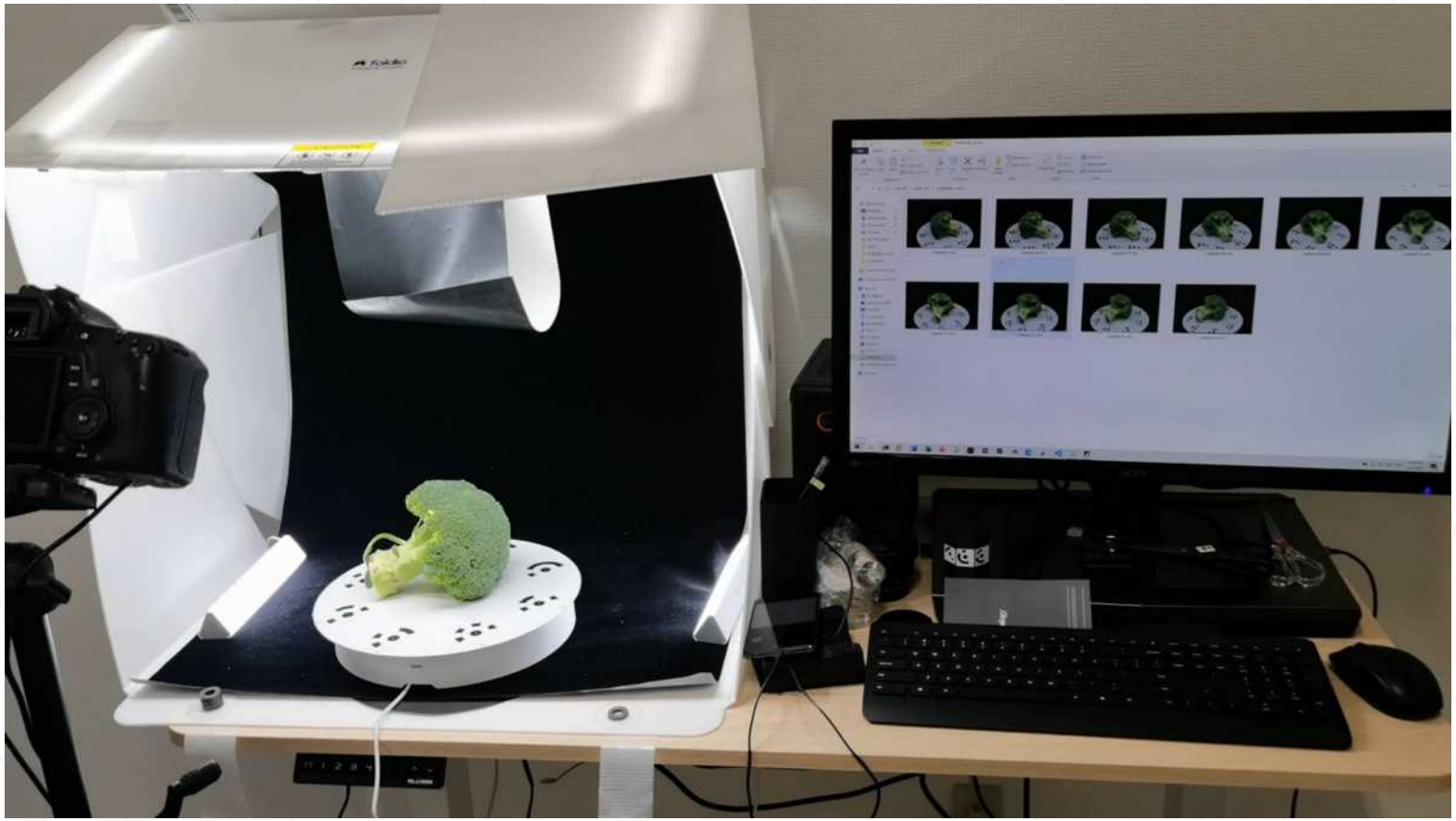


02 Close-range 3D pipeline



2. Close-range 3D pipeline

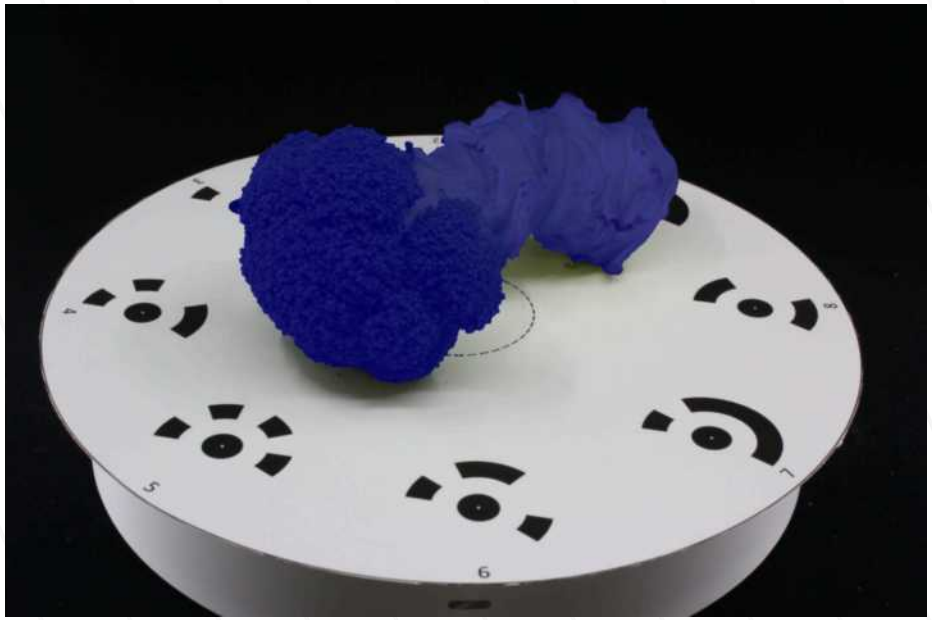
Broccoli head 3D reconstruction



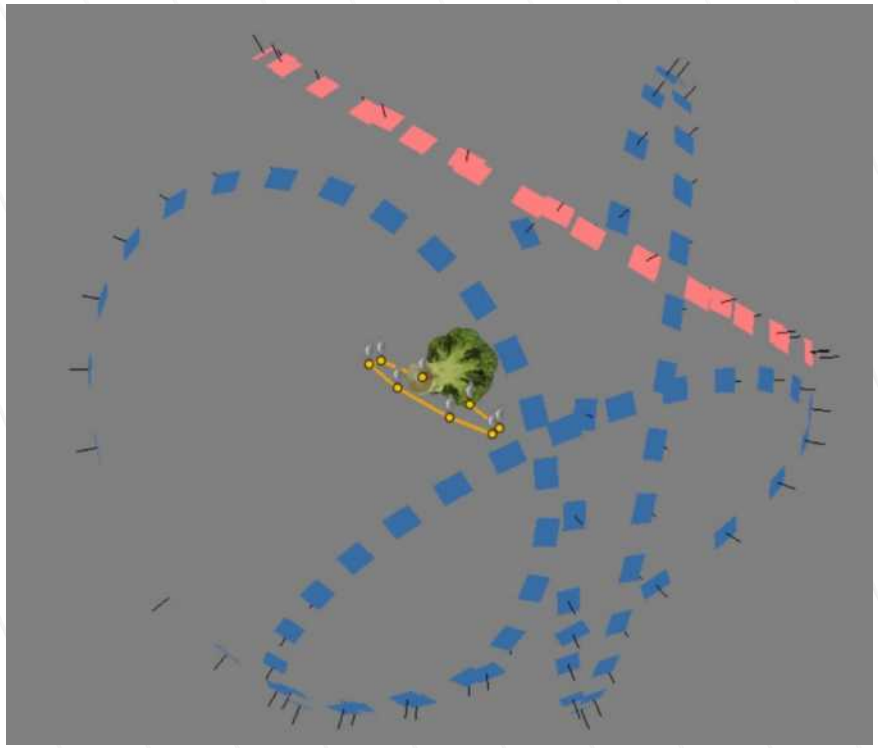
1. Semi-automatic image collection

2. Close-range 3D pipeline

Broccoli head 3D reconstruction



2. Image preprocessing by labor-saving dual deep learning approaches (remove background effects)



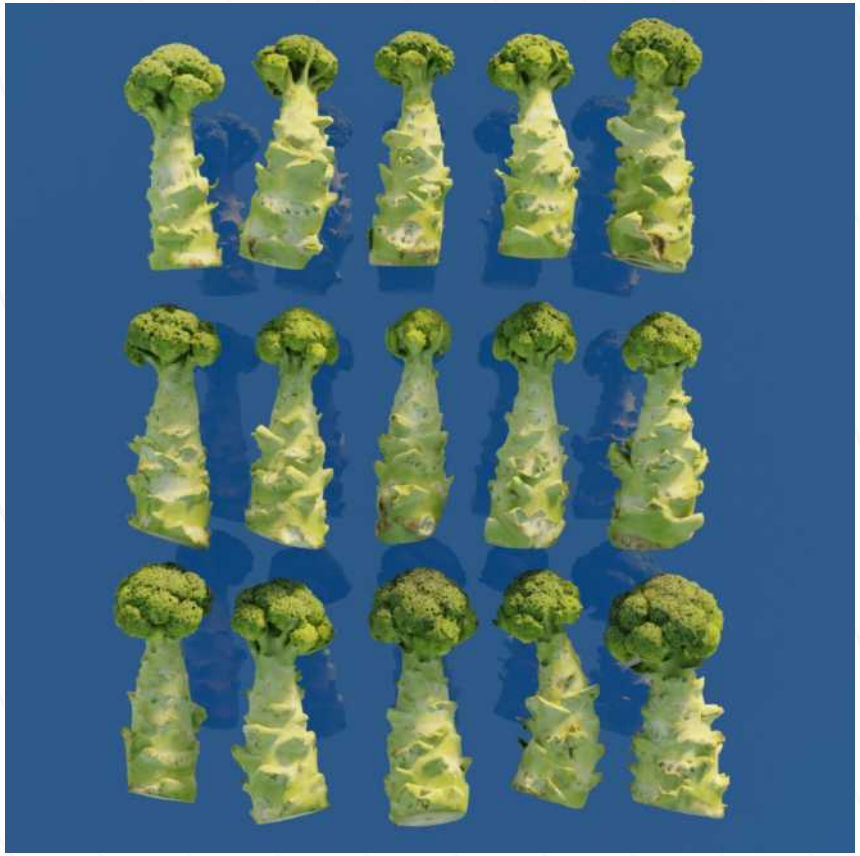
(3D reconstruction)

Metashape PY

2. Close-range 3D pipeline

Broccoli head 3D reconstruction

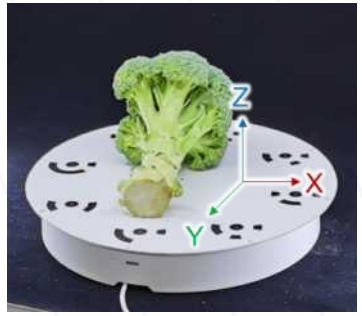
Real world photo

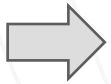


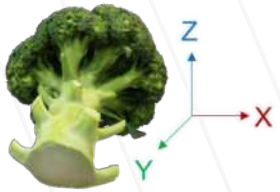
Obtained 3D model

2. Close-range 3D pipeline

Top direction correction



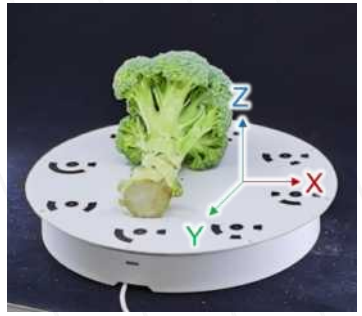




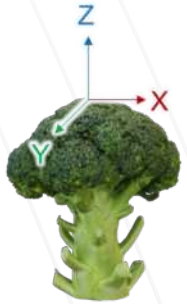
“Lying” Coordinate

2. Close-range 3D pipeline

Top direction correction



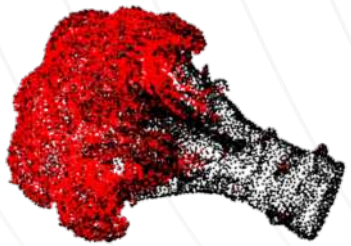
“Lying” Coordinate



Corrected Coordinate

(a) Crown segmentation

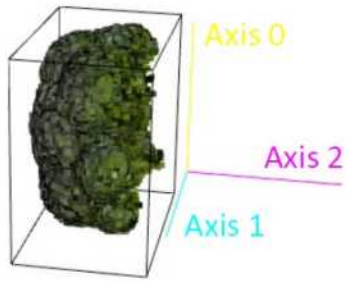
(1) original point cloud of obtained 3D head models



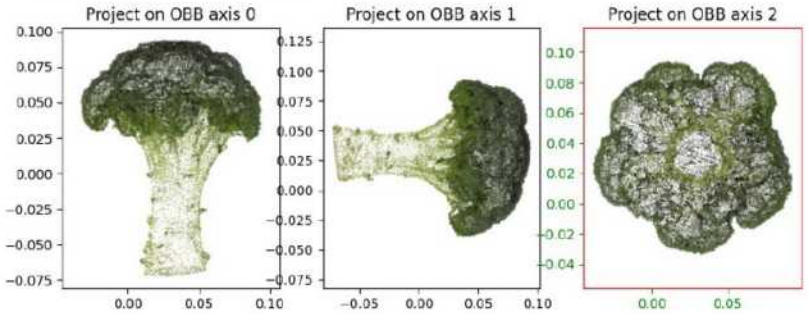
(2) Two-class unsupervised KMeans cluster by RGB color

(3) Unsupervised DBSCAN cluster and remove noise cluster by volume

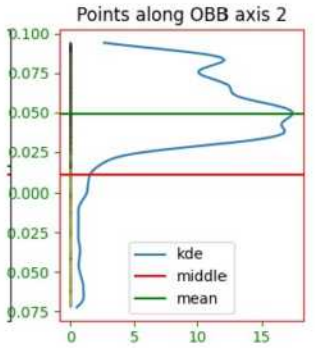
(b) Direction correction



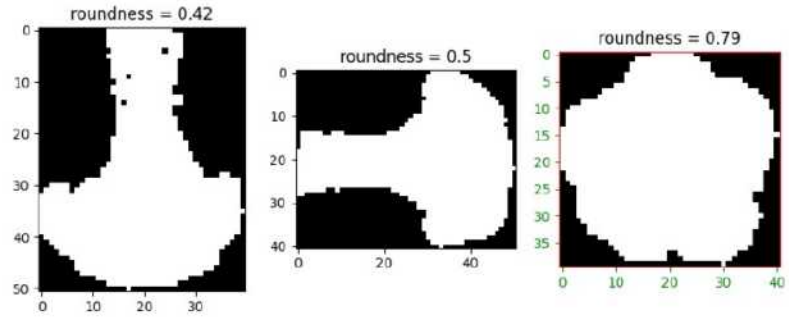
(4) Bounding box vectors



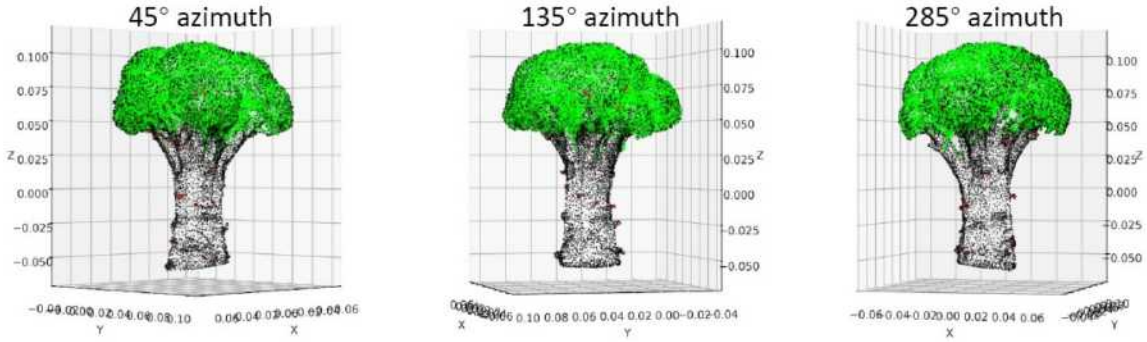
(5) Project broccoli head along vector directions



(7) Judge positive direction



(6) Use the highest roundness as top vector

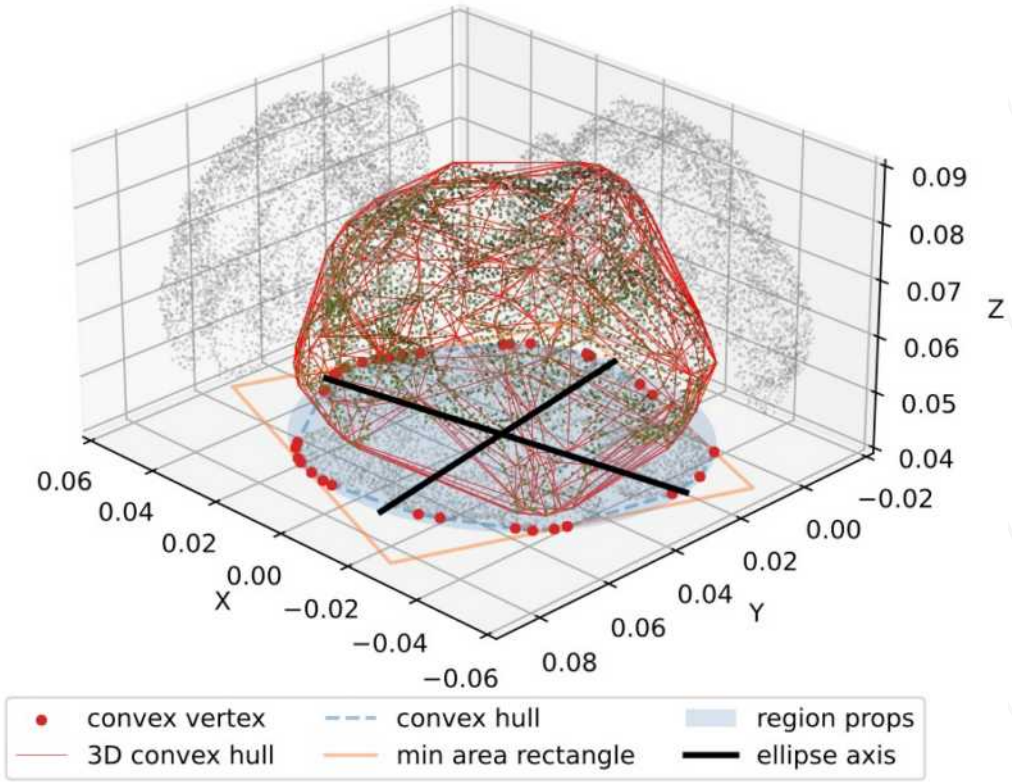


(8) Rotate broccoli head top to z-axis positive direction

2. Close-range 3D pipeline

Traits calculation

(c) Traits calculation



(9) Crown traits visualization

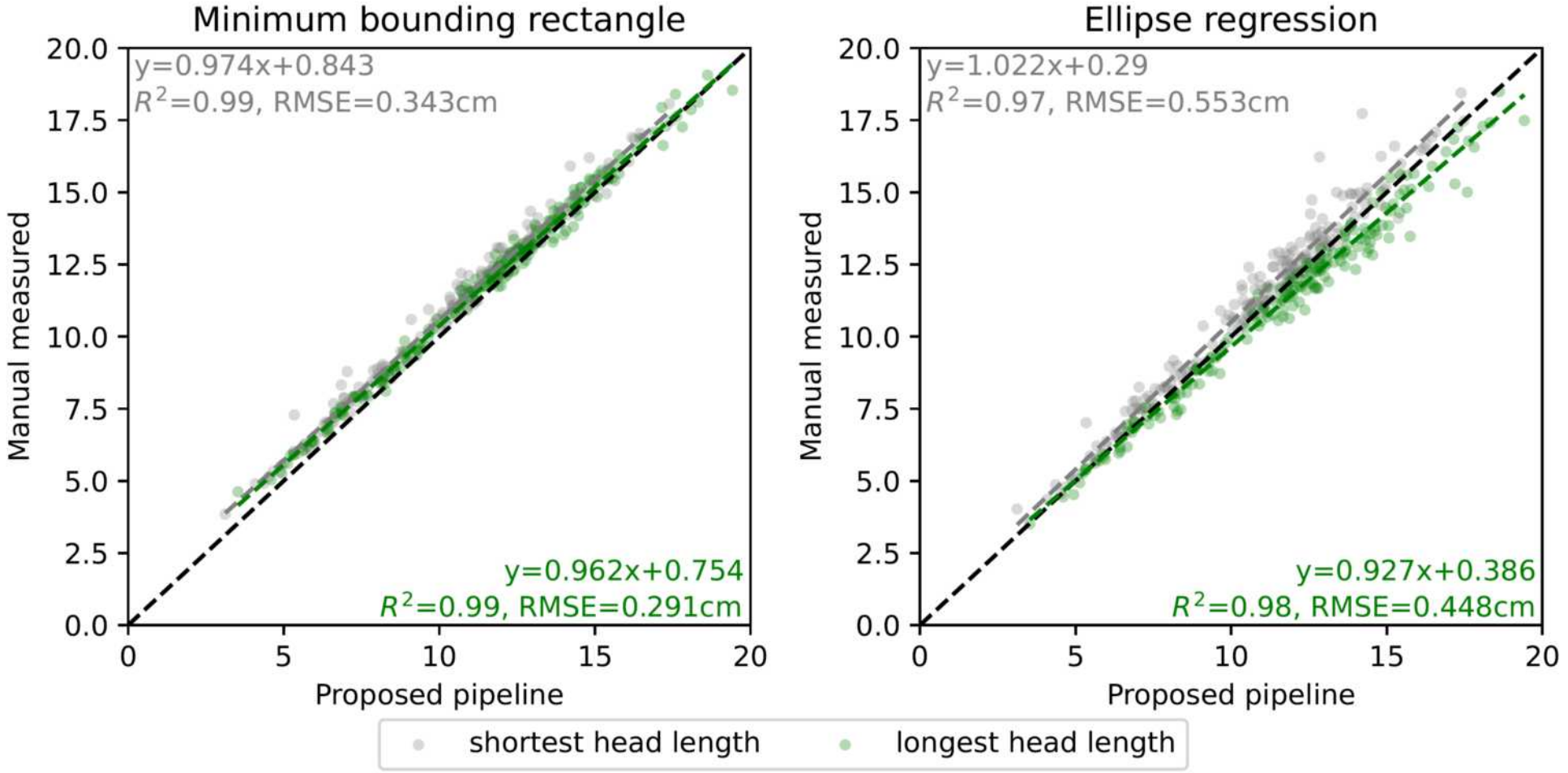
	Traits	Unit
1D	Crown/head height (m)	m
	Center point (x, y)	m
	Centroid point (x, y)	m
	Roundness	-
2D	Minimum area rectangle (width, length)	m
	Ellipse axis length (long, short)	m
	Ellipse orientation	degree
	2D convex area	cm^2
	Projected area	cm^2
3D	3D Convex volume	cm^3
	3D Concave volume	cm^3

(10) Obtained Morphological traits

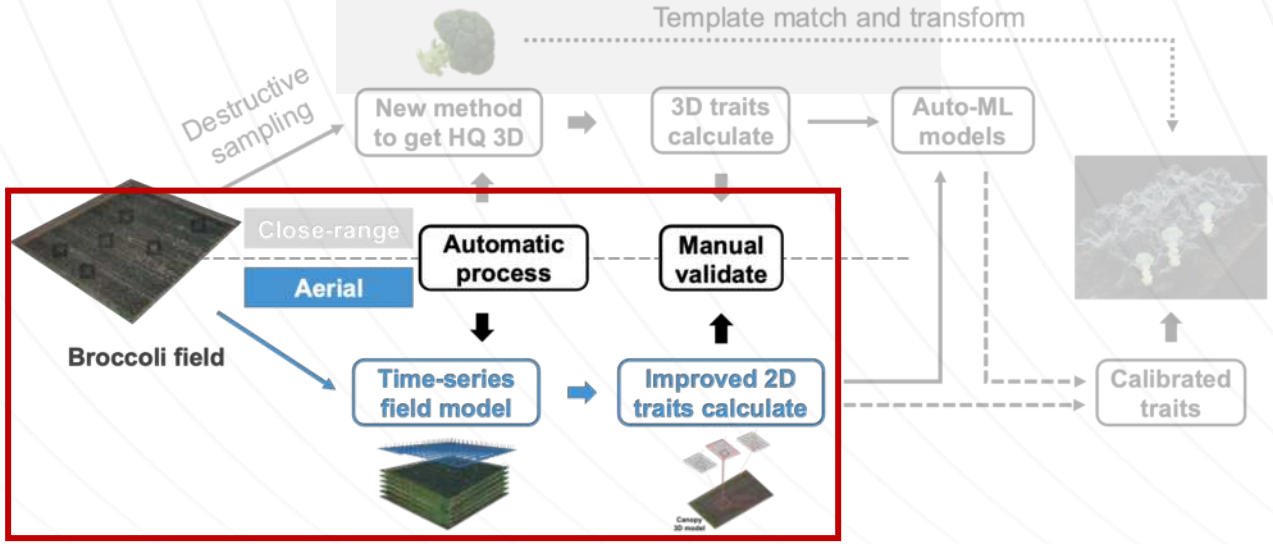
2. Close-range 3D pipeline

Traits validation

Achieve high-correlation with the manual measurements

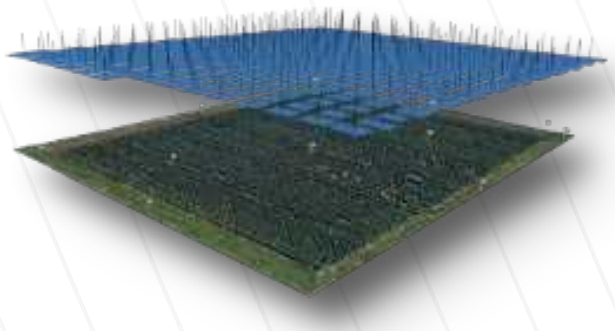


03 Aerial 3D pipeline



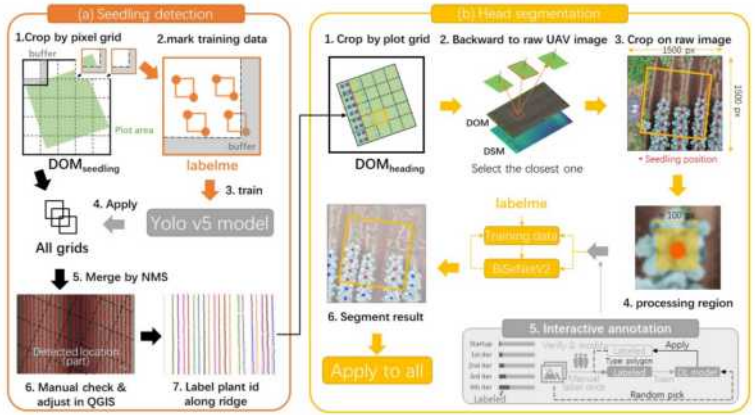
3. Aerial 3D pipeline

Field data collection and analysis

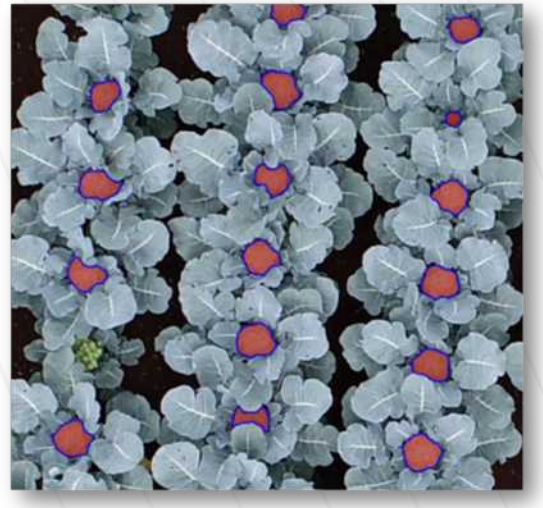


(3D reconstruction)

Metashape PY



Weakly supervised segmentation pipeline (labor saving)

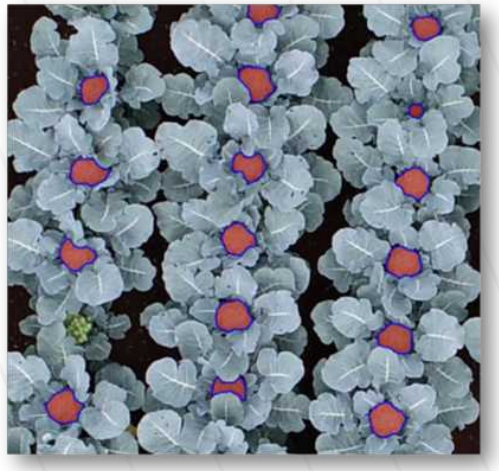


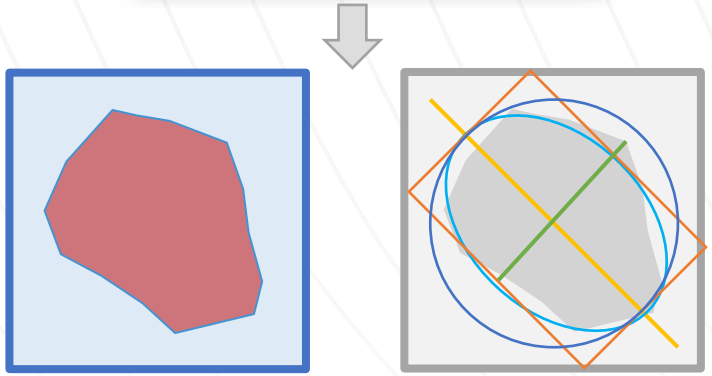
Head segmentation results

3. Aerial 3D pipeline

Morphological traits calculation

For each broccoli head





Minimum area rectangle max/min side-length

Equivalent diameter

Eccentricity, circularity

Major axis length

Minor axis length

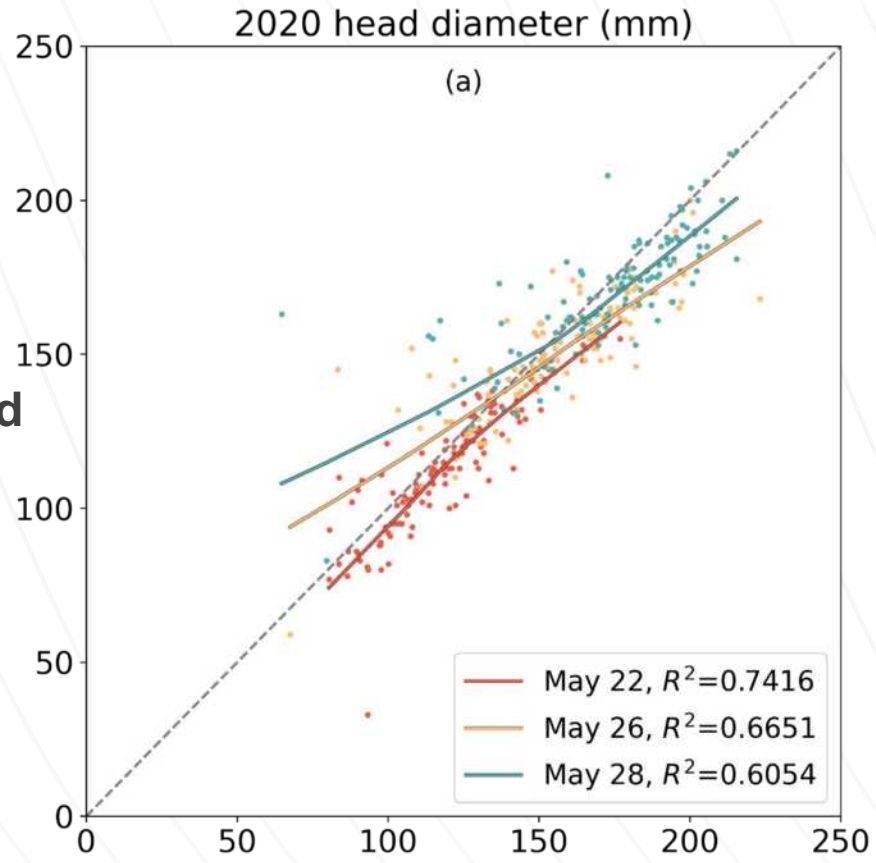
Area, perimeter

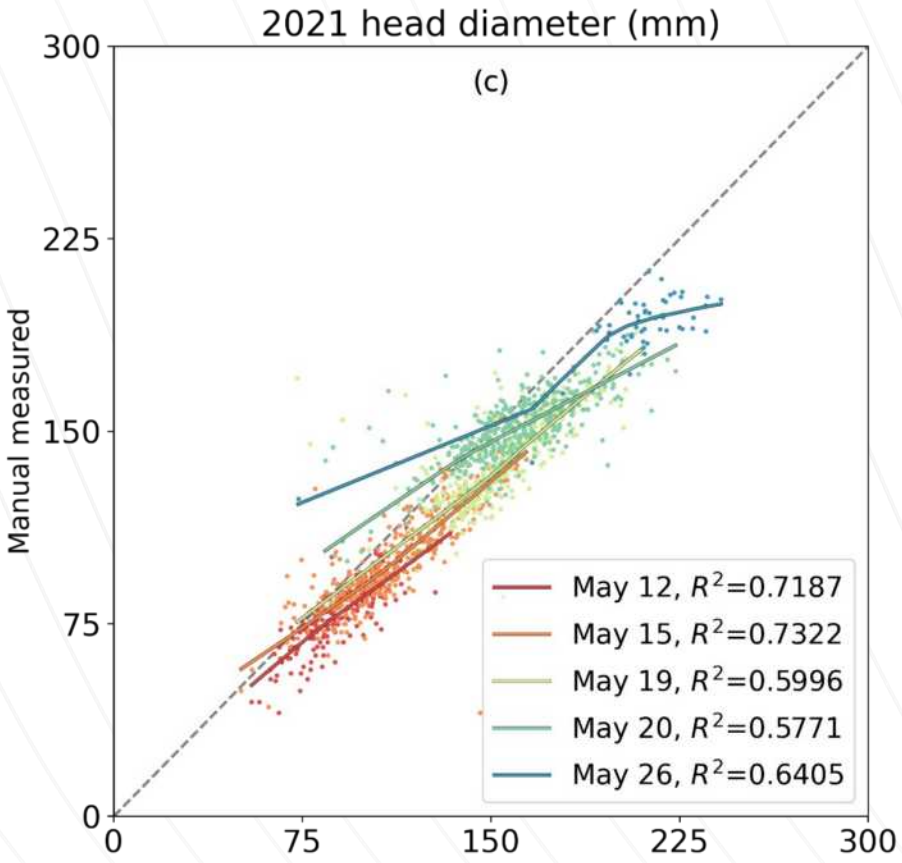
Convex area

3. Aerial 3D pipeline

Traits accuracy validation

- **Has acceptable correlation with manual measured head size**





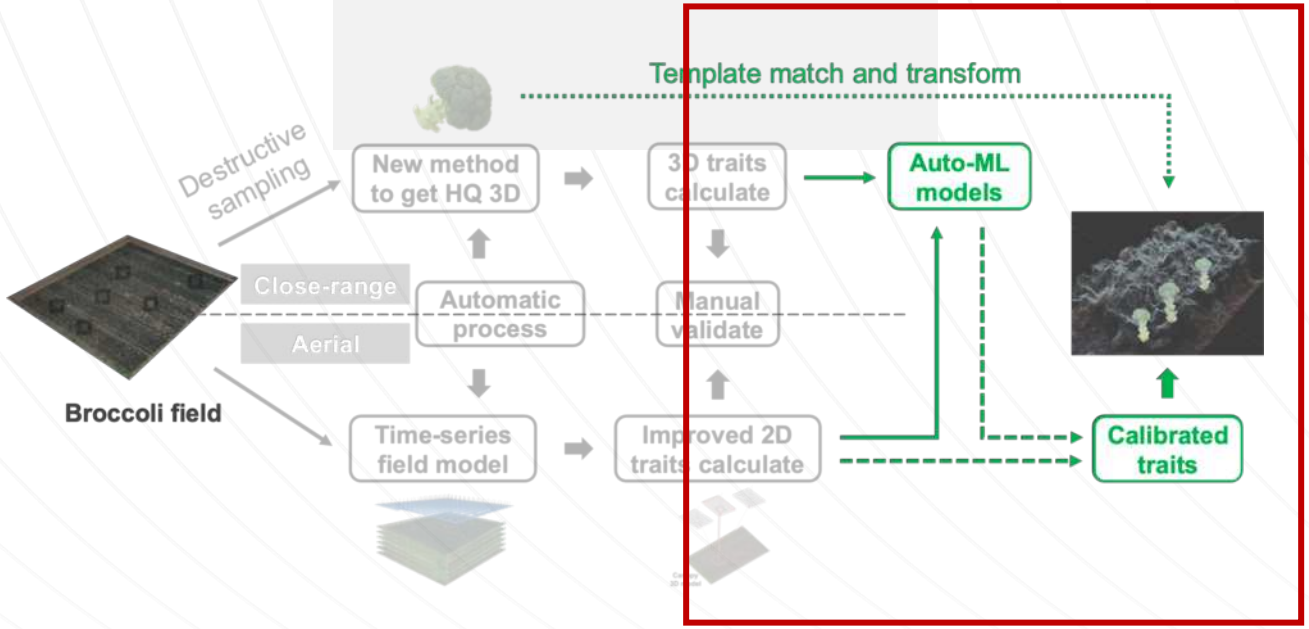
Y: Manual field measured

X: Aerial measured

Error source

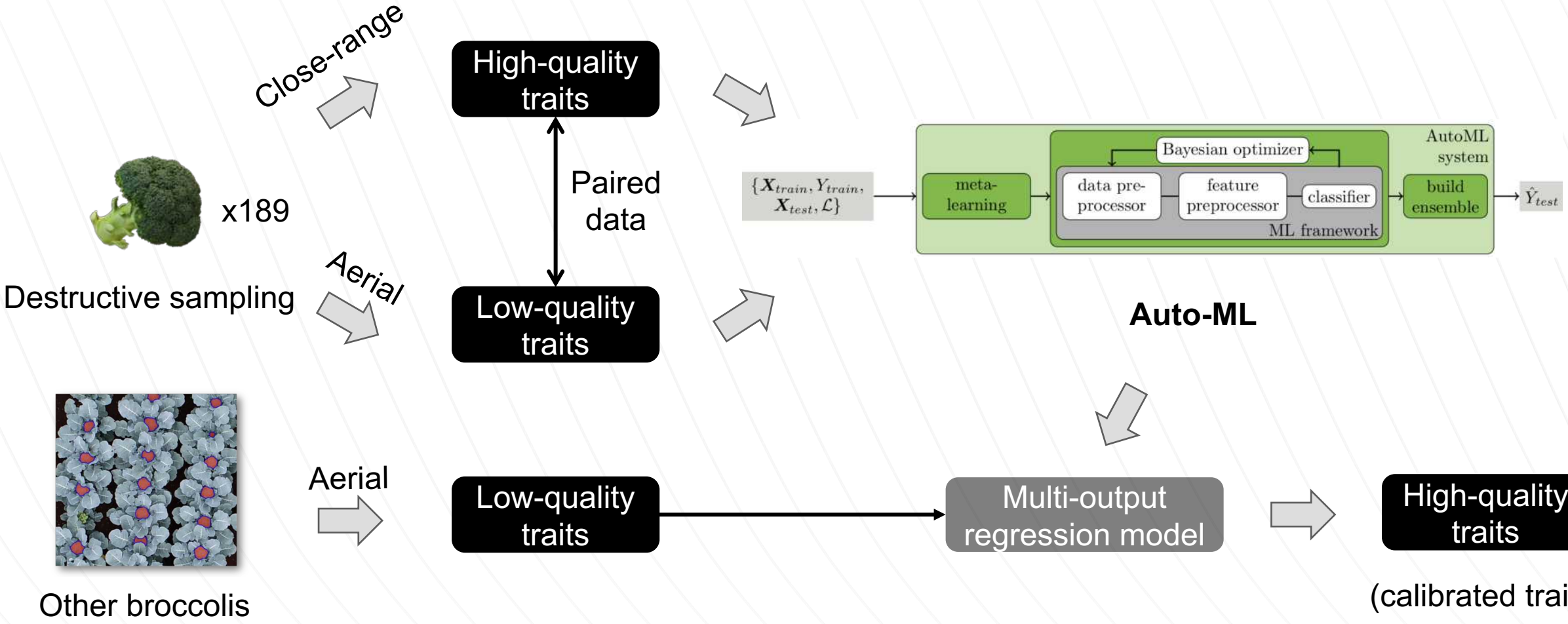
04

Cross-scale data fusion



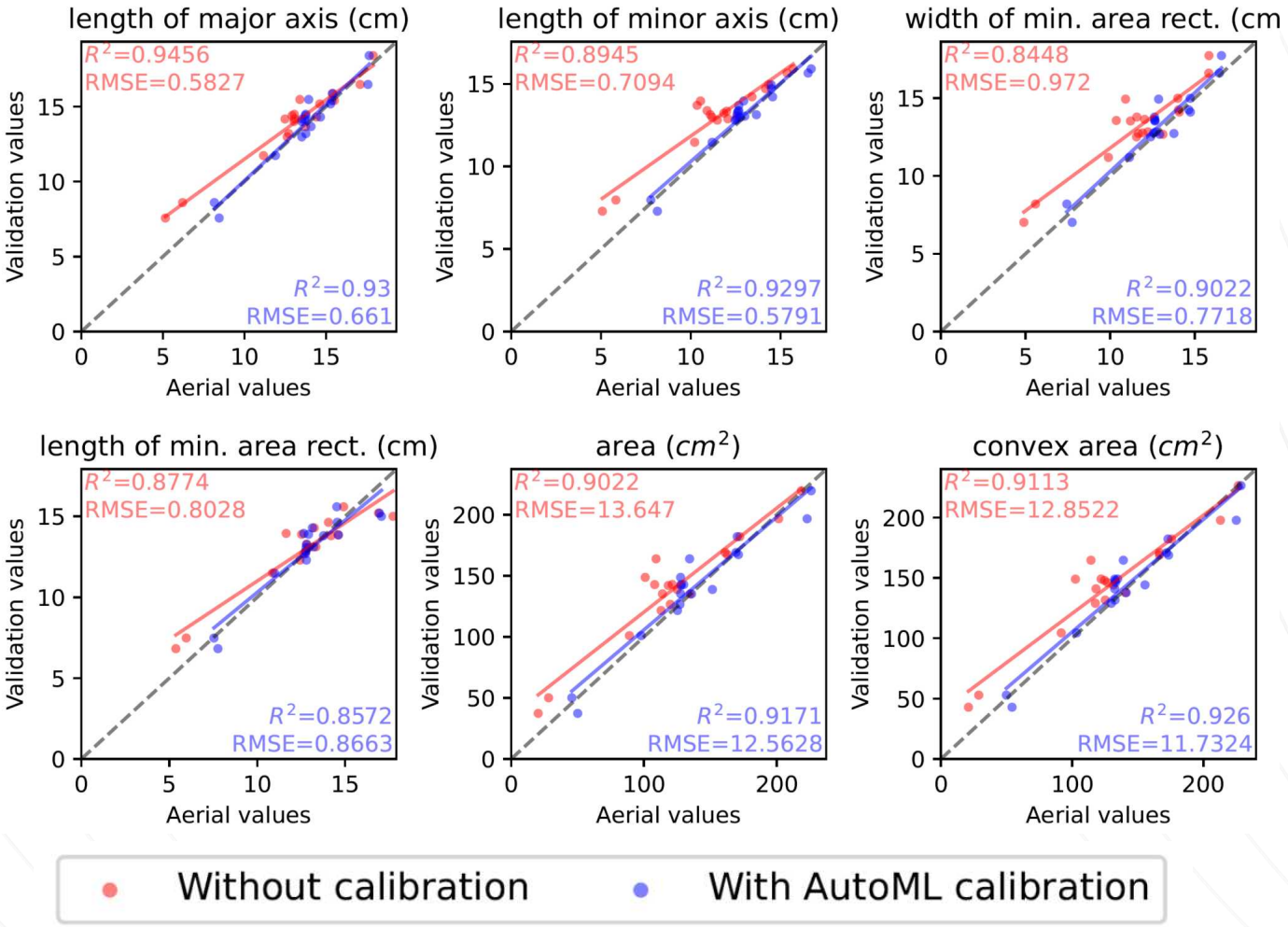
4. Cross-scale data fusion

Model calibration by auto-machine learning



4. Cross-scale data fusion

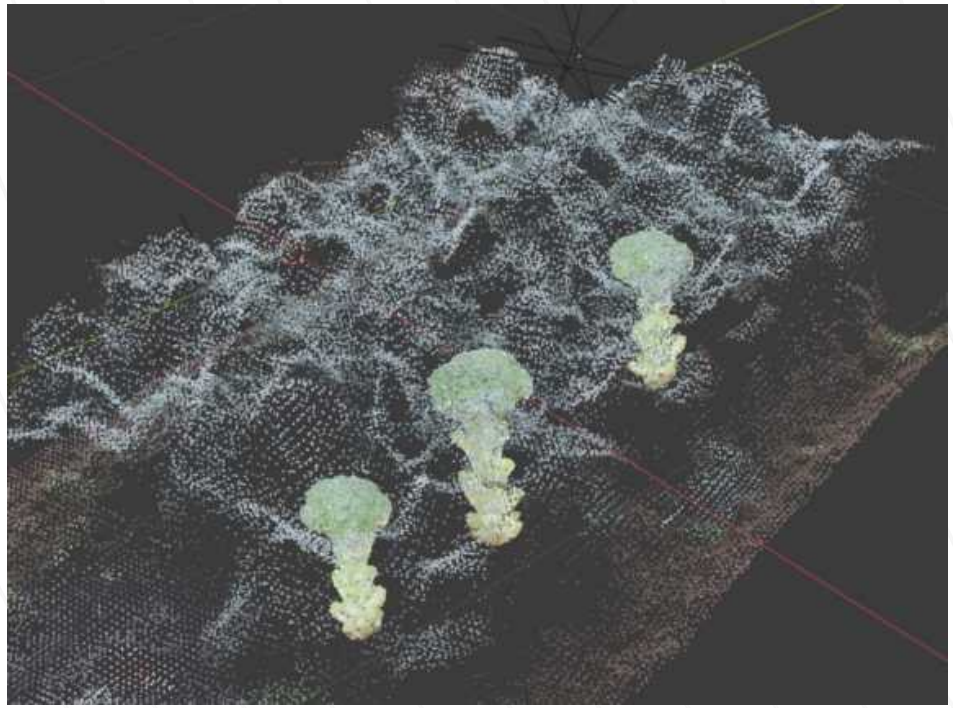
Performance of Auto-ML calibration



- **The Auto-ML calibration improved the traits closer to actual size**

Error source of underestimation

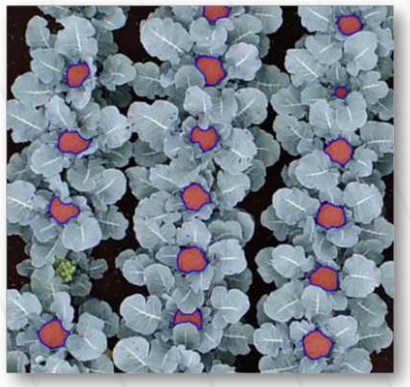
4. Cross-scale data fusion



How to put high-quality close-range models back to low quality field model?

4. Cross-scale data fusion

Template matching between aerial and close-range models



Broccolis from aerial

head position

Put the template back to field model

calibrated traits

Lmin'

Lmax'

Size transform

Lmin

Lmax'

Z
X
Y

Adapted template

x189

Broccoli from close-range

1
2
3 High quality 3D traits
4
5
…

Calculate difference

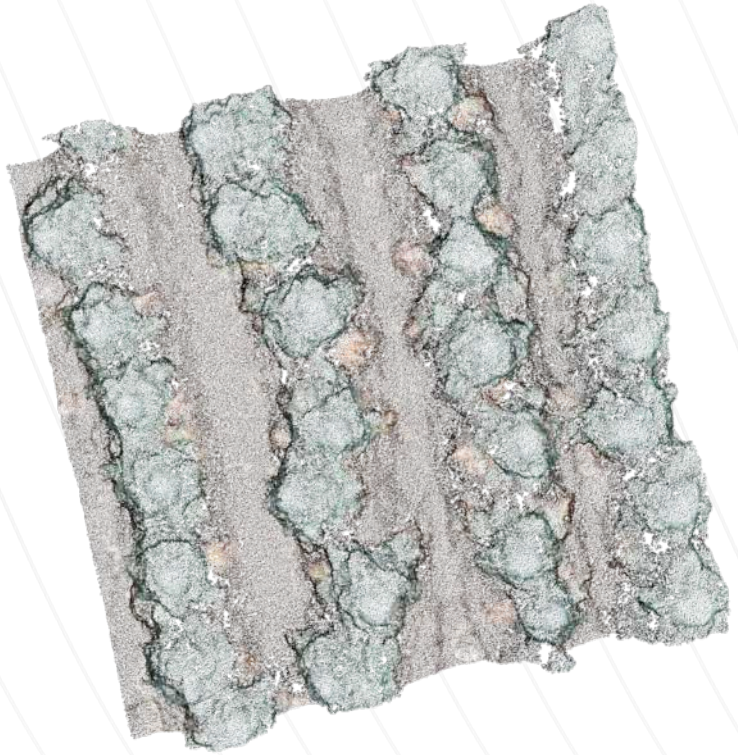
Template database

Pick out one with smallest differences

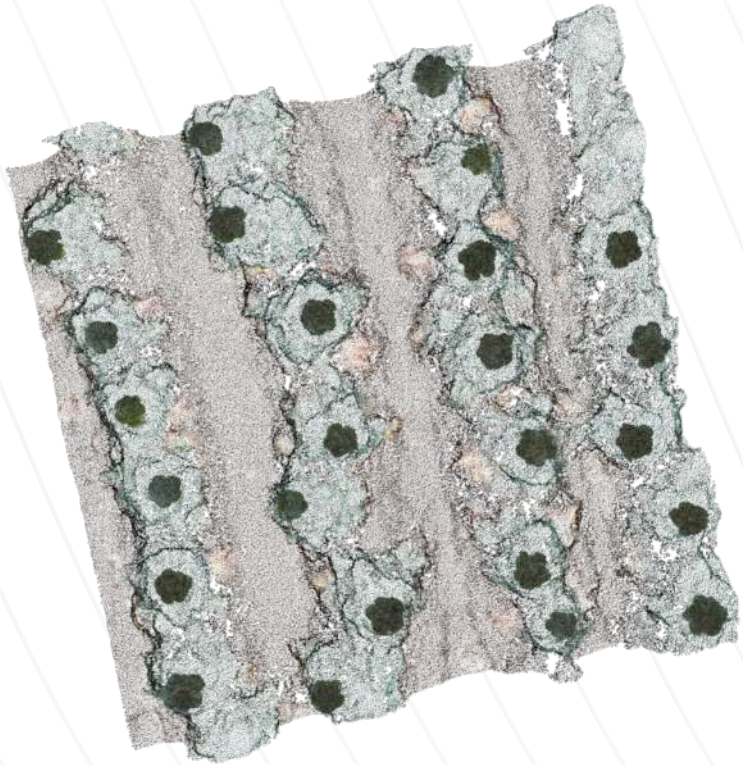
4. Cross-scale data fusion

Template matching results

Aerial segmentation results



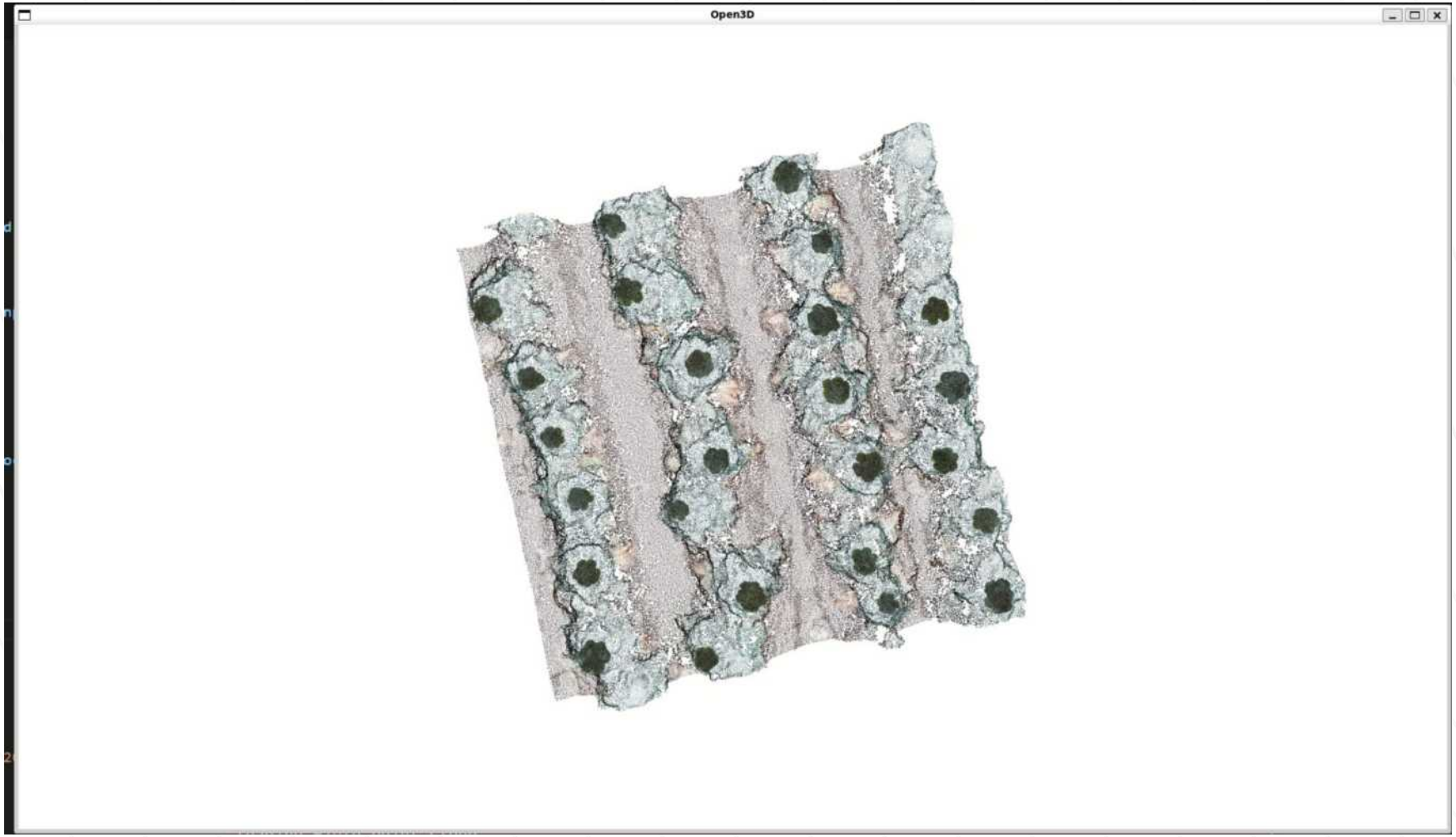
Aerial field 3D models



Template matched models

4. Cross-scale data fusion

Template matching results



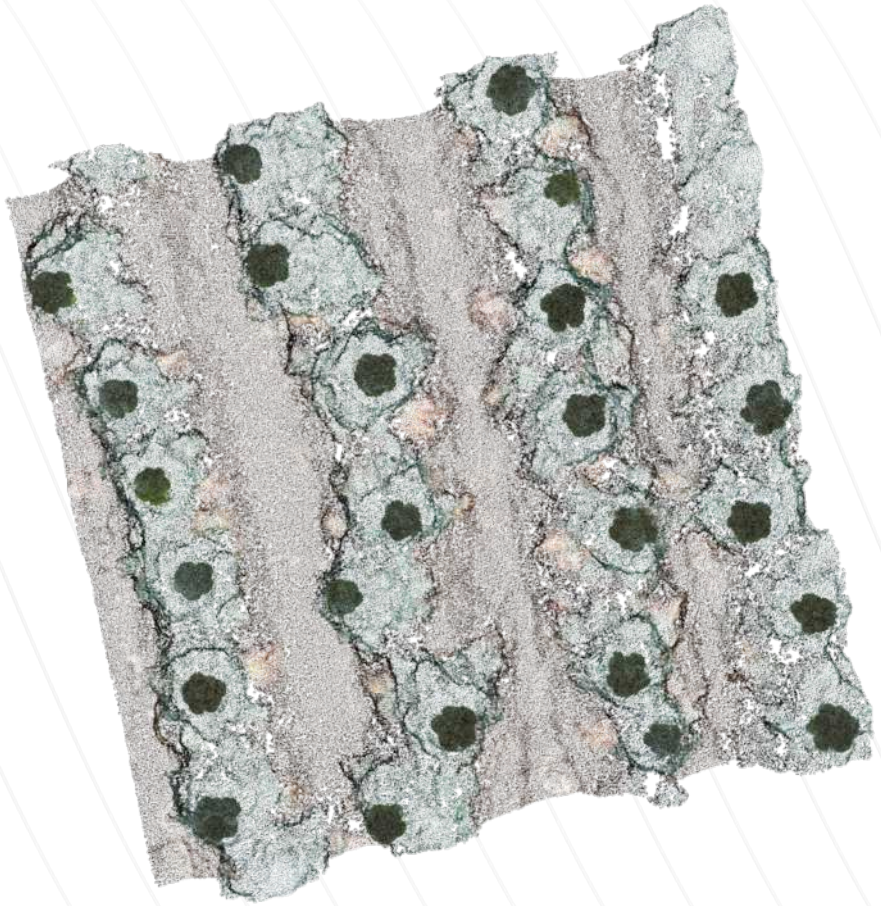
05 Discussion & Conclusion

5. Discussion & Conclusion

- We obtained the 3D structure model and calculated the morphological traits of broccoli head from aerial and close-range
- Implemented the virtual broccoli farm by fusing the model data from aerial and close-range

For future work

- Implement a more user-friendly UI and apply to actual farmland
- Update the template matching and transformation to shape-based rather than current numerical-based



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Thank you

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