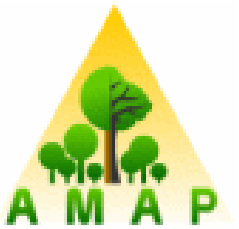
AMAPstudio:
a 3D Interactive Software Suite for Plants Architecture Modelling

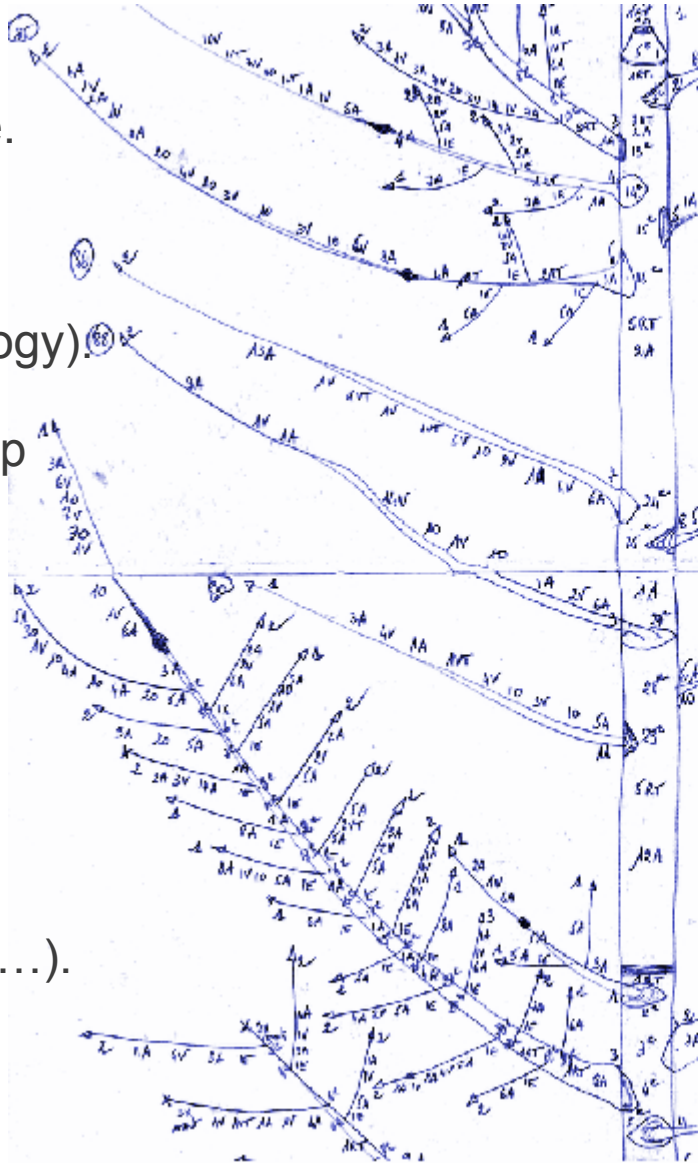
Sébastien Griffon (Cirad-AMAP)
François de Coligny (INRA-AMAP)



December 6th 2013, Montpellier

Objectives

- Build, simulate, edit, explore and analyse plant architecture.
- User-friendly and end-user oriented.
- Multi-purpose application (botany, agronomy, forestry, ecology).
- Single framework and methodology for modellers to develop their own models.
- Scenario oriented.



Y. Caraglio

Context

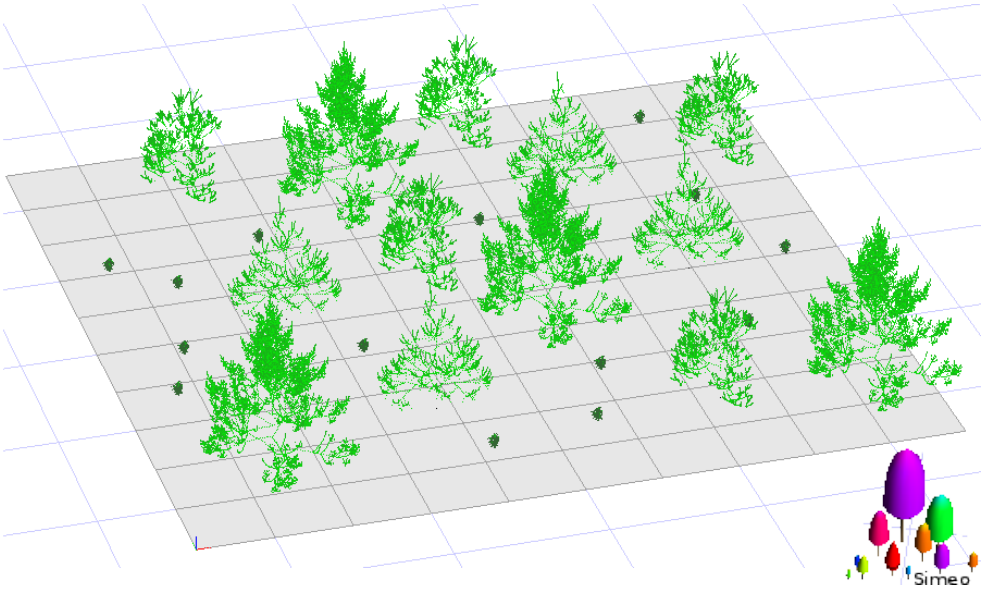
- Many existing tools (GroImp, OpenAlea, L-studio, Lignum, …).
- AMAP develop software for plant modelling since the 80's.
- In 2008, scientists synergy to design all those features in a single software suite to share knowledge and methods with a long-term support.

AMAPstudio : features for plant architecture modelling

1- Central plant data structure

2 - Xplo

Individual scale = detailed representation



3 - Simeo

Scene scale = simplified representation

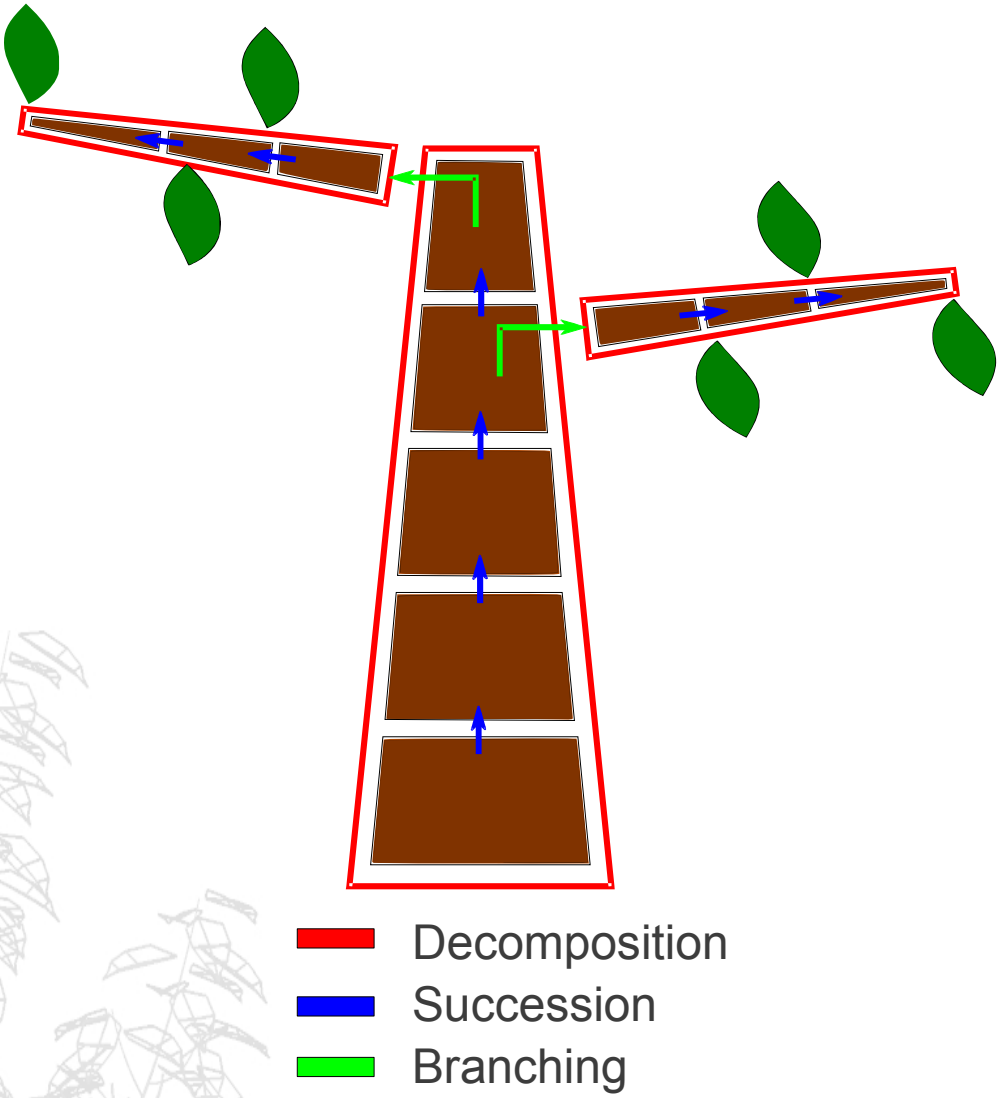
4 - Simulation framework

5 - Common features

I. Central plant data structure 1/3

Topology based on the Multiscale Tree Graph (MTG) formalism

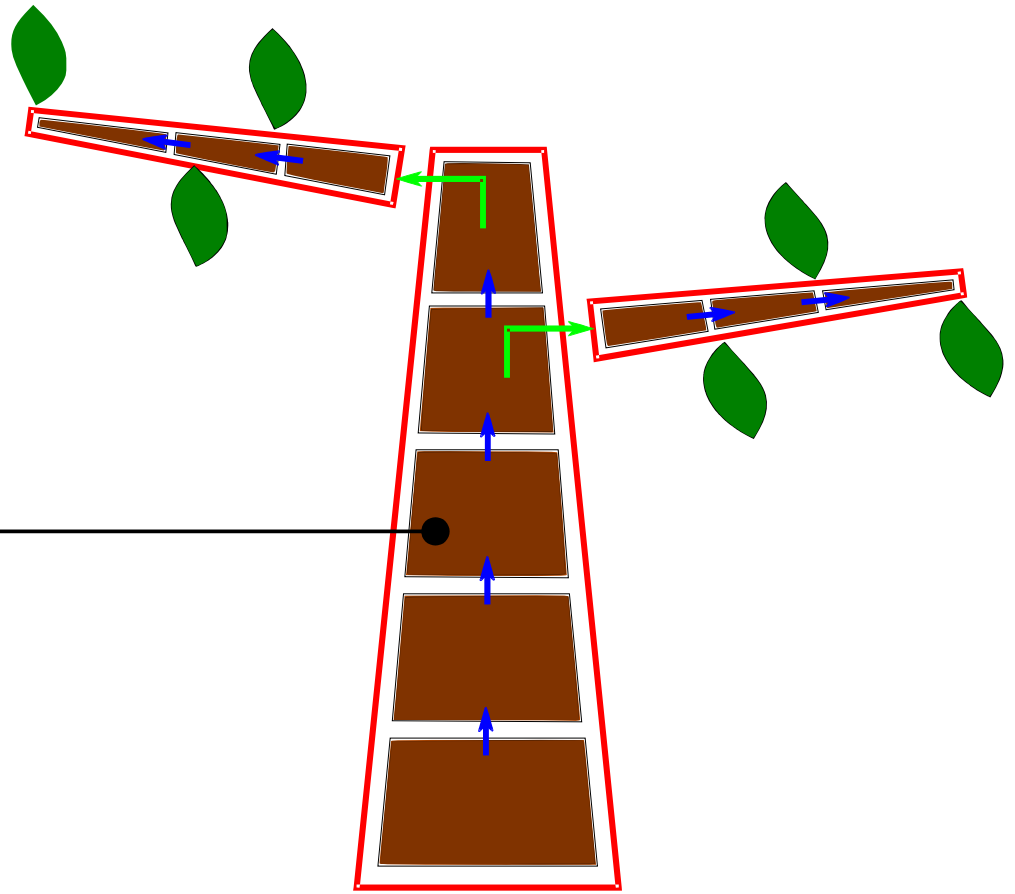
C. Godin and Y. Caraglio, "A multiscale model of plant topological structures", 1998 (1)



(1) Godin C, Caraglio Y. A multiscale model of plant topological structures, Journal of Theoretical Biology 1998; 191:1–46.

I. Central plant data structure 2/3

Data base : attributes can be attached to the plant components



- Length
- Diameter
- Phyllotaxy
- Color
...

Predefined attributes

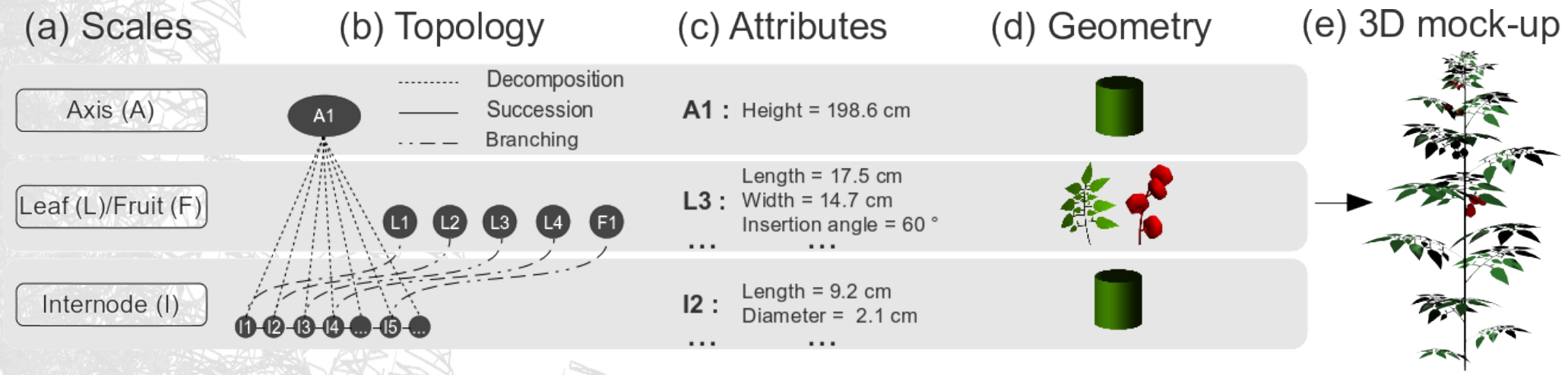
- Weight
- Free text
- Picture
...

User defined attributes

I. Central plant data structure 3/3

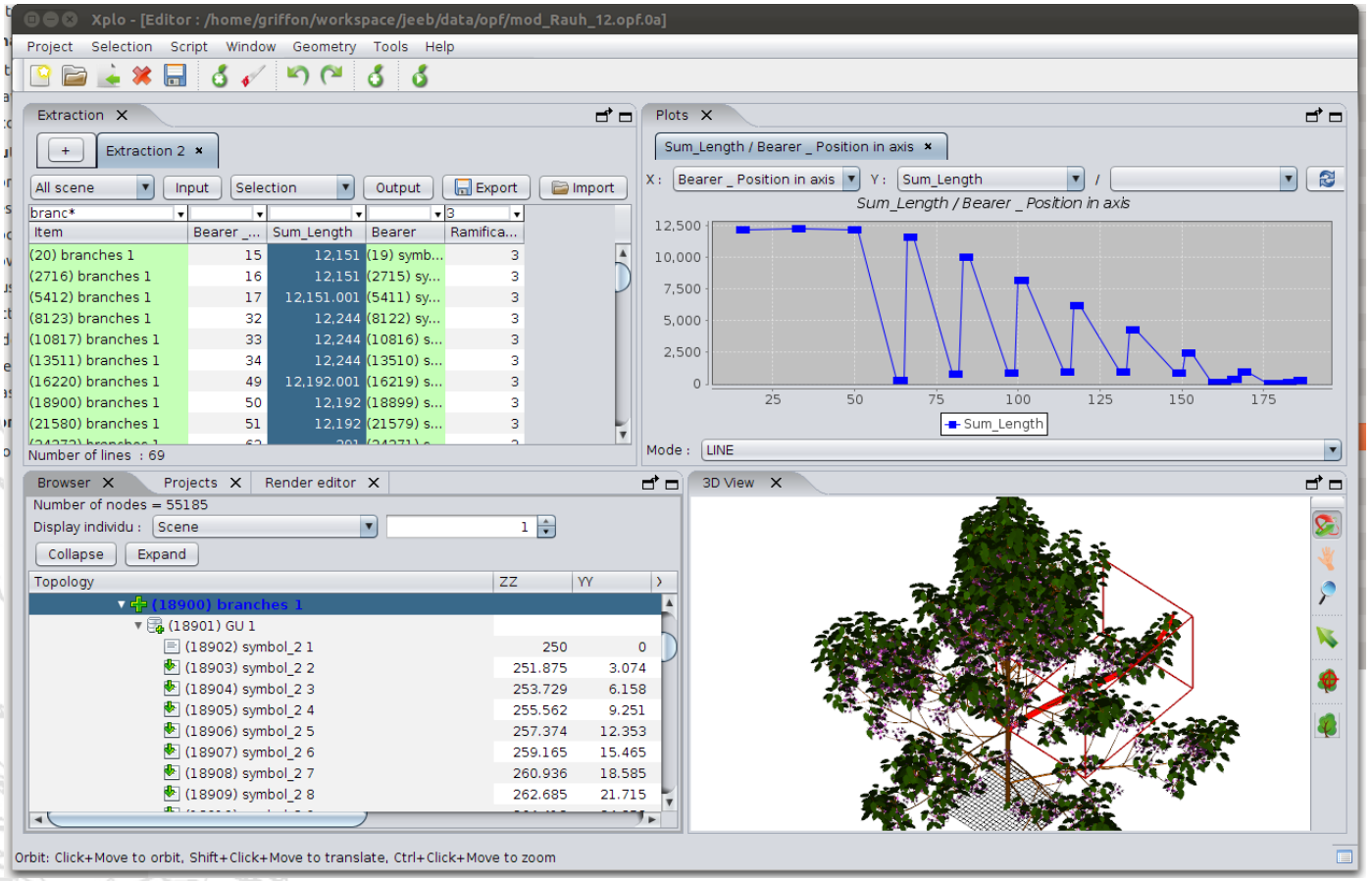
Topology
+ Geometrical attributes
+ Geometrical additionnal rules
+ Shape builder

→ 3D Mock-up



II. Xplo : main features

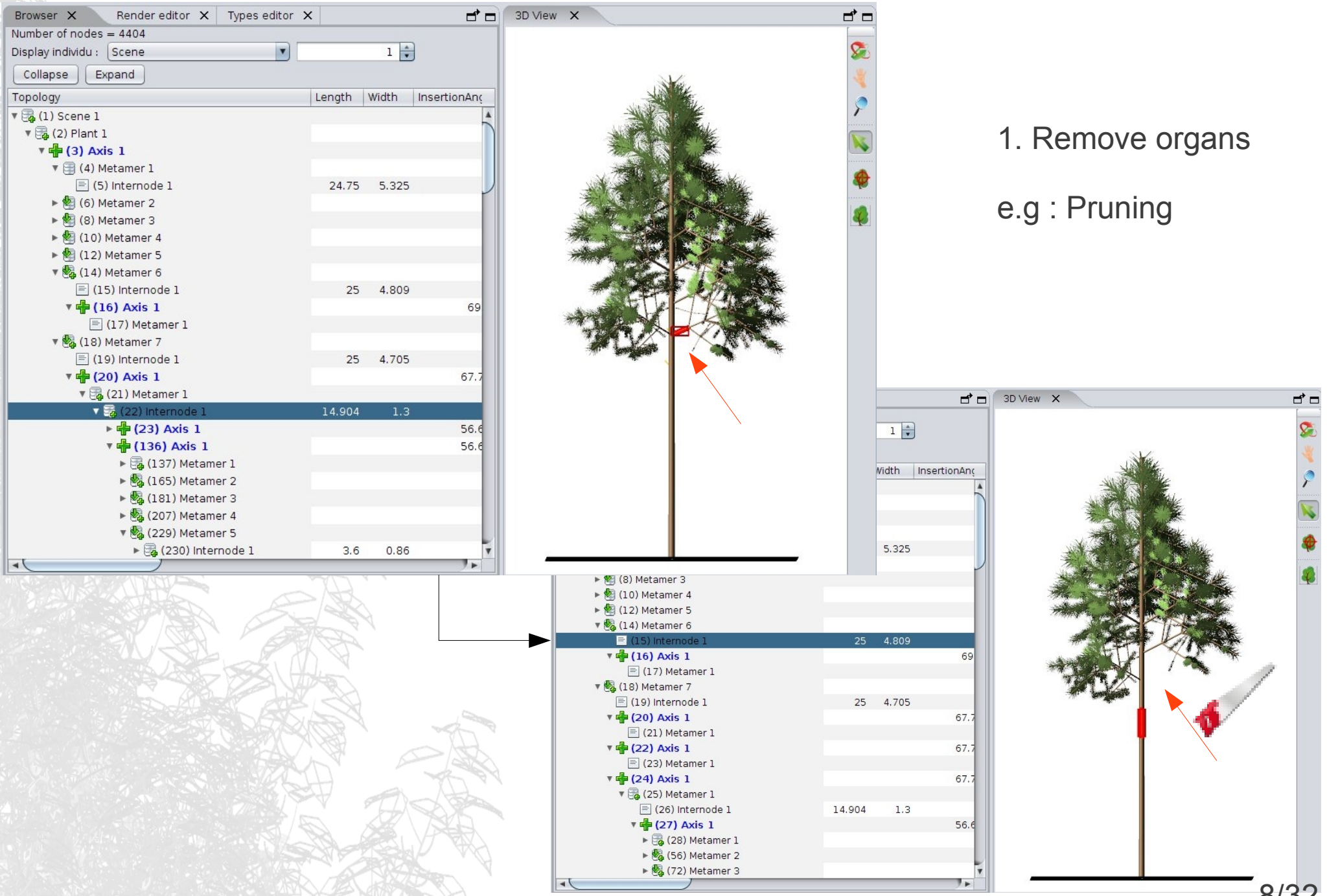
Detailed plant representations in several views



1) **Edit and explore** plant architecture

2) **Simulate** plant growth with one of the integrated model.

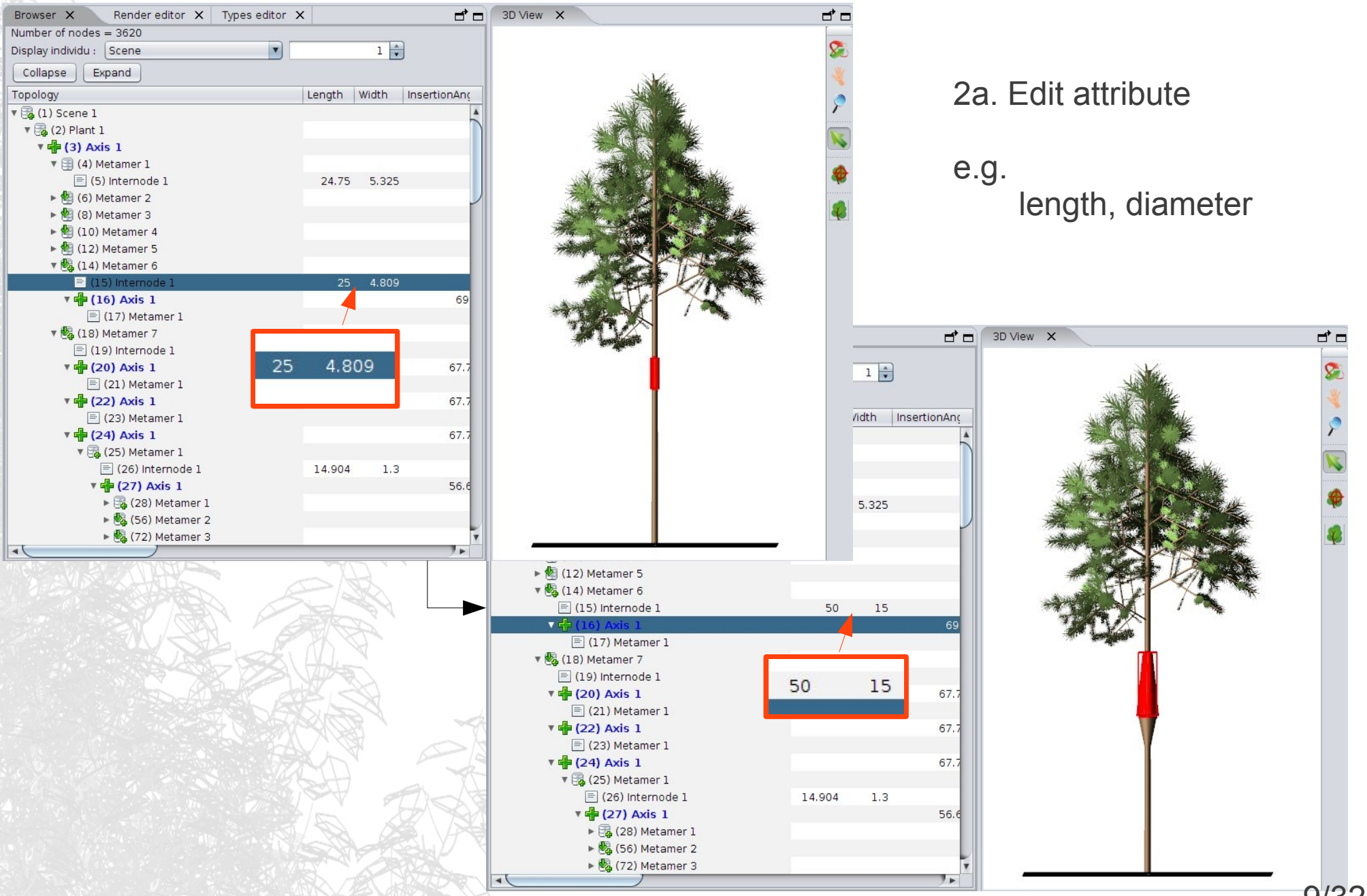
II. Xplo editor : plant edition (table view)



1. Remove organs

e.g : Pruning

II. Xplo editor : plant edition (table view)

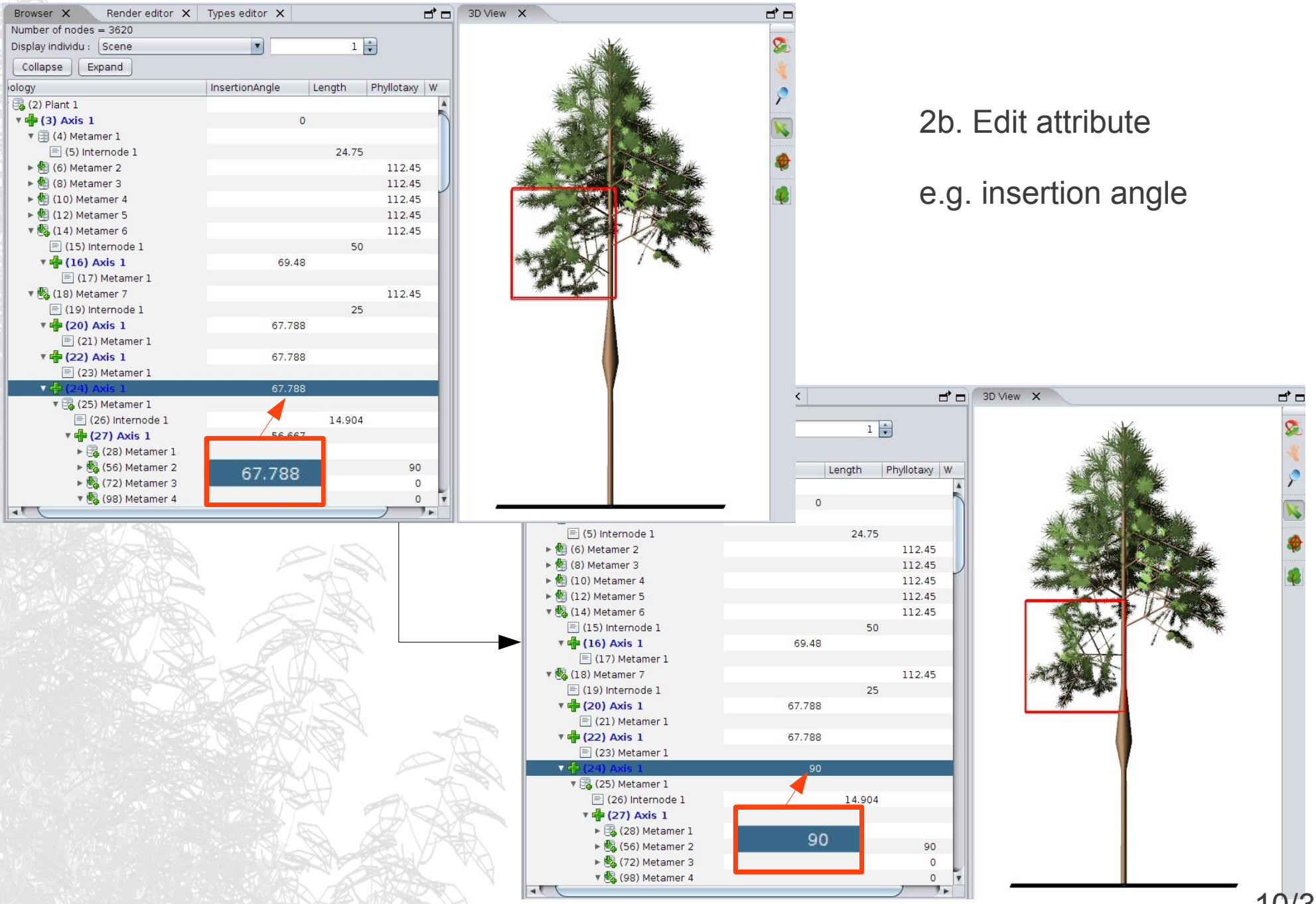


2a. Edit attribute

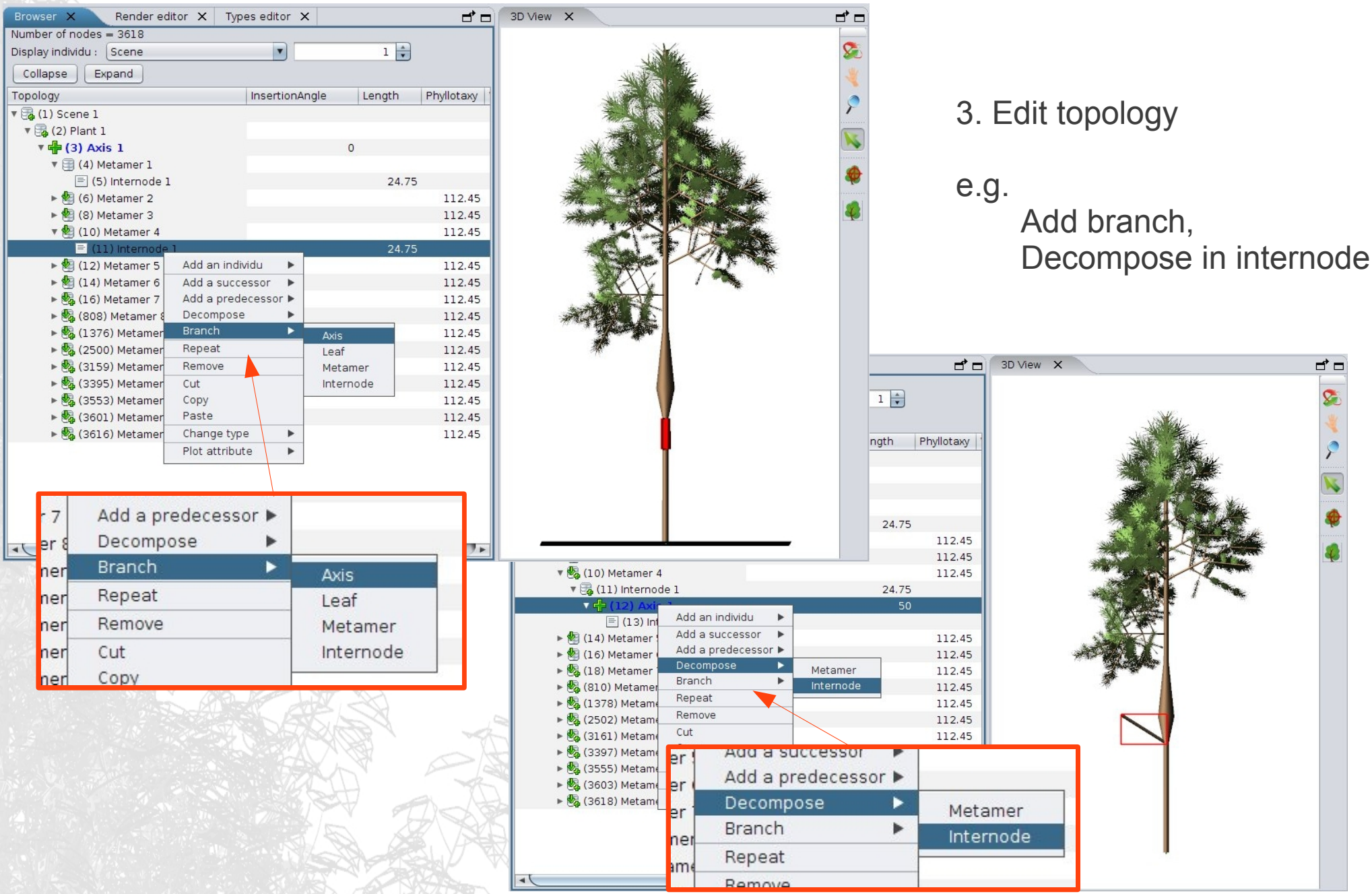
e.g.

length, diameter

II. Xplo editor : plant edition (table view)



II. Xplo editor : plant edition (table view)

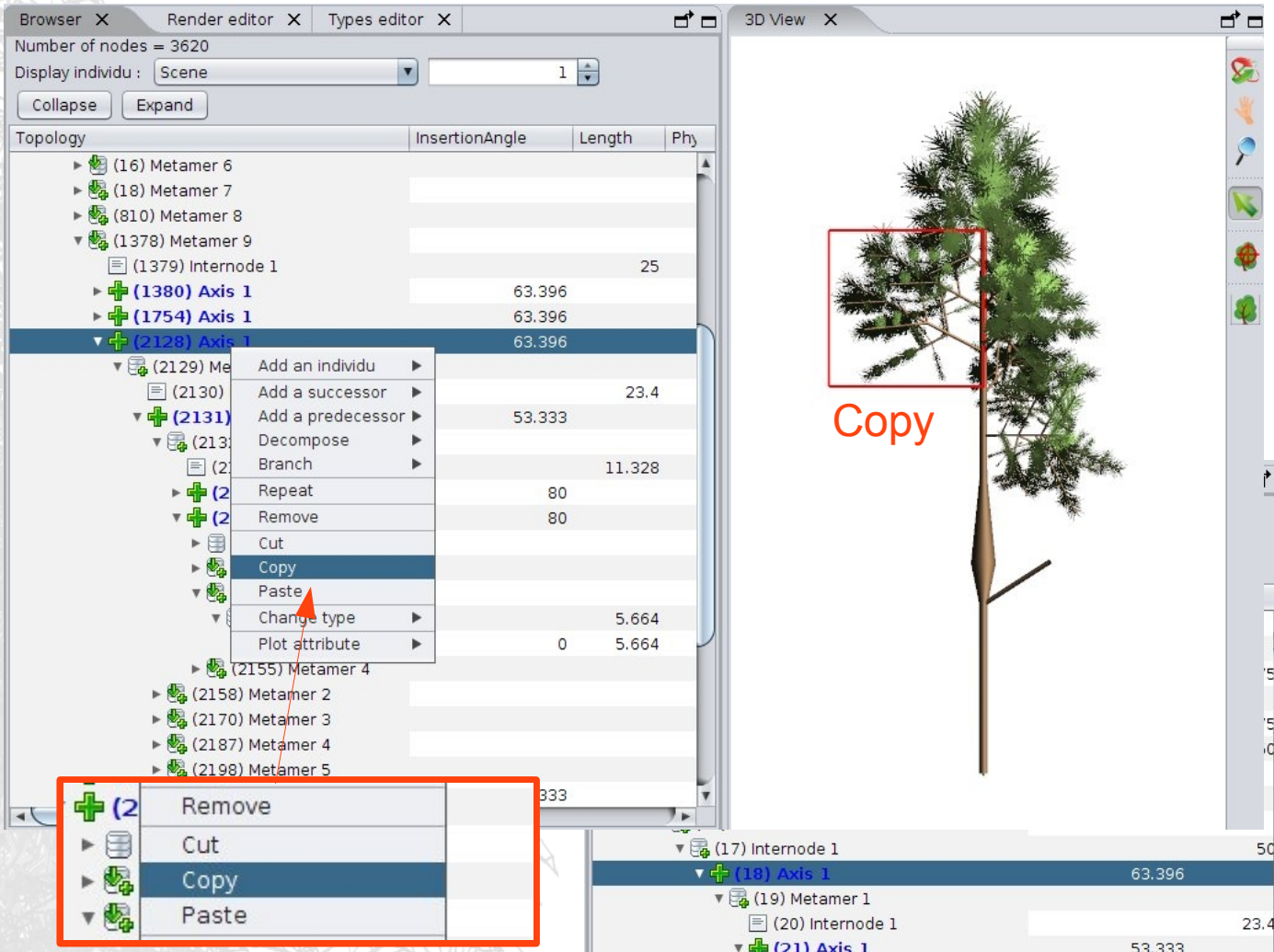


3. Edit topology

e.g.

Add branch,
Decompose in internode

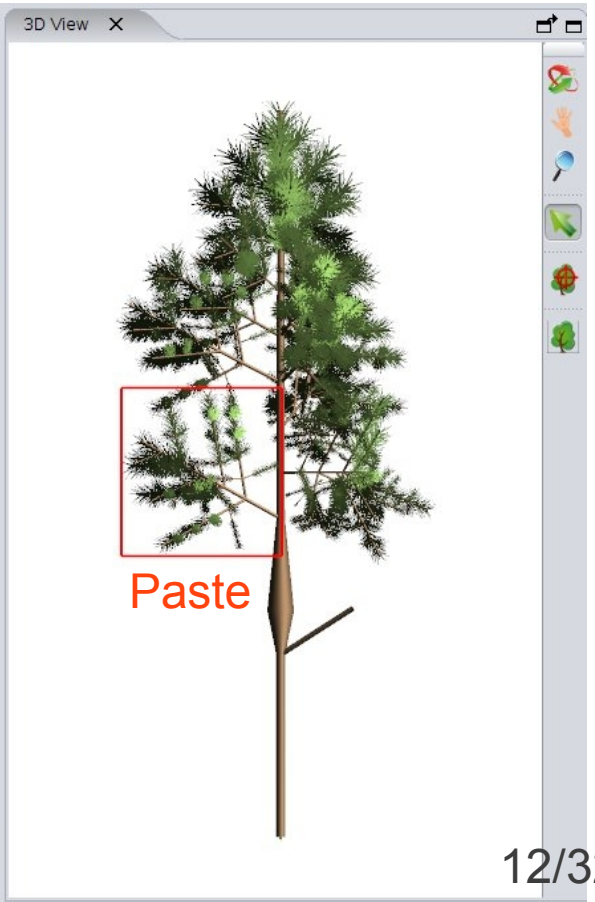
II. Xplo editor : plant edition (table view)



3. Edit topology

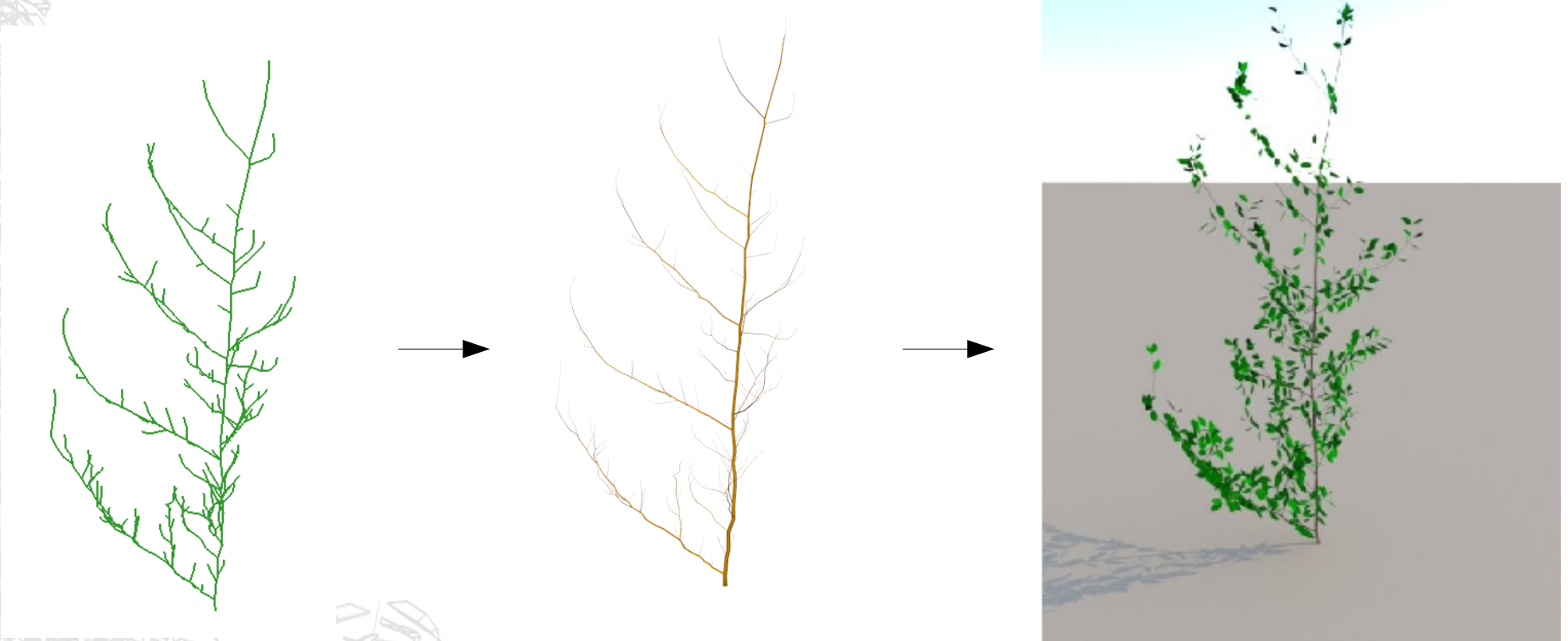
e.g.

Copy and paste branches



II. Xplo editor : 3D geometry reconstruction

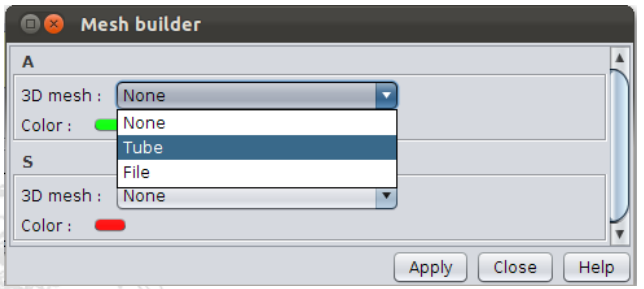
Example : Digitized plant geometry reconstruction

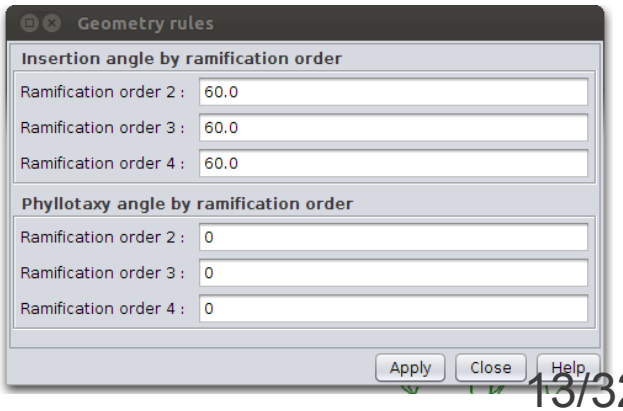


1

2

3

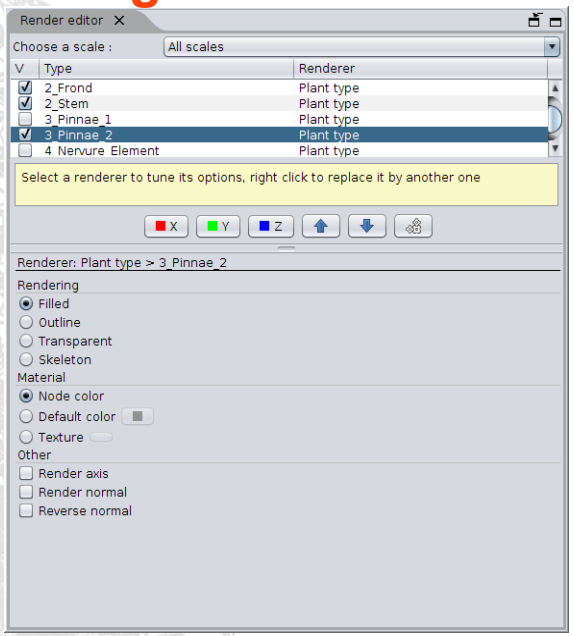




MTG from University of Natural Resources and Life Sciences (Vienna)

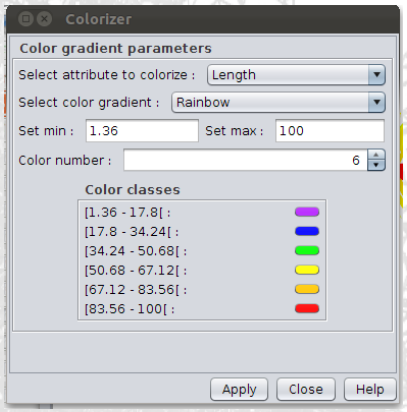
II. Xplo editor : configurable 3D view

Configurable renderers



Customisable layer rendering

Colorizer tool



Colors vs attributes

II. Xplo editor : data extraction

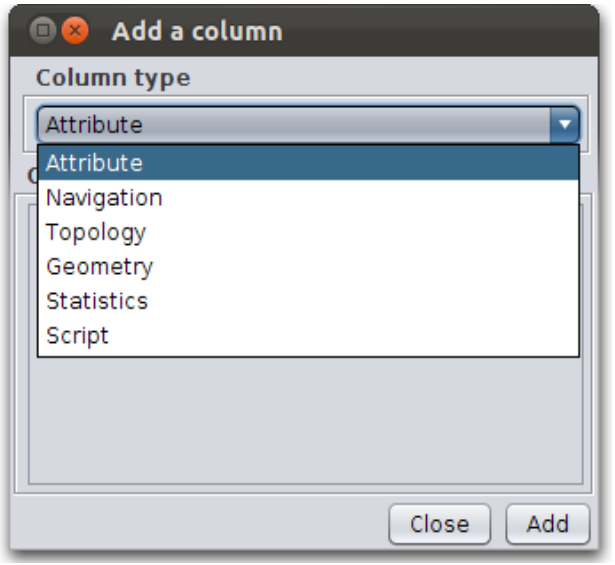
Interactive extraction table

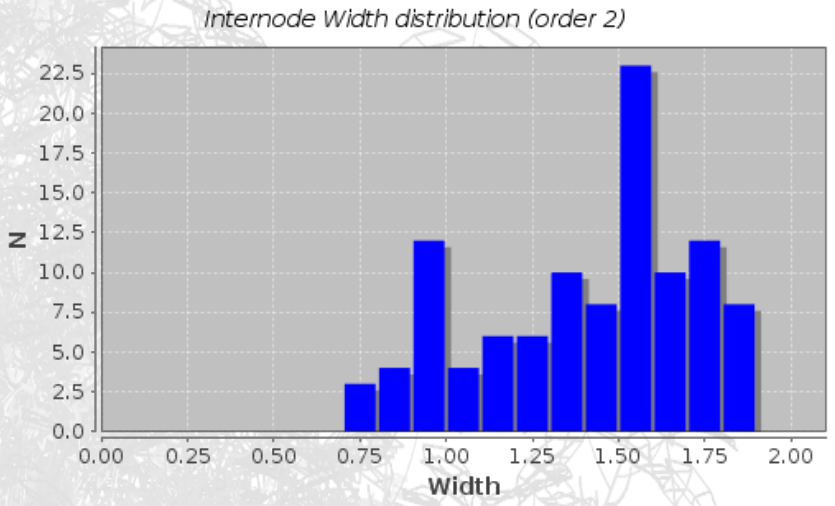
All scene | Input | Selection | Output | Export | Import

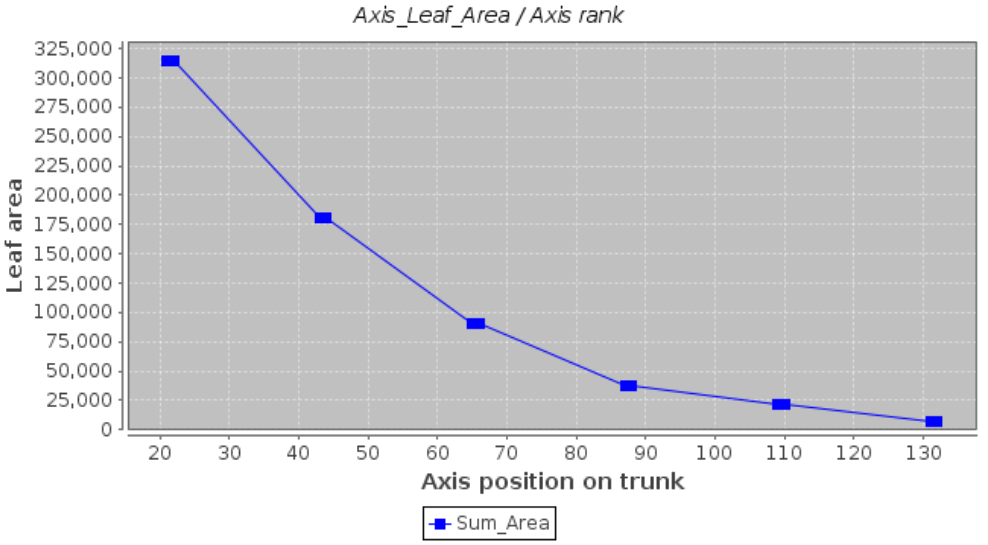
branches | 2

Item	Ramification order	Bearer	Bearer _ Position ...	Sum_Area
branche...	2	branches1 21	21	314966.989
branche...	2	branches1 22	22	314966.999
branche...	2	branches1 21	43	180814.383
branche...	2	branches1 22	44	180814.397
branche...	2	branches1 21	65	90407.193
branche...	2	branches1 22	66	90407.203
branche...	2	branches1 21	87	37912.693
branche...	2	branches1 22	88	37912.694
branche...	2	branches1 21	109	21386.648
branche...	2	branches1 22	110	21386.648
branche...	2	branches1 21	131	7128.882
branche...	2	branches1 22	132	7128.882

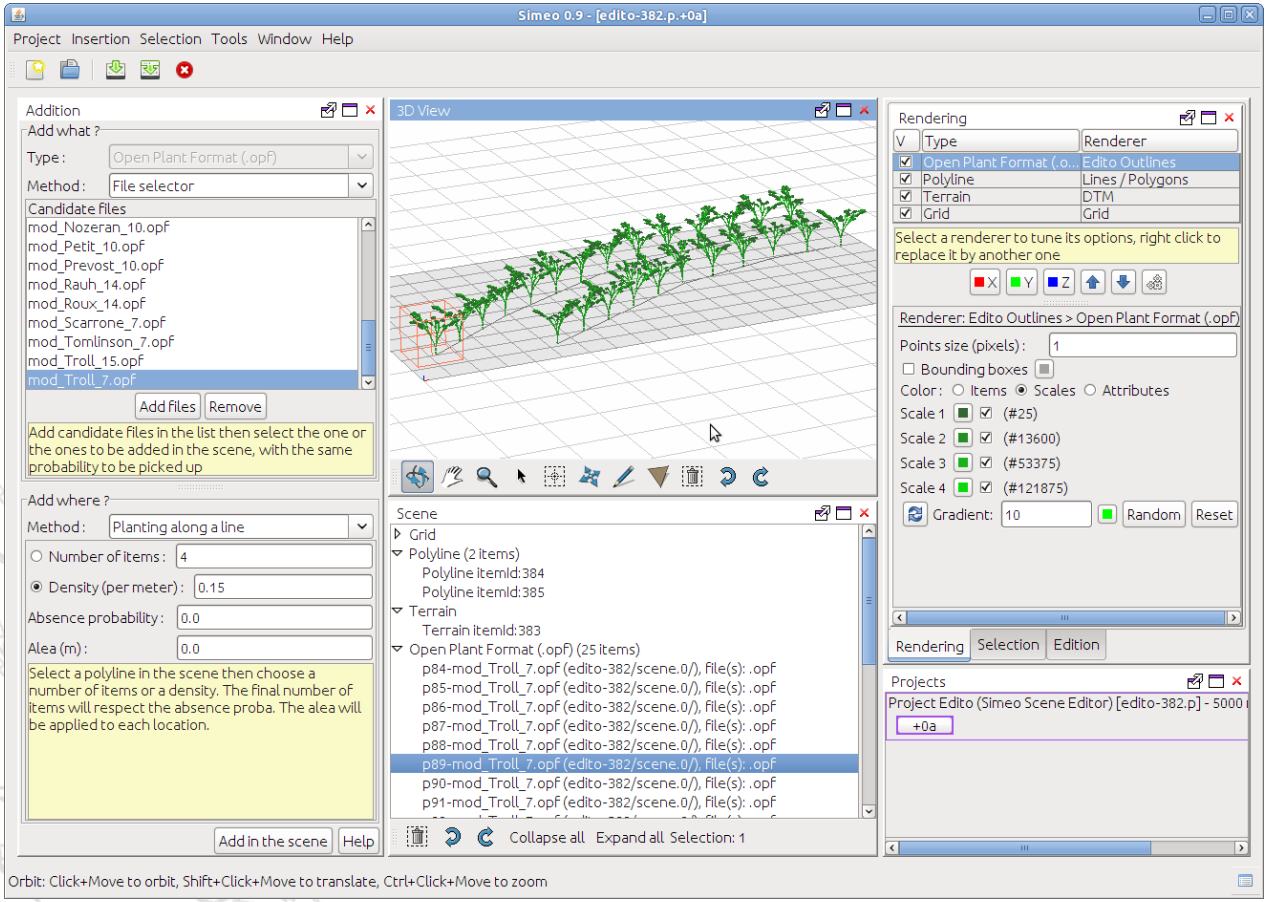
Number of lines : 12







III. Simeo : main features



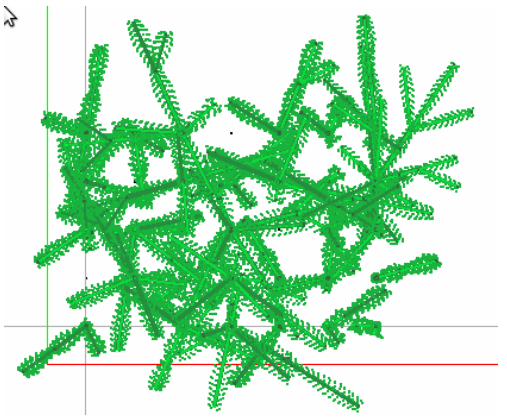
1 – **Edit** high detailed vegetal scenes (adaptative memory management)

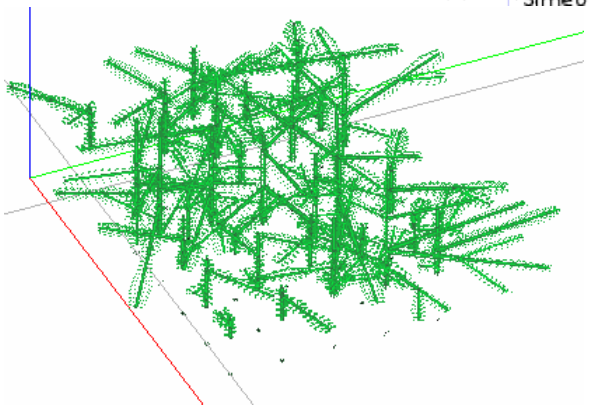
2 – **Connect** with scene level biophysics models (integrated or external) or **simulate** vegetal scene growth.

III. Simeo editor : scene creation and edition

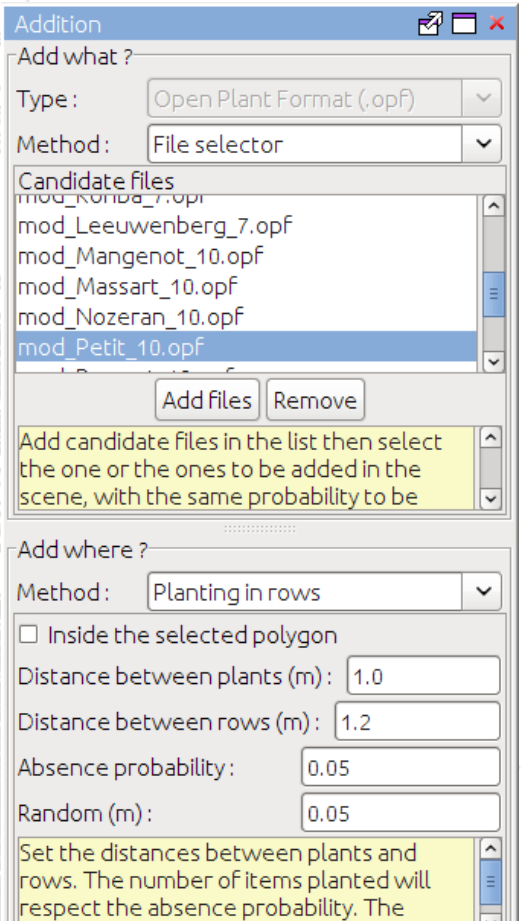
Load scene files

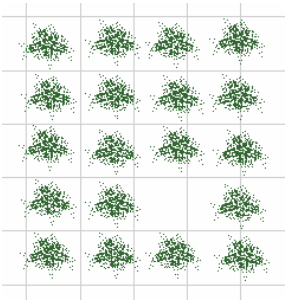
```
1   1   501.opf 0.04    0.24    0   1   0   0   0
1   2   502.opf 0.04    0.19    0   1   0   0   0
1   3   503.opf 0.04    0.14    0   1   0   0   0
1   4   504.opf 0.04    0.09    0   1   0   0   0
1   5   505.opf 0.04    0.04    0   1   0   0   0
1   6   506.opf 0.09    0.24    0   1   0   0   0
1   7   507.opf 0.09    0.19    0   1   0   0   0
1   8   508.opf 0.09    0.14    0   1   0   0   0
1   9   509.opf 0.09    0.09    0   1   0   0   0
```



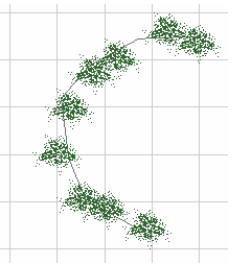


Create scenes with pattern plugins

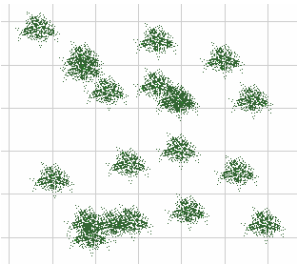




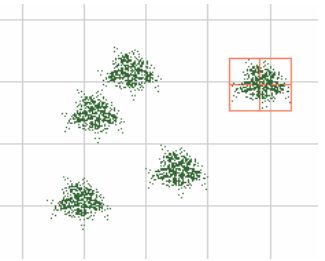
In rows



On a line



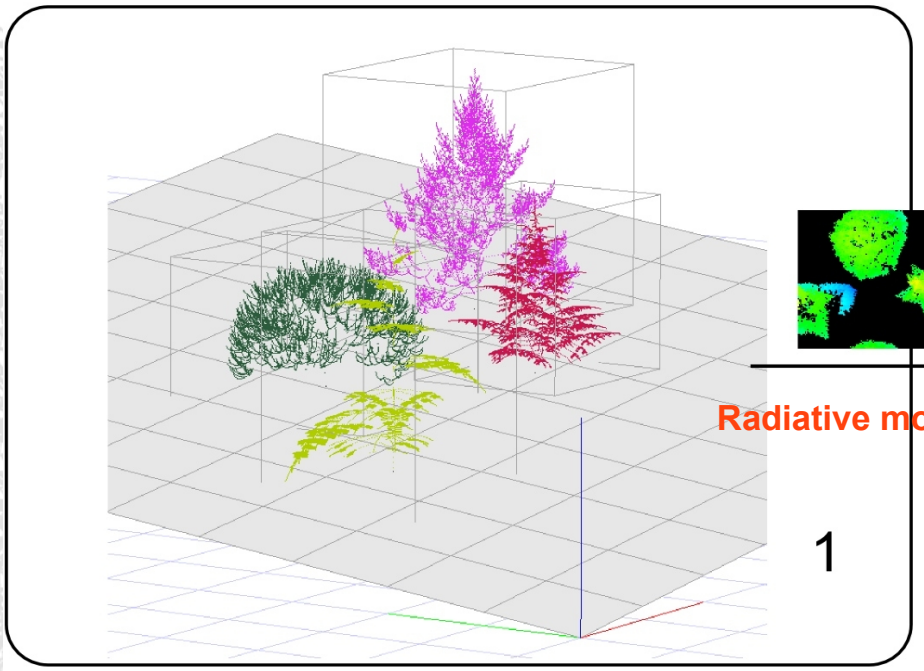
Random



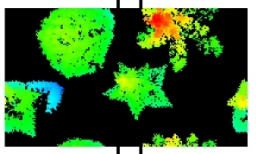
On mouse clicks...

And yours ...

III. Simeo : scene level processing integration

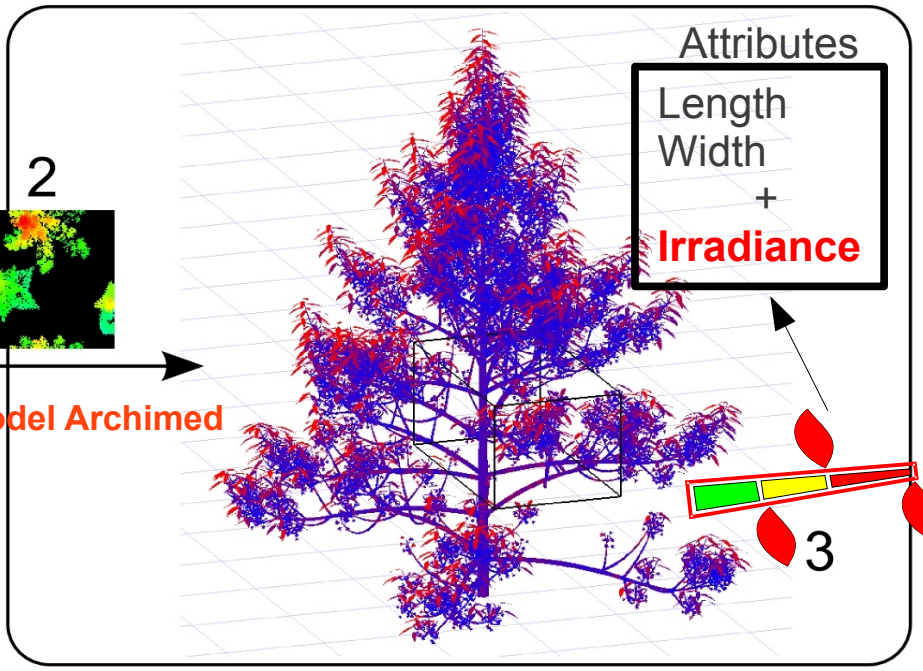


1



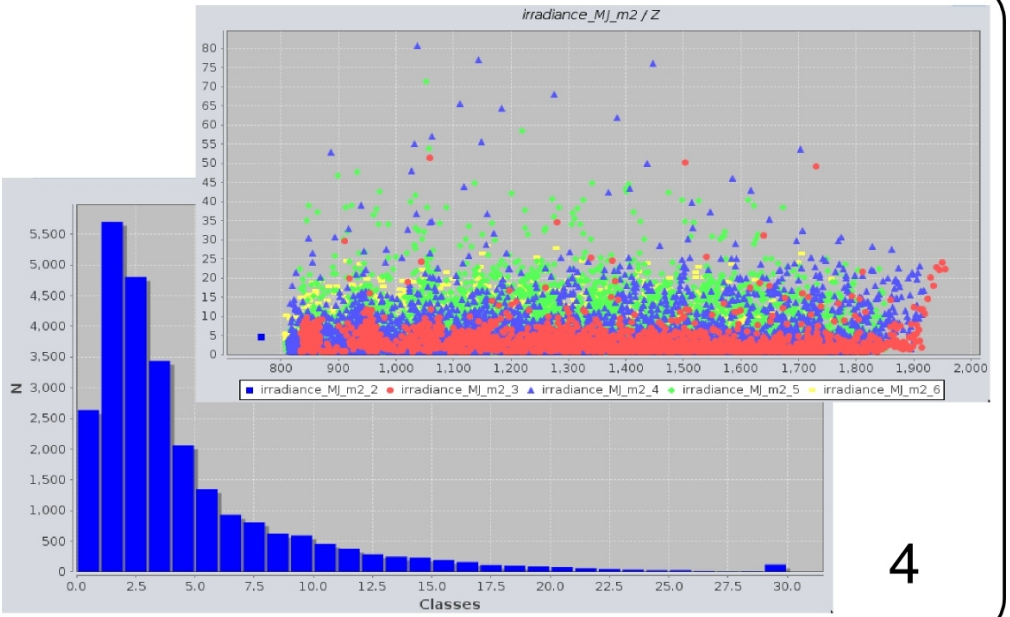
2

Radiative model Archimed



3

Item	Z	Area	Ramification order	irradiance_MJ_m2
branches1...	765.07	45467.3...	2	4.422
inflo5 1	807.936	98.304	6	5.271
branches4...	808.507	105.562	5	2.976
inflo5 1	808.507	98.306	6	10.148
branches4...	809.527	106.424	5	3.393
inflo5 1	809.527	98.305	6	4.935
inflo5 1	809.637	98.305	6	4.285
branches4...	809.692	31.133	5	1.049
inflo5 1	809.692	98.308	6	3.484
branches4...	809.961	31.133	5	1.987
inflo5 1	809.961	98.308	6	5.687
branches4...	810.018	63.836	5	2.647
branches4...	810.924	32.721	5	1.819
inflo5 1	810.924	98.309	6	1.327
inflo5 1	811.436	98.305	6	2.759
branches3...	811.908	140.948	4	3.334
inflo5 1	812.348	98.309	6	2.15
branches4...	812.385	34.308	5	0.952
inflo5 1	812.385	98.307	6	0.992

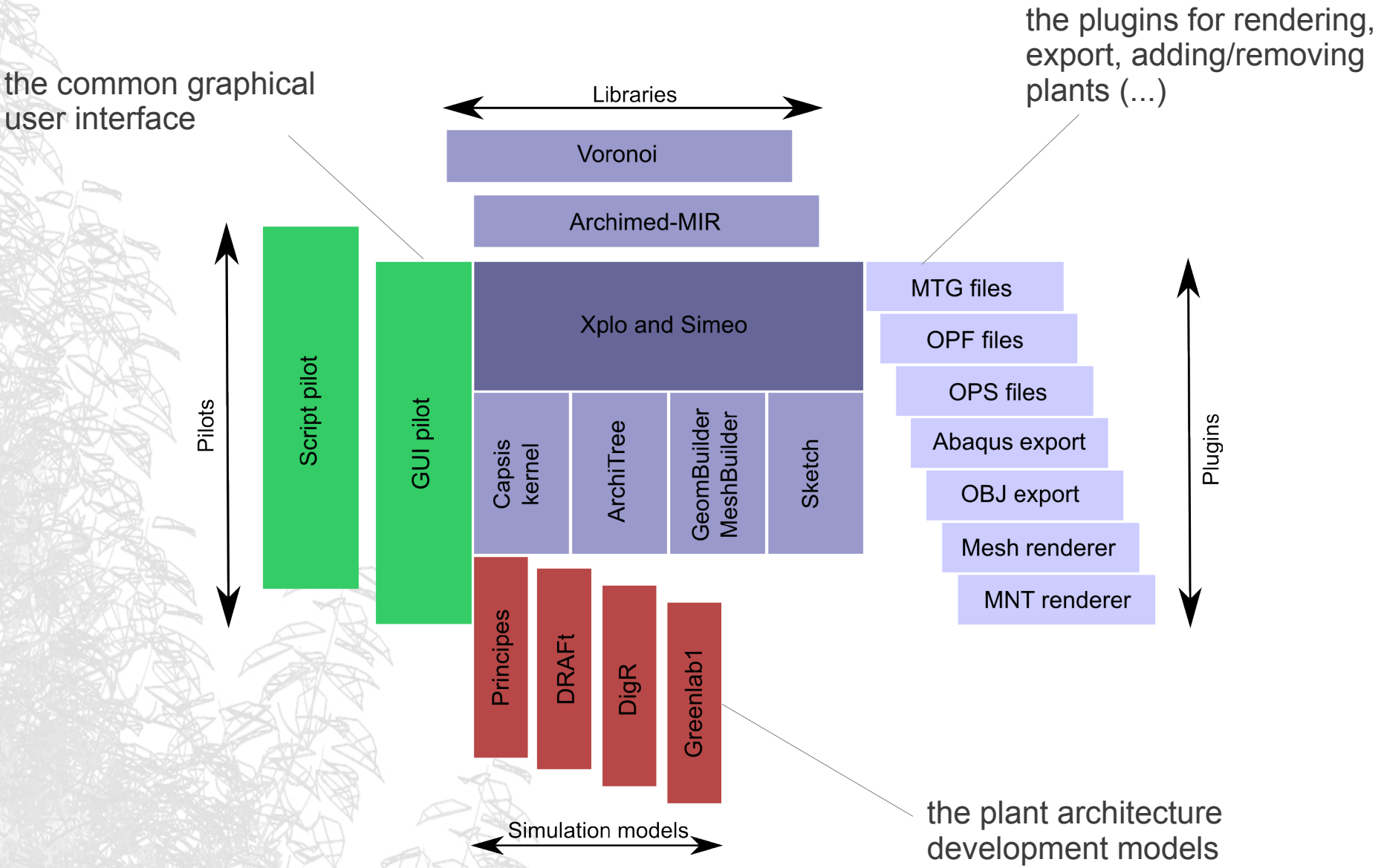


4

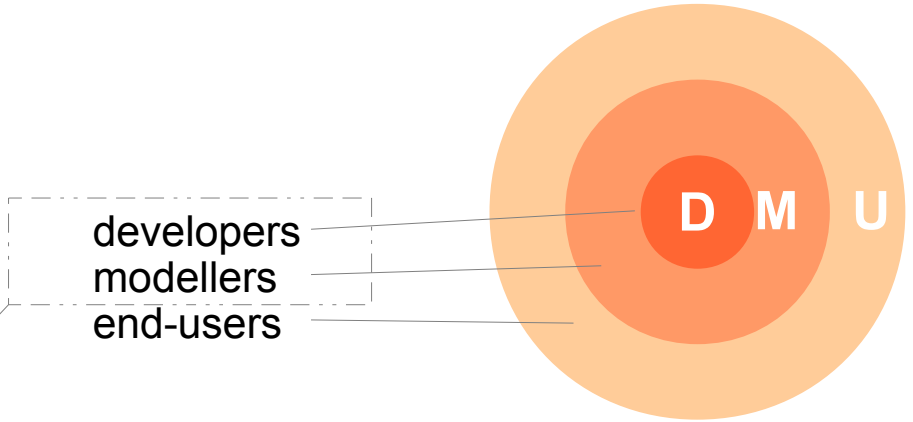
1 - Barczi J-F, Rey H, Caraglio Y, de Reffye P, Barthélémy D, Dong Q, Fourcaud T. AMAPsim: an integrative whole-plant architecture simulator based on botanical knowledge, Annals of Botany 2008; 101:1125-1138.

2 - Dauzat J, Clouvel P, Luquet D, Martin P. Using virtual plants to analyse the light-foraging efficiency of a low-density cotton crop, Annals of Botany 2008; 101:1153-1166.

IV. Simulation framework : Software design



IV. Simulation framework : Actors and roles



The AMAPstudio community:
developers + modellers
co-develop together

Modeller
Christophe Proisy
IRD AMAP
Lollymangrove

Developer
Sébastien Griffon
Cirad AMAP Montpellier

Developer
Francois de Coligny
INRA AMAP Montpellier

Modeller
Hervé Rey
Cirad AMAP
Principes, Sunflower

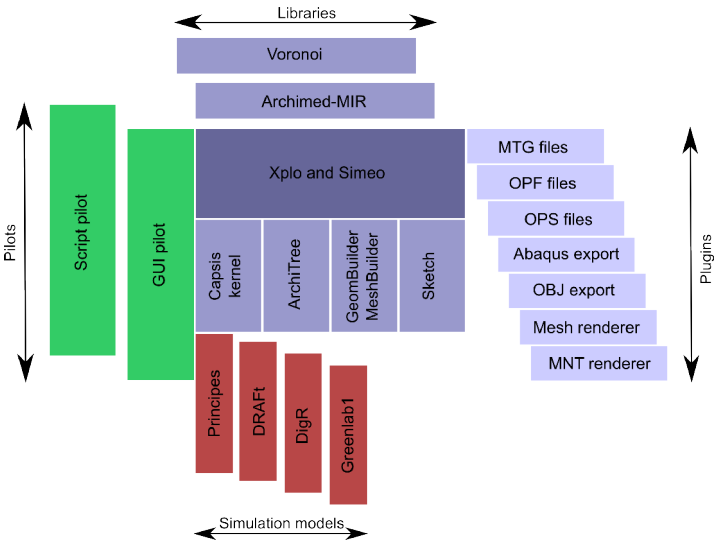
Modeller
Jean Dauzat
Cirad AMAP
Archimed MMR, ART, Lidar

End-user
The StemLeaf
project partners

End-user
The MOCAF
network partners

IV. Simulation framework :

The AMAPstudio Charter

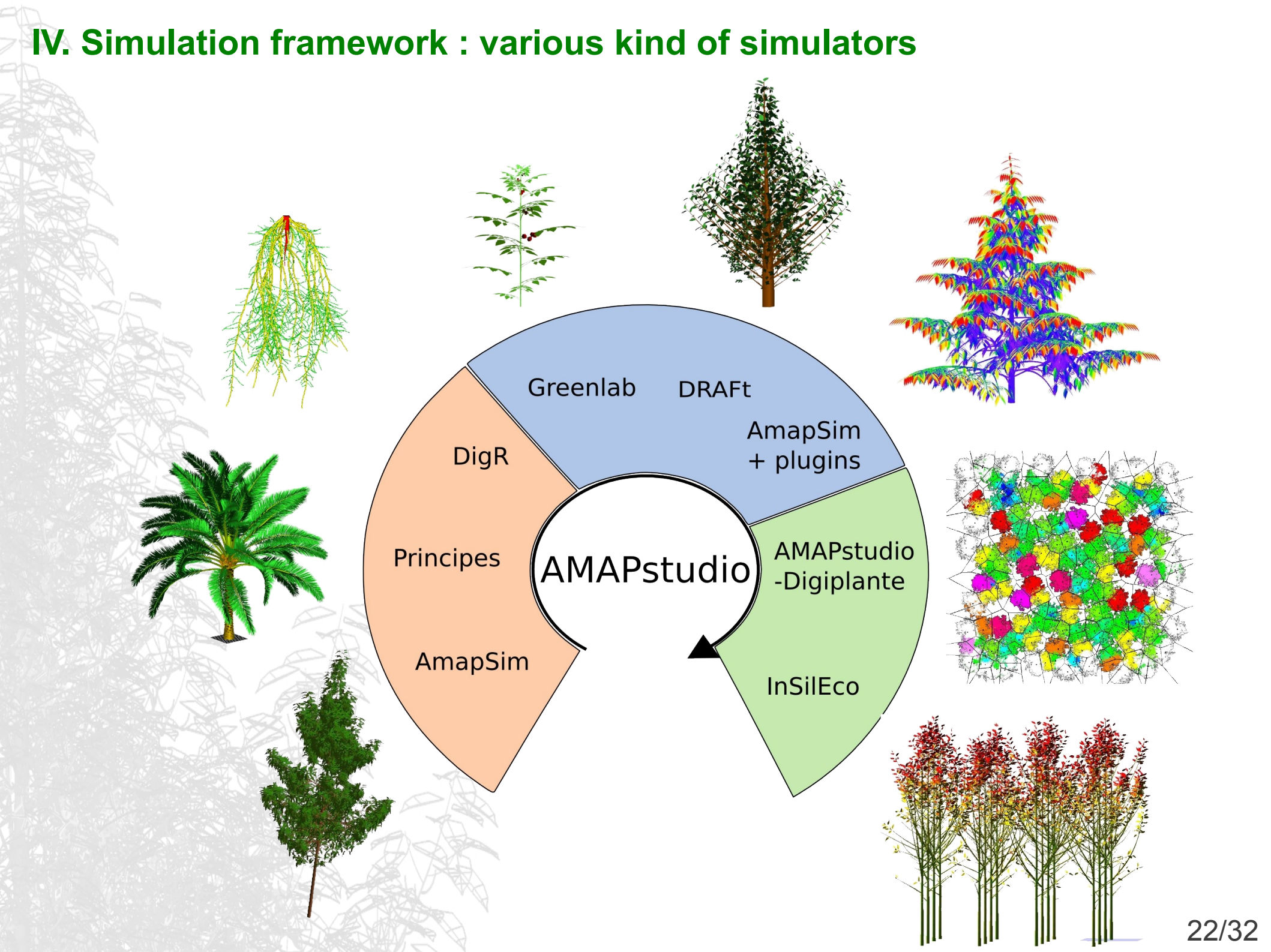


Clear participation rules

All the common parts are free software (LGPL), they are reusable by everyone
-> all **except the workspace/, xplo/module/ and simeo/module/ directories**

- **Free kernel**: the AMAPstudio kernel is a free software (LGPL licence) : **kernels** + **generic pilots** + **extensions** + **libraries**
- **Development**: the modellers are in charge of the development of their models in AMAPstudio
- **Support**: They can have support from the developers : training sessions, design, starting help, further assistance
- **Free access in the community**: All the source codes are freely accessible by all members in the AMAPstudio community, modules may become the base for new modules, code can be shared…
- **Respect of intellectual property**: all members respect the intellectual property of the other members
- **Validations**: developers deal with technical validation, modellers deal with functionnal validation
- **Distribution**: the stabilized / validated modules may be distributed when the author decides and chooses a licence (LGPL free license suggested)
- **Decentralization**: modellers manage directly the relations with their end-users: financing, training, assistance, models documentation, contracts…

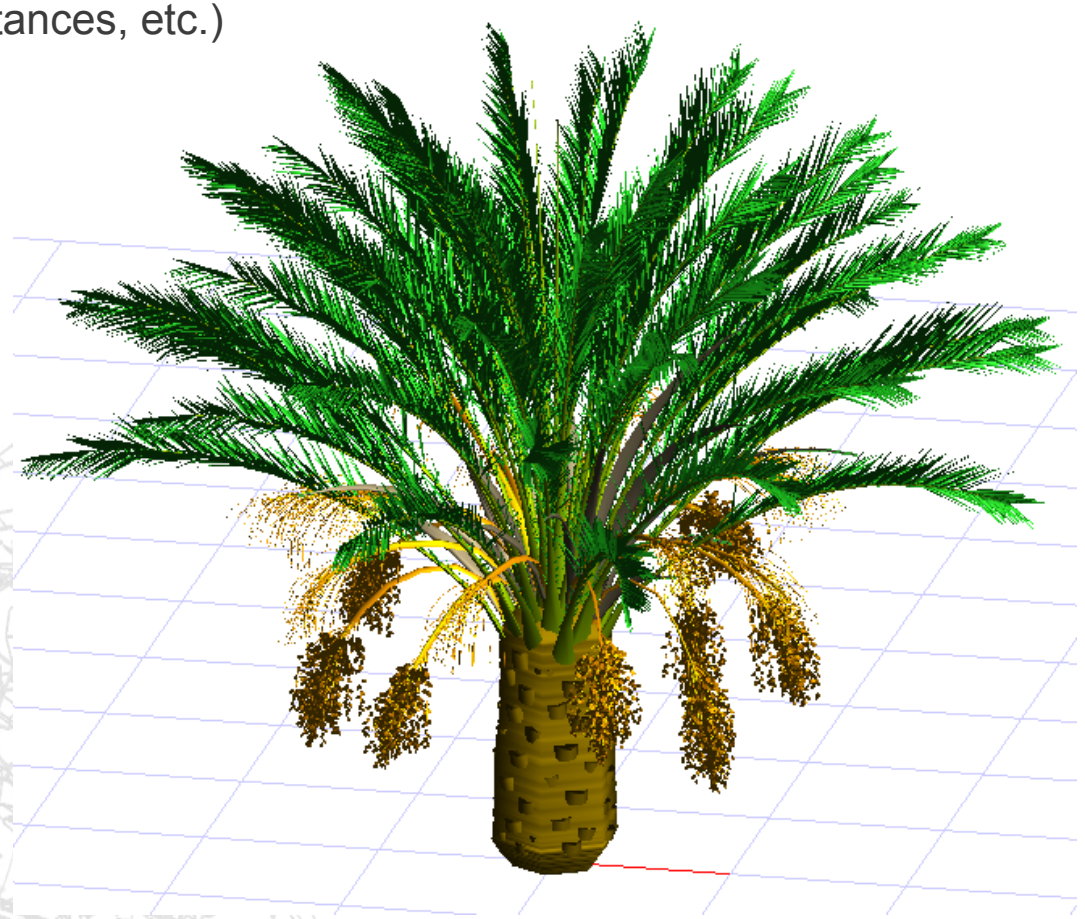
IV. Simulation framework : various kind of simulators



Hervé Rey (Cirad AMAP)

Principes

- models and simules the development and architecture of vegetative and reproductive parts of palm tree from germination to any age
- a continuation of studies that have been carried out for almost 20 years on palm-tree architecture
- Principes brings a generic, multi-scale, structural model for palm-trees based on the organisation of the various organs
- each organ carries its own attributes (lengths, diameters, branching or deviation angles, inter organs distances, etc.)



Hervé Rey, Jean-Francois Barczi (Cirad AMAP)

DigR

- DigR (Rey et al., 2011) is a root architectural model and simulator
- it relies on topological concepts as apical growth, lateral branching, senescence and death, and geometrical features as secondary growth and axes spatial positioning
- each of these properties are sorted into a root typology
- the current version runs without functional processes, however AMAPstudio will help developing further versions including functional – structural interactions during growth simulation and dealing with environmental influence (i.e. soil properties or aerial part contribution)

Philippe de Reffye et al. (Cirad AMAP)

Greenlab 1

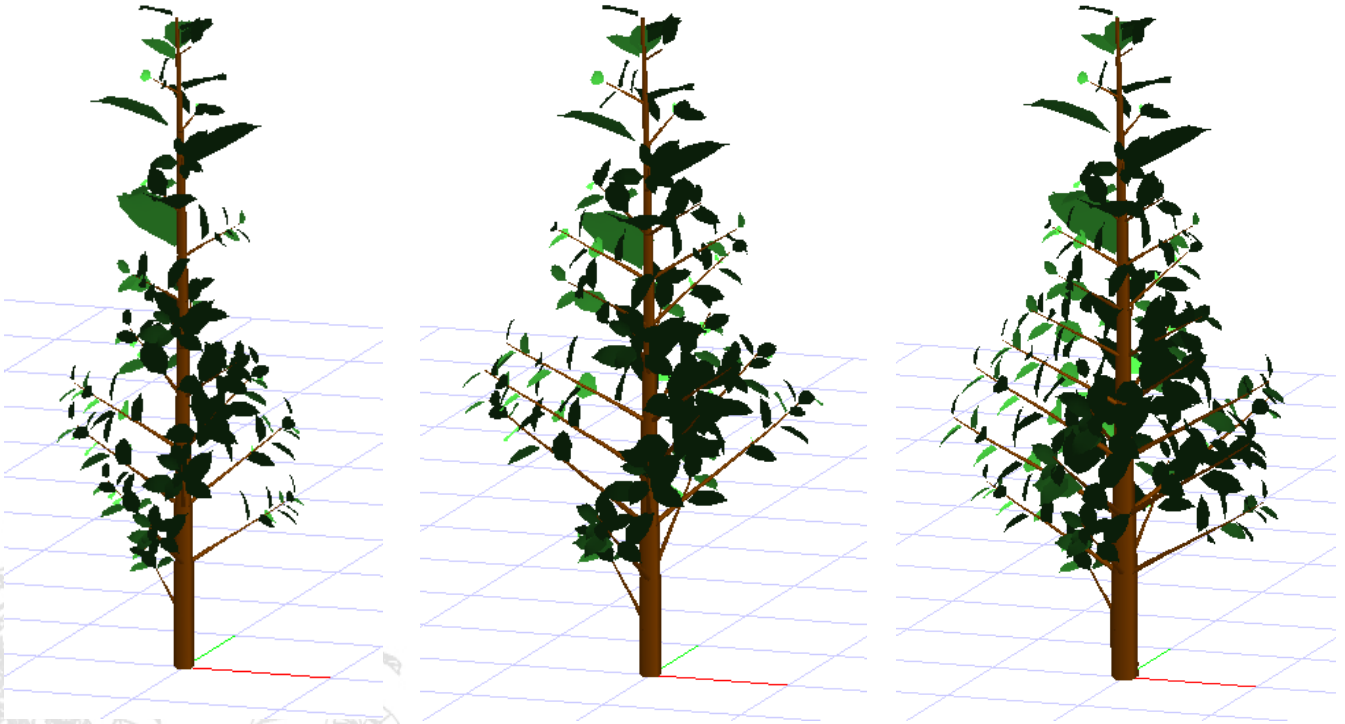
- Greenlab is a mathematical plant model simulating interactions between plant structure and functions
- biomass produced by organs (sources) is allocated to expanding organs (sinks) according to their relative demand
- plant parameters can be adjusted by fitting on real measurements
- Greenlab can compute the plant architecture for various species in interaction with their environment
- this model's underlying concepts can potentially predict the plant's phenotypic plasticity, for instance, pruning affects the internal competition for the resources and may lead to different leaf sizes

de Reffye P, Hu B-G. Relevant qualitative and quantitative choices for building an efficient dynamic plant growth model: GreenLab case. In: Hu B, Jaeger M, eds. Plant Growth Modeling and Applications (PMA03); Proceedings of the 2003 International Symposium on Plant Growth Modeling, Simulation, Visualization and Their Applications; Tsinghua University Press, Springer; 2003. p. 87-107

Olivier Taugourdeau, Jean-Francois Barczi (Cirad AMAP)

DRAFt (Demand, Resource, Architecture and Functioning at discrete time)

- a minimal FSPM designed to simulate emerging plants morphogenetical gradients
- tree architecture gradients is an emerging property of the interplay between structure function and iterative development
- DRAFt simulates the development and functioning of the tree aerial part at a yearly step
- it is based on biomass allocation, and relies on a 6 parameters equations system
- minimalist approach -> possible to use analytical tools to study the model sensitivity and behaviour



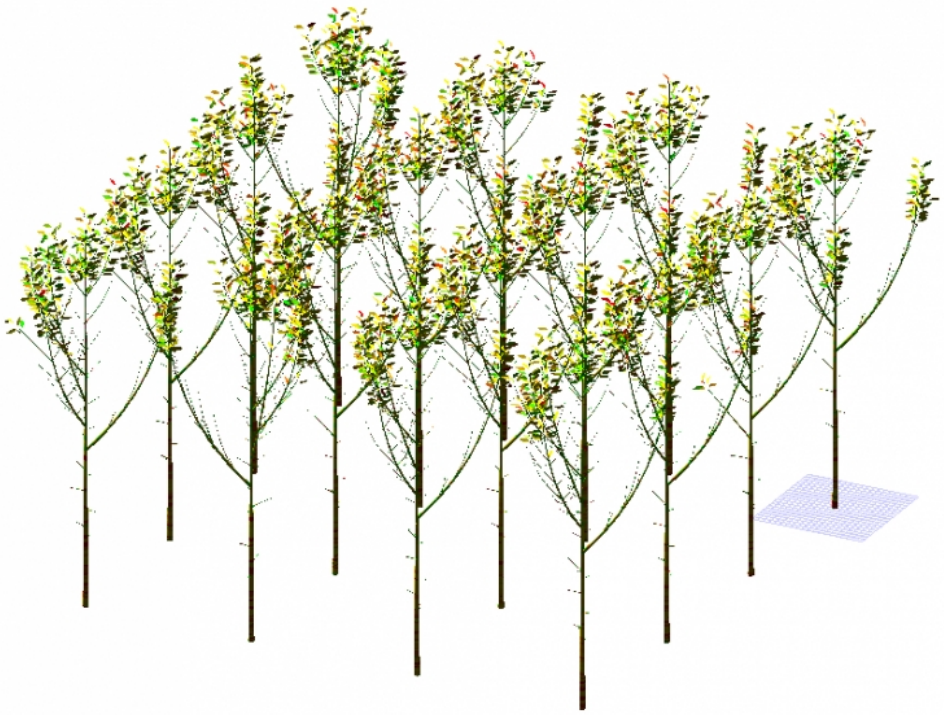
Taugourdeau O, Barczi J-F, Caraglio Y. Simulation of Morphogenetical Gradients Using a Minimal Functional-Structural Plant Model (FSPM). In: Kang M., Dumont Y., Guo Y., eds. Plant Growth Modeling, Simulation, Vizualization and Applications. Proceedings of PMA12. Shanghai, China: IEEE press; 2012. p. 379-387.

Tristan Charles-Dominique (Cirad AMAP), Francois Munoz (UM2 AMAP),
Yves Caraglio, Jean-Francois Barczi, Jean Dauzat (Cirad AMAP)

InSilEco - Architectural plasticity in ecological communities

- simulate the growth of several tree individuals in a forest stand
- the growth of an axis depends on the amount of light that it and its leaves receive
- the simulation process then combines architectural rules defined at species level (AmapSim), an illumination module used to assess light interception by leaves (MIR), and a coupling of axis growth and ramification capabilities with local light interception

The objective is to assess the effect of competition for light within and between species on the overall structure of the forest stand

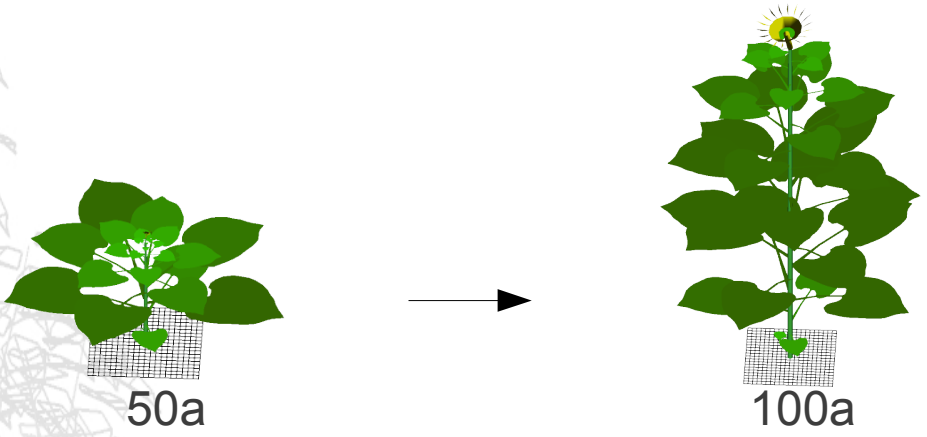


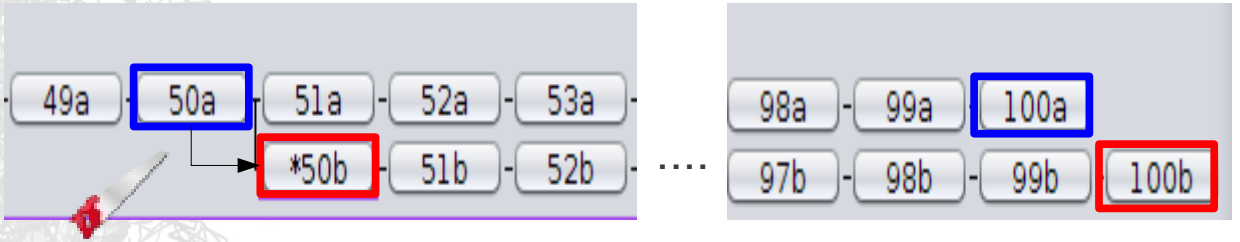
Powered by AmapSim, Simeo and Archimed-MMR

IV. Simulation framework : plant growth scenarios

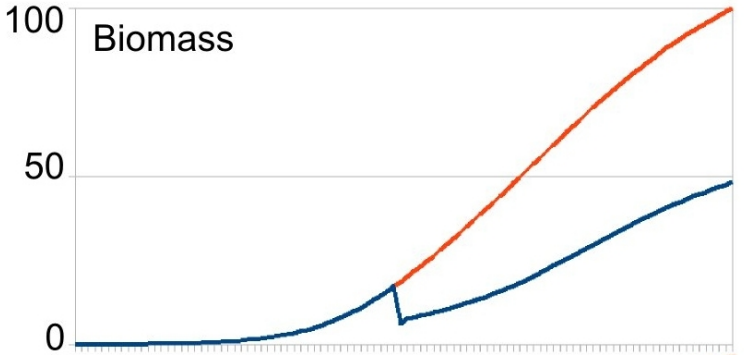
Greenlab simulator - Sunflower

Scenario a : control scenario





Normalized plant growth



Scenario b : leaf pruning at 50

V. Common features

Import/Export various file formats : plug-ins

IMPORT format

AMAPstudio formats :
OPF (Open Plant Format)
OPS (Open Plant Scene)

Other formats :
MTG
LIG + DTA

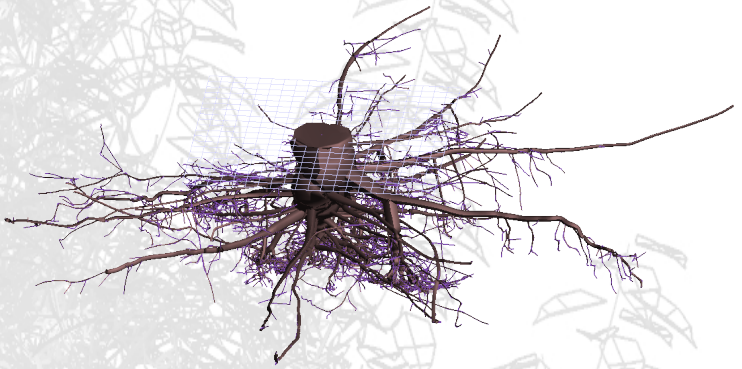
… Add your formats ...

EXPORT format

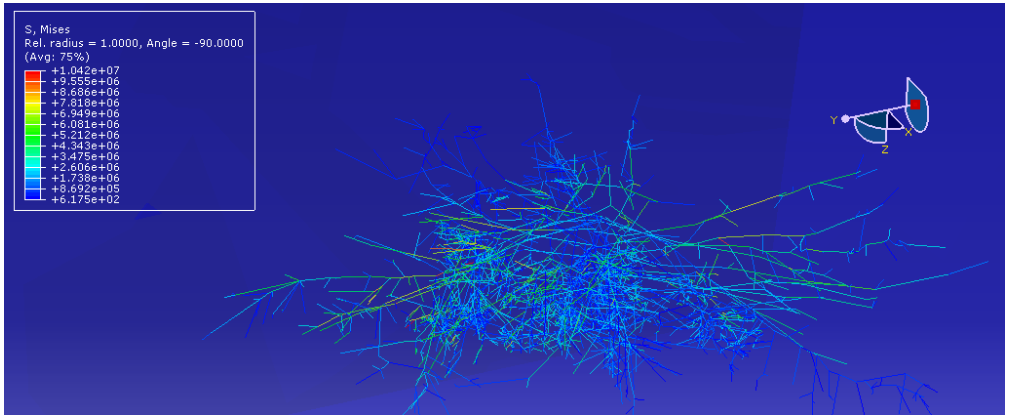
AMAPstudio formats :
OPF (Open Plant Format)
OPS (Open Plant Scene)

Other formats :
MTG
LIG + DTA
Sunflow
Abaqus INP
Obj (Wavefront)

… Add your formats ...



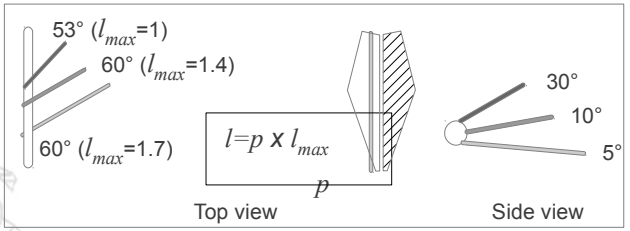
Digitized Maritime pine root system with PiafDigit
(F. Danjon - INRA)



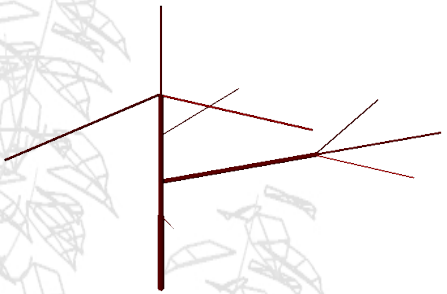
Abaqus export for tree overturning simulation
(T. Fourcaud - CIRAD)

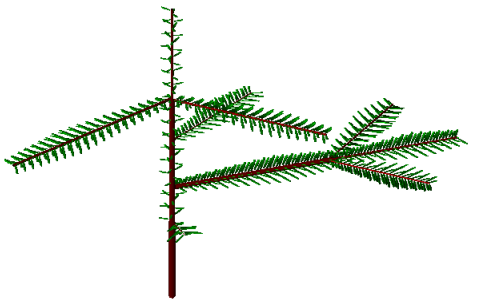
V. Common features

Scripts




```
114
115 SetOrientation= {vtx, X, Y, Z, Len, Xe ->
116
117     if (Length(vtx.getBearer().getComplex())!=null) longPa=( Length(vtx.getBearer().getComplex()) *10 )
118         else longPa=1
119     propLong = Index( vtx.getBearer() ) / longPa
120     LenAdj=Adj(Len,propLong)
121
122     if (vtx.getOrder()==3 | estRad(vtx) ) LenAdj=Len
123
124     vtx.set("RotBearerX",X)
125     vtx.set("RotBearerY",Y)
126     vtx.set("RotBearerZ",Z)
127     vtx.set("Length",LenAdj/coefLongSymboleAig)
128     vtx.set("RotLocalX",Xe)
129     return ""
130     }
131
132
133 Orientation = { vtx ->
134     NeedleType= Index(vtx.getBearer())%6
135
136     if (vtx.getOrder()==3 | estRad(vtx) )  { NeedleType="A1"}
137     if (vtx.getOrder()==4) {AngleA3=180}//90+
138         else {AngleA3=90}//180
139
140
141    switch( NeedleType ){
142
143         case "A1" : An=(An+141)%360
144                     SetOrientation(vtx,         An                    ,          -AngleAigA2, 0,              0.
145                     break
146
147         case 0    : SetOrientation(vtx,   AigLayer_1_AngPhyl +AngleA3, AigLayer_1_AngInsert, 0, AigLayer_1_Lengt
148                     break
149
150         case 1    : SetOrientation(vtx, - AigLayer_2_AngPhyl +AngleA3, AigLayer_2_AngInsert, 0, AigLayer_2_Lengt
151                     break
```

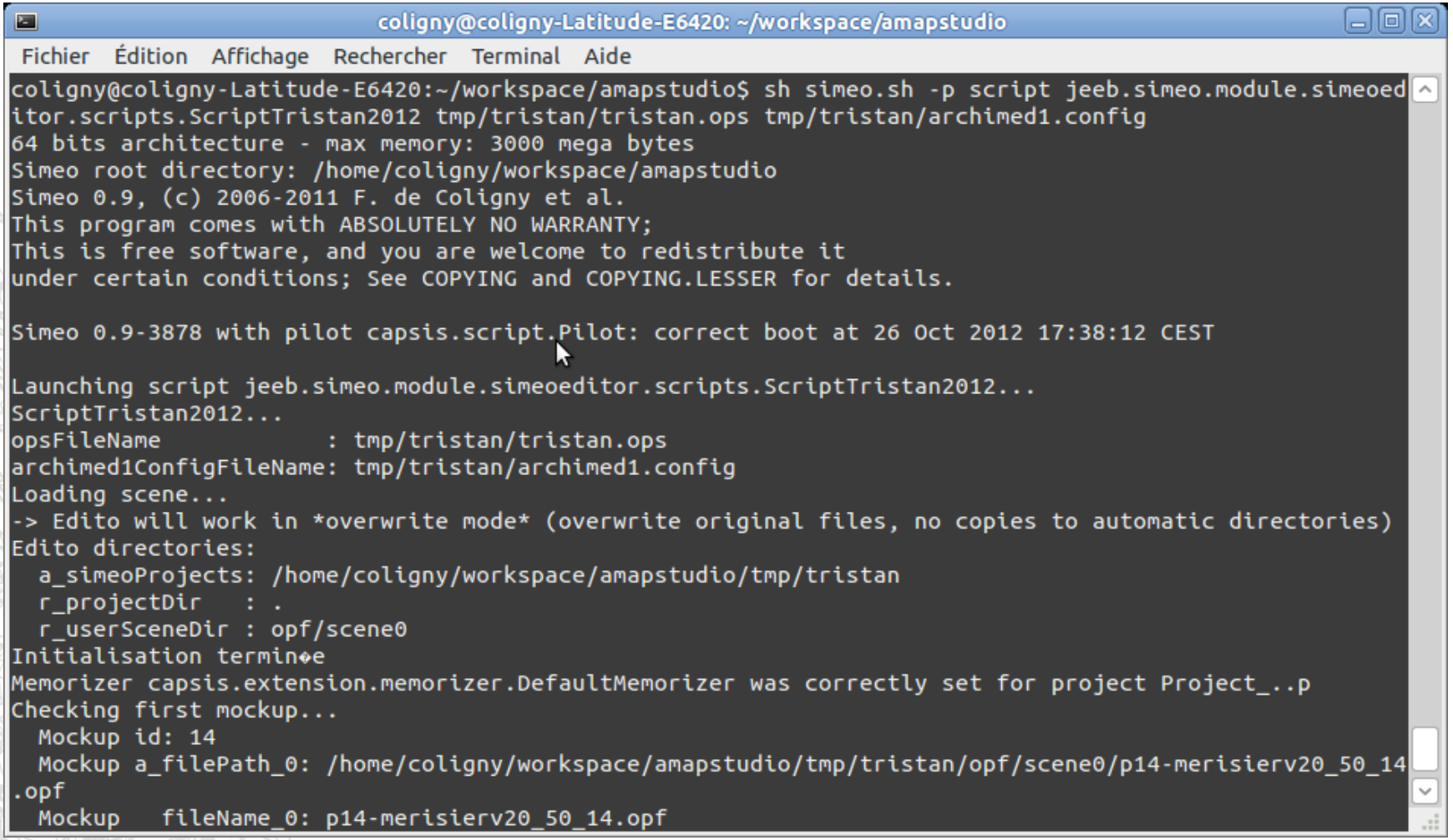




Taugourdeau, O., Dauzat, J., Griffon, S., Sabatier, S., Caraglio, Y., Barthélémy, D., 2012. Retrospective analysis of tree architecture in silver fir (Abies alba Mill.): ontogenetic trends and responses to environmental variability. Annals of Forest Science, 69(6) : 713-721 p.

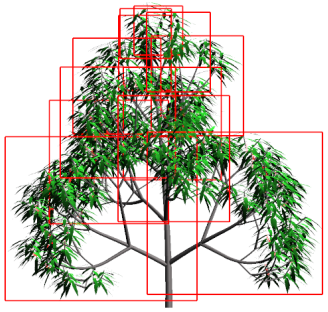
V. Common features

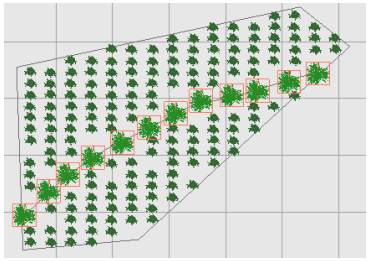
Batch mode : run without Graphical User Interface



Repetitive simulation
Run on clusters
Sensitivity analyses
...

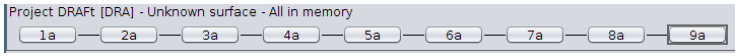
Conclusion





AMAPstudio assets

- For end-users : interactive editors, 3D view
- For modellers : collaborative frawework, methodology and human support
- Scenario oriented : alternate growth and intervention steps to build scenarios



- Long-term mutualisation and capitalisation
- Easy distribution and transfer : free licence kernel, multi-OS (Windows, Linux, Mac)

Communication

Griffon S., de Coligny F. 2012. AMAPstudio: a Software Suite for Plants Architecture Modelling. In: Kang M., Dumont Y., Guo Y., eds. Plant Growth Modeling, Simulation, Vizualization and Applications. Proceedings of PMA12. Shanghai, China: IEEE press, pp. 141:147

- presented in PMA'12 in Shanghai, China
- presented in FSPM2013 in Saariselka, Finland
- a web site
  - documentation for the modellers: http://amapstudio.cirad.fr/
  - up to date projects list
- a reference paper accepted in Ecological Modelling

Sitemap Login

- Home
- **News**
- Projects
- Screenshots
- Download
- FAQ
- Documentation
- Publications
- Charter
- Contact
- AMAP

- AmapSim
- Archimed
- Simeo
- Xplo

Community news

- Chloé Bourden (Master student, IRD AMAP) used Simeo - Lollymangrove in order to (1) upload and verify her field inventory data, (2) calculate the plots' biomass and carbon with different allometry models and (3) visualise the type of structure for mangrove populations. (C. Bourden, 2.7.2013)
- AMAPstudio was presented by S. Griffon at FSPM2013, the 7th International Conference on Functional – Structural Plant Models in Saariselka, Finland (9-14th june). (F. de Coligny, 14.6.2013)
- A Palm tree workshop related to ecophysiology and modelling has been organized by Cirad last 22nd May 2013. During this workshop, the AMAP lab presented a collective contribution showing the past collaborations with the other teams in Montpellier, the new projects, the goals regarding sciencific results and applications, and the possible partnerships to reach them. 2013-05-22-rey-journee-palmier-a-huile-agap.pdf (H. Rey, 23.5.2013)
- René Lecoustre, Jean-Francois Barczi and Hervé Rey attended the First International Meeting on Phytogenetic Resources of Date-Palm from 15 to 17 April 2013 in Djerba, Tunisia. They presented two communication on (i) statistical studies on the allometric relationships for the vegetative part (PRINCIPES model) and (ii) root architecture analysis and modelling (DigR model) of Phoenix dactylifera. After this meeting, a working program was built for the next two years concerning the MOCAF and PHC Maghreb projects. (H. Rey, 29.4.2013)

- A paper about AMAPstudio was published in the IEEE proceedings of the PMA'12 international conference, see the Publications page for more details. (F. de Coligny, 25.11.2012)

http://amapstudio.cirad.fr/

Thank you for your attention !

AMAPstudio SDK

AMAPstudio :

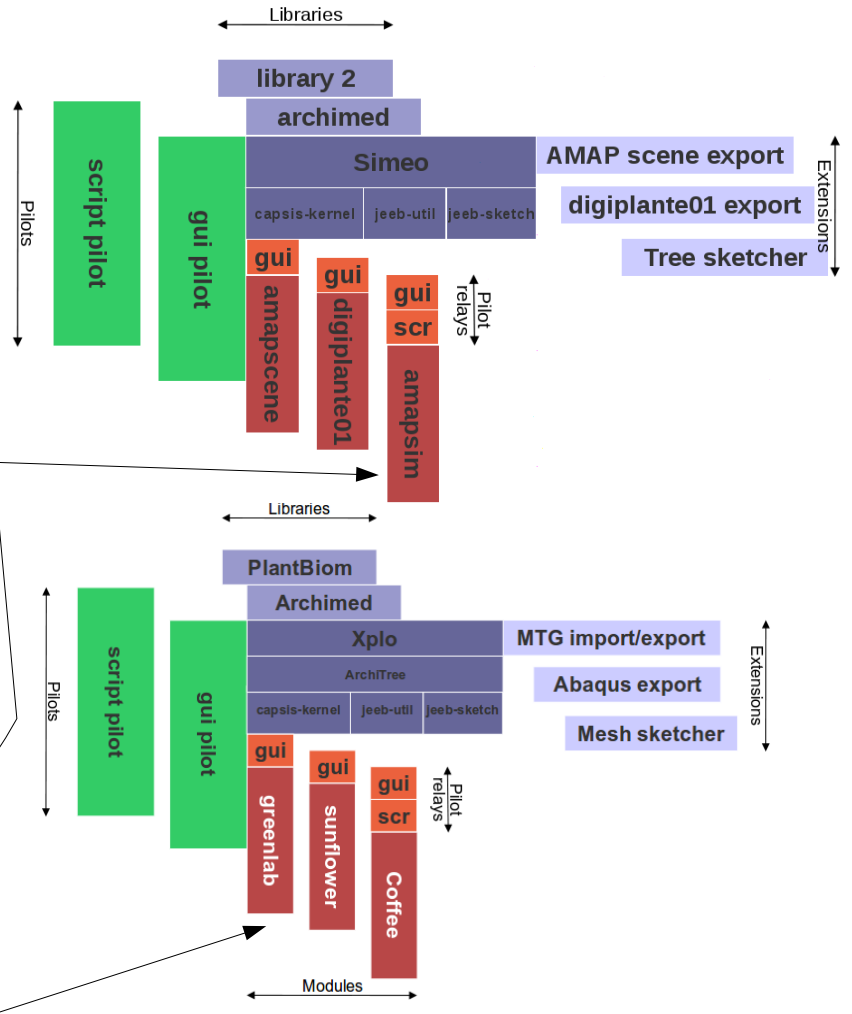
- **Libraries** :
  - Maths : common math functions
  - Formats : OPF, OPS, MTG readers/writers
  - Sketch : MVC GUI library
  - Structures : ArchiTree and Geometry builder.
  - SimulationTools : Scheduler, Listeners, Meristems, Organs.
  - Utils : common usefull functions (e.g. AutoUI)

- **Workspace** :
  - Sunflower model
  - Principes model
  - Draft model
  - Greenlab model
  - ...

Modeller inputs

- **Xplo** :
  - Kernel
  - Gui
  - Extensions
  - Modules :
    - PlantEditor
    - Sunflower
    - Greenlab
    - ..

- **Simeo** :
  - Kernel
  - Gui
  - Extensions
  - Modules :
    - AmapScene
    - Greenlab



AMAPstudio singularities

Software aiming at mutualisation in the domain of plants modelling may all have intersections of their scopes.

Here are the AMAPstudio's singularities :

- Editors for end-users, to do simple things quickly (development skills not needed).
- Modellers comfortable with programming can write scipts or plugins.
- Focusing on the plants architecture, from the plant to the forest stand.
- A simulation framework to build and compare scenarios.
- Co-development and charter based methodology.
- Simple procedure to build custom installers for distribution and installation.