Carambole

Plant leaf growth capture and modelling

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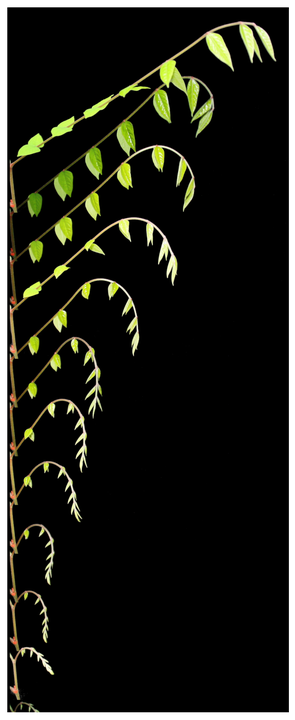
Motivation



Plant motion
- External constrains, stimuli (*eg.* objects, wind, light, heat)
- Internal conditions (*eg.* compression, hormones, …)
- Complex, not fully understood

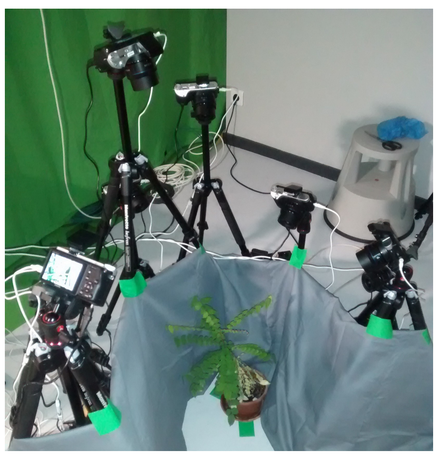
Consortium
- Morpheo, LJK/Inria Grenoble: video-based motion capture and geometric modelling
- Lab. Matière et Systèmes Complexes, Paris Diderot: biophysics
- Highly complementary

Aim: capture and model the 3D motion of an *Averrhoa Carambola* leaf

Proposed approach
- Motion capture from multiple videos
- 3D geometric modelling over time
- Centreline motion estimation
- Inverse mechanical modelling

Capture platforms

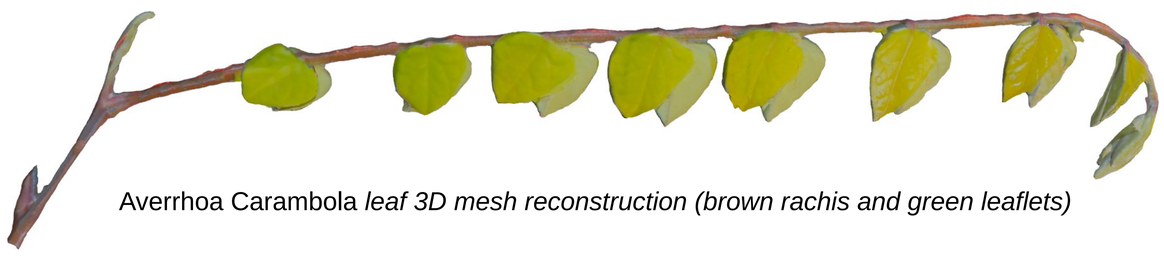
Kinovis mobile capture platform @ Inria Grenoble
- 10 cameras
  - 27 Mpix
  - 1 frame per minute (typical)
  - Flash to limit constant light
- 3D volume
  - 30x30x30 cm^3
  - Resolution: 30µm



Similar platform @ Paris Diderot

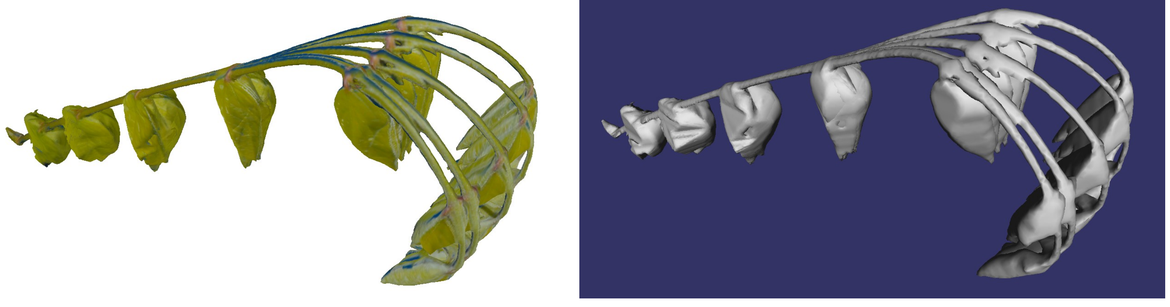
Experiments

***Averrhoa Carambola* leaf growth capture**
- One compound leaf (composed of a rachis and several leaflets)
- One nutation cycle: approx 2 hours
- Over night, since nutation & growth are more pronounced
- Initial 3D reconstruction using image-based visual hulls [1]



Averrhoa Carambola *leaf 3D mesh reconstruction (brown rachis and green leaflets)*

Mesh sequence
- Overall view on motion
- No explicit temporal coherence



Averrhoa Carambola *leaf 3D mesh reconstruction over time (left: textured, right: raw)*

References

[1] J.-S. Franco and E. Boyer. *Efficient Polyhedral Modeling from Silhouettes.* IEEE Trans. on Pattern Recognition and Machine Intelligence 31(3), 2009.

[2] K. Cole-McLaughlin et al. *Loops in Reeb Graphs of 2-Manifolds.* Discrete Comput. Geom. 32, 2004.

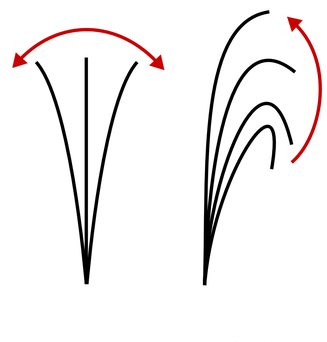
[3] L. Shapira et al. *Consistent Mesh Partitioning and Skeletonization Using the Shape Diameter Function.* The Visual Computer 24, 2008.

[4] F. Bertails et al. *Super-helices for Predicting the Dynamics of Natural Hair.* ACM Trans. on Graph. 25(3), 2006.

Centreline extraction

Main observed motion modes:
- Longitudinal (actual growth)
- Unfurling (unrolling)
- Nutation (sway motion)

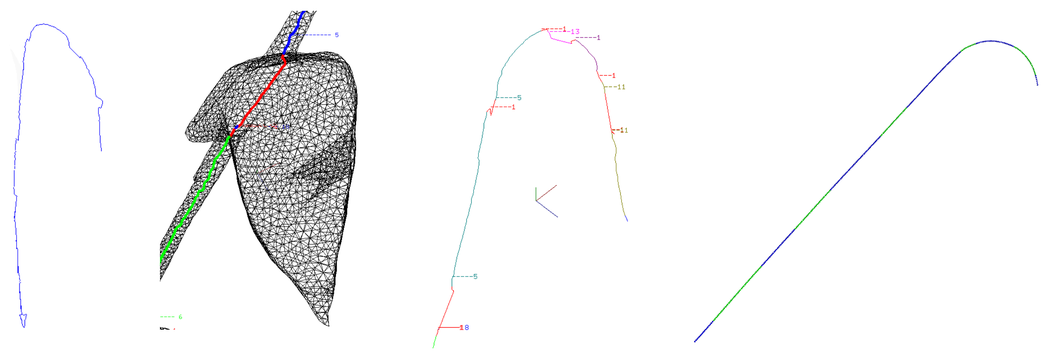
Dimensionality reduction to centreline in order to analyse key motion modes



nutation *unfurling*

Actual centreline motion: nutation

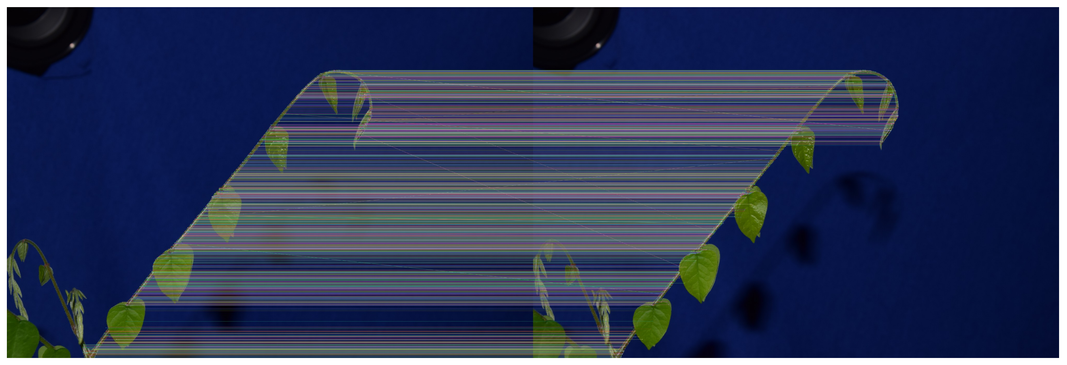
Centreline computation
- Input: one mesh (= one frame of the 3D sequence)
1. Reeb graph computation (diffusion function) [2] and embedding
2. Leaflet segmentation [3] on mesh and graph
3. Spline-based hole filling
- Output: Centreline defining curvilinear abscissa (CLA)



Embedded Reeb graph is noisy (left) because of poor approximation in leaflet areas (centre left). Segmentation (centre right) and spline-based filling generate a smoother curve (right).

2D/3D motion tracking

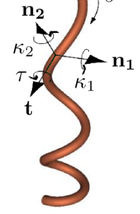
Feature tracking
- SIFT feature detection/tracking in 2D
- Projection on mesh
- Projection on centreline / CLA



Inverse mechanical modelling

Problem statement
- Find the set of physical parameters (curvatures, Young modulus, …) minimizing the distance between the centreline and a mechanical model
- Model (rod): Super-helix [4] / Method: progressive random walk fitting

Progressive random walk fitting



Super-helix model [4]

Conclusion and perspectives

Conclusion
- Proof-of-concept pipeline for plant capture and modelling

Perspectives
- Tracking and inverse mechanical modelling
- Improve methods and adapt to other leaf types (*eg.* avocado: 2-dimensional)

Acknowledgements
This work has been partially supported by the LabEx PERSYVAL-Lab (ANR-11-LABX-0025-01) funded by the French program Investissement d'avenir and by the KINOVIS project (ANR-11-EQX-0024).