# OpenAlea

## A platform for plant modelling, analysis and simulation

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N. Donès, JB Durand, P. Barbier de Reuille,
C. Fournier, H. Sinoquet, C. Godin





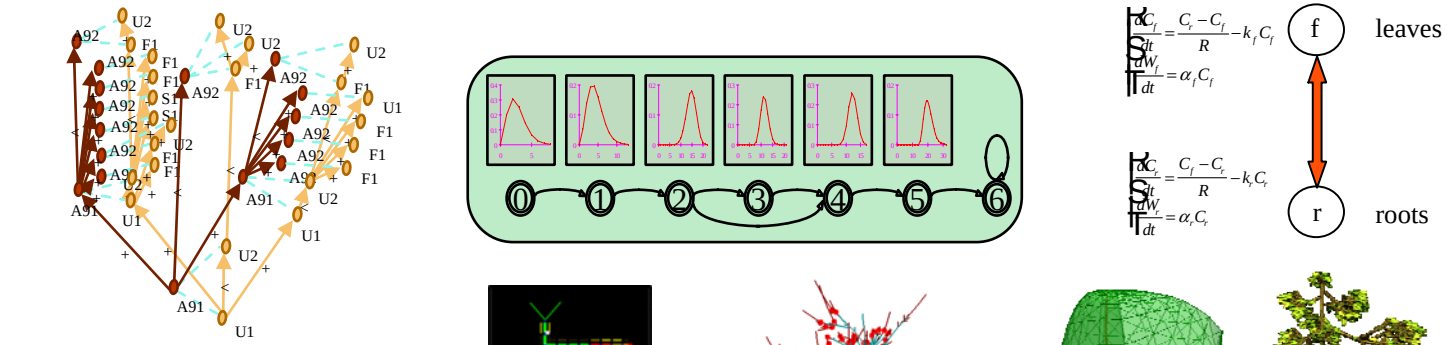


# Plant modelling

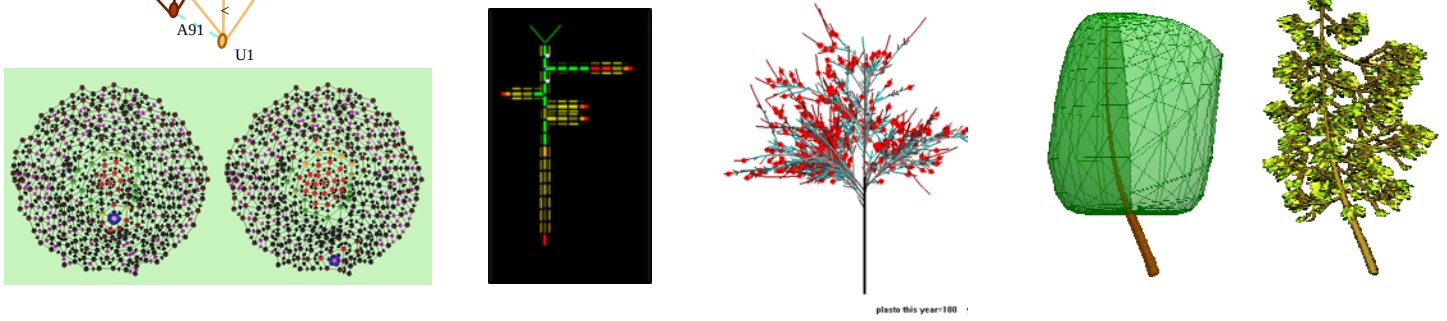
Biological objects

Measure

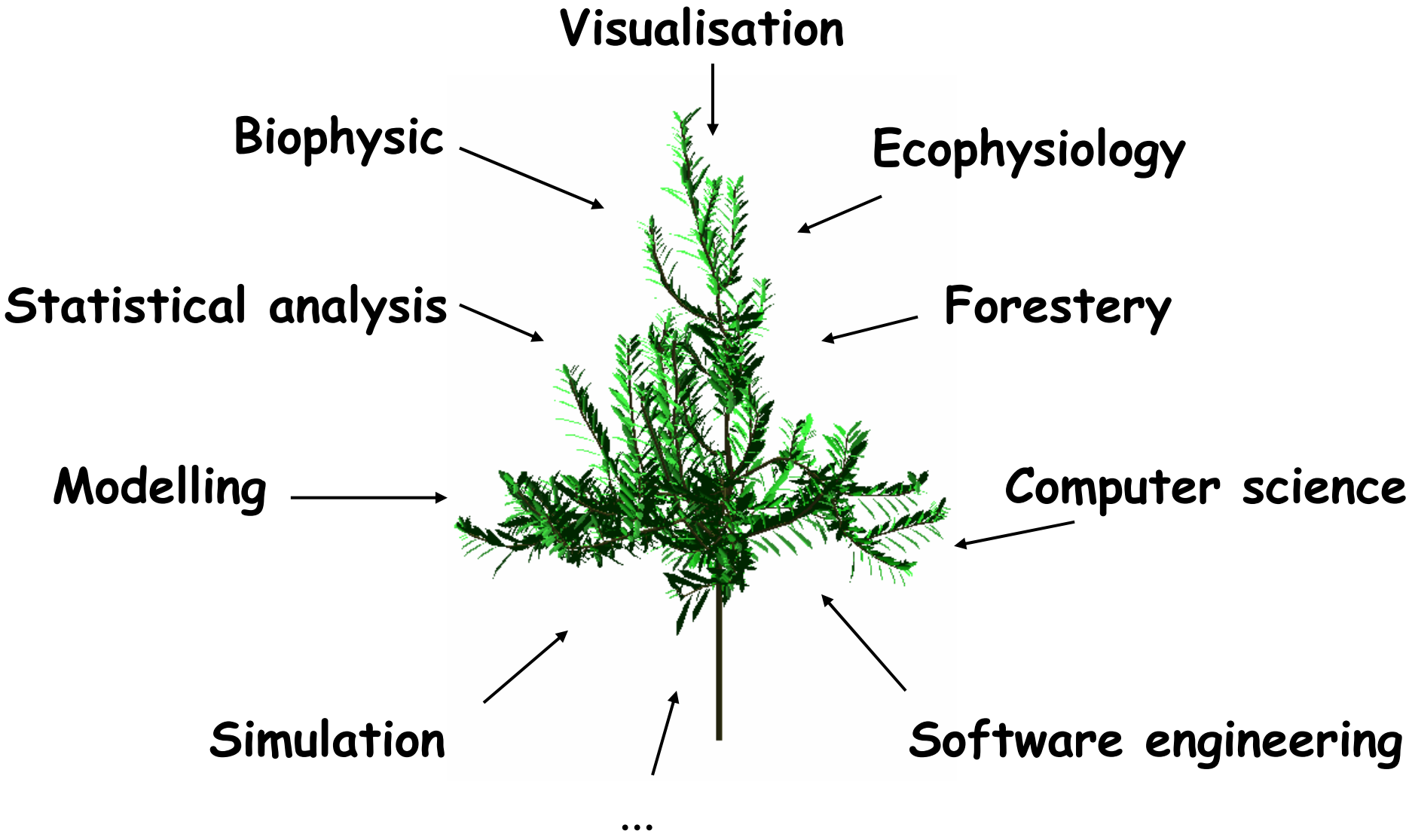
Modelling




Simulation

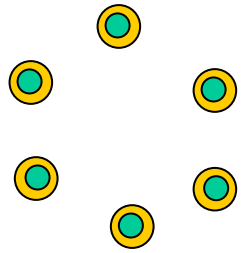


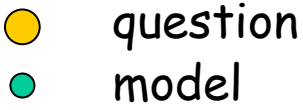
# Pluri-disciplinary research



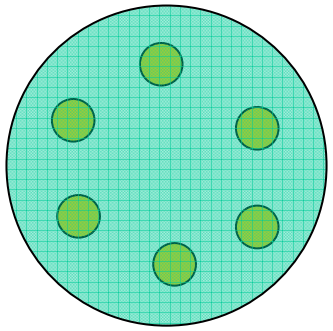
# Modelling strategy

1. Construct the best model (efficient & simple) for each new situation

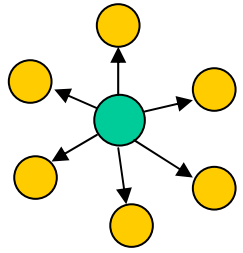





2. A general unified model



3. Defining common phenomenon, concepts and methods:
   - Common to different situations
   - Extensible



# Python as a modelling language [Sanner 06]

Python as a scripting environment

Python as a component framework

- 3D scene graph
- Visualisation
- Graph Data structure
- Plant models

Python as a software Bus

# OpenAlea

**ALEA: Atelier Logiciel en Ecophysiologie et en Architecture 3D des plantes**

- use, evaluate and build experimental models

**Users**

- biologists and modellers

**Components**

- various tools and models for studying plant architecture and its development

**Partners** (French research institutes)

- INRA, CIRAD, INRIA, LABRI, INPG.

# Objectives

## Share knowledge

- Reuse softwares & tools
- Share development between various team
- Exchange experience & data
- Share training effort

## Component based software architecture

- Integration of existing softwares & tools
- Rapid development of new models
- Quality rules

# OpenAlea community

**Designers**

- kernel development
- modellers counsel, training and assistance

**Modellers**

- Models and tools development and integration
- users counsel, training and assistance

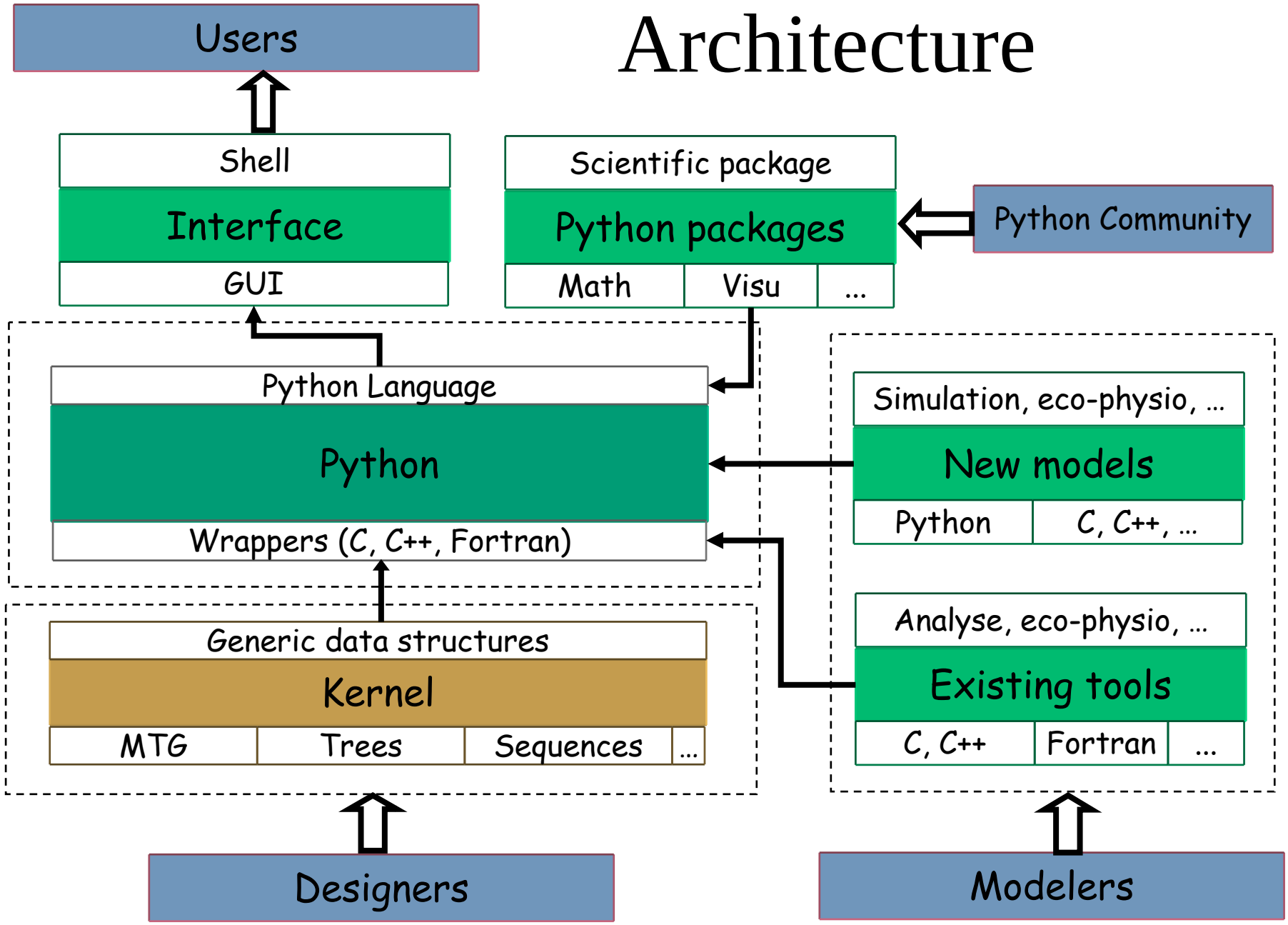
**Users**

- define scenario and provide feedback

**Open Source Community**

- Free kernel licence: LGPL
- Distribution rules

# Architecture



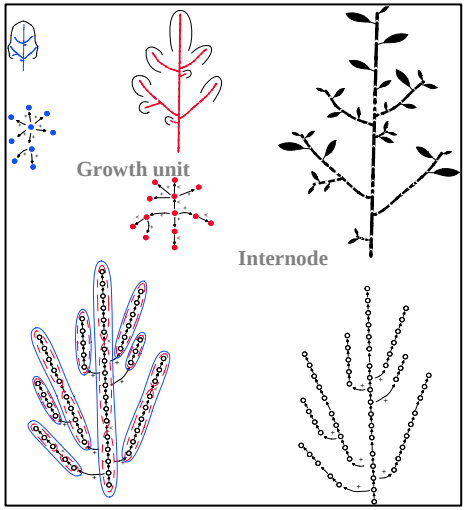
# Data structures

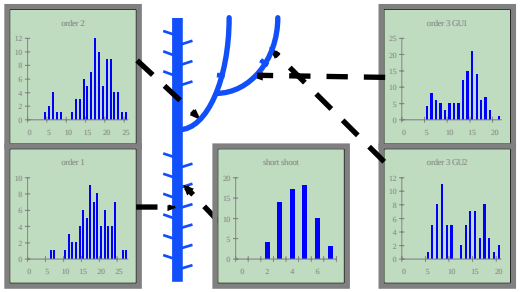
## Common data structures

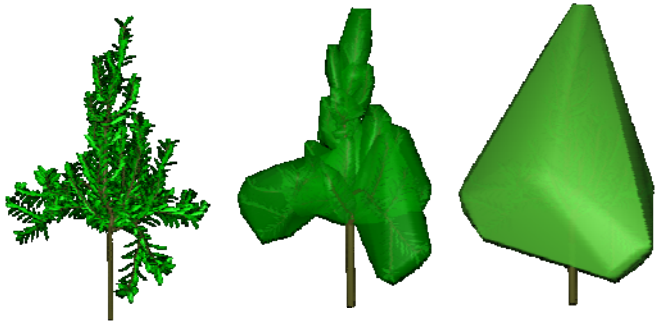
- Sequences
- Graph (Topology)
  - Tree
  - Directed graph
  - Hierarchical tree (**MTG**)
- Scene graph (Geometry)
  - Hierarchical scene graph

## Interfaces and adaptors

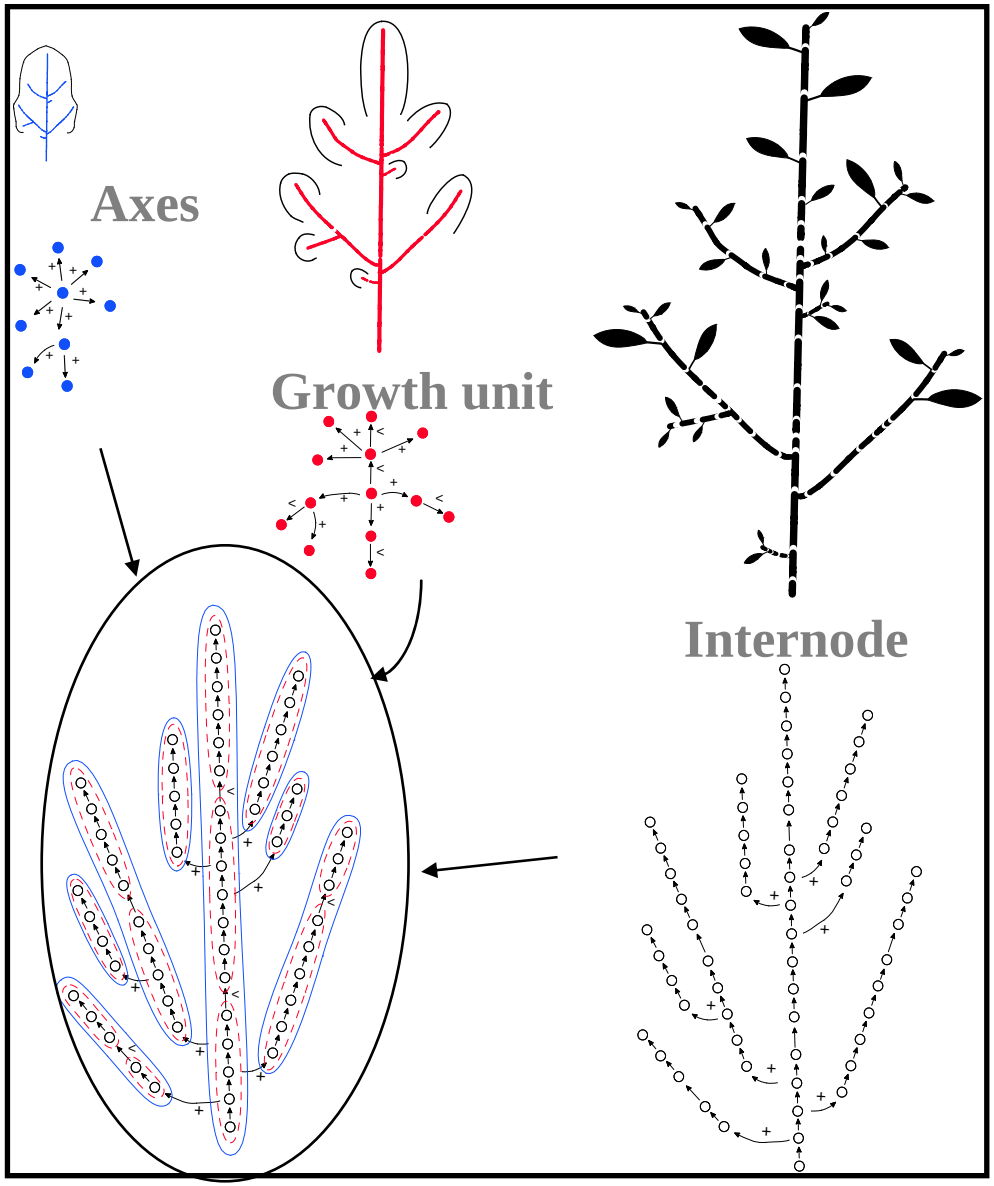
- Zope.Interface
- Well defined interfaces
- Different implementations



# Multiscale representation of trees




MultiscaleTree Graphs (MTG)

(Godin, Caraglio 1998)

# Development tools

**OS**

- Linux and Windows

**Languages**

- C, C++, Fortran and Python

**Wrappers**

- Swig, Boost.Python and f2py

**GUI**

- PyQT

**Test**

- py.test (Python) and Boost.Test (C++)

**Documentation**

- epydoc and doxygen

# Building and Installing

## Scons

- Build C, C++ components and their wrappers

## Scons_utils

Extend **scons** for OpenAlea developers

- Hide the complexity of the build system
- Default options for each tools (Linux, Windows):
  - opengl, boost.python, qt, bison, flex, compilers, …
- Unify the build process for the different packages

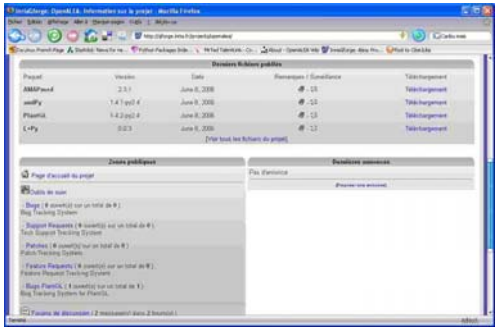
```
ALEALibrary('mylib','*.cpp')
ALEAInclude( 'mylib', '*.h')
ALEAWrapper('mywrapper','*.cpp')
ALEAProgram('prog','*.cpp')
```

## Packaging

- Extend distutils with scons as a build system

# Working together

## Collaborative development



- gforge
- Subversion
- Wiki

## Coding sprint

- Pair programming
- Specification and development

## Training

- **Elearning** platform for modelers and users
  - Python
  - 3D Plant Architecture
- France, Thaïland and Brasil

# Components

**AMAPmod (Godin, Guédon et al.)**

- Analysis of plant architecture

**PlantGL (Boudon, Pradal et al.)**

- Plant Geometric Library & 3D viewer

**TreeAnalysis (Durand et al.)**

- Hidden-Markov Tree Models

**RATP (Sinoquet et al.)**

- Radiative transfer, transipiration and photosynthesis

**Archimed (Dauzat et al.)**

- Modelling biophysical processes on 3D plant models

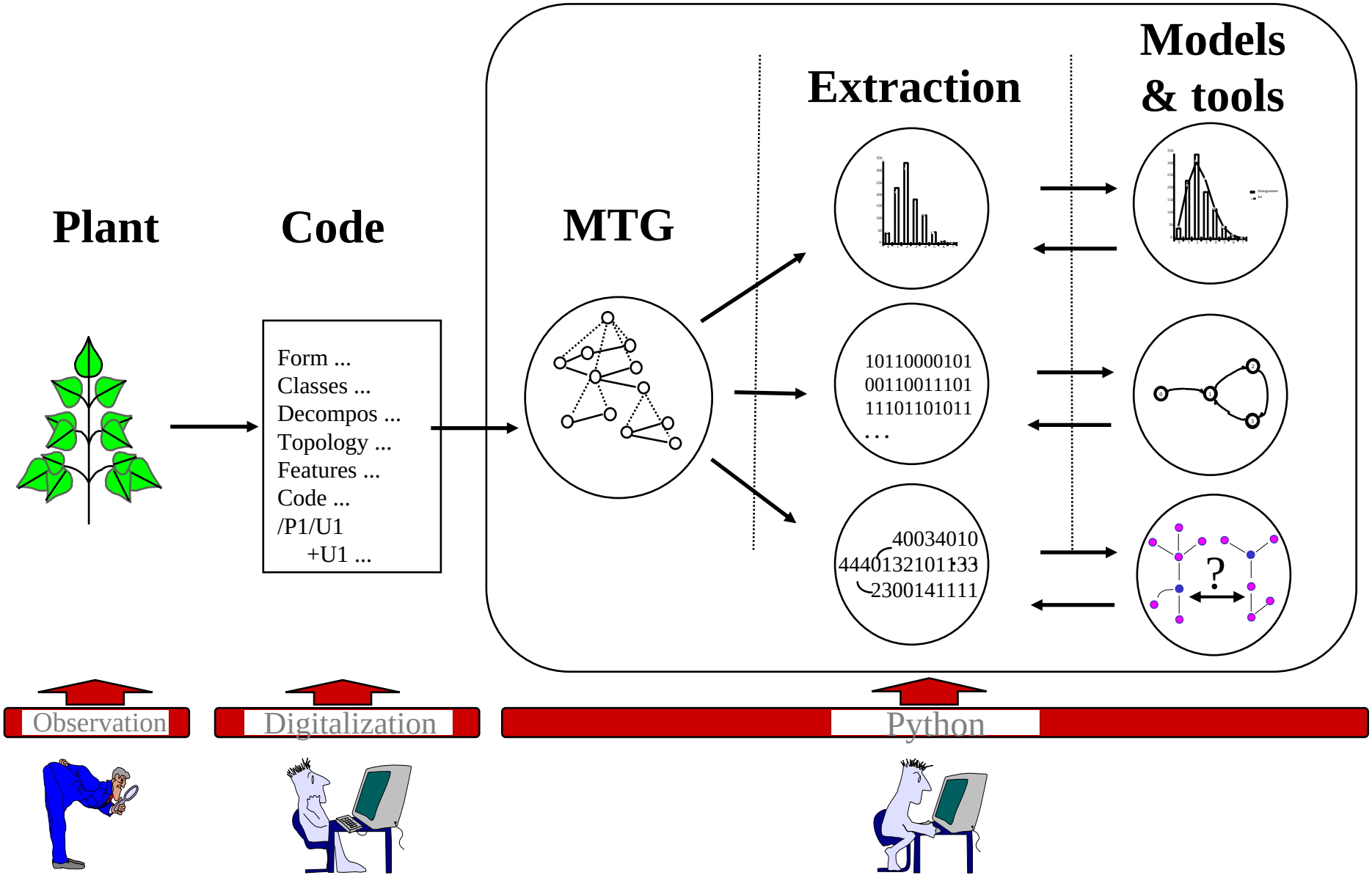
**PyCaRiBu (Fournier, Chelles et al.)**

- Simulation and radiative transfer (Maize and wheat)

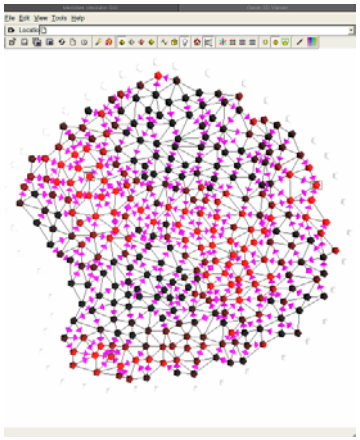
**Merrysim (Barbier de Reuille et al.)**

- Simulation of virtual meristems

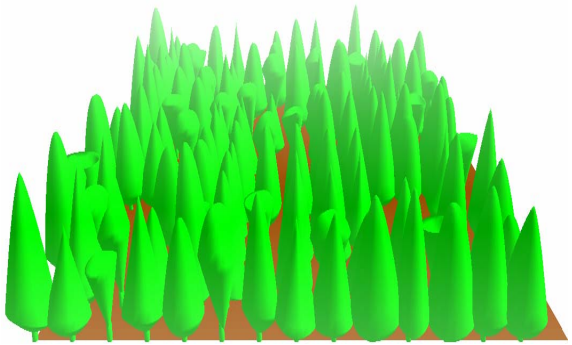
# AMAPmod – AML/C++



# PlantGL – C++

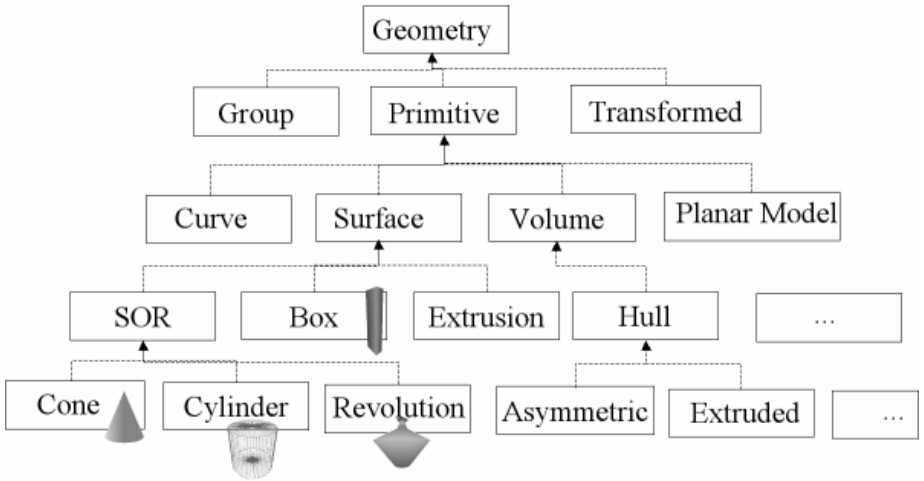


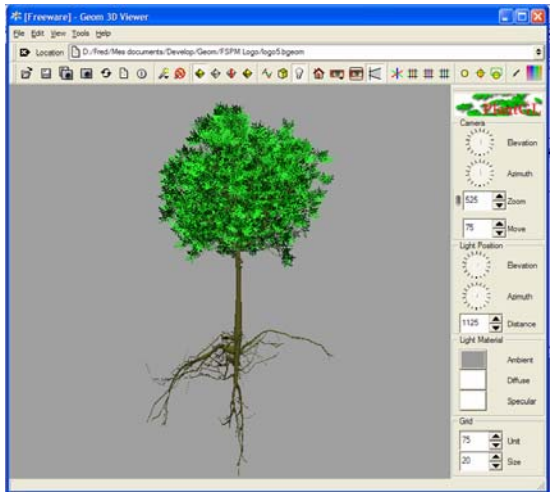
Meristem simulator
(P. Barbier de Reuille)



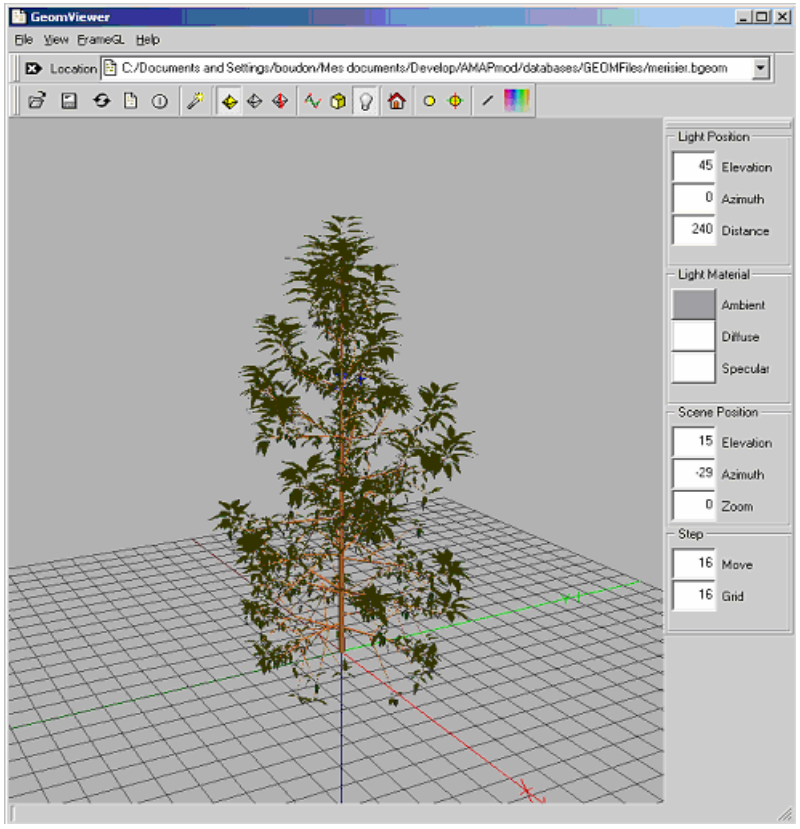
Hemispheric view
(C. Parveaud)

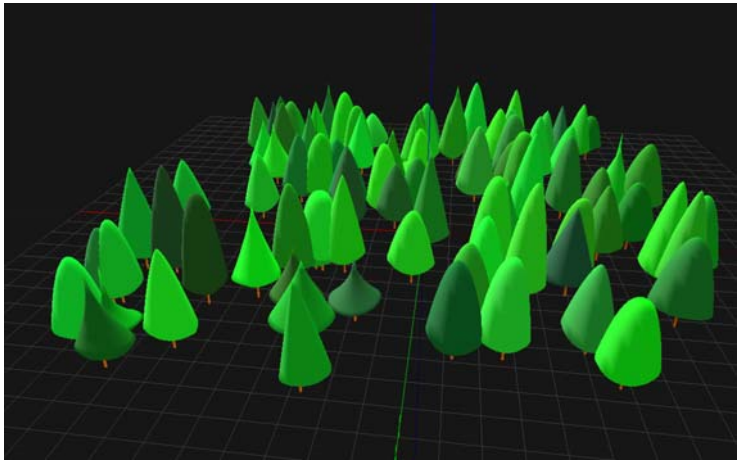
Python

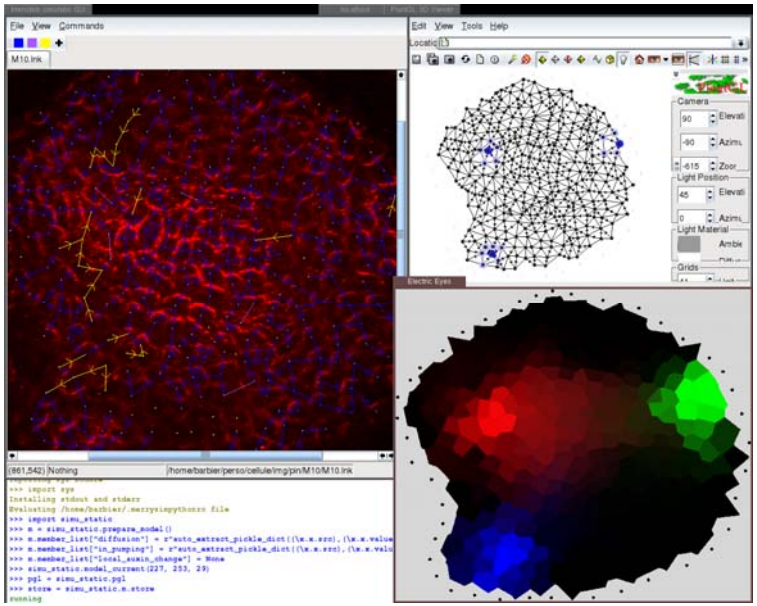


# Biological objects at different scales

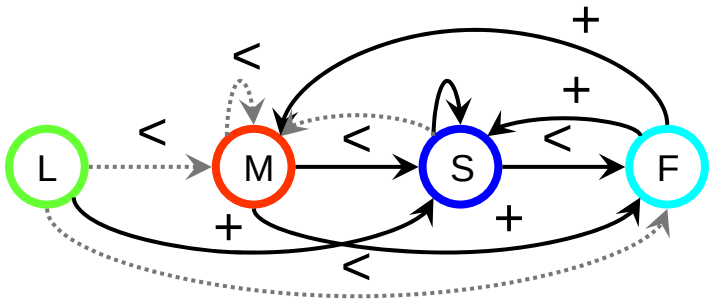


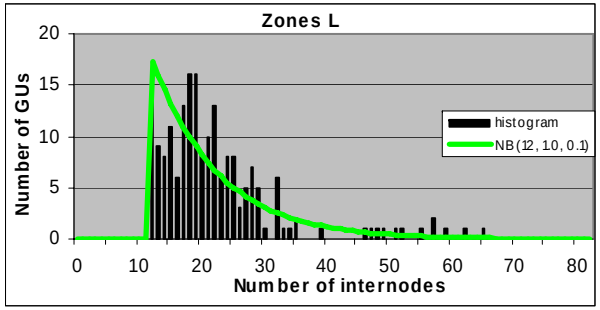


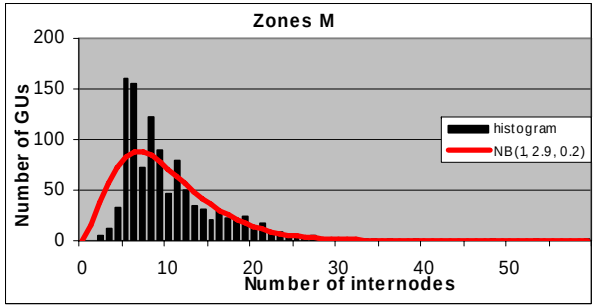
# TreeAnalysis – C++

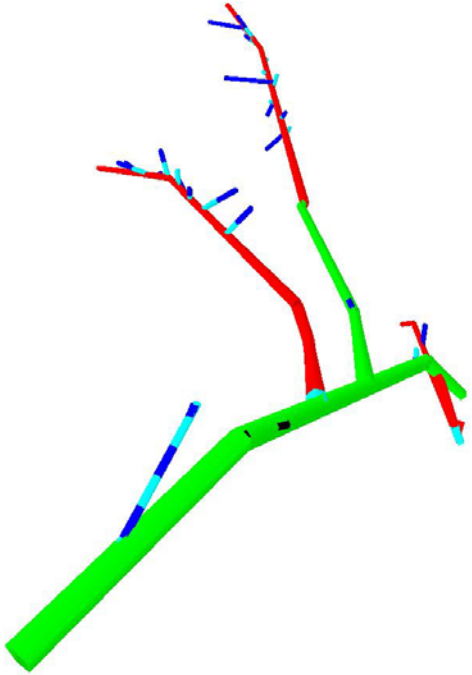
## Hidden-Markov Tree model




- Long, Medium & short Growth Unit (GU)
- Alternation vegetative & flowering GU.



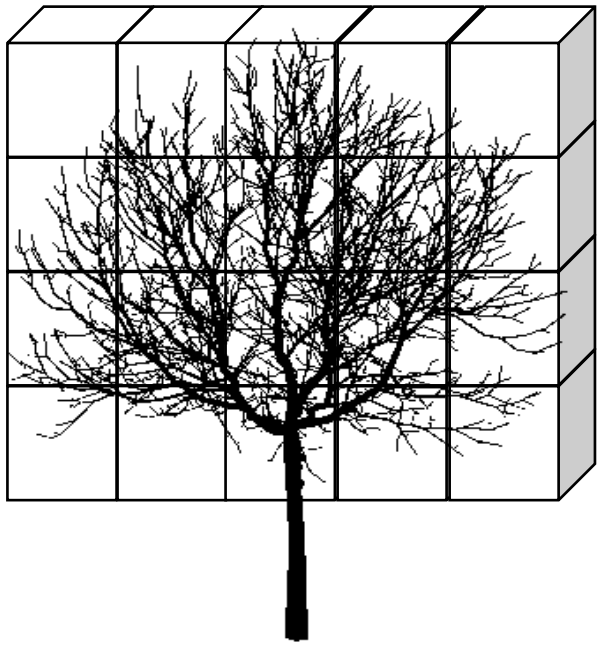




Durand, J.-B., Gonçalvès, P. & Guédon, Y., (2004), *IEEE Trans. Signal Proc.*

Durand, J.-B., Guédon, Y., Caraglio, Y. & Costes, C. (2005), *New Phytologist*

# R.A.T.P. – Fortran

Radiation Absorption,
Transpiration, Photosynthesis



**Structure**
LAD, inclinaisons

**Radiation transfer**
leaf irradiance and light regime
leaf N content
gsmax, Vcmax, Jmax

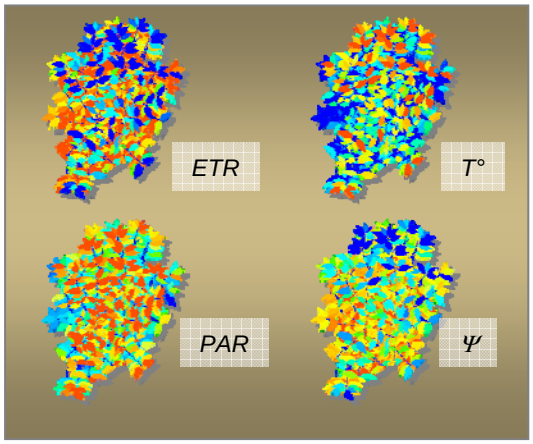
**Wind Speed**
Boundary layer conductance

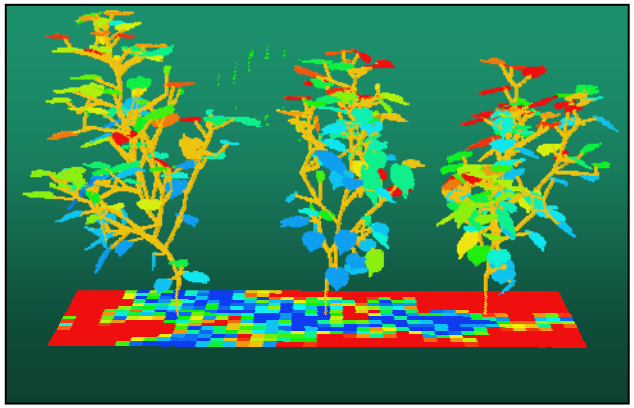
**Energy Balance**
stomatal conductance
transpiration
leaf temperature

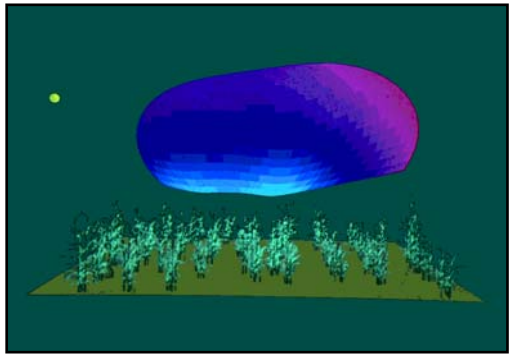
**Photosynthesis**
net $CO_2$ assimilation

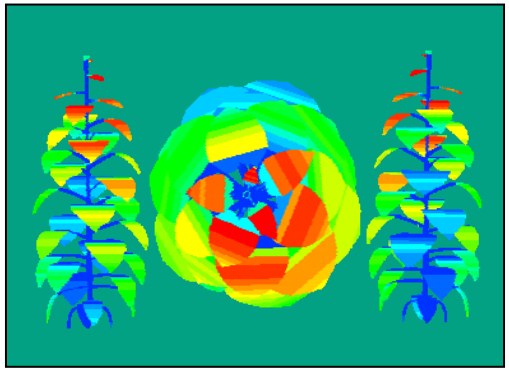
# Archimed – C

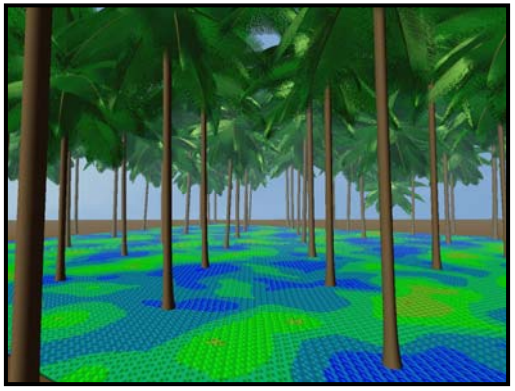
**ARCHI** tectural
**M** odelling
**E** nvironnement
**D** ependant







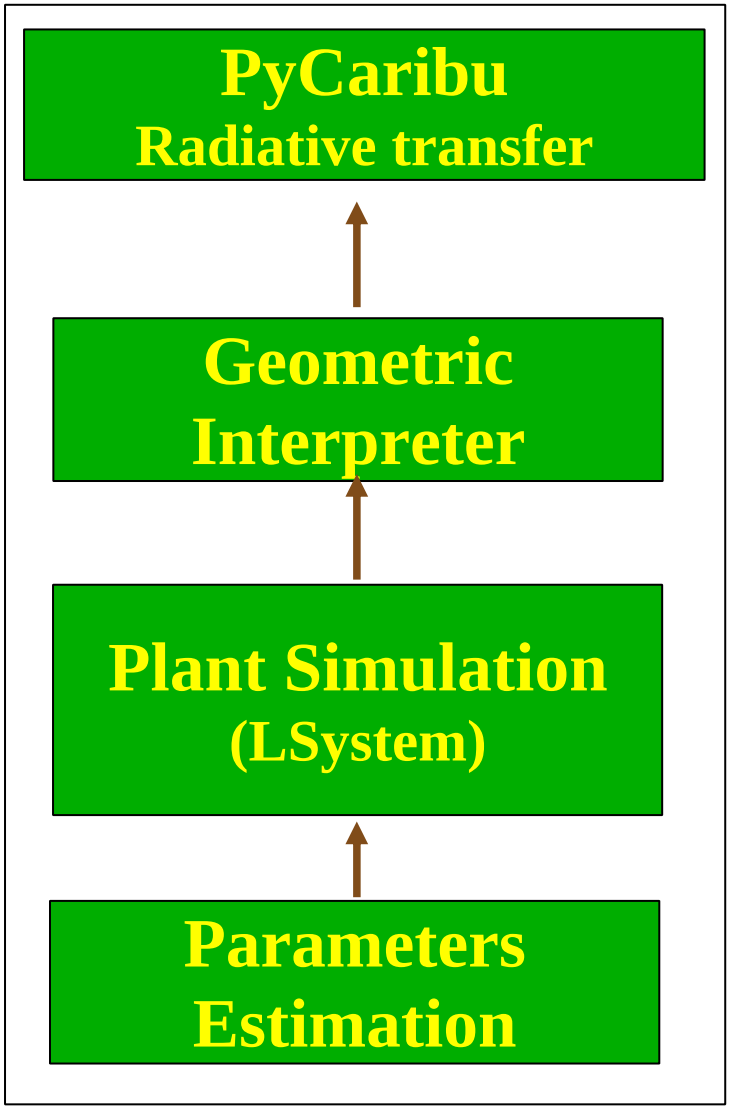


## Modelling biophysical processes on 3D plant models

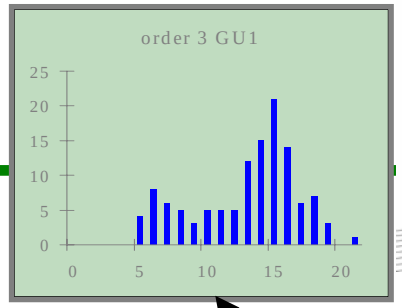
- reflectance
- irradiation
- light transmission
- photosynthesis
- energy budget
- sap flow
- transpiration

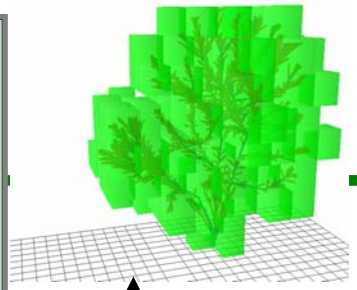
# PyCaRiBu – C++

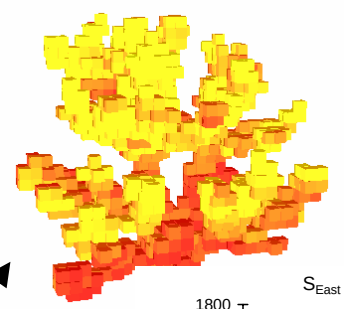
Maize simulation

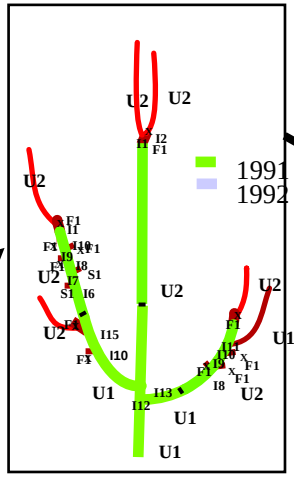


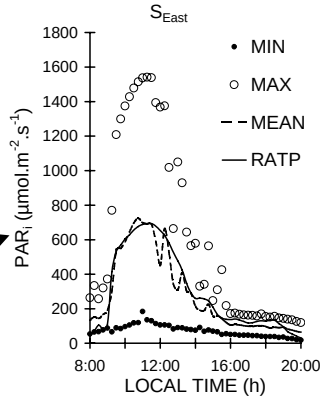
# OpenAlea








PlantGL AMAPmod

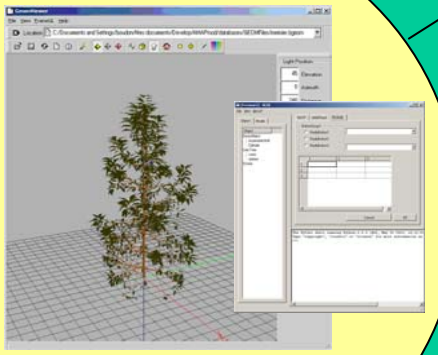
RATP

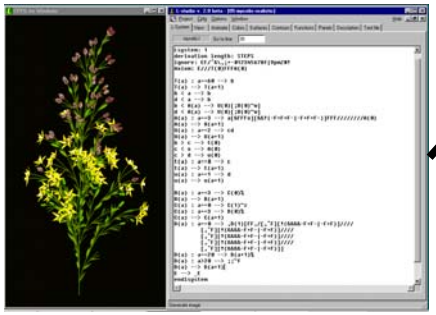
Module

Simulator

R

Python, GUIs





# Conclusion

**Toward a visual programming environment?**

- Vision [Sanner et al. 02]
- Orange [Demsar et al., 04]
- TraitsUI [anvisage, enthought]

**Python as a modelling language**

- Easy to learn, even for botanists.

**Python as a software bus**

- Glue together Fortran, C and C++
- Large scientific community

# Acknowledgements


- OpenAlea community

  INRIA Sophia (VirtualPlants),
  UMR AMAP (Montpellier),
  UMR PIAF (Clermont-Ferrand),
  UMR EPC (Paris-Grignon),
  Labri (Bordeaux),
  Joseph Fourrier University (Grenoble)
  UMR SAGAH (Angers),
  UMR BEPC (Montpellier),
  CEMAGREF (Clermont –Ferrand),
  INRA (Orléans), INRA (Lusignan), INRA (Nancy)

- Guido von Rossum & Python community