GreenLab in XL – usage and more

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Tutorial and Workshop
"Modelling with GroIMP and XL"
combined with the 5th GroIMP user and developer meeting

Göttingen, 2012-02-28
Mathematical model of plant growth
Developed by several teams: Sino-French lab LIAMA (China), Digiplante (INRIA, ECP, France)
Several versions: deterministic, stochastic, mechanistic, ...
Applied to various plant species:
Botanical background

- **Physiological age** (PA) - relates to the degree of differentiation of axes (usually $\leq 5$)
- **Metamer** (phytomer) - basic structural unit of a plant
- **Growth unit** (GU) - portion of an axis which develops during uninterrupted period of extension (growth cycle (GC))

(Letort, 2010)
Growth cycle

- Deterministic case of GreenLab model (GL1)
Software for GreenLab

GreenLab versions: GL1 - deterministic, GL2 - stochastic, GL3 - deterministic with retroaction loop (mechanistic), GL4 - stochastic with retroaction loop

- **GreenScilab**
  - GL1, GL2
  - Open source
  - Several versions (slightly different implementation / input parameter data)
    - with GUI: GreenScilab demo, GreenScilab-Crop
    - without GUI: for pine (GL2), for tomato (GL1), for chrysanthemum (GL1)

- **QingYuan**
  - GL1, GL2, GL3, GL4
  - Licenced

- **DigiPlant**
  - GL1, GL3

- And more (GLOUPS, CornerFit, VisualPlant, . . . )
GreenScilab-Crop V1.0

Parameter Preview & Customization:

- **Number of axillary organs**
  - Leaf: 1
  - Female Organ: 1
  - Male Organ: 1
  - Female organ: 15, 15, 1, 0
  - Male organ: 21, 99, 1, 0

- **Number of branches**
  - branches: 0
  - Branches Time: 1, 99, 1, 0

- **length of axis**
  - length of axis: 21
  - from functioning file: false

Opened Parameter file: C:/Dokumente und Einstellungen/All Users/ksmolen/software/GreenLab/greenscilab-cropv1.0_web/GreenScilab-CropV1.0_Web/
Motivation

Existing Software

DigiPlant

DigiPlante - [abies_massart.slm]

Simulation

Inputs

Parameters

Topology

- Continuous Growth Plant Topology
- Phyllotactic Growth Plant Topology

Growth unit of Phy. age 1

Metamers Organization

Element 0
- Variable Number
- Variable Nb of
- Variable Number
- Variable Number
- Geometry at M

Element 1
- Variable Number
- Variable Nb of
- Variable Number
- Variable Number
- Geometry at M

Element 2
- Variable Number
- Variable Nb of
- Variable Number
- Variable Number
- Geometry at M

Element 3
- Variable Number
- Variable Nb of
- Variable Number
- Variable Number
- Geometry at M

Element 4

Template

- Growth unit of Phy. age 1
- Metamers Organization

Reduction and Control

- Rotator Order
- Reduction Coefficient
- Rotator Control
- Branch Control
- Apical Dominance
- Monopodial / Sympodial

Mutation

- Number of Macrostates
- Next Phy Age
- Complex Macro Num

Geometric Parameters at the level of Growth Units

- Phyllotaxy Angle
- First Angle for Phyllotaxy
- Leaf Insertion Type
- Organ deviation
- Branch Straightening
- Branch Subsidy
- Mechanical Parameters
- Parameters for Bend...

Number of Macrostates

int macro_num
Dual-scale automaton in XL

- **Test structure (according to Kang et al. (2003))**

- **Rule-based representation (1 rule in XL)**

after 30 iterations:
Dual-scale automaton in XL

- Test structure (according to Kang *et al.* (2003))

- Rule-based representation (1 rule in XL)

after 30 iterations:

```
• → • → • → • → • →
```

time: 0 (Axiom)
Dual-scale automaton in XL

- Test structure (according to Kang et al. (2003))

- Rule-based representation (1 rule in XL)

After 30 iterations:

\[
\begin{align*}
&\text{time: 1}
\end{align*}
\]
Dual-scale automaton in XL

- Test structure (according to Kang et al. (2003))

- Rule-based representation (1 rule in XL)

after 30 iterations:
Methods & Results

Test structure (according to Kang et al. (2003))

Rule-based representation (1 rule in XL)

After 30 iterations:

Time: 3
Dual-scale automaton in XL

- Test structure (according to Kang et al. (2003))

- Rule-based representation (1 rule in XL)

after 30 iterations: 

time: 4
Dual-scale automaton in XL

- Test structure (according to Kang et al. (2003))

- Rule-based representation (1 rule in XL)

after 30 iterations: [diagram showing progression over 30 iterations]

time: 5
Probabilistic growth

- $P_C$ - survival probability of a bud
- $P_A$ - growth probability of an apical bud
- $P_I$ - appearance probability of a metamer
- $P_B$ - branching probability of a bud

(Kang et al., 2008)

$P_C = P_B = P_A = P_I = 1$  $P_C = 0.9$  $P_B = 0.5$  $P_A = 0.8$  $P_I = 0.8$
Main attention / Features

- GUI aided input method for parameter input
- Make it “user save”
  - Control of inputs (general)
    - Number fields
    - Choice boxes
    - Check boxes
  - Check input ranges
  - Deactivate not used fields
  - Measurement units
- Description window (parameter description, type, unit, range)
- Provide import and export of GreenLab parameter files ("sci")
- Support AMAPSymbol files ("smb") for shape objects
Future work

- Extensions:
  - Connect to GroIMP’s light model
  - Include more photosynthesis models

- Model comparison:
  GreenLab ⇔ LIGNUM ⇔ GroIMP

- Convert to a component-based model (show case)
Thank you for your attention!

Special thanks:
Cong Ding - GUI
Yongzhi Ong - smb import
Letort V.
Modélisation Mathématique de la Croissance des Plantes : construction des modèles. Presentation, 2010

Structural Factorization of Plants to Compute Their Functional and Architectural Growth. *Simulation* 82 (7), 2006, 427–438
