Functional-Structural Plant Modelling with GroIMP and XL

Tutorial and Workshop at Agrocampus Ouest, Angers,
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Introduction to the workshop

Functional-structural plant models (FSPMs)

"Functional-structural plant models (FSPM), or virtual plant models, are models explicitly describing the development over time of the 3D architecture or structure of plants as governed by physiological processes which, in turn, depend on environmental factors."

(Vos *et al.* 2010)

(Heuret)

Functional-structural plant models (FSPMs)

Basic principle of implementation:

Distribution of the processes to the elementary units (modules) of the plant

Biology: Plants as modular organisms

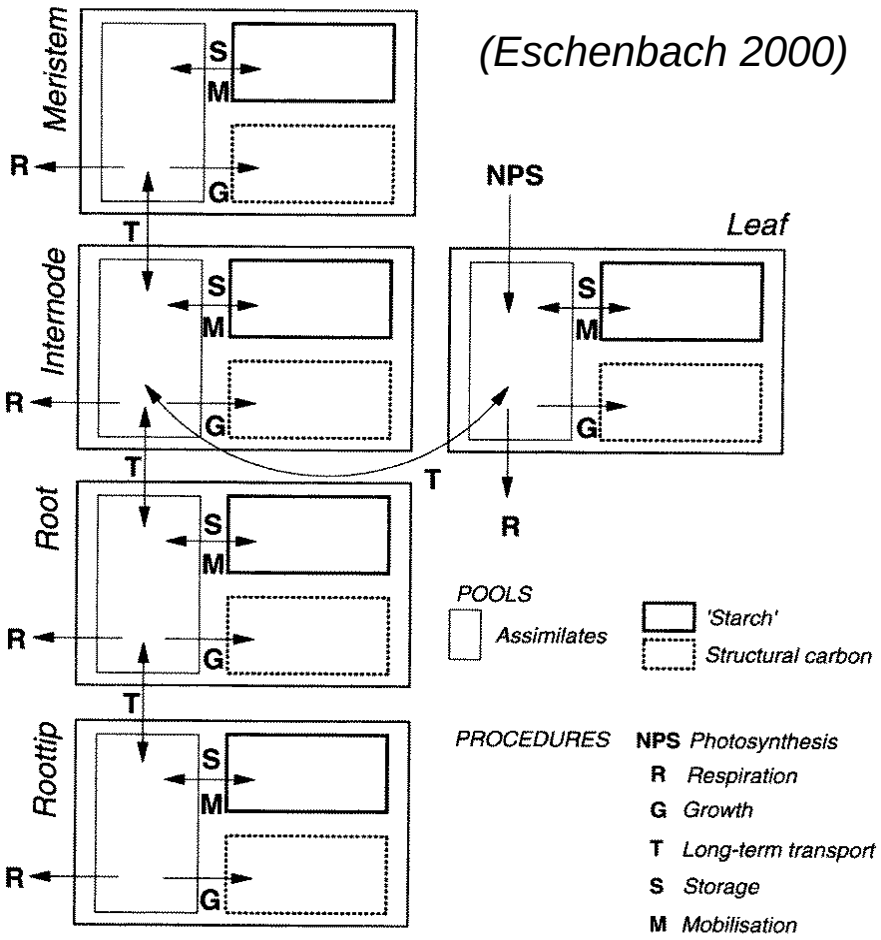
Functional-structural plant models, FSPMs

Idea:
distribution of the processes to the modules

Tool:
object-oriented programming

example of ALMIS

(Eschenbach 2000)



Functional-structural plant models, FSPMs

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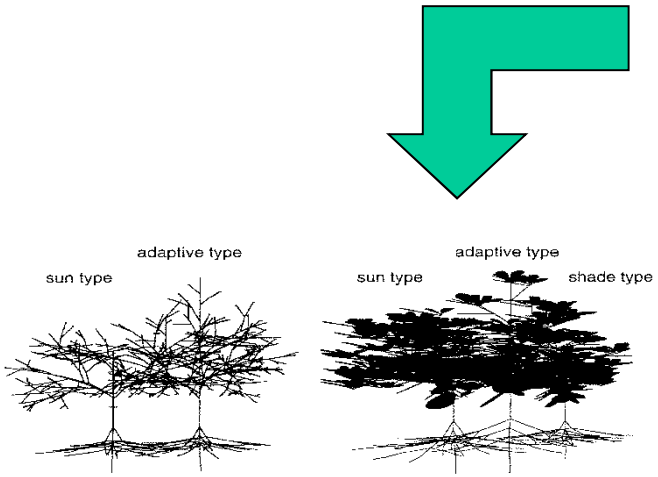

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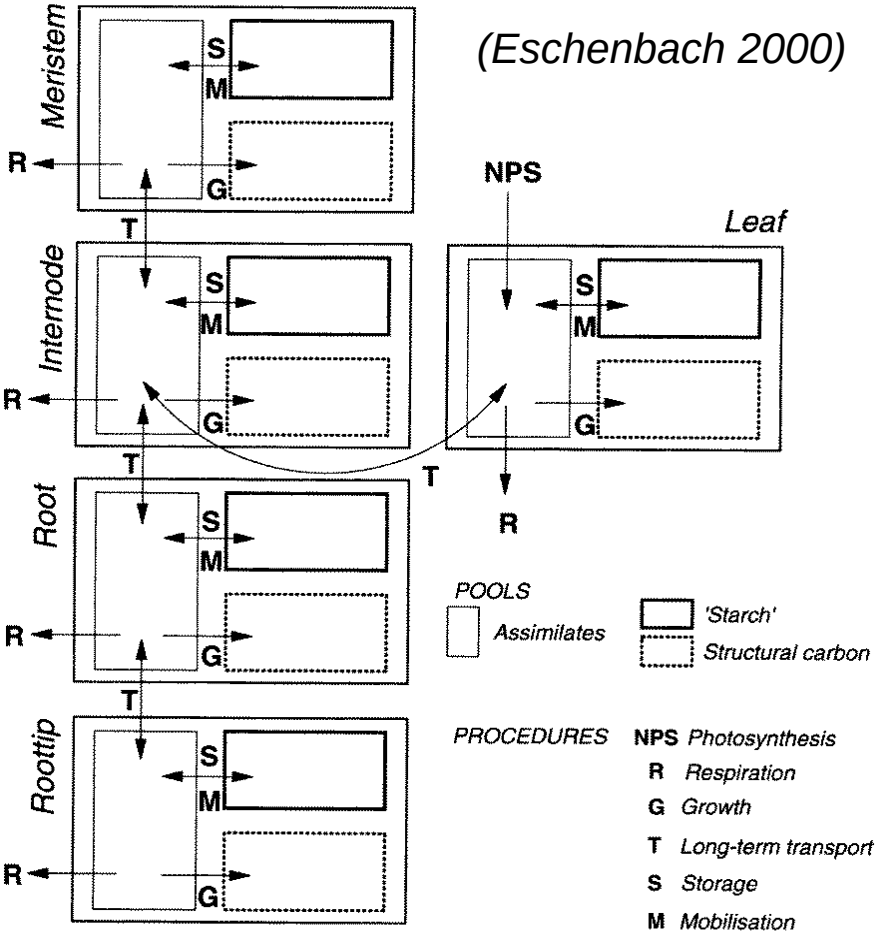

Functional-structural plant models, FSPMs

Representations of structure

3 levels:

1. static description of structure

   plant at a fixed date (e.g., at 5 May 2015)

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   time series of 3-dimensional structures

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   description of development (ontogenesis) of a plant:

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3. dynamics, taking causal impacts / conditions into account
   (sensitive models)

   - different paths of development
   - logical conditions for the decision between them (simplest case: stochastic)

Functional-structural plant models, FSPMs

Some platforms

AMAP family (AMAPsim, Greenlab, …)

uses finite automaton („reference axis“) and Markov chain models for state changes of meristems and organs

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Graph-grammar based platform (**GroIMP**)

Component-based system (OpenAlea)

- connects and controls software packages from different origin
- script language Python as a basis

Functional-structural plant models, FSPMs

Corresponding programming languages

Platform	*Language*	
LIGNUM	L+C	extends C++
OpenAlea	LPy	extends Python
GroIMP	**XL**	extends Java

The software GroIMP

http://www.grogra.de

there you find also the link to the download page:

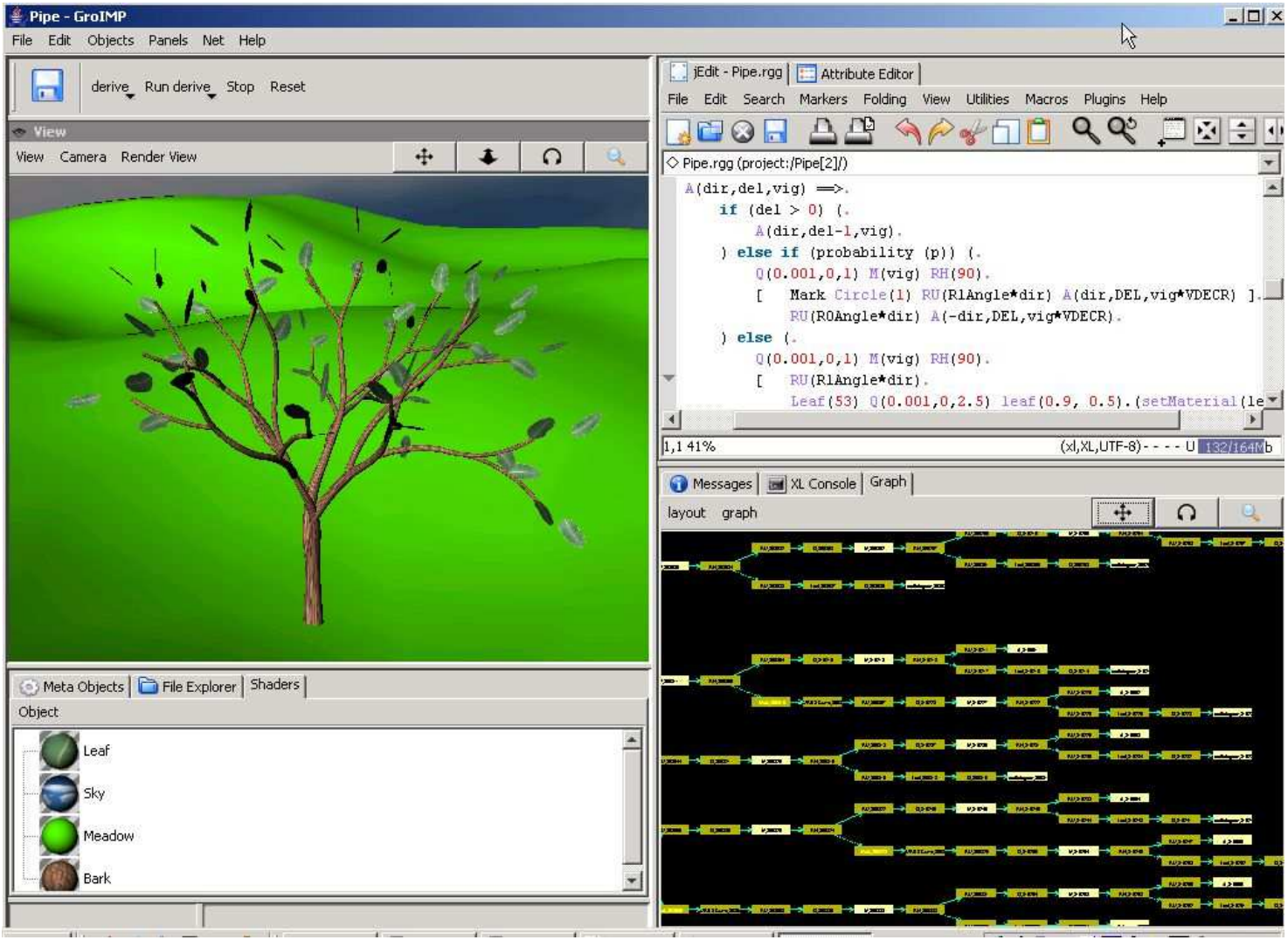
http://sourceforge.net/projects/groimp/

and a gallery of examples.

See also the e-learning units about GroIMP (author: K. Petersen, M.Sc. Forestry, 2009).

GroIMP is an open source project!

GroIMP (Growth-grammar related Interactive Modelling Platform)



GroIMP is a combination of:

- compiler and interpreter for the language XL
- development environment for XL
- 3-d modeller (interactive)
- 3-d renderer (several variants)
- 2-d graph visualizer
- editor for 3-d objects and attributes
- tool for generating textures
- display for DTD and MTG files
- tool for simulating light distribution

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- support for multiscale transformations

- free and open source

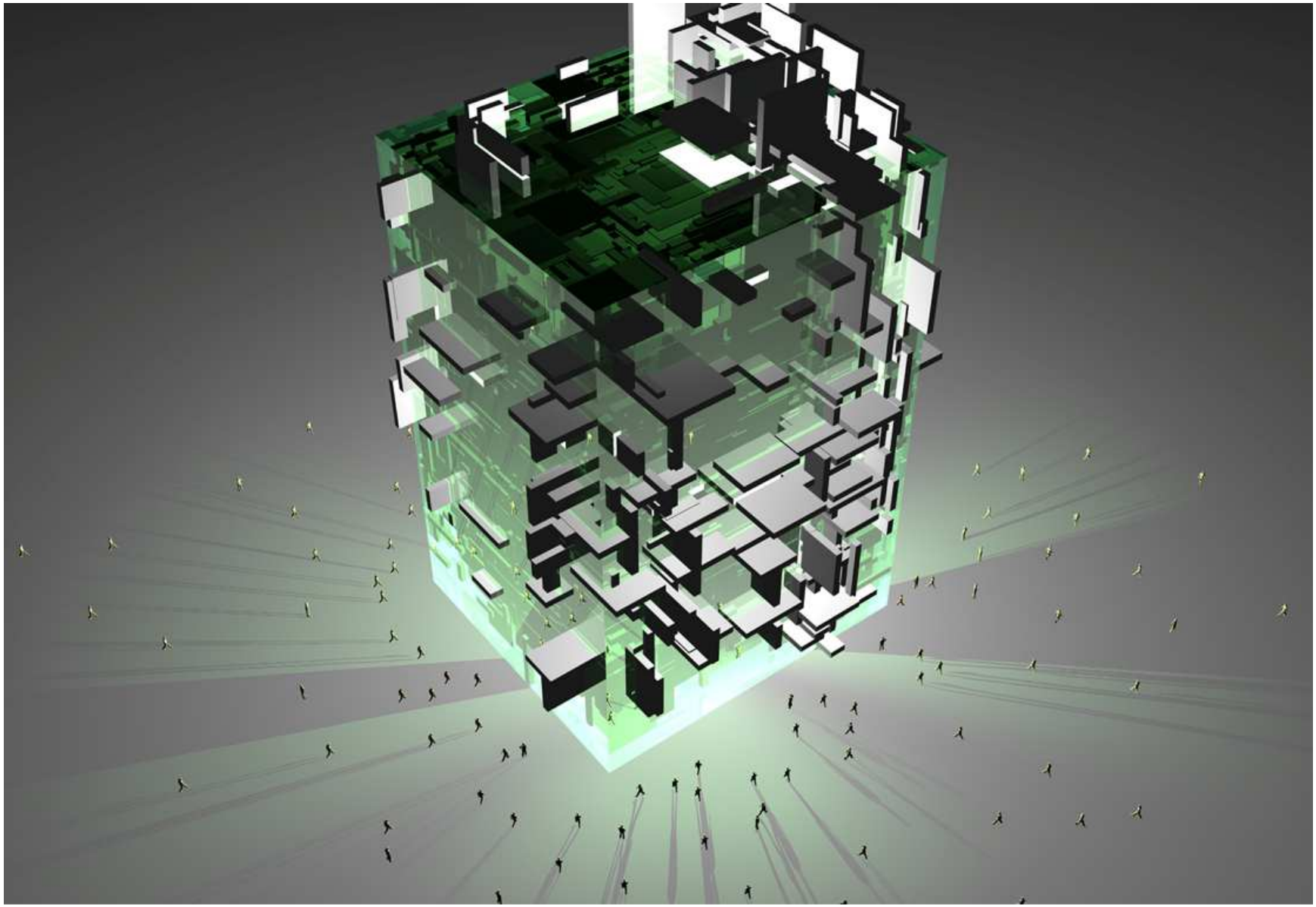
Application example: Modelling a park landscape

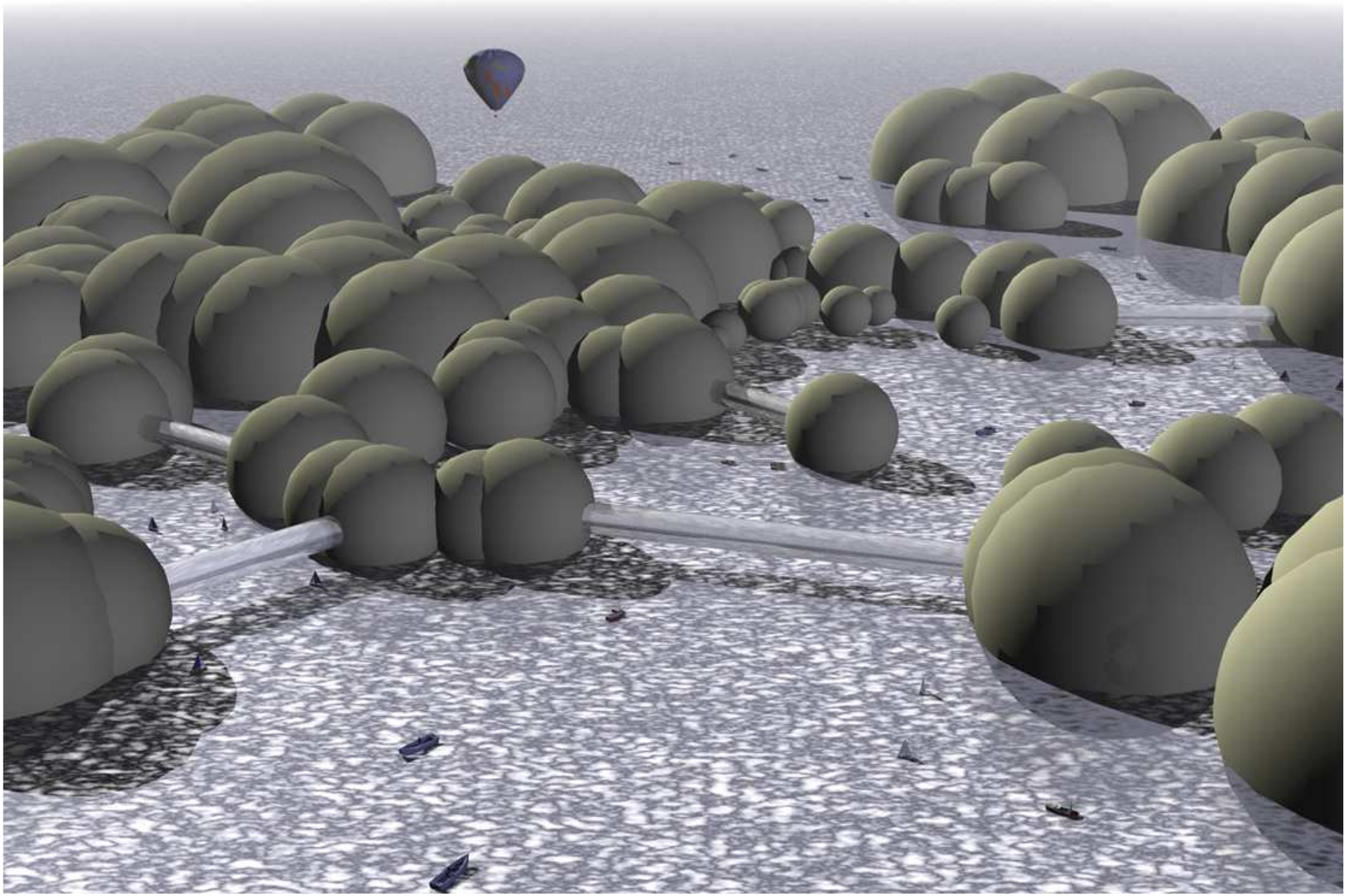
(Rogge & Moschner 2007, for Branitzer Park foundation, Cottbus)

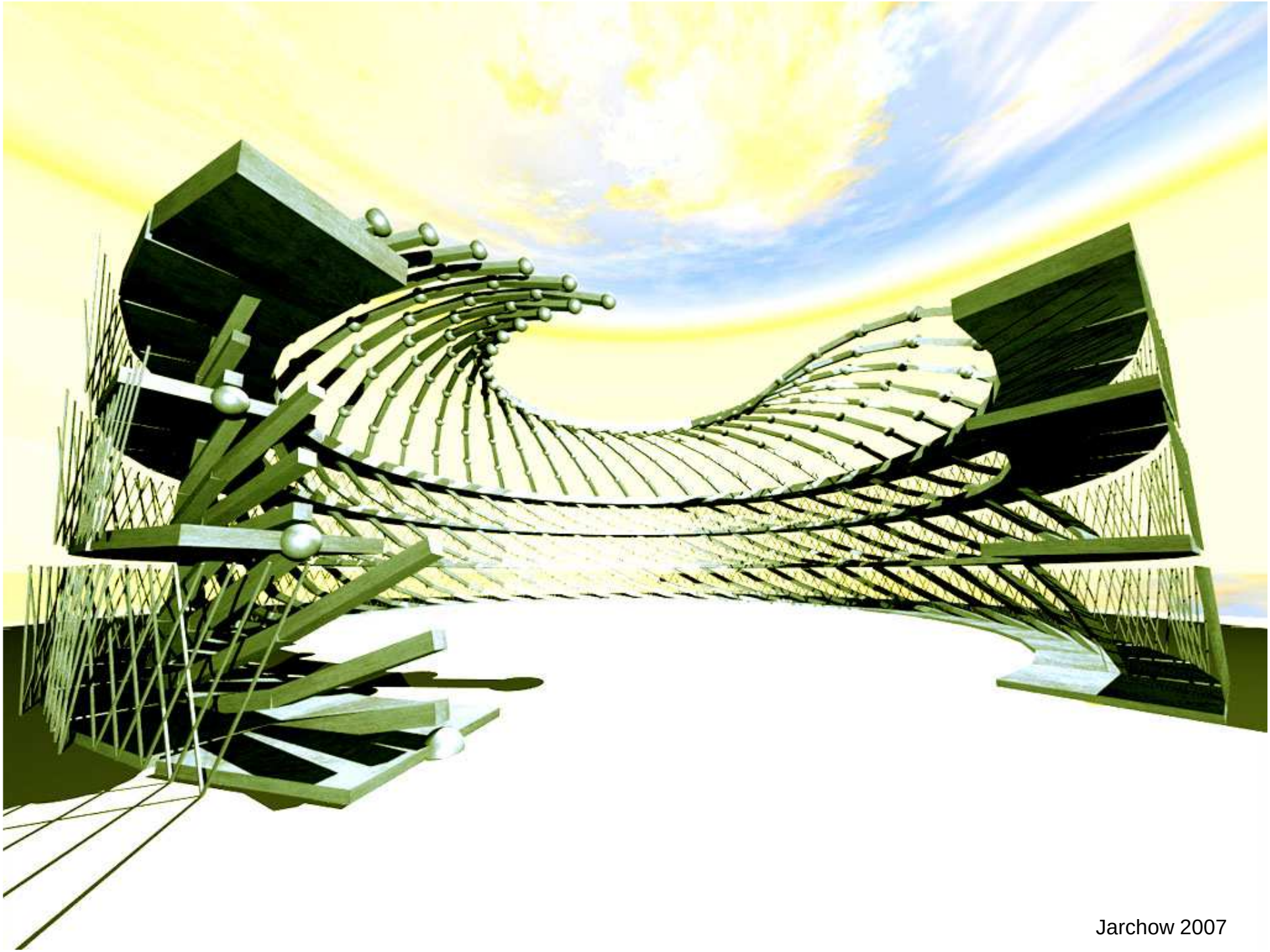
Black alder tree generated with GroIMP in VRML world

Results from XL seminar with students of architecture:

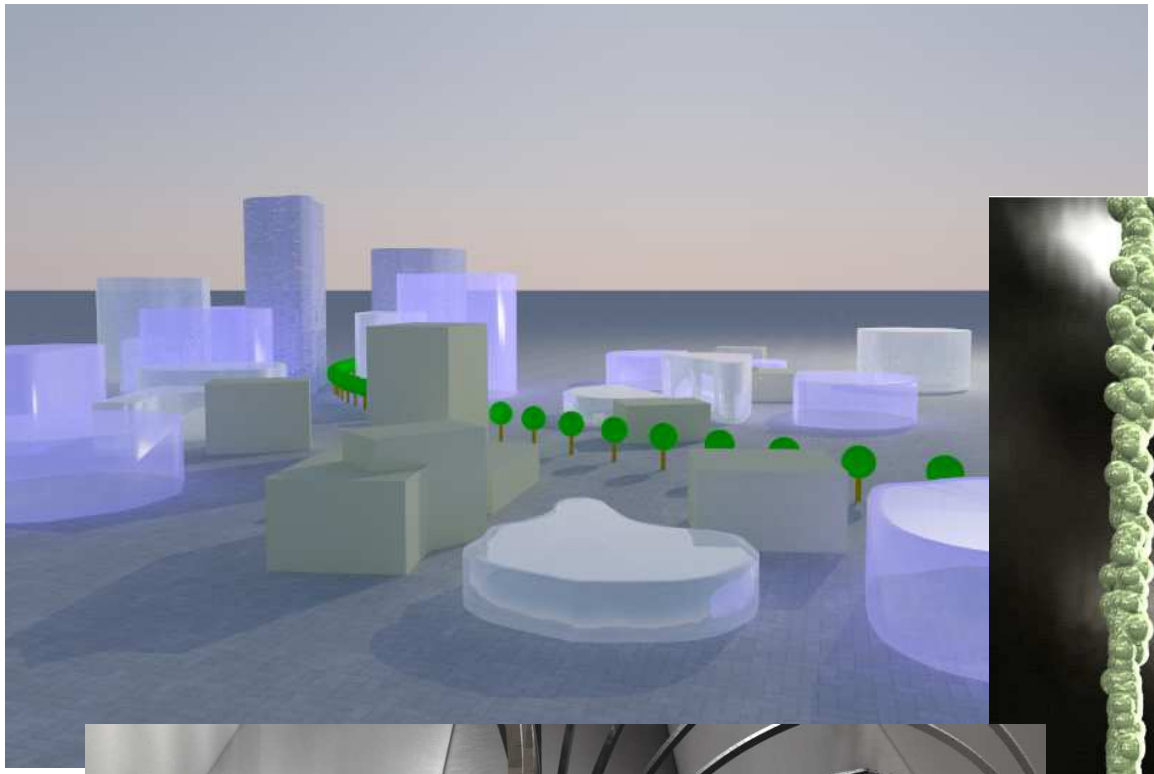
Liang 2007



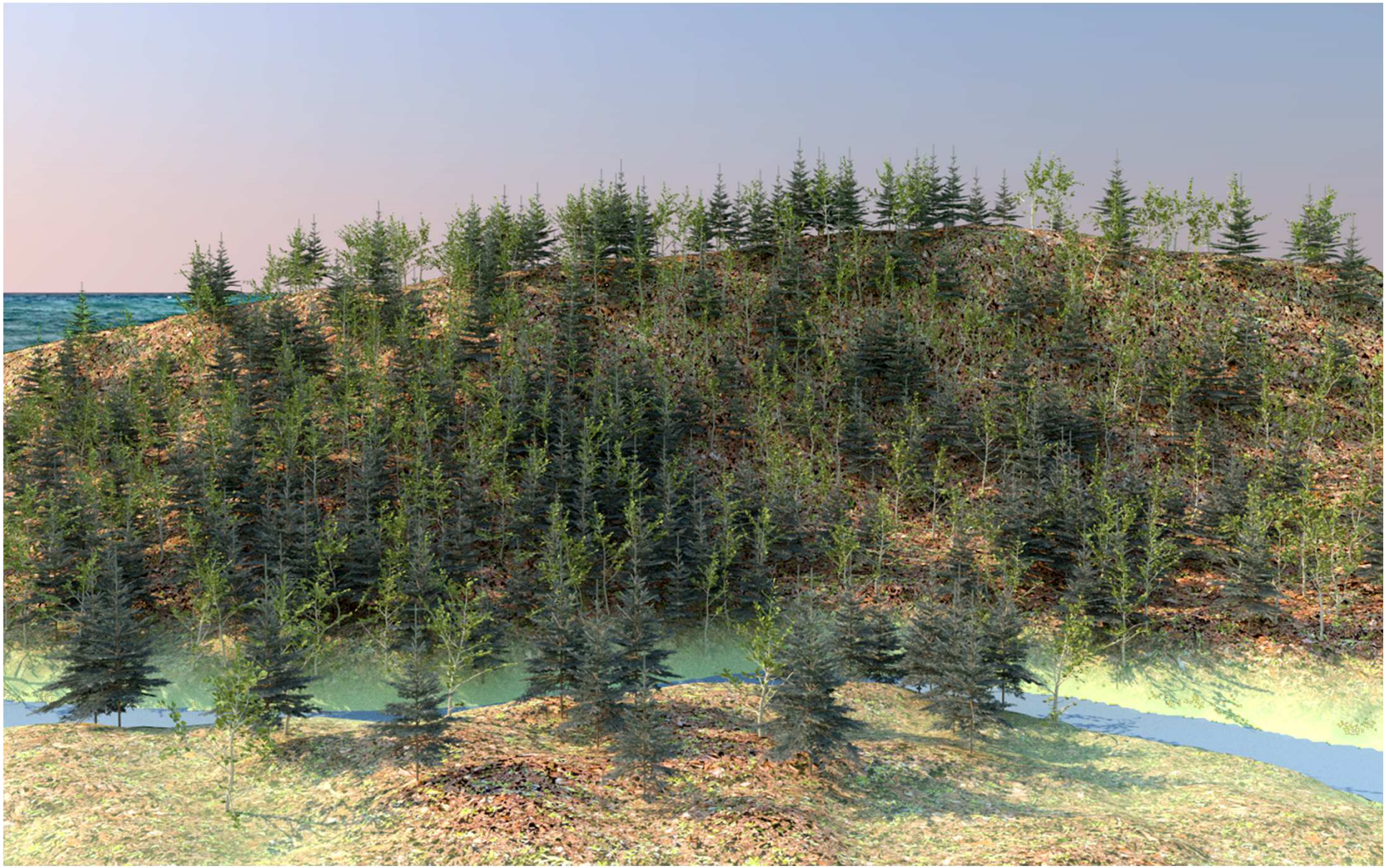




Jarchow 2007

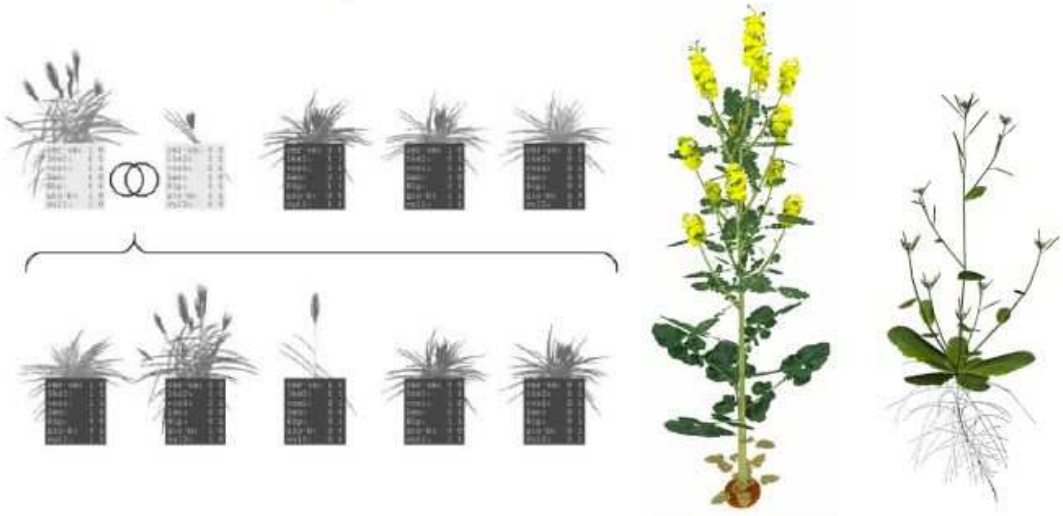


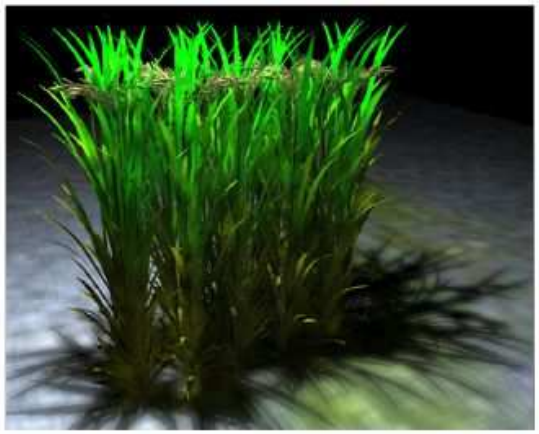
virtual landscape (with beech-spruce mixed stand)



GroIMP application results:

More examples of FSPMs

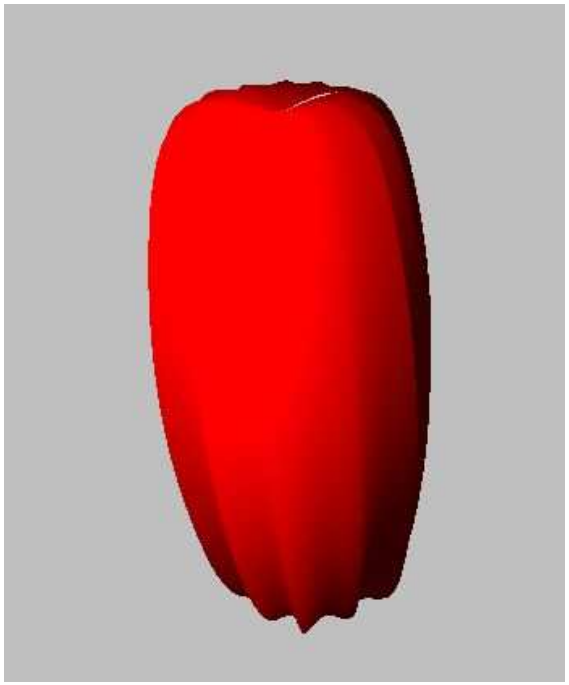


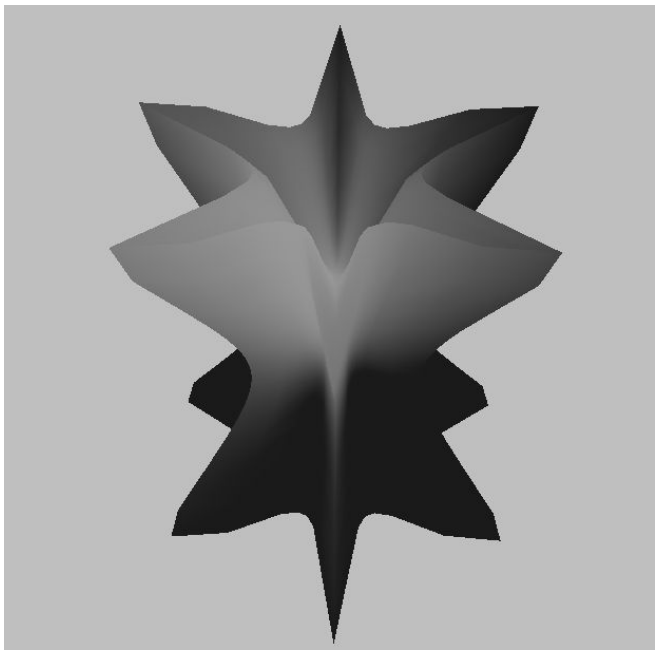


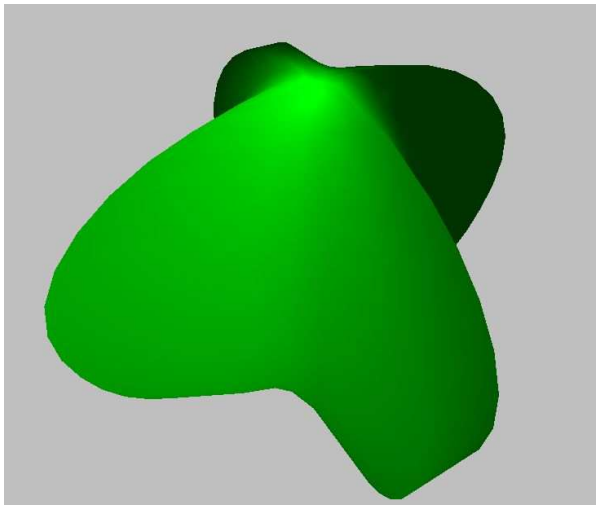
- Barley (Buck-Sorlin *et al.*)
- Rice (Xu *et al.*)
- Rapeseed (Groer *et al.*, Henke *et al.*)
- Arabidopsis (Evers *et al.*)
- Tomato (Buck-Sorlin *et al.*)
- Beech, Spruce (Hemmerling *et al.*, Kurth *et al.*)
- ...

GroIMP: Extensions

„Supershape“ (class of mathematically defined surfaces) as geometrical primitives







GroIMP: Extensions

Rate assignment operator

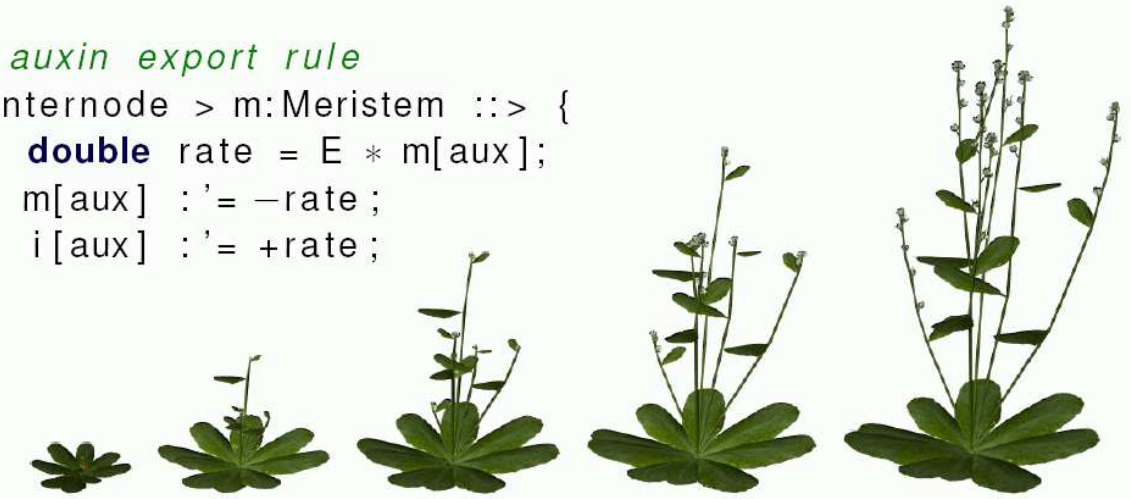
allows to call efficient and numerically stable solution methods for ordinary differential equations in a simple way in the code of a plant model

(Hemmerling 2012)

Example:

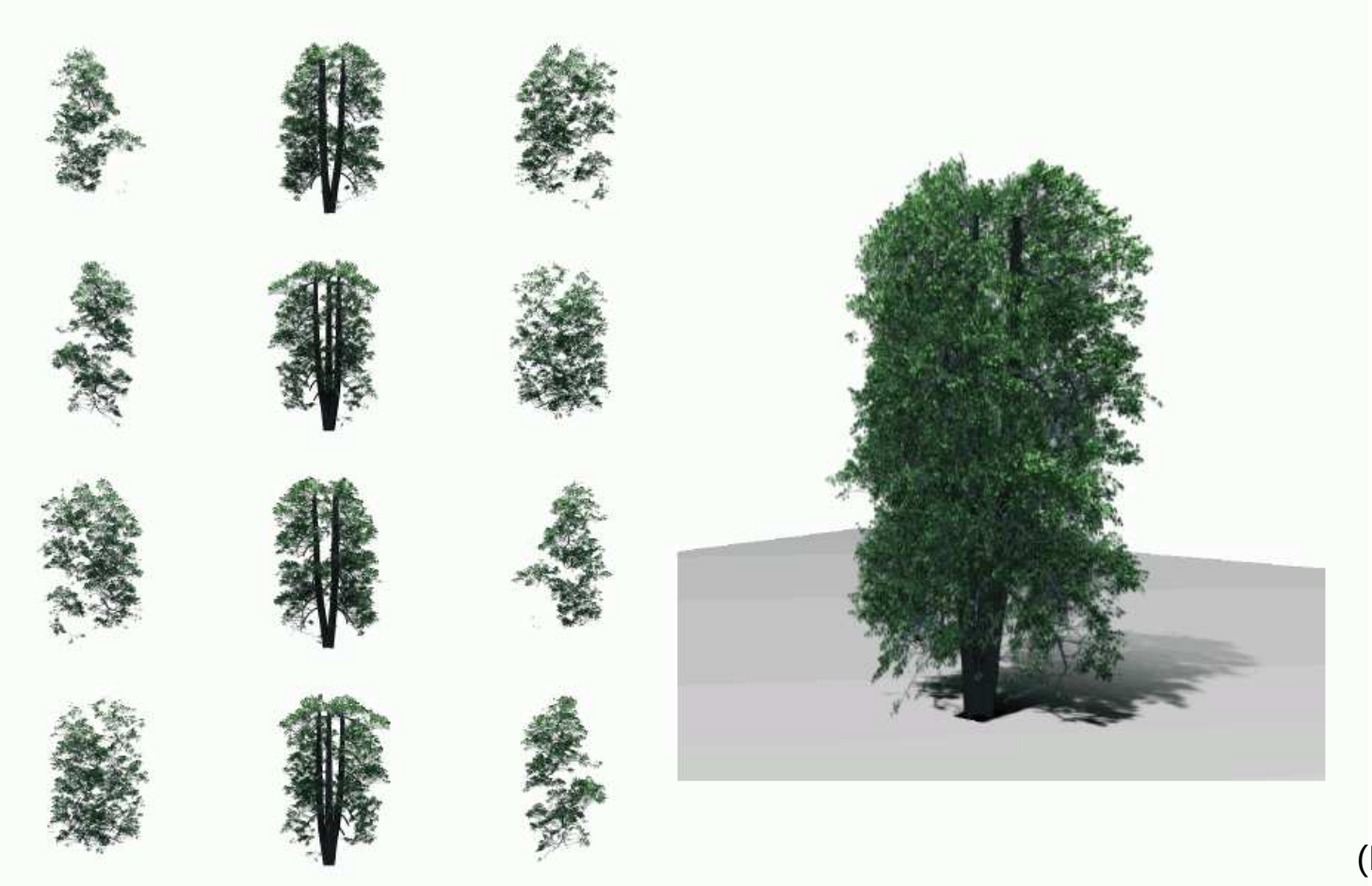
```
// cytokinin biosynthesis in root system
r:Roots ::> { r[cyt] :'= P - Q * r[aux]; }

// auxin export rule
i:Internode > m:Meristem ::> {
    double rate = E * m[aux];
    m[aux] :'= -rate;
    i[aux] :'= +rate;
}
```



GroIMP: Extensions

integrated tool for the generation of
„billboard objects“ for fast rendering of vegetation

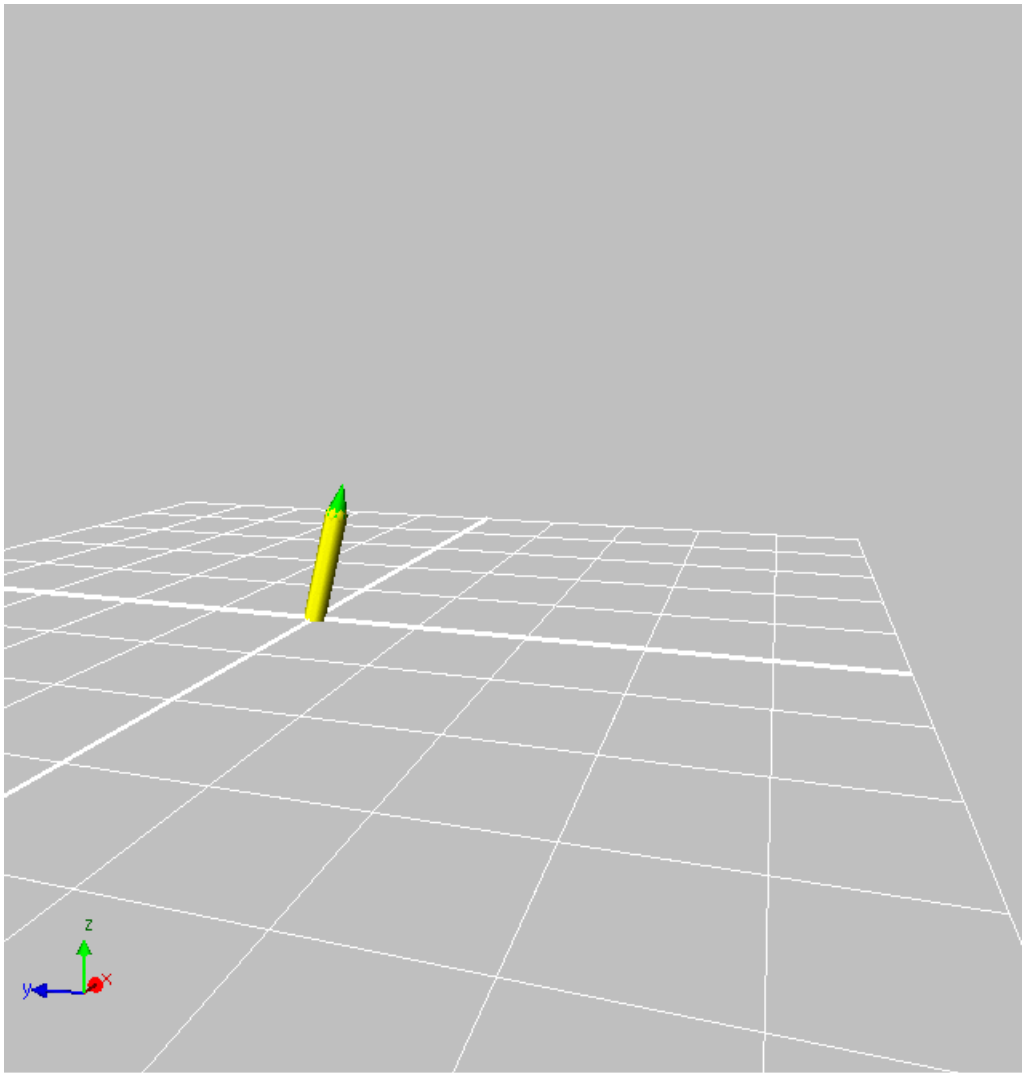


(Hemmerling 2010)

GroIMP: Extensions

physics engine

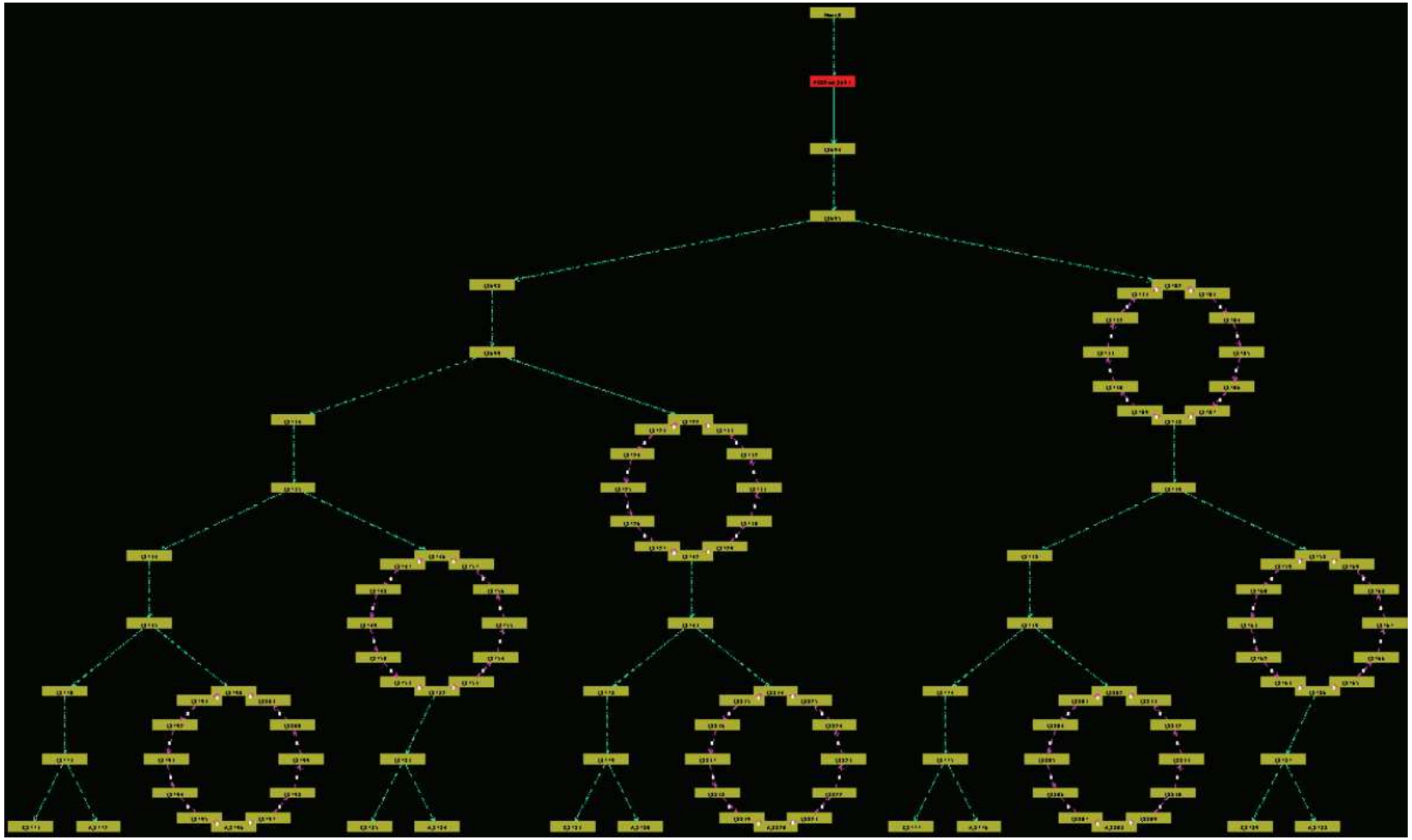
(realized by Paul Masters, University of Southampton)



GroIMP: Extensions

optimized automatic 2-d graph layout

(realized in cooperation with Ecole Centrale Paris, internship by Octave Etard in Göttingen)

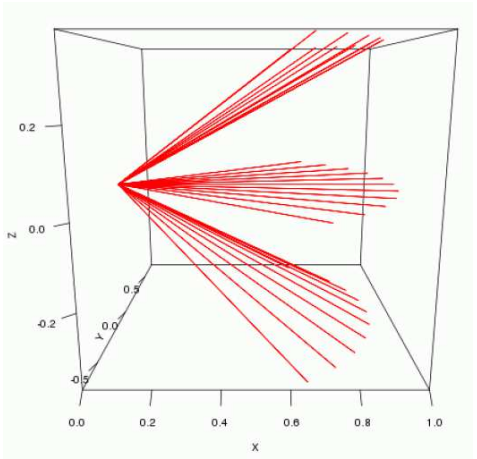


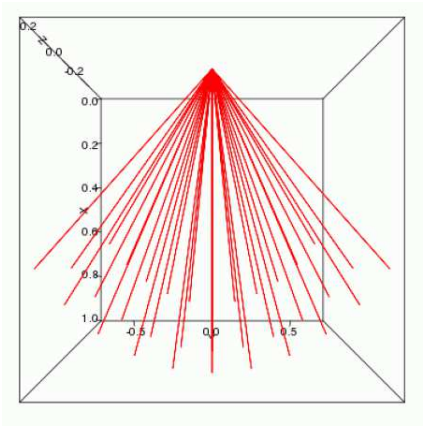
(Etard 2011)

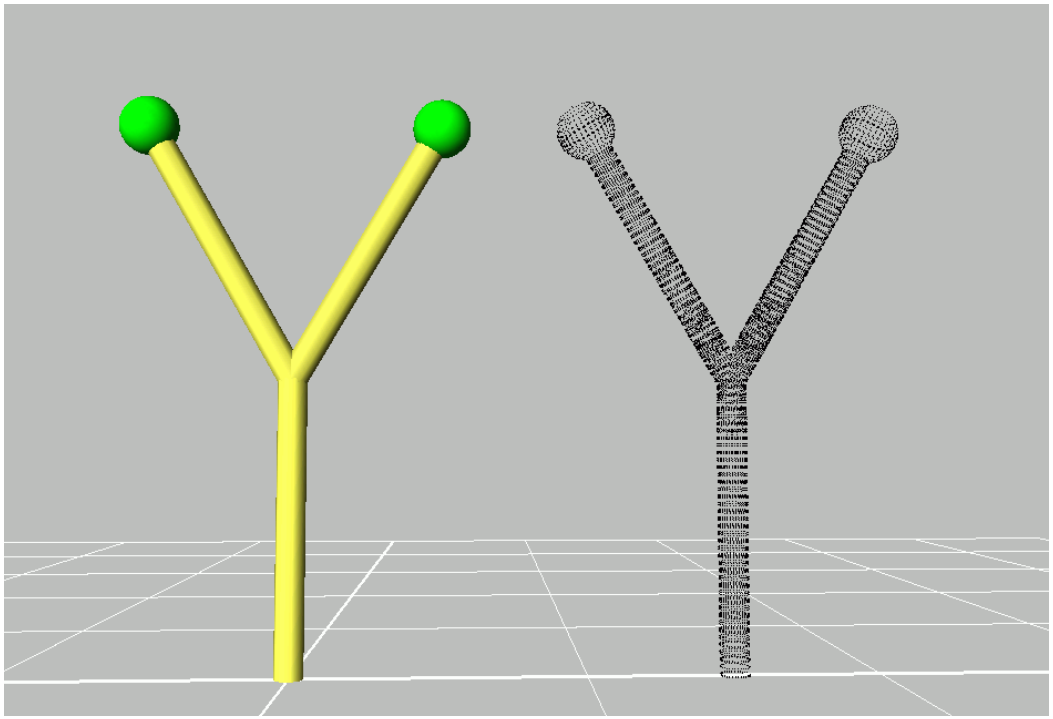
GroIMP: Extensions

integrated virtual laser scanner

(realised with Ecole Centrale Paris, internship Etard)





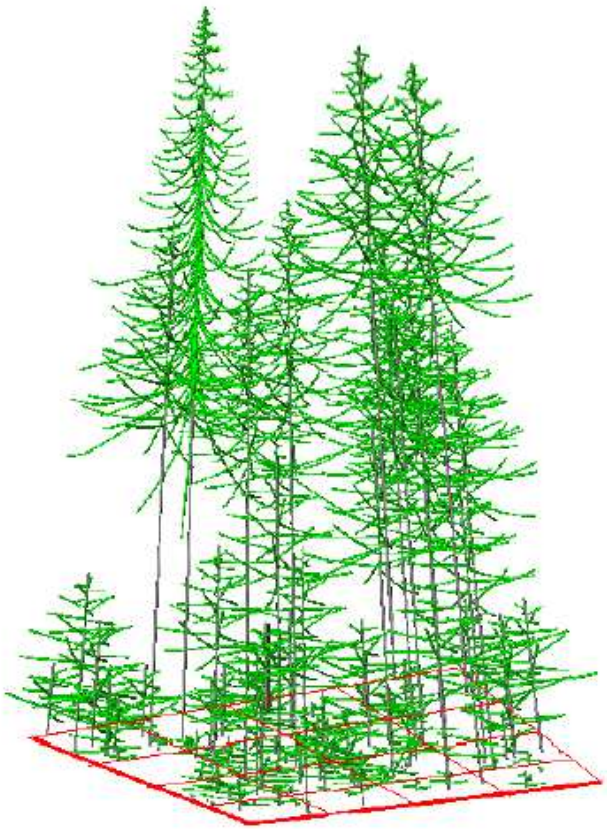


(Etard 2011)

GroIMP: Extensions

multiscale modelling framework

(realised by Yongzhi Ong, PhD thesis 2015:
http://hdl.handle.net/11858/00-1735-0000-0022-5FC5-B)



(Ong & Kurth 2014)

Acknowledgements

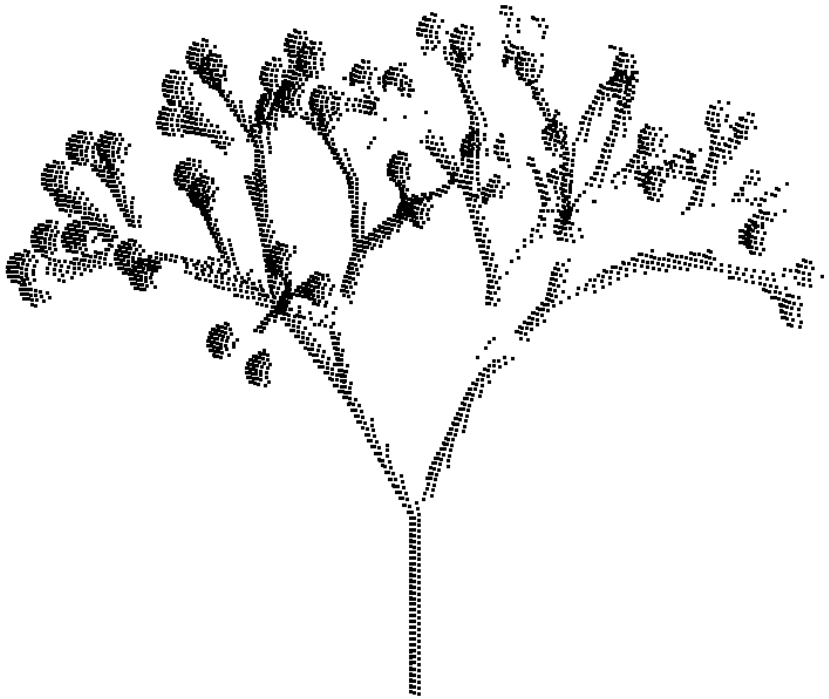
(for this and for the subsequent tutorials...)

- Gerhard Buck-Sorlin
- Octave Etard
- Reinhard Hemmerling
- Michael Henke
- Ole Kniemeyer
- Yongzhi Ong

and particularly

- Katarína Streit

for providing a lot of images...



www.grogra.de