Efficient Building of Forestry Modelling Software with the Capsis Methodology

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The Capsis project

Objectives: Build a **software platform** to **integrate** many forest growth, yield and dynamics models for forestry modellers, forestry managers and education

Details:
- An integration tool
- Growth / dynamics models for forests / plantations
- Various intervention to build management scenarios
- Interactive or not for long simulations
- Integrated tools to check the results
- Easy export to data analysis tools
- Possible connection to other simulation software
- Free software to ease partnerships
- Multi-OS and multi-language (french, english)
**Forestry models**

Stand level models:

Distribution models:

Individual based models:

Spatialized models:

... and also Mixt models:

Process-based + growth and yield
Distribution + spatial structure
Individual based + genetics
Various representations in memory

<table>
<thead>
<tr>
<th>Kind of model</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lemoine model</strong> (stand-level, plantation):</td>
<td>- Age</td>
</tr>
<tr>
<td></td>
<td>- Number of trees</td>
</tr>
<tr>
<td></td>
<td>- Girth (dominant, mean tree) (cm)</td>
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<td>- Basal area (m²)</td>
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<td>- Height (dominant, mean tree) (m)</td>
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<tr>
<td></td>
<td>- Volume (mean tree) (m³)</td>
</tr>
<tr>
<td><strong>PP3 model</strong> (distribution, plantation):</td>
<td>A collection of bars</td>
</tr>
<tr>
<td></td>
<td>- Age</td>
</tr>
<tr>
<td></td>
<td>- Diameter (cm), Height (m), Tree volume (m³)</td>
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<tr>
<td></td>
<td>- Number of trees in the bar</td>
</tr>
<tr>
<td></td>
<td>- Crown (base height, diameter) (m)</td>
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<tr>
<td></td>
<td>- Other (biomass, carbon mass, leaf area, etc.)</td>
</tr>
<tr>
<td><strong>Samsara model</strong> (individual-based, spatialized):</td>
<td>A collection of trees</td>
</tr>
<tr>
<td></td>
<td>- Age</td>
</tr>
<tr>
<td></td>
<td>- Diameter (cm), Height (m)</td>
</tr>
<tr>
<td></td>
<td>- Location x, y, z (m)</td>
</tr>
<tr>
<td></td>
<td>- Species</td>
</tr>
<tr>
<td></td>
<td>- Crown (base height, radius) (m), Light (MJ)</td>
</tr>
</tbody>
</table>

Other...
Capsis Software Architecture

**Kernel**: stability

**Libraries**: additional tools

**Modules**: Stand growth models

**Extensions**: evolutive part

**Pilots**: interactive or not
The Capsis project organisation

A Actors roles:

**Developers**: computer developers, design, training courses, assistance

**Modellers**: scientists, build their models inside Capsis

**End-users**: interested by using the models

The Capsis Community:

Developers + Modellers are co-developing together
Clear participation rules

The Capsis charter:

1. **Free kernel**: the Capsis kernel is a free software (LGPL licence)
2. **Development**: the modelers are in charge of the development of their models
3. **Support**: They can have support from the developers
4. **Free access in the community**: All the source codes are freely accessible by all members in the Capsis community
5. **Respect of intellectual property**: all members respect the intellectual property of the other members
6. **Validations**: developers deal with technical validation, modelers deal with functional validation
7. **Distribution**: the stabilized / validated modules may be distributed when the author decides and chooses a licence
8. **Decentralization**: modelers manage directly the relations with their end-users
The Capsis methodology

Initial training session

Capsis charter acceptance

Starting stage together with a developer

Co-development

Possible distribution outside the Capsis community

Autonomy with simple tools

Support and possibly new stages for evolutions
Focus: Integrated Stand Growth Model (1)

ISGM is a model by Dr. Tang Shouzheng (since 1994)
The Research Institute of Forest Resource Information Techniques (IFRIT) of the Chinese Academy of Forestry (CAF), Beijing

- Implemented in Capsis by Hong LingXia in June 2006 during her visit in France

- ISGM is a Stand-level model


- The structure (without equations) of the ISGM model in Capsis was reused to begin implement the new Lemoine project in Capsis (Céline Meredieu, Thierry Labbé, INRA-EPHYSE, October 2006)
Focus: Integrated Stand Growth Model (2)

A group of correlated equations to calculate the growth of an **even-aged stand**:
- Basal area
- Density index
- Self-thinning model
- Dominant tree growth
- Mean tree growth
- Stand volume

Outputs:
- different kinds of growth tables with different site index, stand density, thinning methods
- A stand density control graph

Implemented:
- in ForStat (Chinese, CAF)
- in Capsis (English, INRA-AMAP)
Focus: Integrated Stand Growth Model (3)
Focus: Integrated Stand Growth Model (4)
Focus: Integrated Stand Growth Model (5)

Limit Panel
Current age: 4.0
End age: 5.0

Thinning panel
Enable thinning

Number | Cutting age | Cutting ratio of tree number | Cutting ratio of basal area
---|---|---|---
1 | 10.0 | 0.4 | 0.5
2 | 20.0 | 0.3 | 0.4

Total basal area / Age

Cutting age: 20
Cutting ratio of tree number: 0.3
Cutting ratio of basal area: 0.4
The Capsis Methodology - PMA06 - Beijing - November 13-17, 2006

Focus: ISGM (6)

Table: ISGM Stand Table

<table>
<thead>
<tr>
<th>Date</th>
<th>Age</th>
<th>Volume</th>
<th>Volume y.e.</th>
<th>Volume c.o.</th>
<th>Total basal</th>
<th>Average c.e</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>3.543</td>
<td>0</td>
<td>0.886</td>
<td>1.637</td>
<td>3.877</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>10.319</td>
<td>6.776</td>
<td>2.064</td>
<td>3.433</td>
<td>5.691</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>20.594</td>
<td>10.275</td>
<td>3.432</td>
<td>5.582</td>
<td>7.35</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>34.1</td>
<td>13.506</td>
<td>4.871</td>
<td>8</td>
<td>8.824</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>50.448</td>
<td>16.348</td>
<td>6.306</td>
<td>10.619</td>
<td>10.121</td>
</tr>
<tr>
<td>6</td>
<td>9</td>
<td>69.146</td>
<td>18.696</td>
<td>7.683</td>
<td>13.373</td>
<td>11.26</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>89.612</td>
<td>20.466</td>
<td>8.961</td>
<td>16.189</td>
<td>12.262</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>44.806</td>
<td>-44.806</td>
<td>4.481</td>
<td>8.095</td>
<td>17.262</td>
</tr>
</tbody>
</table>
Focus: Integrated Stand Growth Model (7)

A specific tool: the ISGM density control graph
A distribution model: Sylvestris (1)

Sandrine Perret\(^{(1)}\), Thomas Pérot\(^{(1)}\), Céline Meredieu\(^{(2)}\)

\(^{(1)}\)Cemagref - Forest ecosystems
\(^{(2)}\)INRA - EPHYSE

- Scientific purpose: studying and modelling Scots Pine growth in pure and even-aged stands

- Applied purpose: helping forest managers to build various silvicultural scenarios adapted to different stand structure, site fertility or management purpose.

5 equations:
- Dominant height – age – fertility model
- Diameter increment model
- Height-diameter model
- A self-thinning model (Hynynen, 1993)
- Volume table (Goupil, 1981)
A distribution model: Sylvestris (2)

Sandrine Perret, Thomas Perot (Cemagref), Céline Meredieu (INRA)
Samsara: individual-based, spatialized (1)

Benoît Courbaud - Cemagref

- A model of forest dynamics designed for the study of stand structure / stand dynamics and silviculture interactions

- To compare thinning strategies and to understand how demographic processes at the tree level (regeneration, growth, death) generate patterns at the stand level

- Trees: location (x, y, z), height, diameter at breast height, crown base height and crown base radius

- Light interception is calculated for every tree and every cell, growth, death and competition are modelled at the tree level for every individuals higher than 1.30 m. Regeneration is modelled at the ground cell level

Samsara: individual-based, spatialized (2)
Samsara: individual-based, spatialized (3)
Other examples

Large scales - Ventoux - Ph. Dreyfus (INRA)

Wood quality - Fagacées - F. Mothe (INRA)

Branches - NZ1 - D. Pont (ENSIS NZ)

Dispersion - Cytisus - E. Chambon-Dubreuil (INRA)
Groups management

The Capsis Methodology - PMA06 - Beijing - November 13-17, 2006
About 400 extensions in Capsis, either generic or specific to one model.
Main reusable libraries

**Biomechanics** - Philippe Ancelin (Cemagref)
Calculates wind effects, considered as a natural disturbance, on forest stands managed by a tree-based forest growth or dynamics model

**Economics** - Christophe Orazio (IEFC)
Economic balance of a scenario by allocating expenses and incomes to the interventions

**Genetics** - Christian Pichot et al. (INRA)
Genetics information and processes to study interactions between gene flows and trees demography

**Spatial** - Francois Goreaud (Cemagref)
Generation and characterization of spatial structures
**Integrated modules: various types**

<table>
<thead>
<tr>
<th>IBM</th>
<th>Diameter class + Spatialized</th>
<th>Fish</th>
<th>Stand level</th>
<th>AgroForestry</th>
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</thead>
<tbody>
<tr>
<td>Fagacées</td>
<td>CA1, Luberon</td>
<td>Bidasoa</td>
<td>ISGM</td>
<td>HiSafe</td>
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<tr>
<td>Easy</td>
<td>Eucalypt</td>
<td>Dynet</td>
<td>Lemoine (new)</td>
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<td>OakPine1 (new)</td>
<td>IfnCa</td>
<td>Guppy</td>
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<tr>
<td>IBM + Spatialized</td>
<td>Laricio</td>
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<td>Cytisus</td>
<td>NZ1</td>
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<td>Fiesta / NRG</td>
<td>PNN</td>
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<td>Mountain</td>
<td>PP3</td>
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<td>Paletuviers</td>
<td>QS1</td>
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<td>Presage</td>
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Recent publications


Perspectives

- Integration of new projects
- Progress on the common parts
- Better documentation -> for self-training
- More connections with AMAP plant architecture simulators
- Support for other european projects
- More partnerships with european / other foreign countries
- Web site completely in english

http://capsis.free.fr