UTokyo Field Phenomics Lab

Procedural Geometric Modeling for Plant Phenomics by Blender: Case Study of Maize

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Background

01

1.1 Digital Clone for Agriculture

[1]

Digital Clone

"Digital clone is the digital equivalent of real-life object mirrors its behavior and status over lifetime in a virtual space" [2]

If apply in agriculture:

- Manage operation remotely based on digital information
- Simulate the operation effects and find the best operation.

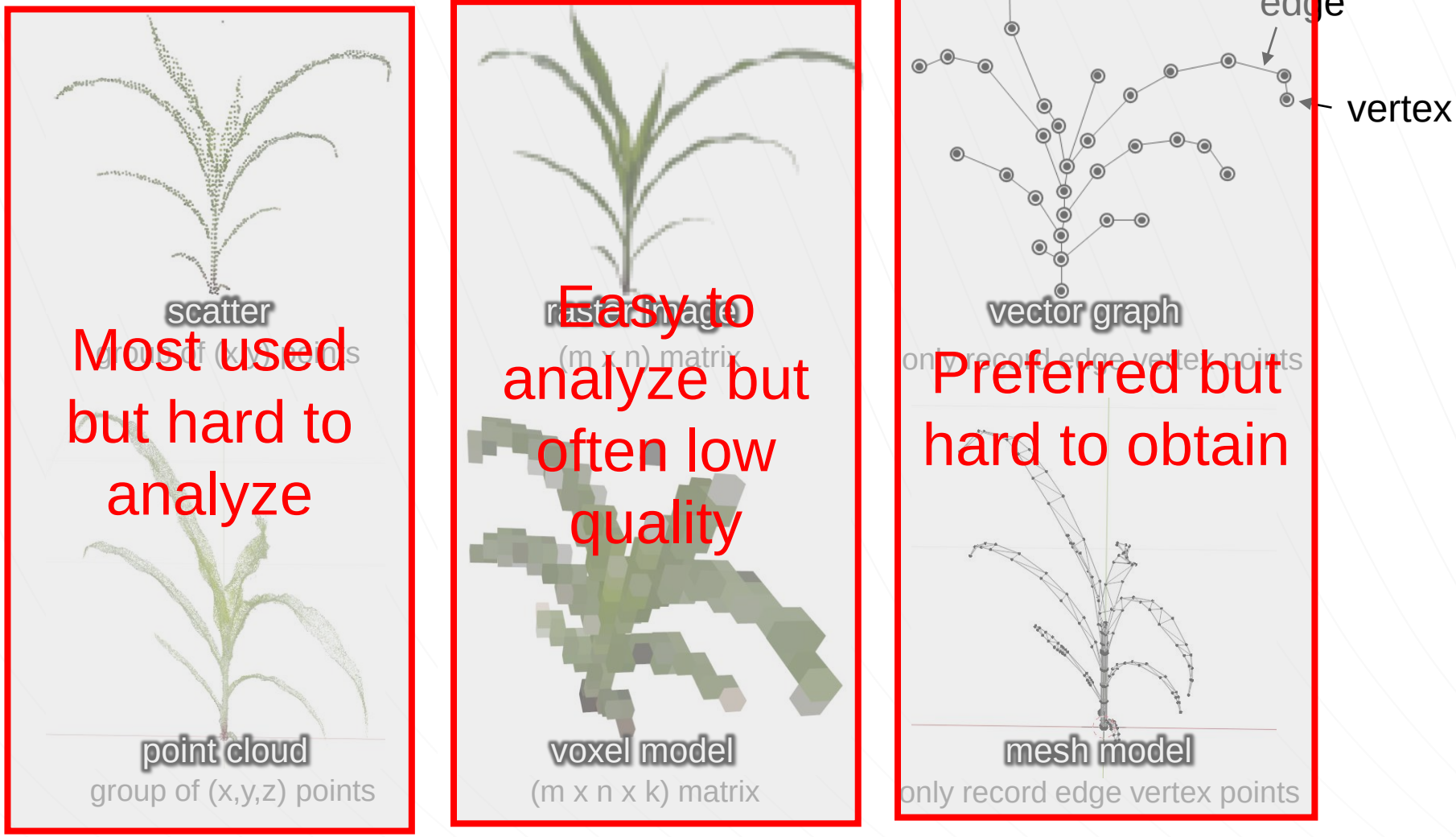
Plant 3D model is the fundamental

[1] https://www.wur.nl/en/newsarticle/WUR-is-working-on-Digital-Twins-for-tomatoes-food-and-farming.htm
[2] Verdouw, C., Tekinerdogan, B., Beulens, A., Wolfert, S., 2021. Digital twins in smart farming. Agricultural Systems 189, 103046. https://doi.org/10.1016/j.agsy.2020.103046

1.2 Digital Plant Data Formats

2D images

3D models



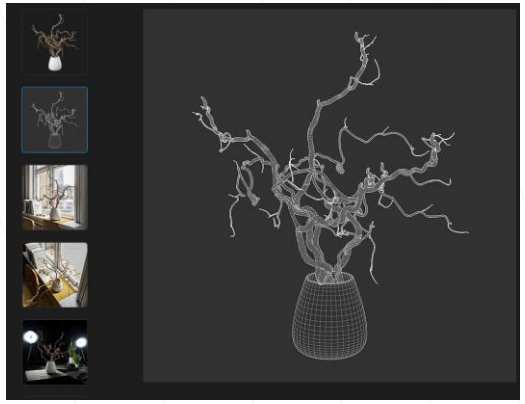
1.3 Obtain Plant 3D Models

- **Modeling**

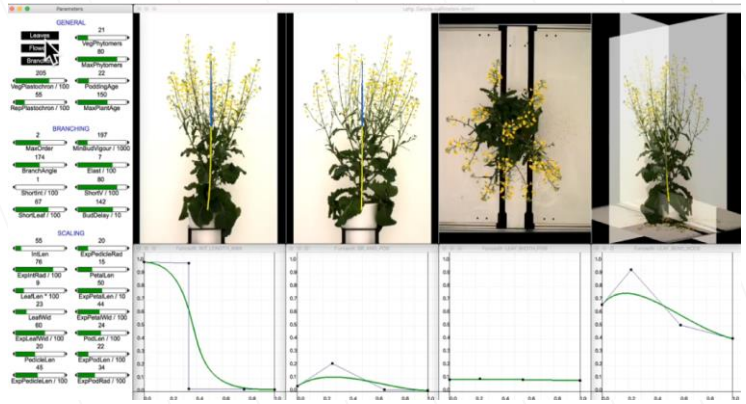
  Non-exist plant based

  Create “Non-existent” plant model from shape and structure simulation

manual modeling [1]



procedural modeling [2]



- **Reconstruction**

  Exist plant based

  Build model from existing plants, by photos or 3D scanning devices

Laser based scanning

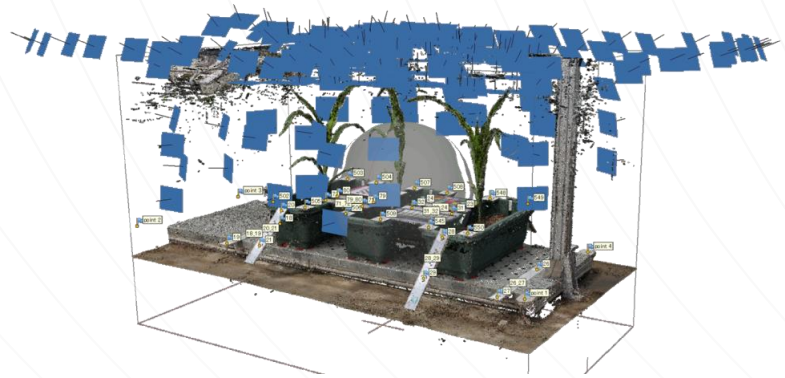


Image based reconstruction

[1] https://www.poliigon.com/models/plants

[2] M. Cieslak, N. Khan, P. Ferraro, R. Soolanayakanahally, S.J. Robinson, I. Parkin, I. McQuillan, P. Prusinkiewicz, L-system models for image-based phenomics: case studies of maize and canola, In Silico Plants. (2021) diab039. https://doi.org/10.1093/insilicoplants/diab039.

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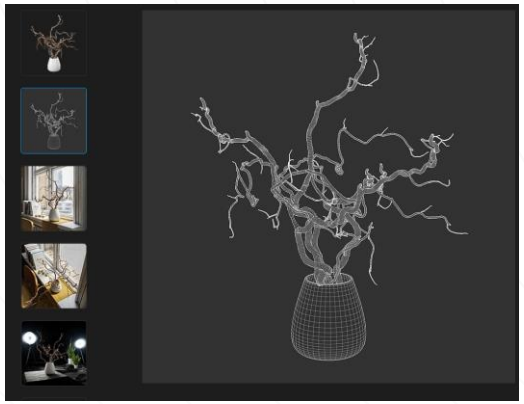

The most common way to get plant models, the performance highly relies on the modeler

Commercial models are also available on some website [1], the price around $10 each

Suitable for CG / game industry assets, **NOT** a good choice for agricultural purposes (**variation for each plant**)

[1] https://www.poliigon.com/models/plants

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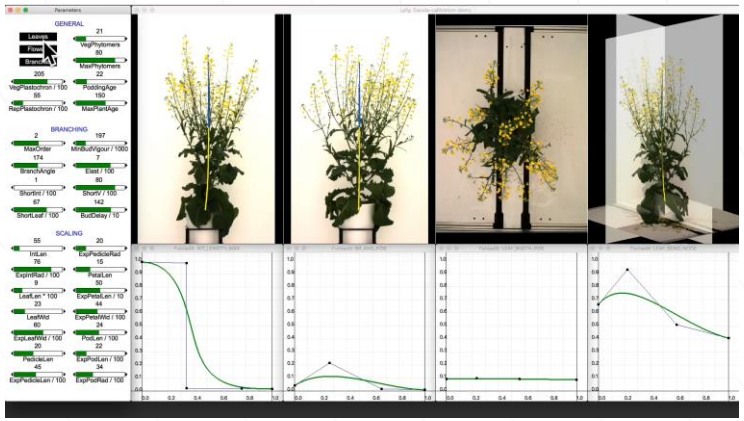

Advanced demo

Using parameters to control the shape of model

L-system use string iteration to draw figures

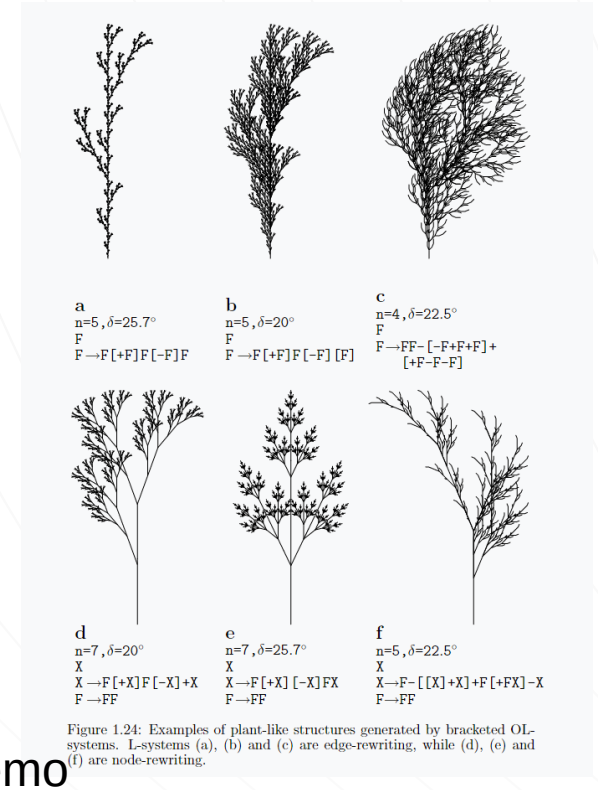

Figure 1.24: Examples of plant-like structures generated by bracketed OL-systems. L-systems (a), (b) and (c) are edge-rewriting, while (d), (e) and (f) are node-rewriting.

n=7, δ=22.5°

ω : A
p_1 : A → [&FL!A]/////’[&FL!A]///////’[&FL!A]
p_2 : F → S ///// F
p_3 : S → F L
p_4 : L → [’’’^^{-f+f+f-|-f+f+f}]

Figure 1.25: A three-dimensional bush-like structure

[1] M. Cieslak, N. Khan, P. Ferraro, R. Soolanayakanahally, S.J. Robinson, I. Parkin, I. McQuillan, P. Prusinkiewicz, L-system models for image-based phenomics: case studies of maize and canola, In Silico Plants. (2021) diab039. https://doi.org/10.1093/insilicoplants/diab039.

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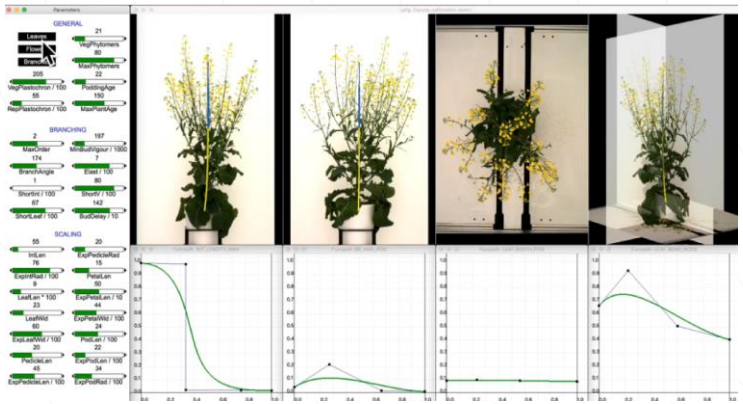
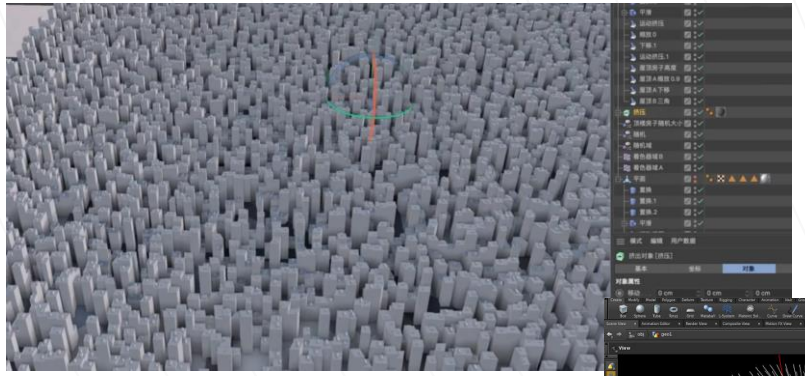


Using parameters to control the shape of model

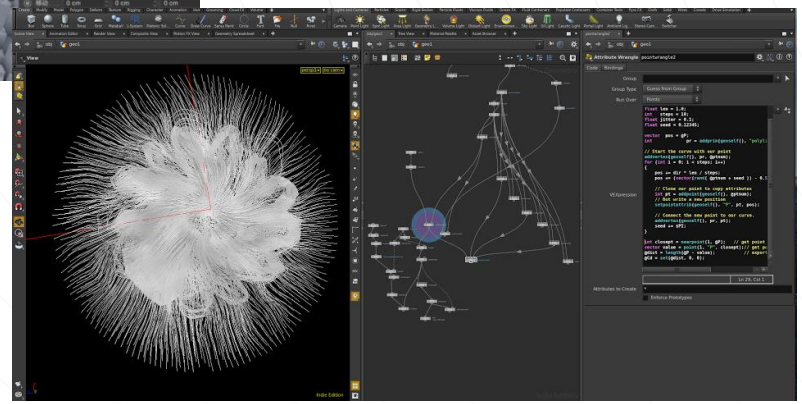
L-system Commercial software

Most for buildings or arts



Cinema4D [2]

Houdini [3]



[1] M. Cieslak, N. Khan, P. Ferraro, R. Soolanayakanahally, S.J. Robinson, I. Parkin, I. McQuillan, P. Prusinkiewicz, L-system models for image-based phenomics: case studies of maize and canola, In Silico Plants. (2021) diab039. https://doi.org/10.1093/insilicoplants/diab039.

[2] https://www.bilibili.com/video/BV1a7411w7EU/ [3] Fractals and Procedural Production | Houdini, Fractals, Tutorial (pinterest.com)

1.3 Obtain Plant 3D Models

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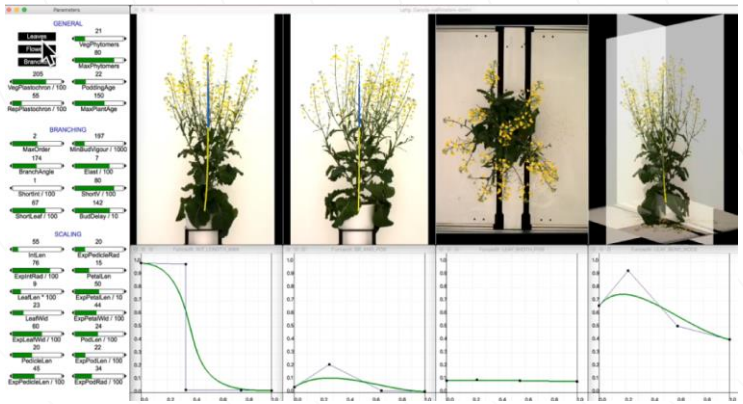
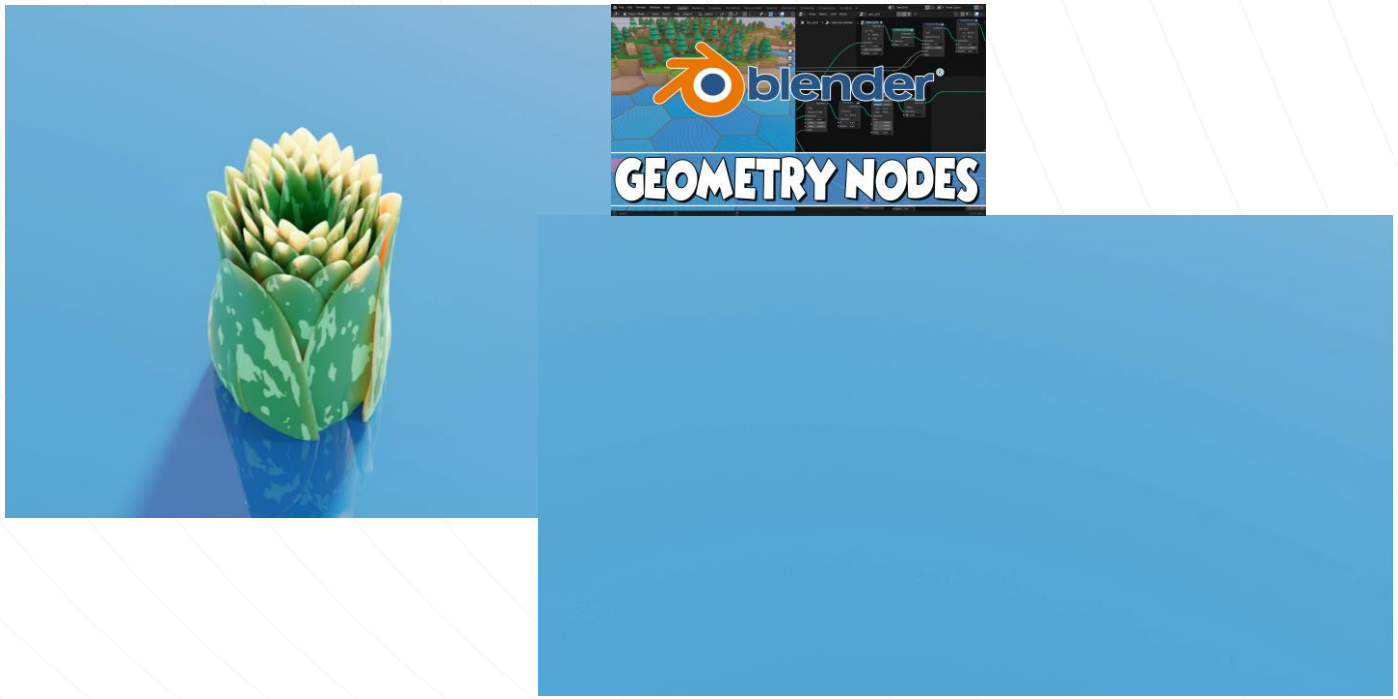


L-system Commercial software

Most for buildings or arts, and possible for plants



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- **Reconstruction**

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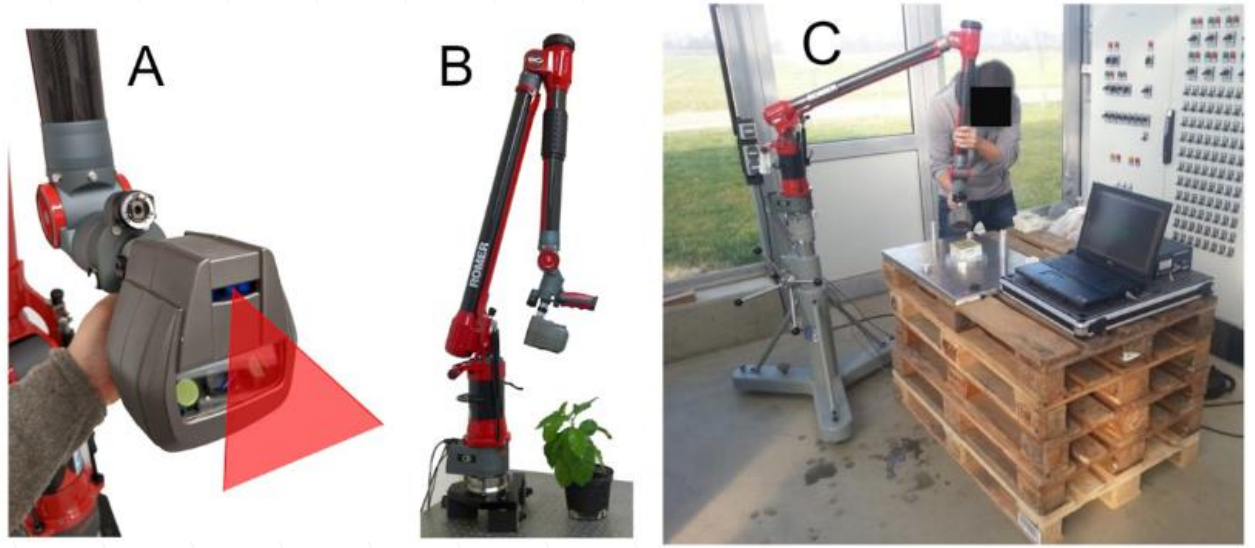

Laser based scanning

Accurate but device expensive

[1] Schunck, D., Magistri, F., Rosu, R.A., Cornelißen, A., Chebrolu, N., Paulus, S., Léon, J., Behnke, S., Stachniss, C., Kuhlmann, H., Klingbeil, L., 2021. Pheno4D: A spatio-temporal dataset of maize and tomato plant point clouds for phenotyping and advanced plant analysis. PLoS One 16, e0256340. https://doi.org/10/gnzfdm

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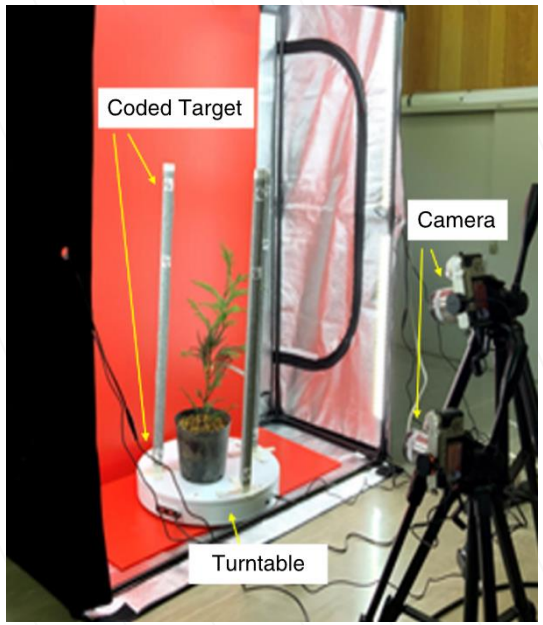


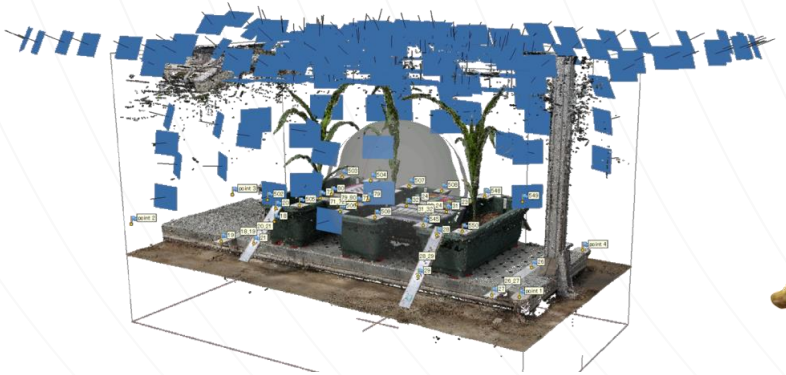


Image based reconstruction

Cheap but need quality control

[1] Kochi, N., Isobe, S., Hayashi, A., Kodama, K., Tanabata, T., Research Center for Agricultural Information Technology, National Agriculture and Food Research Organization Kintetsu-Kasumigaseki Bldg., 3-5-1 Kasumigaseki, Chiyoda-ku, Tokyo 100-0013, Japan, R&D Initiative, Chuo University, Tokyo, Japan, Kazusa DNA Research Institute, Kisarazu, Japan, 2021. Introduction of All-Around 3D Modeling Methods for Investigation of Plants. IJAT 15, 301–312. https://doi.org/10/gpdm58

1.4 Research object

- **Modeling**

  Non-exist plant based

  Flexible to adjust but **not “real”** plants

+

- **Reconstruction**

  Exist plant based

  Real plants but **not flexible** to adjust

=

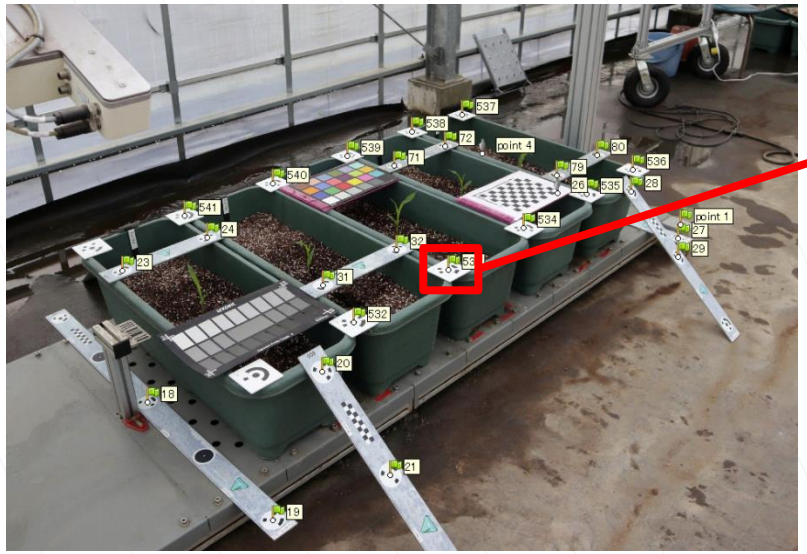
Adjustable real plants?

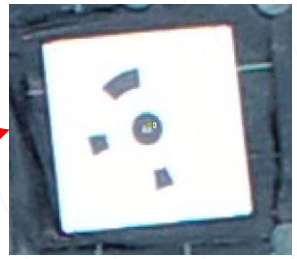
02

Methods & Results

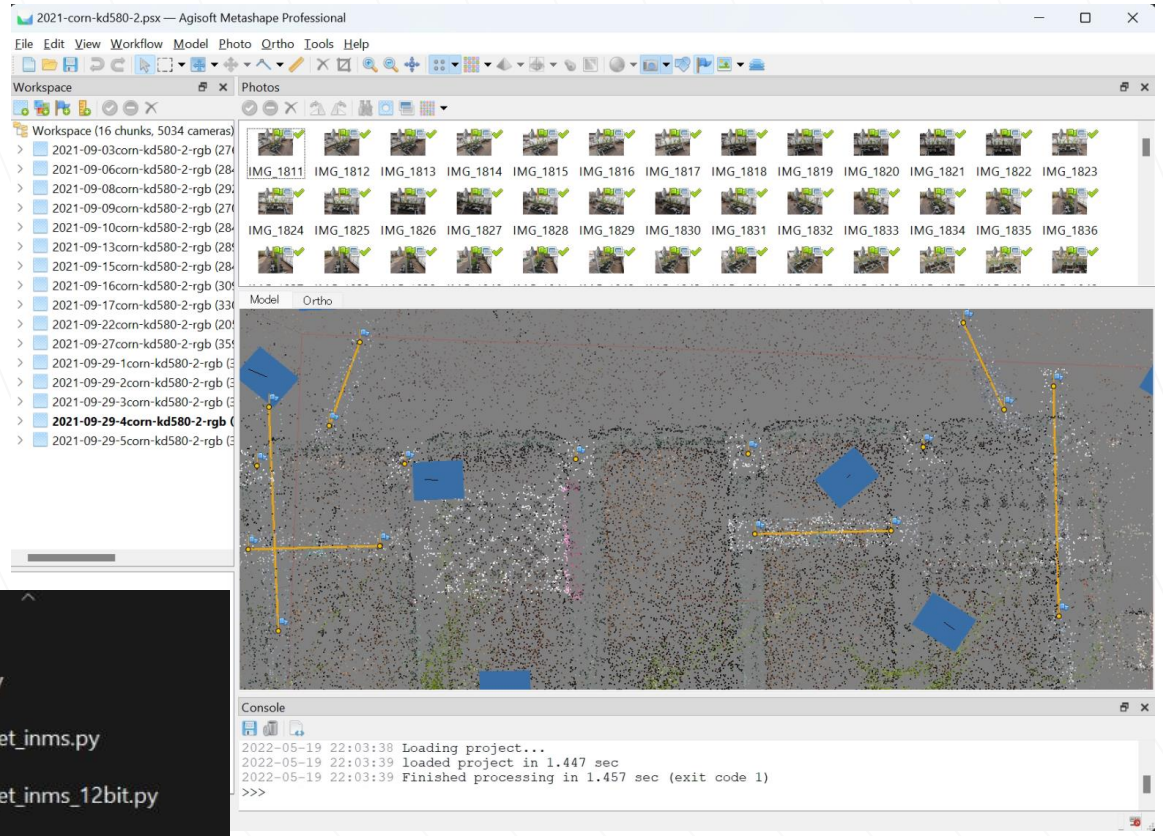
2.1 Collecting “real” maize by reconstruction

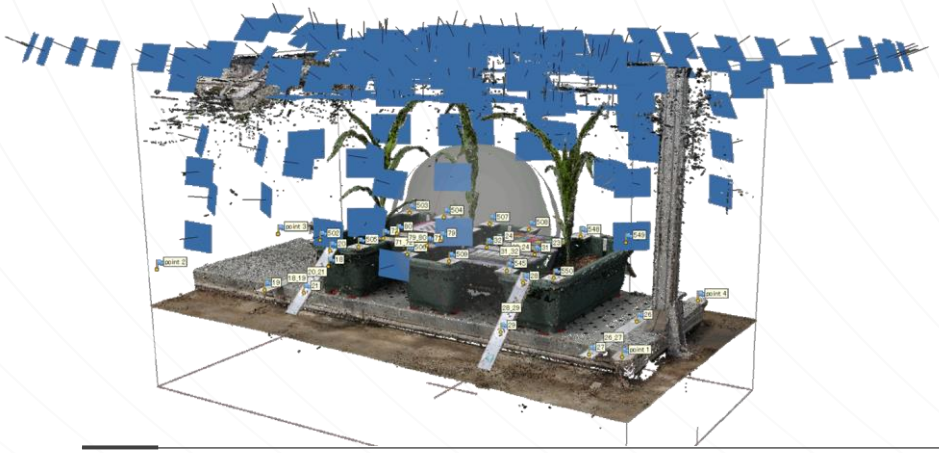
3D reconstruction platforms

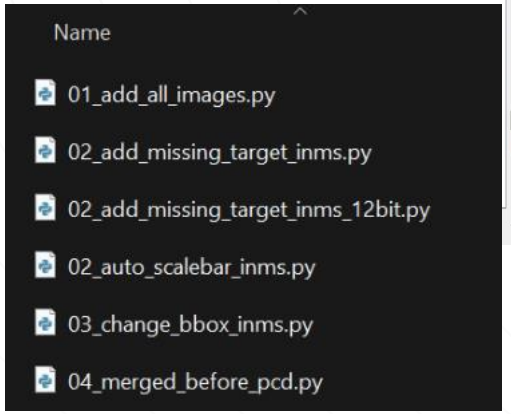




Auto-detectable markers



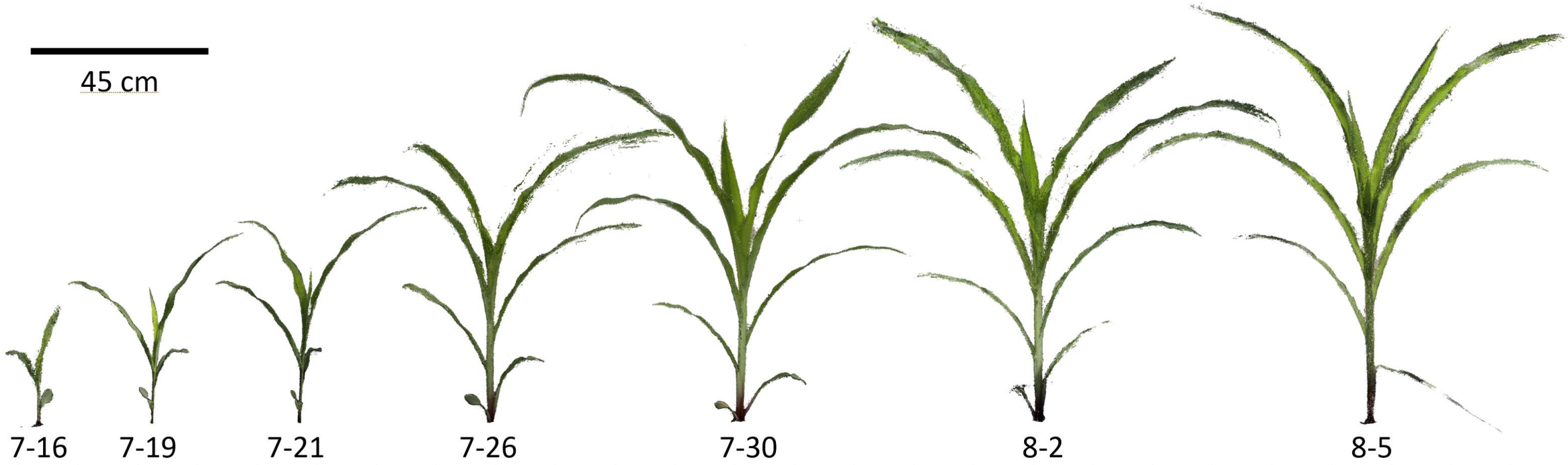




Batch processing scripts

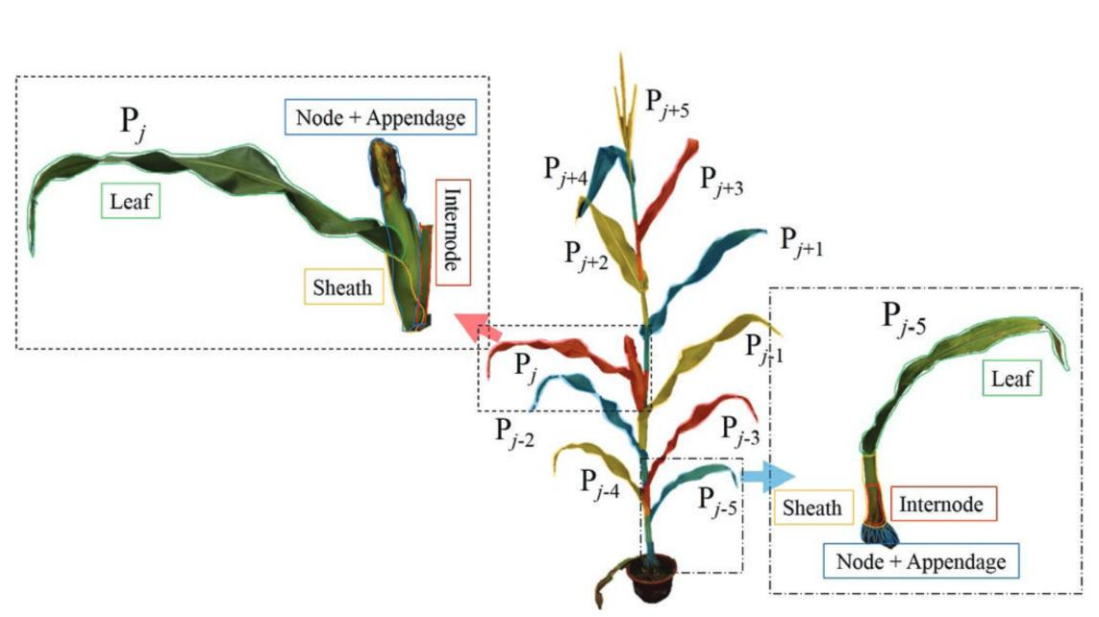
2.1 Collecting “real” maize by reconstruction

Obtained time-series “real” maize point cloud

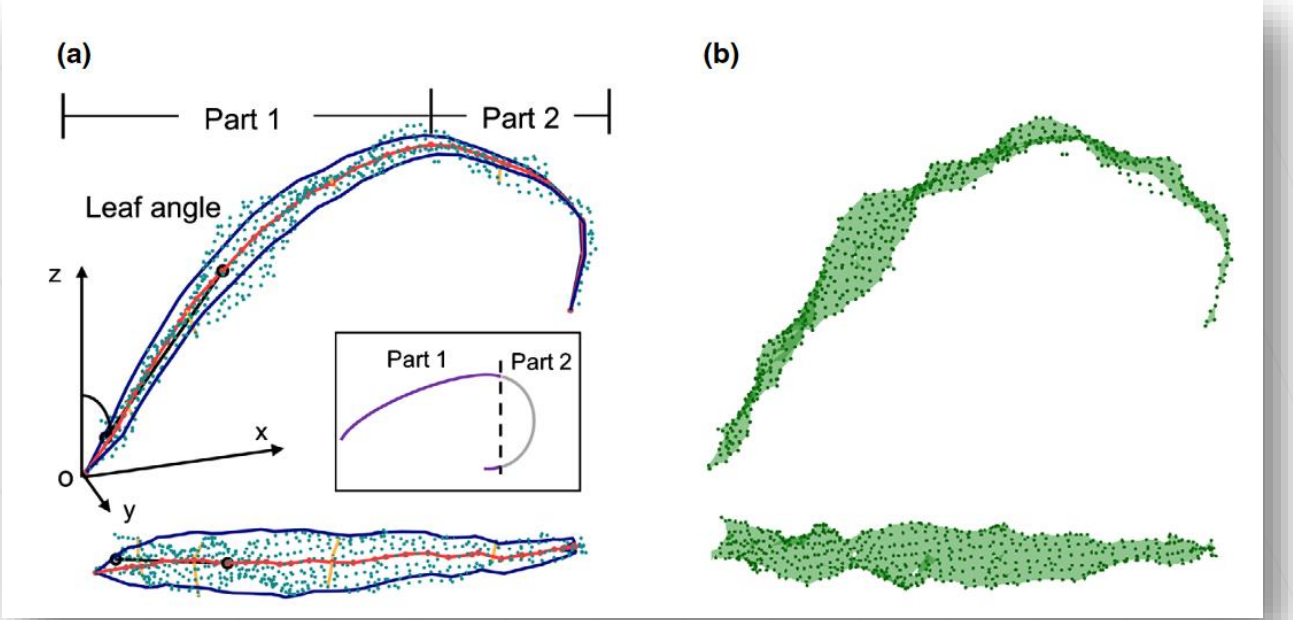


2.2 Link reconstruction data with adjustable model

Published maize model



Proper maize model unit – phytomer [1]

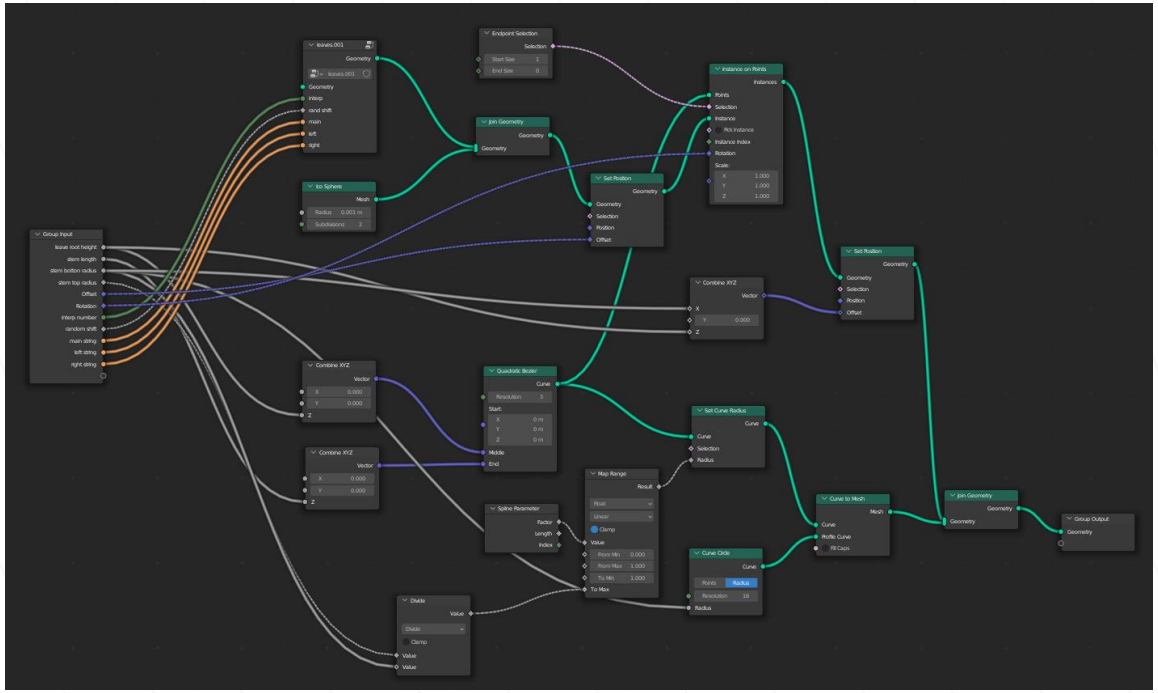


Method of maize leaf shape description [2]

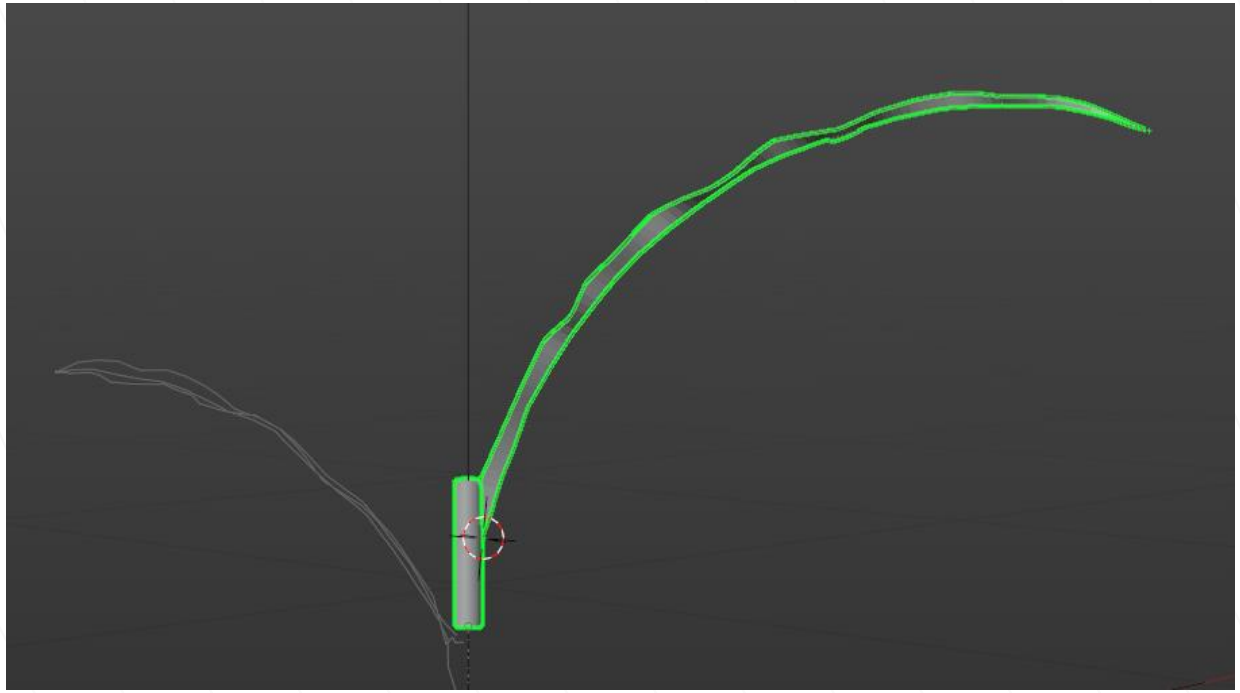
[1] Wen, et.al., 2021. 3D phytomer-based geometric modelling method for plants—the case of maize. AoB PLANTS 13, plab055. https://doi.org/10.1093/aobpla/plab055
[2] Liu, et. al., 2021. Canopy occupation volume as an indicator of canopy photosynthetic capacity. New Phytol 232, 941–956. https://doi.org/10.1111/nph.17611

2.2 Link reconstruction data with adjustable model

Implementation in Blender



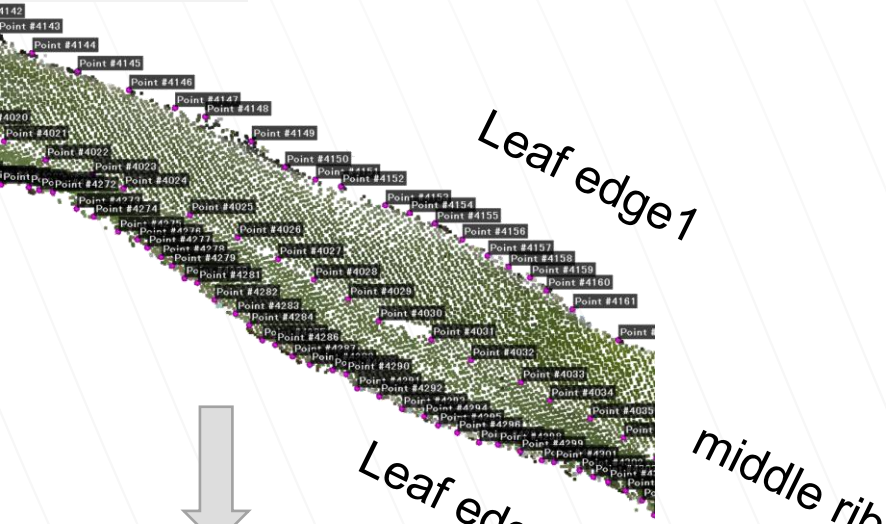
Geometry Node Graph (parts)

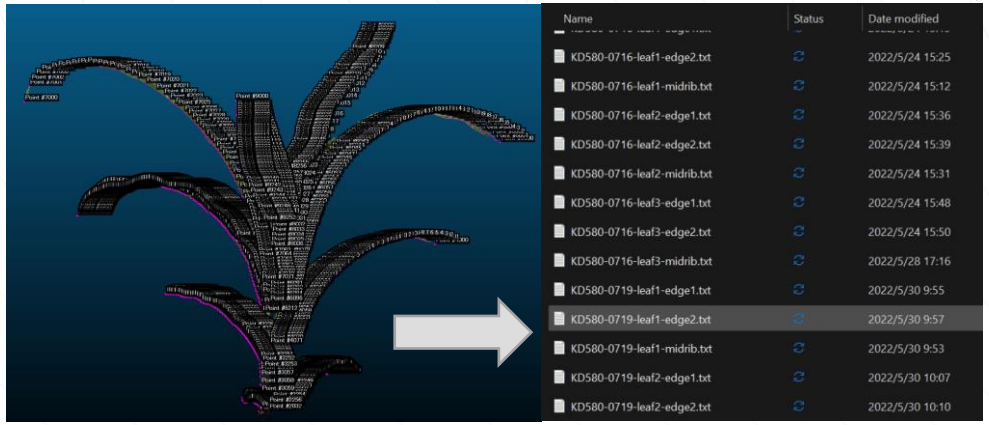


Maize phytomer in Blender

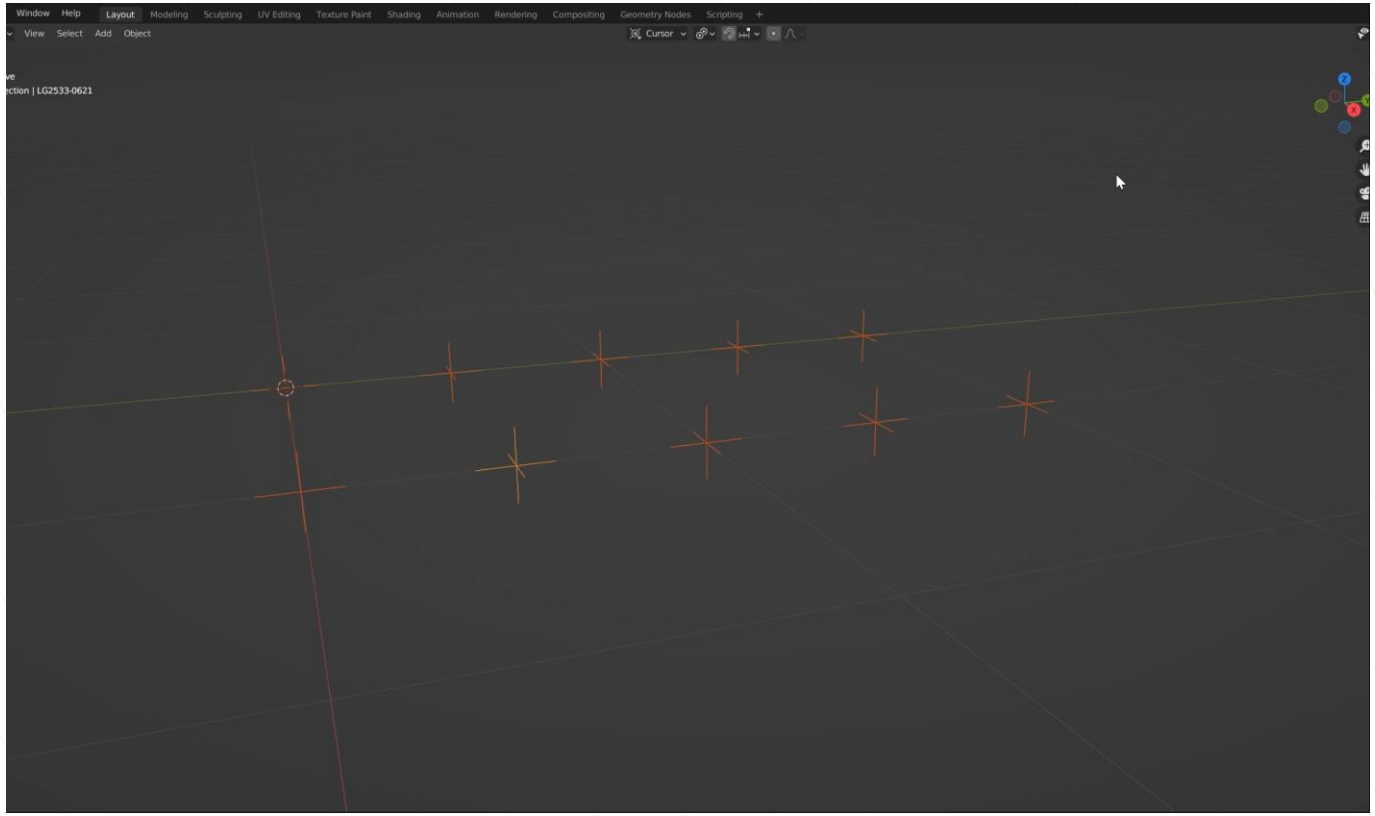
2.2 Link reconstruction data with adjustable model

Control models by parameters





Batch loading skeletons to get mesh models



Pick each leaf

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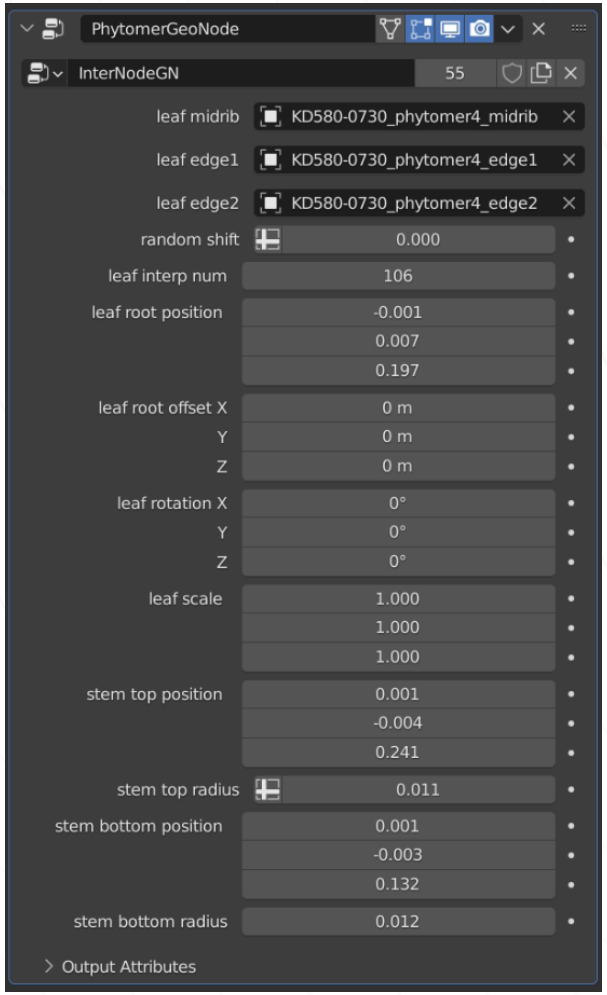
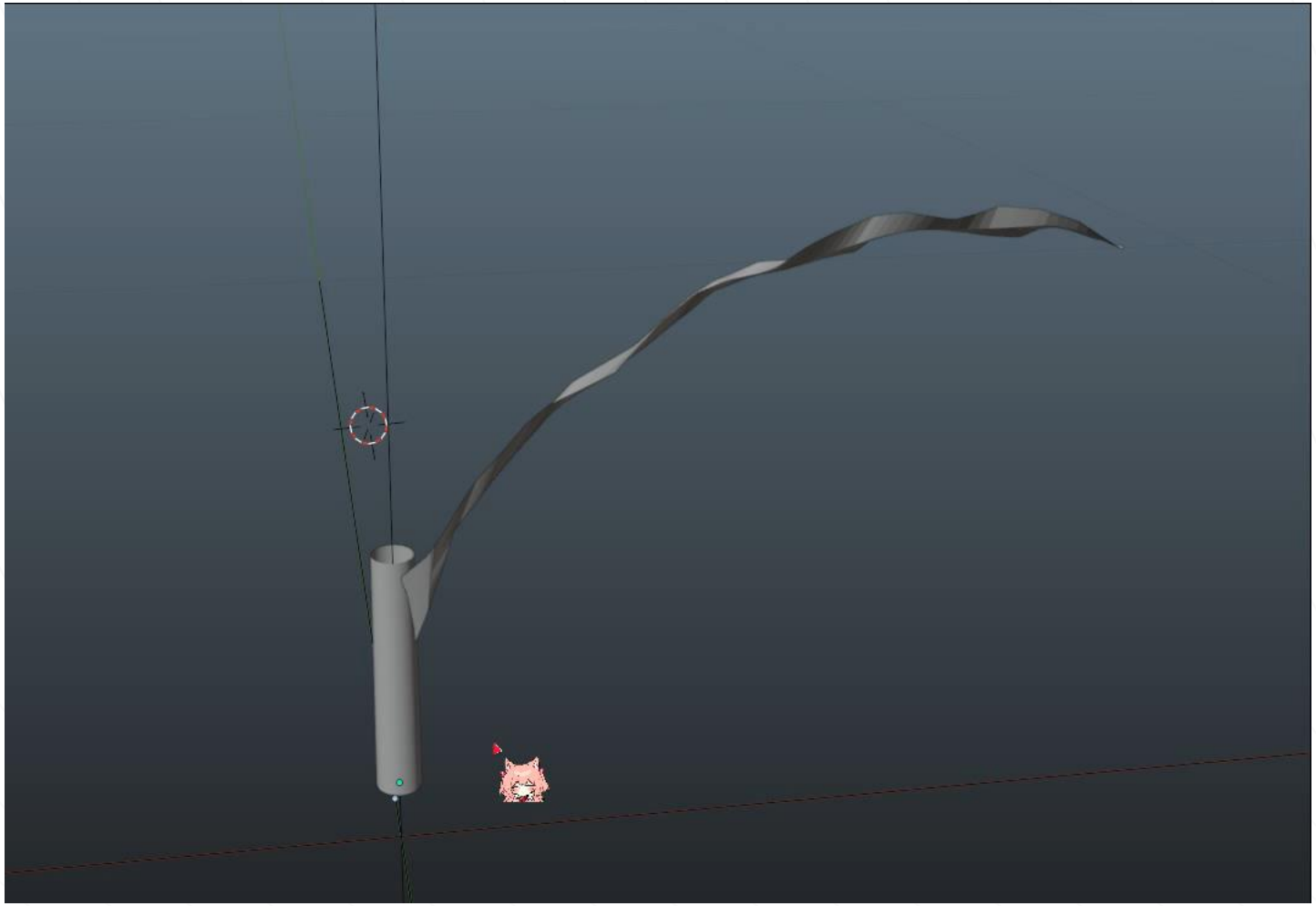




Summary

03

3 Summary

Study workflow

photos

Backward projection

Get leave texture & uv

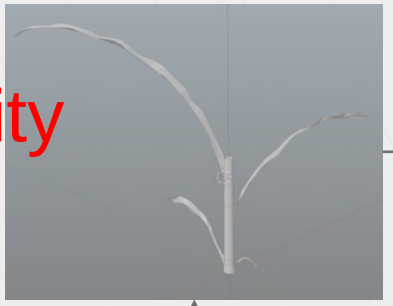
Need further explore

EasyIDP

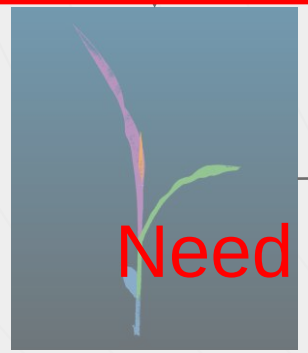
Room SfM platform

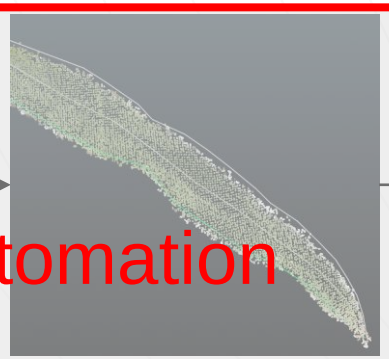
Used demo to validate feasibility

individual level point cloud data



Paint texture





Need automation

Get geometry node model

Python API

Organ segmentation

Leaf edge detection

template database

Batch generate maize models

For simulation, deep learning training data, etc.

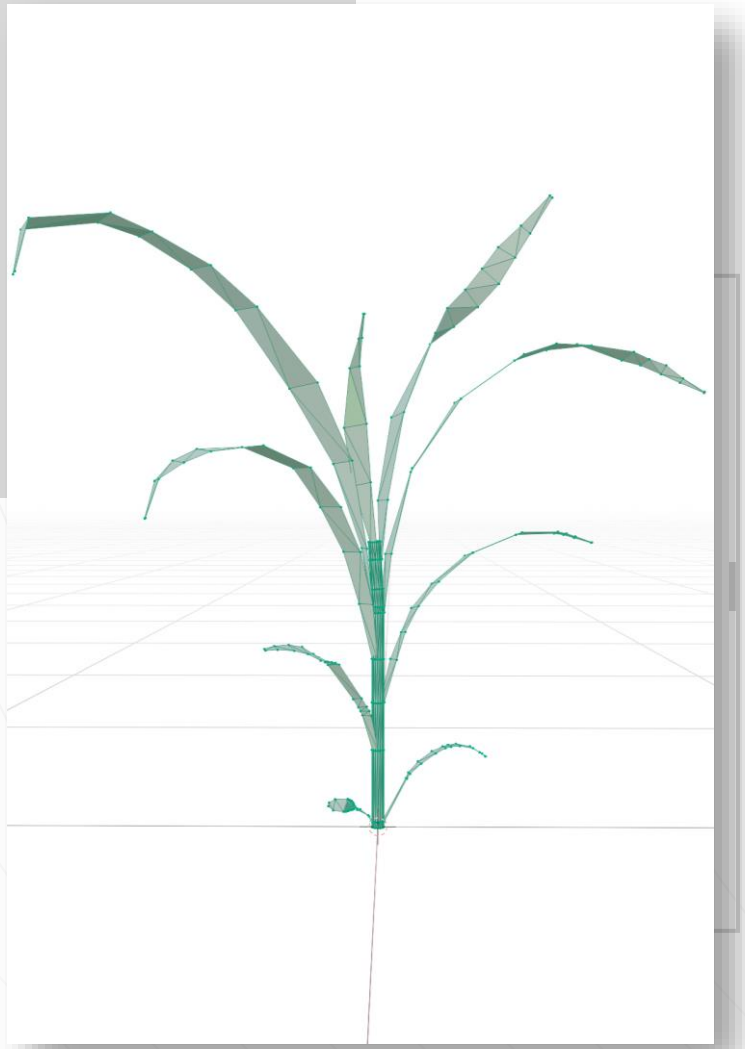
legend

Done

Doing

Todo

Thank you



2022

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