Estimate Optimal Harvest Time by Cross-scale Assimilated Digital Broccoli Farmland

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Background

In field food loss of fresh broccoli caused by non-standard shipping size is a common problem nowadays, which is mainly affected by non-proper harvesting time. A proper harvesting time means the maximum the proportion of standard shipping size, hard to estimate by conventional method.

Contribution

Propose a solution to predict the proper harvesting time.

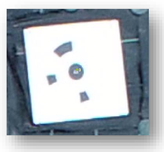
1. Build digital twin of 7000+ broccoli from individual to whole field.
2. Calculate the cross-scale assimilated size of broccoli.
3. Predict the broccoli size by growth model.
4. Predict profits by market price and growth model.

❶ Digital twin of in-field grown broccoli

Aerial scale by drone

RTK Phantom 4

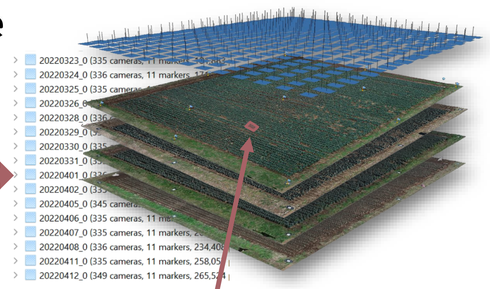
Coded ground control points (scales)



(3D reconstruction) Metashape

PY

Batch processing scripts



Time-series geo-referenced data

Ground scale by smart phone

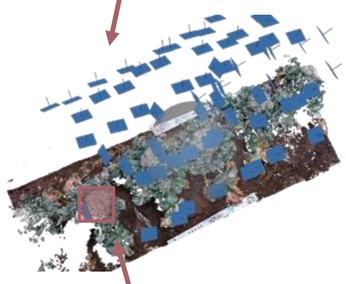
Selfie stick

Ground scalebar

(3D reconstruction) Metashape

PY

Batch processing scripts

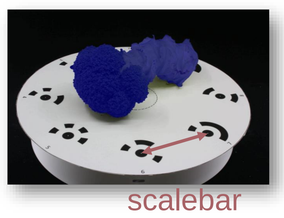


Time-series ground data

Same sampled region

Indoor scale by photo studio

Rotating platform
(also rotate object itself)



scalebar

Deep learning broccoli masking
(UNet +CascadePSP)

(3D reconstruction) Metashape PY

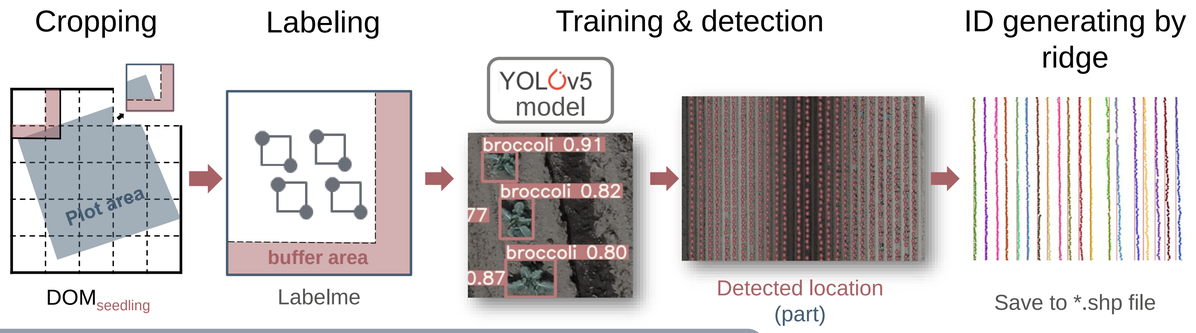
Masked 3D reconstruction
(fix camera, rotate object)

Same sampled broccoli

High quality 3D model
(200+ databases)

❷ Calculate cross-scale assimilated size

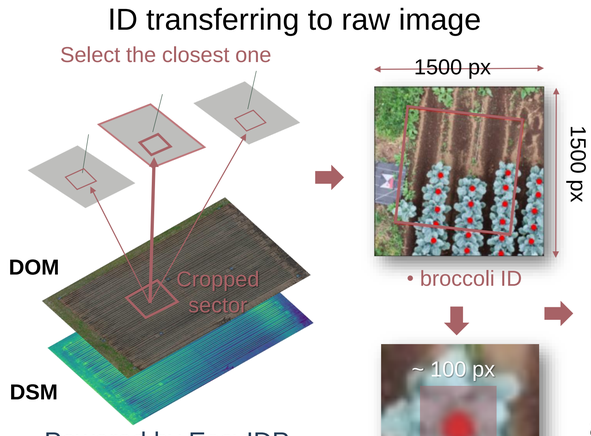
Automatic ID generation for individual broccoli



DOM$_{seedling}$ Labelme Detected location (part) Save to *.shp file

Head identification & segmentation

ID transferring to raw image



Powered by EasyIDP GitHub

ROI defining

Interactive annotation

Segment result

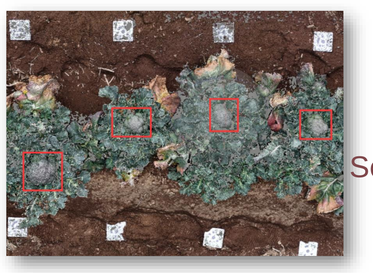
On raw UAV image

Cross-scale head assimilation

Poor UAV (15m) 3D model & DOM

DL transfer

Simple 2D polygon



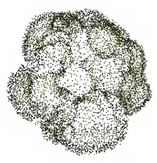
Normal quality ground 3D point cloud

Segment

Normal 3D point cloud

High quality indoor 3D point cloud

Pick vertex



High quality 3D point cloud

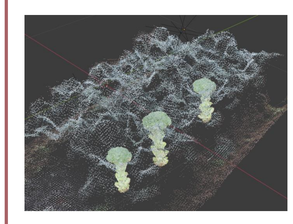
Simple **2D** geometry traits

Simple **3D** geometry traits
(validation)

Accurate 3D geometry traits

Link by sampled broccoli ID

Obtain the regression model from UAV traits to indoor traits



Put indoor model back to outdoor by template matching and transformation

(still in processing)

❸ Size prediction by growth model

Model definition

$$ln(HD) = a - b \cdot e^{-c \cdot T}$$

HD: head diameter
T: Sum of daily average temperature

Model initialization

By field measured data

id	Field Measured Head Diameter (cm)					
	May 18		May21		May23	…
1	~~2.3~~	ΔT_1	3.1	ΔT_2	4.6	…
2	3.2		4.5		5.4	…
3	~~1.1~~		~~2.3~~		4.3	…
…	…		…		…	…

Normalized T

id	T	HD
1	0	3.1
1	0+ΔT_2	4.6
…	…	…
2	0	3.2
2	0+ΔT_1	4.5
2	0+ΔT_1+ΔT_2	5.4
…	…	…
3	0	4.3

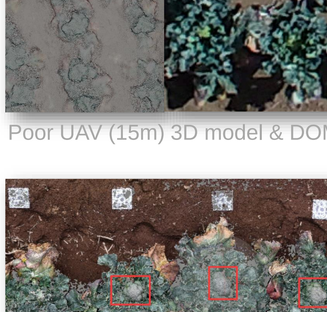
Model prediction

For this year:
Flight when broccoli size is visible (May 12), using model 1 get T_0, and weather forecast ΔT and model 2 to predict size

id	UAV Measured Head Diameter (cm)						
	May 12	T_0	May 13	ΔT_1	May 14	ΔT_2	…
1	4.3	21.0	21.0+ΔT_1		T_0+ΔT_1+ΔT_2		…
2	5.1	25.4	25.4+ΔT_1		T_0+ΔT_1+ΔT_2		…
3	4.2	20.8	20.8+ΔT_1		T_0+ΔT_1+ΔT_2		…
…							

❹ Income prediction model

Market survey and broccoli grading



Shipping standard in Japan
(11cm – 14cm)
other size can not be sold and wasted (grade-out)

Market manager consultation

Case 1: grades with largest difference ΔC_1

Case 2: grades with smallest difference ΔC_2

L size = $1

Case 1:	Case 2:
2L = $1 + ΔC_1	2L = $1 + ΔC_2
M = $1 - ΔC_1	M = $1 - ΔC_2

Income predict

$$Income = \sum_{g}^{M,L,2L} Count_g \times Price_g$$

Grade-out price = 0

In this case, May 17 is the optimal harvest date

It can be more precise with time going (weather data & UAV measure iteration)