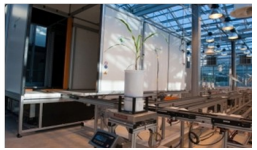
Repro Hackaton Algorithm

25/11/2019

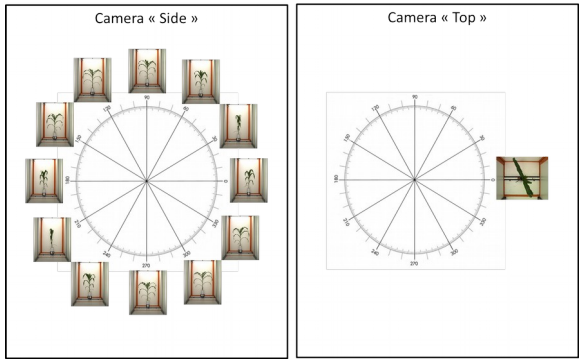
Context - LEPSE & Phenoarch

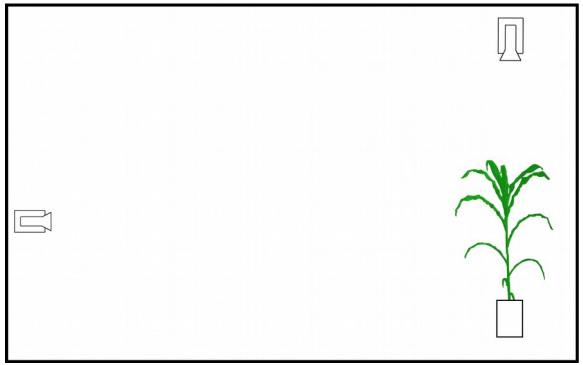
- A high throughput phenotyping platform
- Greenhouse with multiple sensor, controlling environment (water and illumination)
- ~1600 plants
- Different plants
  - Maize
  - Coton
  - Sorgho
  - Apple
  - Vines
  - ...



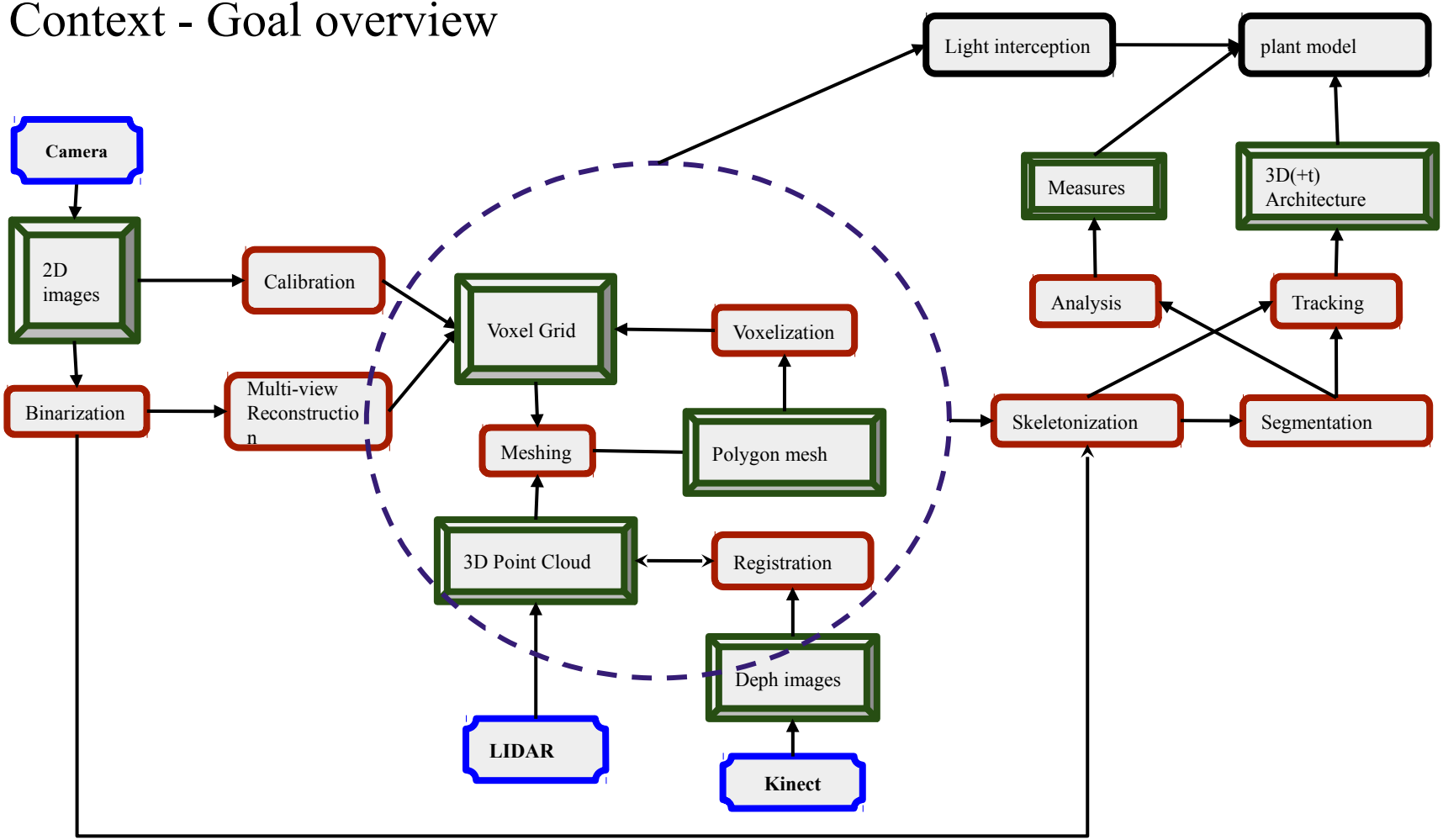
Context - The imaging system acquisition

- Select the image angle of each plant (for each view) with a turntable of high precision.
- Two camera
  - “side” and “top”
  - image resolution of 2056x2454
- Several setup of of images number per plants (3, 13, 25, …)
- It’s improved (or will be) along the time
  - Extension (More plants)
  - Camera on robot arm
  - More Camera
  - Changing background
  - Changing illumination





Context - Goal overview



Multiple Camera Calibration
&
Multi-view Reconstruction
&
Meshing / Voxelization

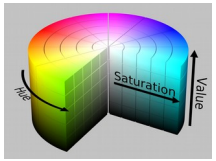
Context - Binarization Algorithm

- Side binarization
  - Meanshift threshold :

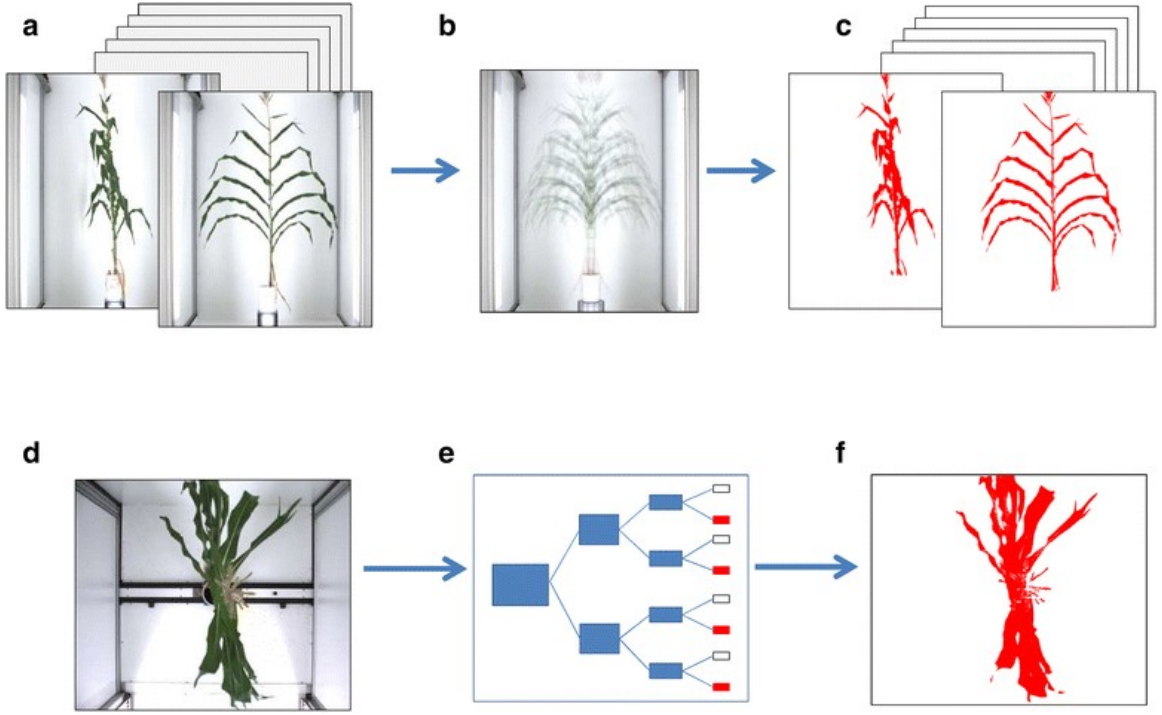
$$min_{RGB}\left(\frac{image_k}{image}\right) \leq 0.70$$

  - HSV threshold

$$H_{lowerb} \leq H_{image} \leq H_{upperb} \wedge$$
$$S_{lowerb} \leq S_{image} \leq S_{upperb} \wedge$$
$$V_{lowerb} \leq V_{image} \leq V_{upperb}$$



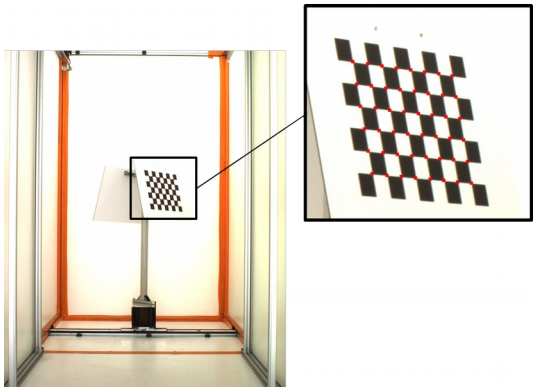
- Top binarization
  - decision tree learning
    - with seven colour space (RGB, HSV, Luv, Lab, HLS, xyz, Yuv)

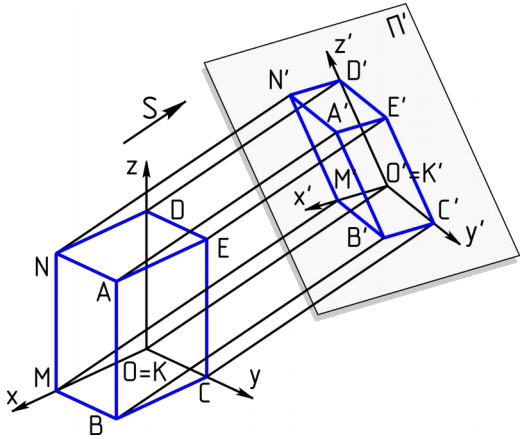


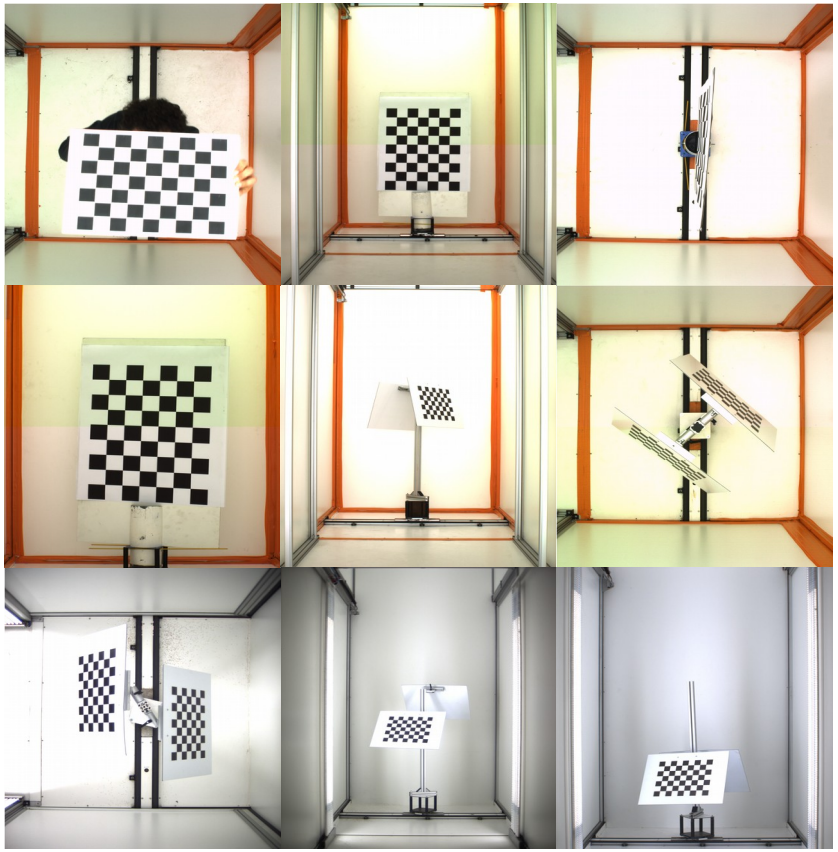
Brichet et al, 2017

Multiple Camera Calibration - Principle

- Define a 3D frame reference centred on the pot axis.
- Before : Automatic detection of chessboard corner position. (Thanks to Opencv function)
- According all the camera view and the targets position.
- Project 3D position to 2D on a desired view.
- Estimate the intrinsic and extrinsic camera parameters

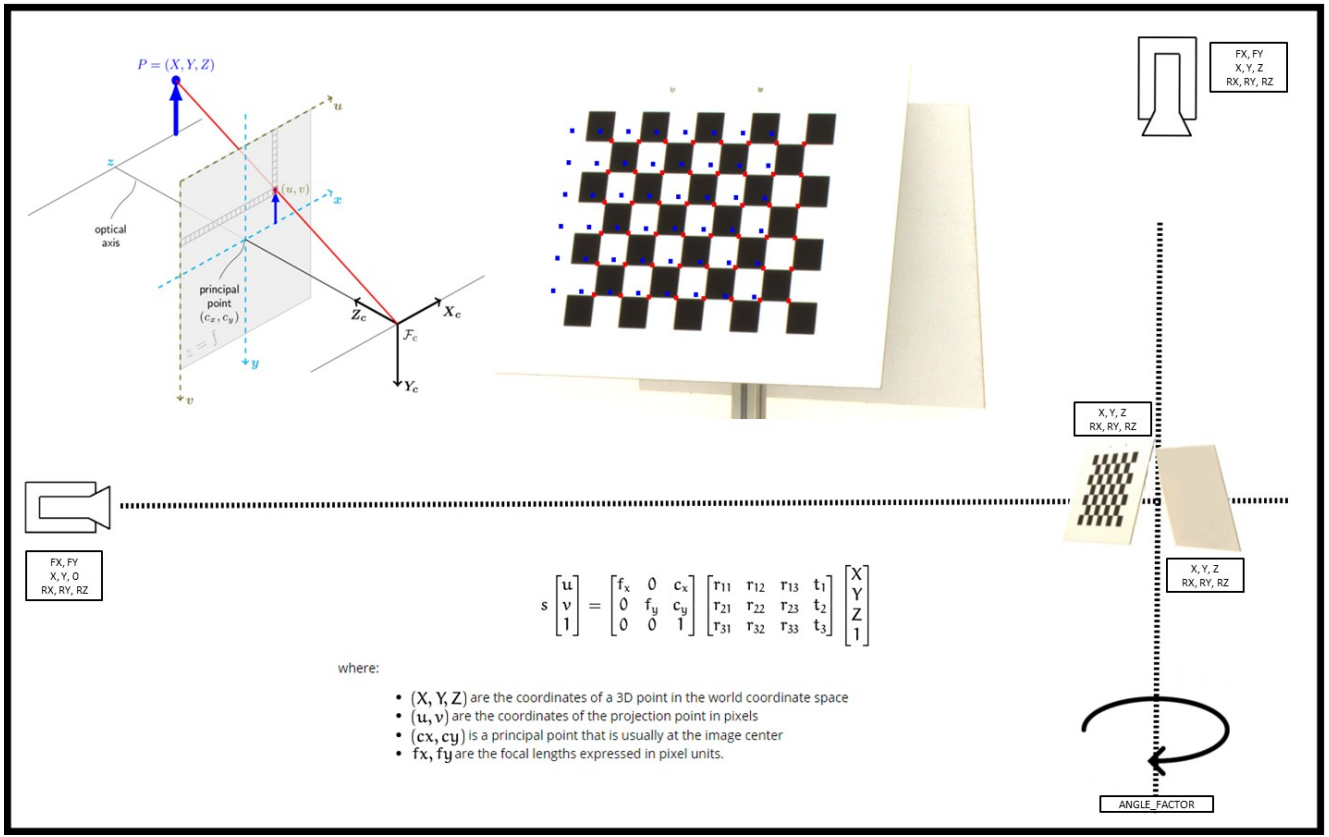






Multiple Camera Calibration - Model calibration

- Several camera with several target (currently plane position) rotated around a axis (not define) according a defined angle.
- Optimization Methods :
  - BFGS - (Broyden, Fletcher, Goldfarb, Shanno algorithm)
- Modulable :
  - 1+ Camera
  - 1+ Target
  - Interoperable with OpenCv camera calibration

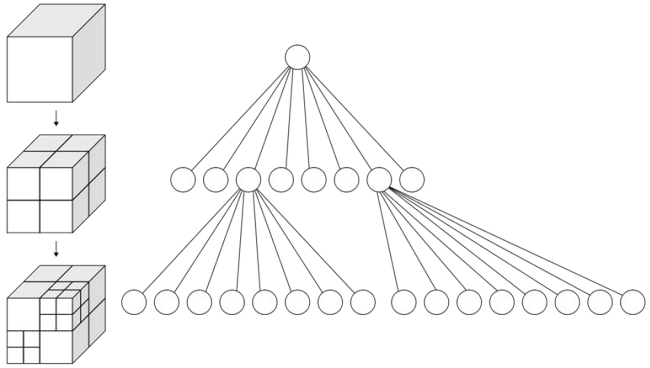


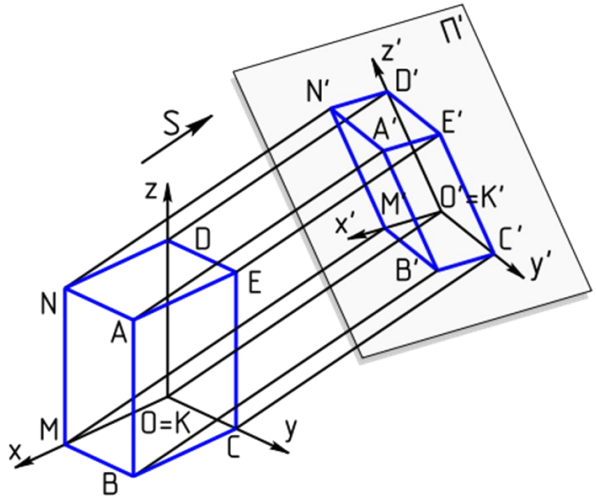
Multi-view Reconstruction - Space carving algorithm with octree optimization

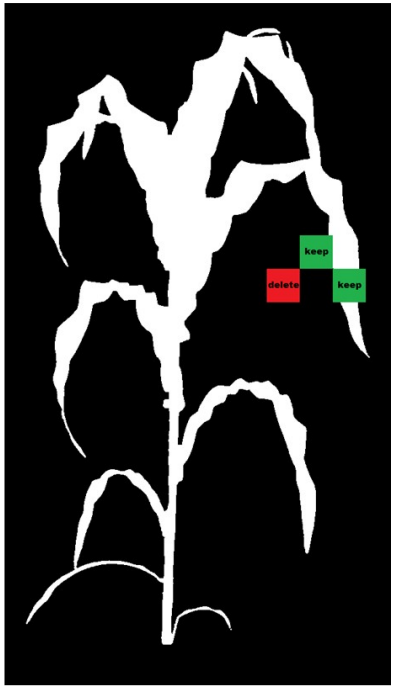
- Let V be the set of all voxels representing the volume of the scene
- I the set of binary images
- P(img, v) the projection function of the voxel v on the img image (that returns true if at least one pixel of the voxel projection is a part of the plant).

Then, the set of photo-consistent voxel is named R and can be express as follow

- **R = {v ∈ V/ ∀ p ∈ {P(img, v) / ∀ img ∈ I}, p = True}**

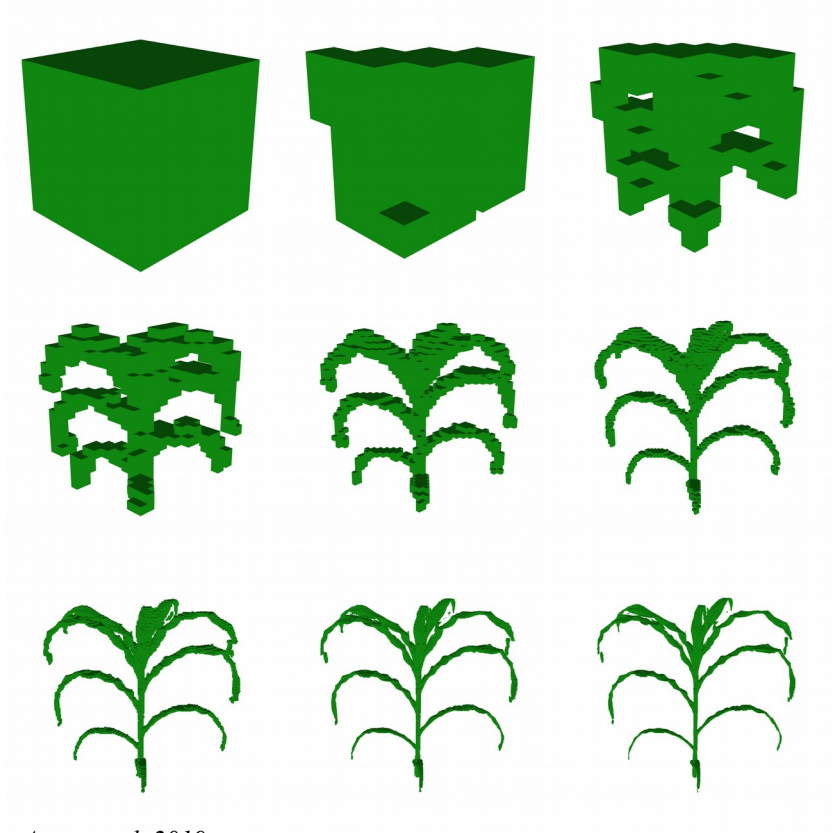




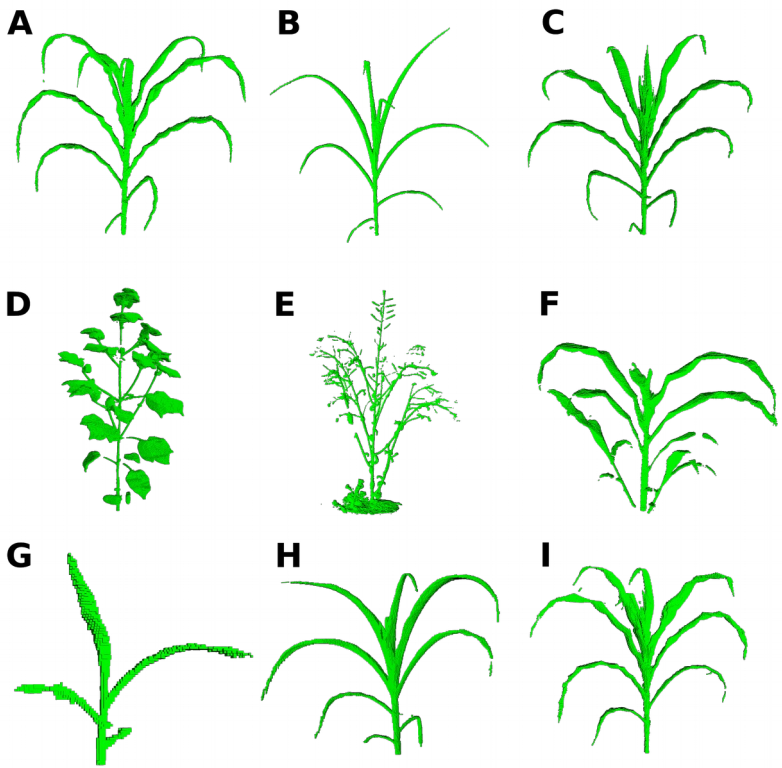


A Theory of Shape by Space Carving, Kutulakos et Seitz, 2000

Multi-view Reconstruction - Multi Resolution, multi species



Artzet et al, 2019



Artzet et al, 2019

Multi-view Reconstruction - Tutor and moving leaf problem

Multi-view Reconstruction - Space Carving extension

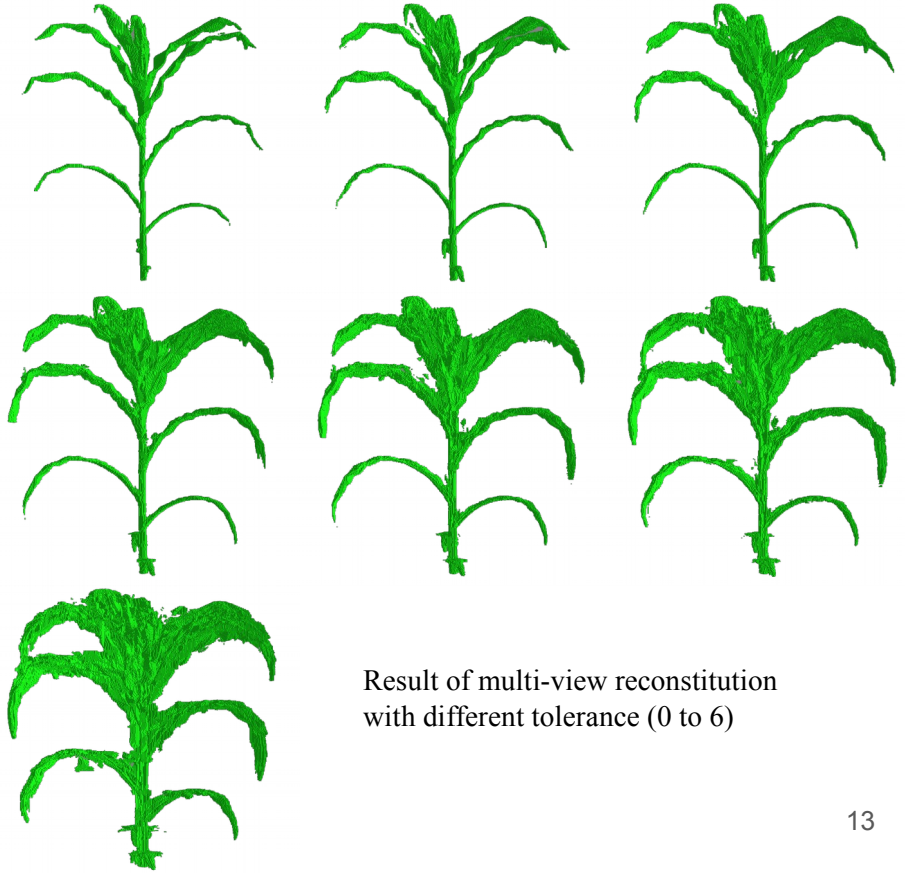
- To avoid this, we extend the classical space-carving algorithm to accept voxels that are only photo-consistent in a subset of views :

  Define Weight as : **$W(v) = |\{p \in \{P(img, v) / \forall img \in I\} / p = True\}|$**

  and then Rt the set of remain voxel as **$Rt = \{v \in V / |I| - t = W(v)\}$**

Multi-view Reconstruction - Space Carving visual comparison on a specific view

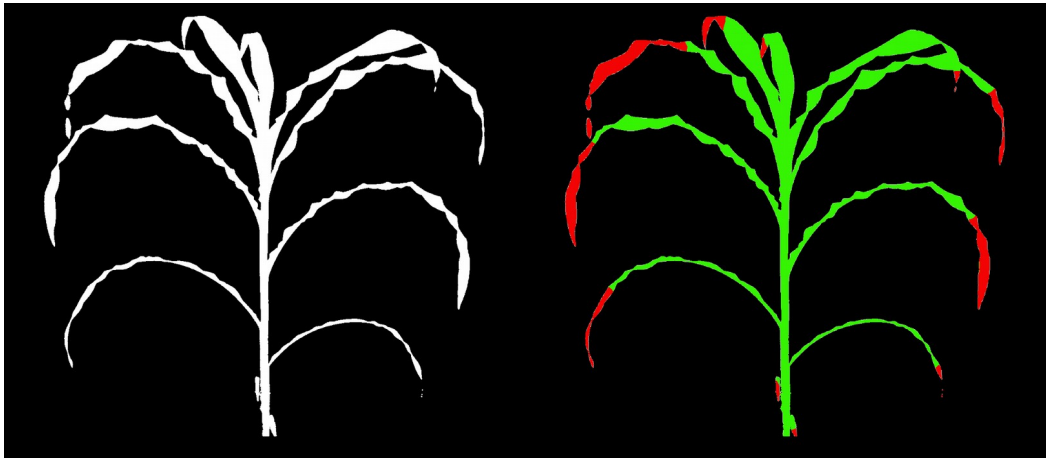
- Space carving is adapted to rigid object like building



Result of multi-view reconstitution with different tolerance (0 to 6)

Multi-view Reconstruction - Specific reference view

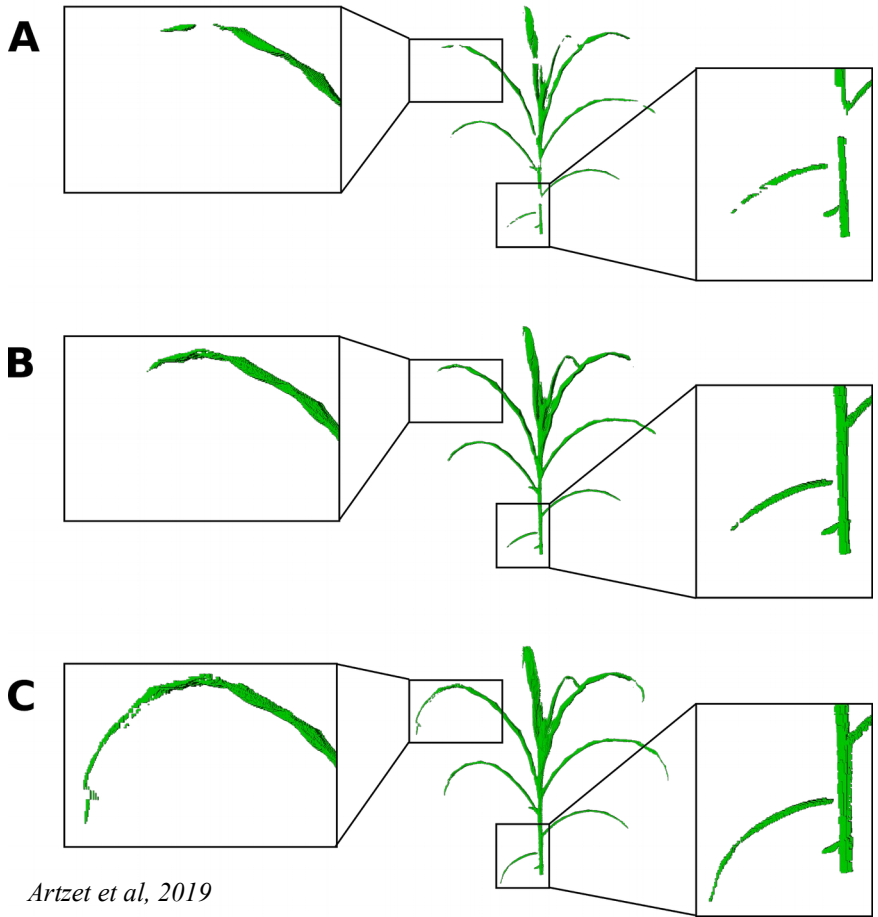
- Post-processing algorithm was developed to keep the voxels which are photo-consistent on the image with the largest convex hull of the plant.
- First the algorithm select the voxels who have been removed by the previous step and who are also photo consistent on the image having the largest convex hull.
- Then, the selected voxels are grouped by their pixels projection correspondence and then for each pixel, the twenty closests voxels from the already photo-consistent voxels are kept
- Finally, all the kept voxels are added to the voxels plant.



Multi-view Reconstruction - Comparison

Comparison of three different 3D geometric maize reconstruction.

- (A) 3D maize reconstructed with a strong photo-consistency check criteria (21.5% of false negative, 0.3% of false positive)
- (B) 3D maize reconstructed with a photo-consistency check criteria set to 11 (i.e. all images minus one). (13.1 % of false negative, 0.6% of false positive)
- (C) 3D maize reconstructed with photo-consistency check criteria of 11 images coupled with voxel recovery Phenomenal post-processing algorithm. (8% of false negative, 0.9% of false positive)



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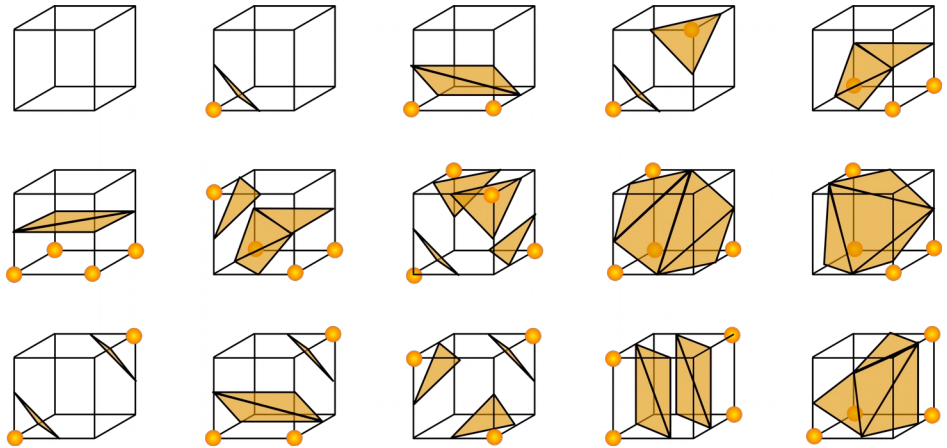
Multi-view Reconstruction - Vidéo démo

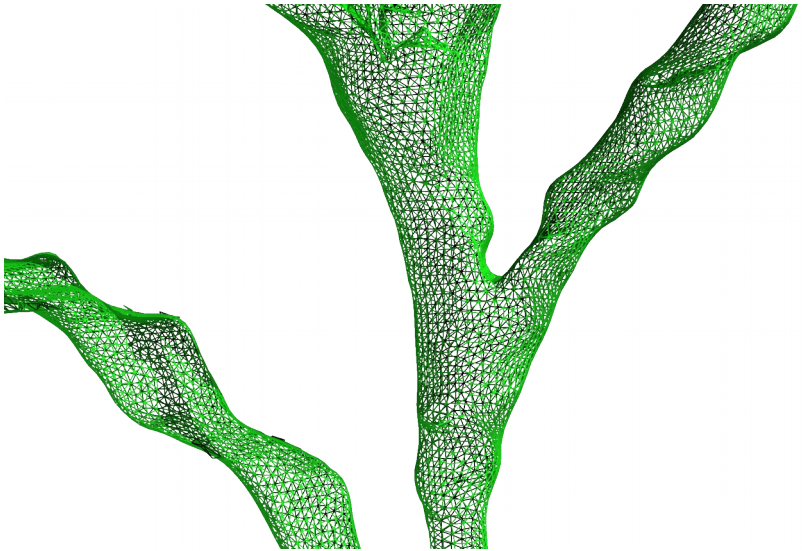
Meshing / Voxelization - Marching Cube & Smooth

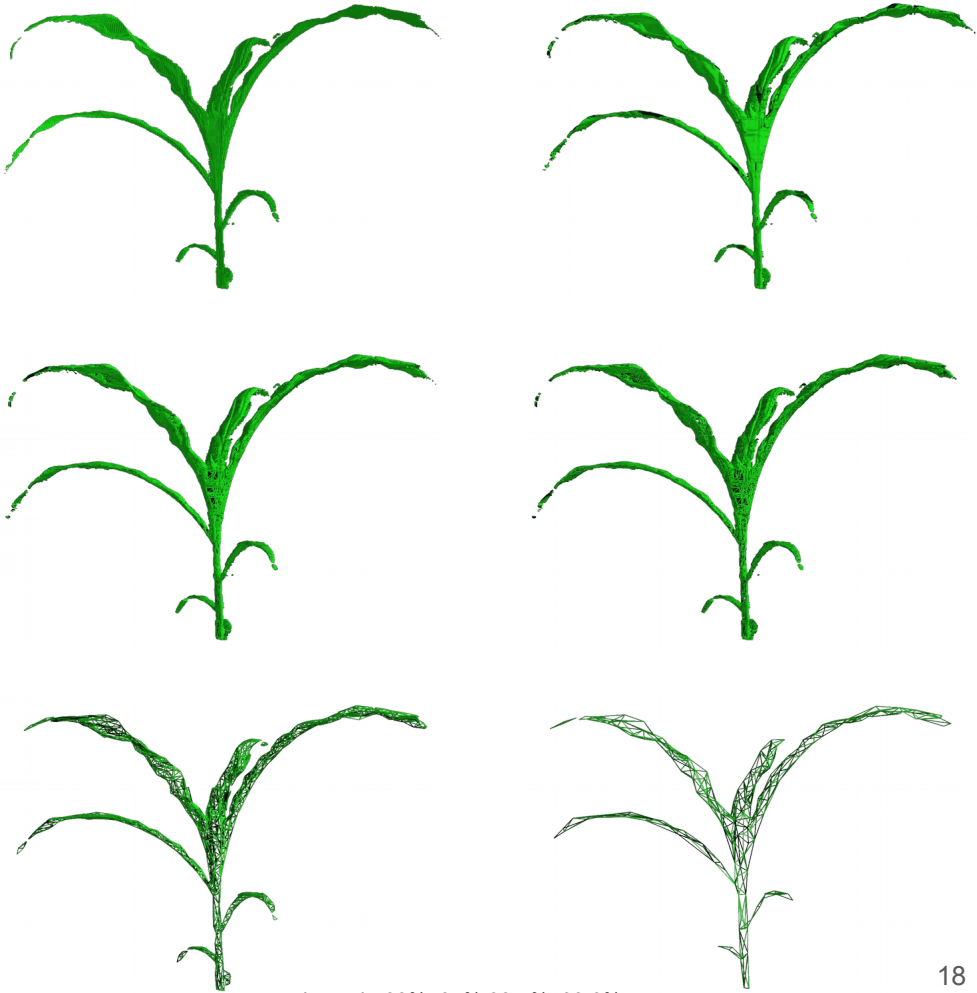
- Meshing
  - “Marching cubes : A high resolution 3d surface construction algorithm” (Lorensen et Cline, 1987)
- Smooth
  - Optimal surface smoothing as filter design (Taubin et al, 2005)



Meshing / Voxelization - Decimation

- *Surface Simplification Using Quadric Error Metrics*, Garland and Heckbert, 1997



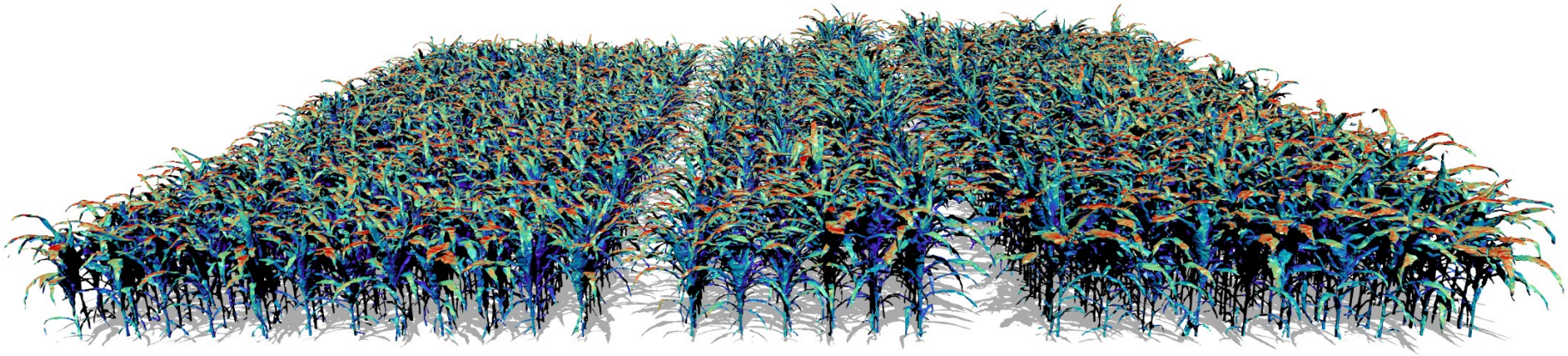


voxel, mesh, 90%, 95%,99.5%, 99.9%

Meshing / Voxelization - Voxelization

- *Fundamentals of surface voxelization*. Cohen-Or and Kaufman, 1995

Meshing / Voxelization - Phenoarch Canopy



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Skeletonization
&
Maize Organ Segmentation
&
Analysis

Skeletonization - Existing skeletonization methods

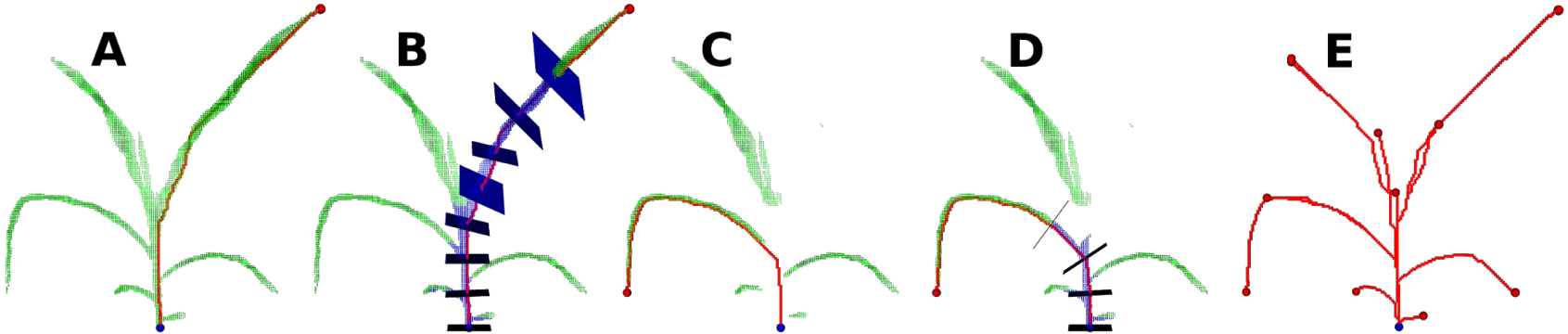
Building skeleton models via 3-D medial surface axis thinning algorithms, Lee et al, 1994

Reconstructing Plant Architecture from 3D Laser scanner data, Preuksakarn et al, 2010

3D 6-subiteration thinning algorithm for extracting medial lines, Palàgyi et al, 1998

Skeletonization - Algorithm

- Based on the unordered weighted graph of 3D neighborhood position
  - Select the source node
  - L = all the shortest paths
  - Select the longest shortest path
    - For each point P of this path, compute a plane whose the normal is equal to the vector's orientation of P.
    - Tag all voxels who are connected to P in the sub-set of voxels intercepted by the plane
    - Remove all the paths whose the extremity have already been marked in L
  - Repeat until L is empty



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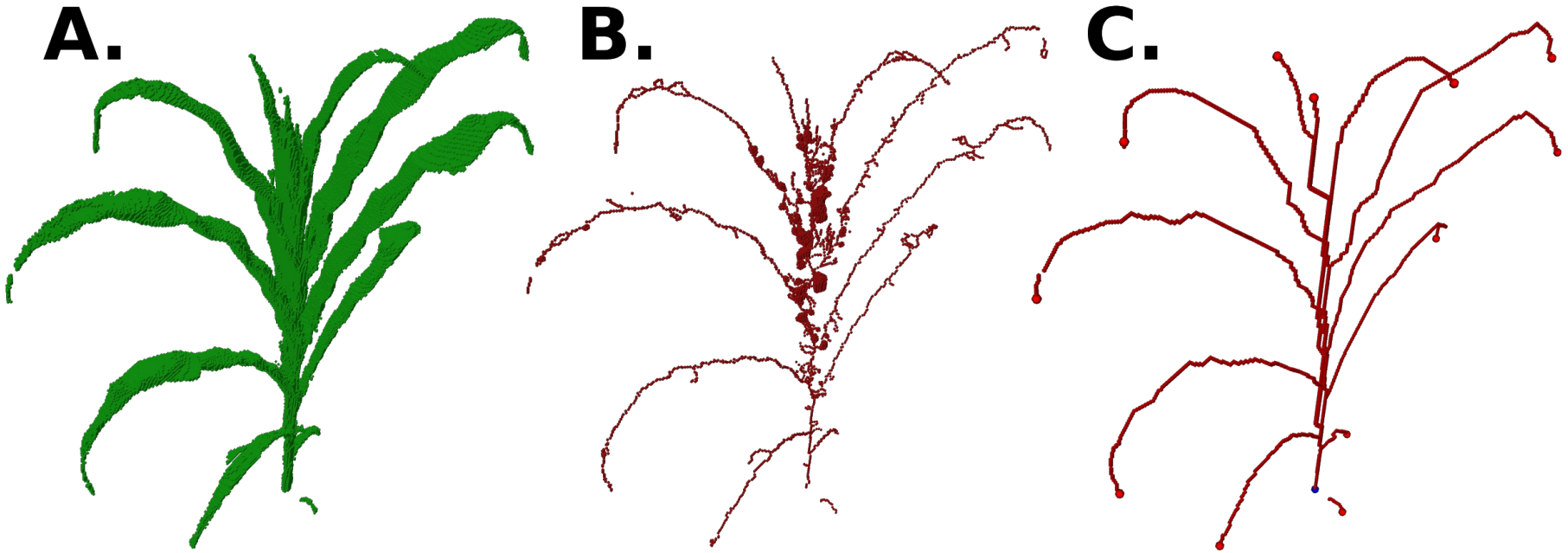
Skeletonization - Comparison



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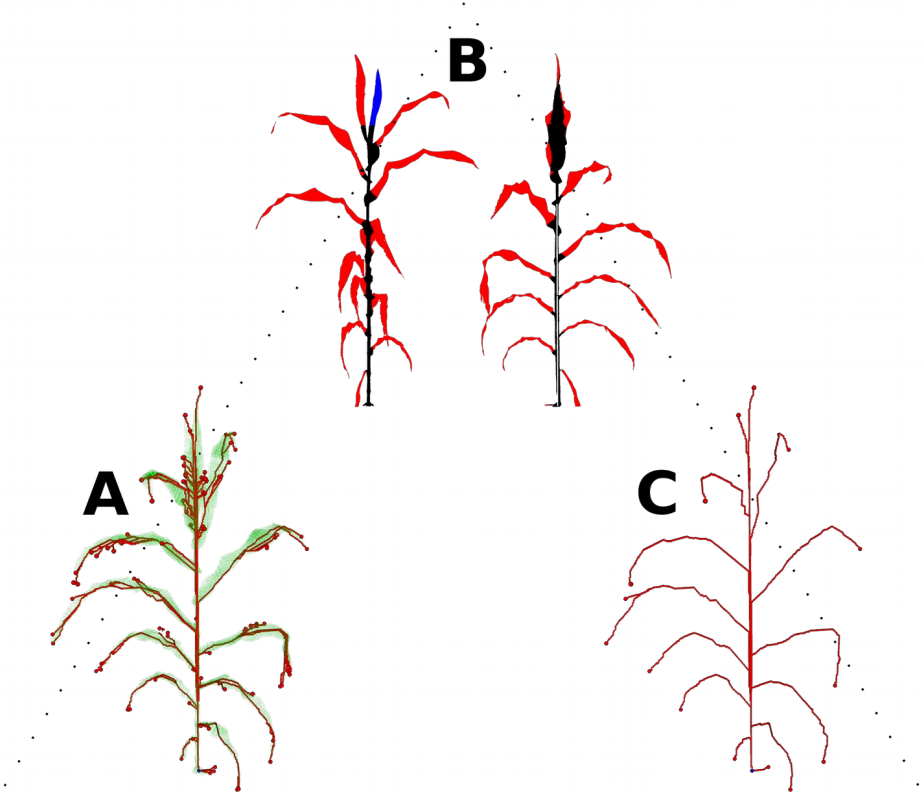
Skeletonization - Denoising skeleton



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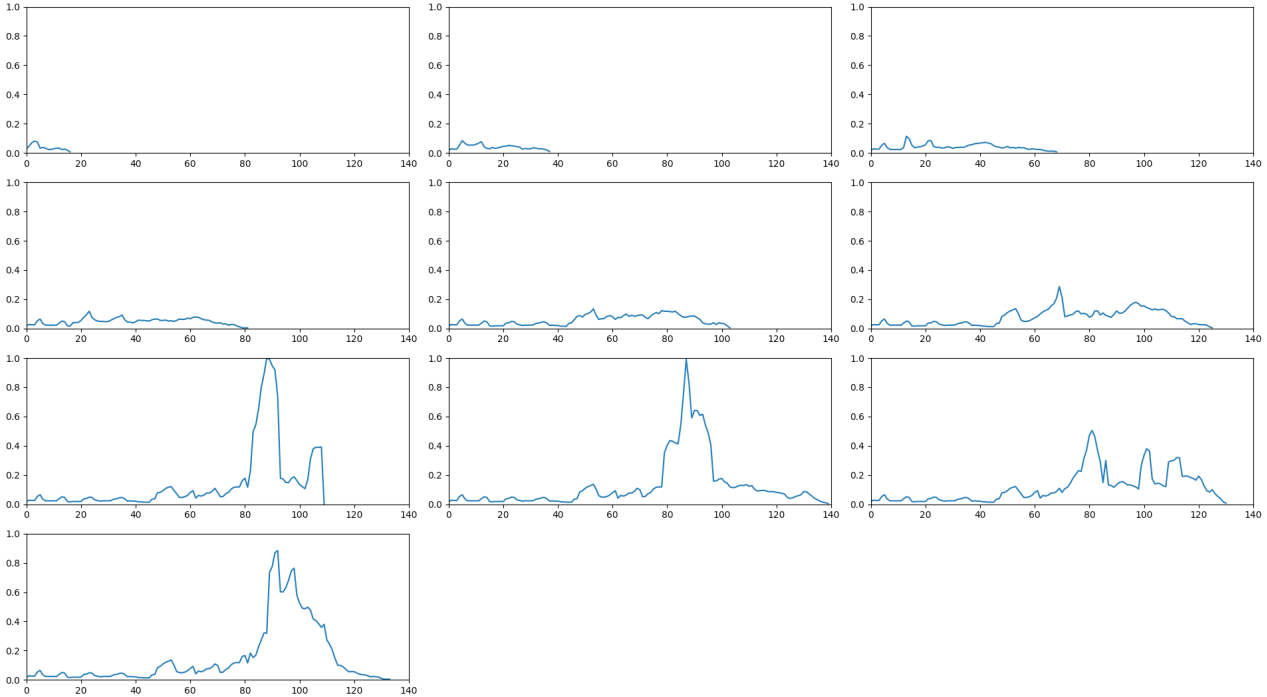
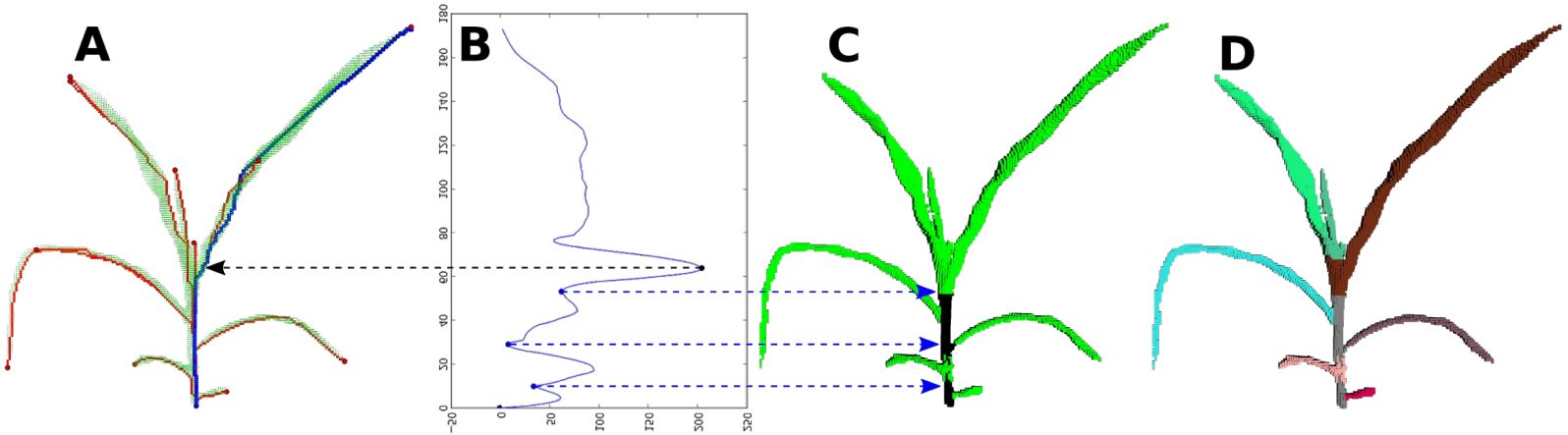
Skeletonization - Analyse path have associate voxels



Maize organ segmentation - Algorithm

BALL



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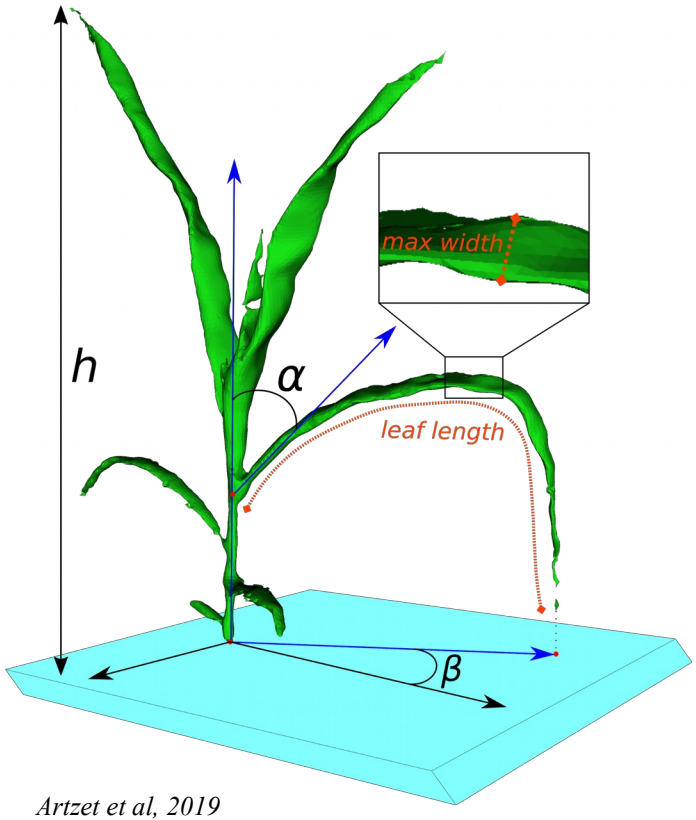
Analysis

- Plant :
  - Number of leaf
  - Volume, surface
  - Maximal height
  - Convex hull
  - Projection area
- Leaves
  - volume
  - azimuth
  - insertion & inclinaison angle
  - length
  - full length (to the pot)
  - visible length (for growing leaves only)
  - maximum and mean width
- Stem:
  - Length
  - Heigth
  - Diameter



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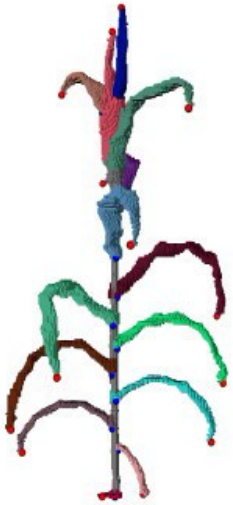
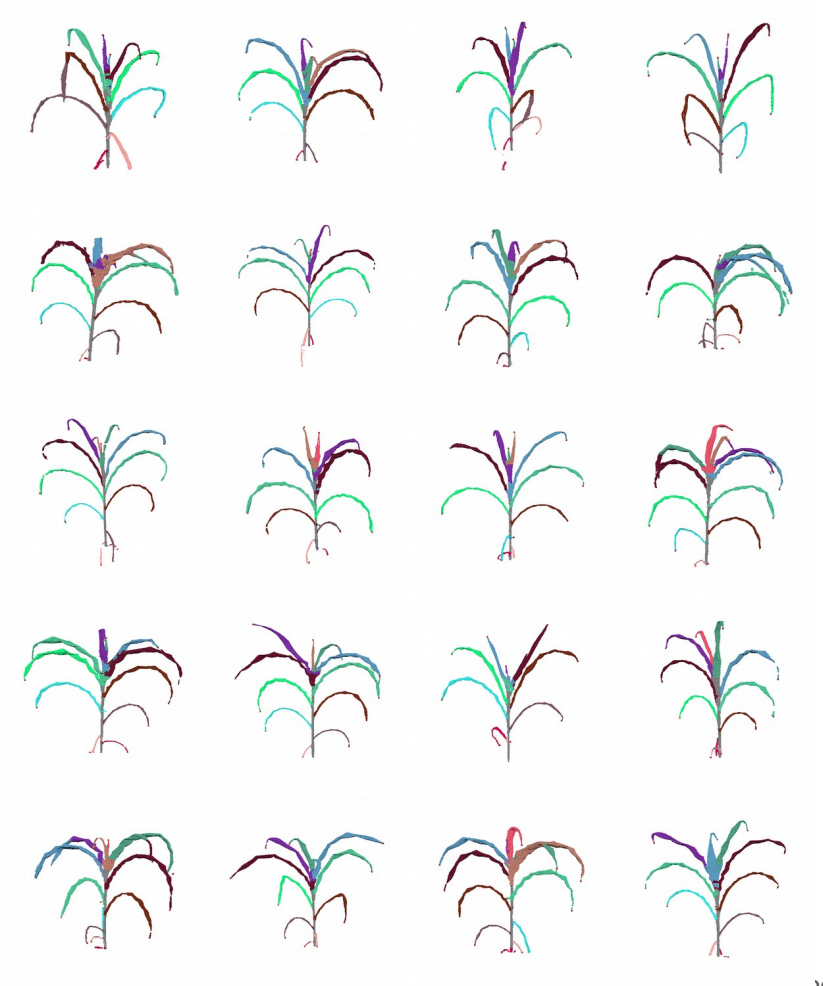
Somes visuals





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