Capsis : Computer-Aided Projection for Strategies In Silviculture, a software platform for forestry modellers

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ABSTRACT

Capsis is an object-oriented software environment designed for hosting a wide range of forest dynamics and stand growth and yield models. It has been designed together by scientists from various French research organizations since 1994.

Each model can have its own underlying stand (and if needed tree) description, thus very different kinds of models can be integrated: from stand models to distance-dependent or independent tree models with or without spatialization. Capsis can host heterogeneous models up to the region level and provides libraries to study spatial structures, biomechanics and trees genetics. For a given model and after having loaded a root step from an inventory file or through virtual generation, the user can create different scenarios by alternating growth sequences calculated by the model and silvicultural interventions. The simulated data can then be checked in various viewers, tables and graphics, and can be exported easily to other tools for closer analysis.

The project is organized in three circles: (1) a single developer in charge of designing and maintaining the generic core application, but also dealing with animation, coordination and technical support ; (2) forest growth and dynamics scientists who create the models and implement them in the platform ; (3) end users who use these models for their activities. Every scientist can join the project on condition that he accepts the Capsis Charter explaining the rules for co-development.

Capsis can be run in interactive mode with a multi-language user interface or in batch mode for long simulations or repetitions. New tools can be added quickly for new applications by building extensions to the platform : viewers, graphics, intervention methods (including thinning, pruning, fertilization, plantation...), export tools for various formats. Tools can also be built for connection with other simulation software : 3D tree geometrical models, study of wind damage risk, or agricultural crop model when dealing with agroforestry.

1. **INTRODUCTION**

Scientists in the forestry field need to simulate stand growth and yield and forest dynamics. For such purposes, they build models at the forest level. These models can then be used to test and compare various silvicultural scenarios to evaluate the consequences of the interventions of the forest managers.

In this context, there is a strong need for software simulators to run various and numerous simulations in a convenient and flexible way. Such simulators should help reuse and share methods and algorithms, they should promote integration and should ease partnerships arround federative and perennial choices and techniques.

The capsis project (de Coligny et al., 2004) has been developped in France since 1994 with the following objective: to simulate the consequences of the silvicultural treatments considering the scientific knowledge and build an integration platform for forestry growth and yield models.

2. **A SINGLE SOFTWARE FOR VARIOUS KIND OF MODELS**

There are different possible ways to build a simulation software, each having advantages and drawbacks. The first way is to build a specific tool for each model. The result can be very valuable, but this approach results in building many prototypes which are generally not very evolutive and difficult to reuse.

A better approach would be to build one tool arround a reusable model (Pretzsch et al., 2002) and adapt it to different species and situations by changing the model parameters. This process leads to a more efficient and integrative application whith more reusability. The fact it can be used in several cases can justify more investment in finishing, documentation and training. The main drawback is the limitation to one model : individual-based or not, spatially explicit or not, limited to a certain type of competition and without changes possible for such model related topics.

Descriptive modelling (Muetzelfeldt & Massheder, 2003) offers a completely general approach to build domain independent tools for every kind of subject. These very general tools can deal with all problems but their interface will not have the same possibilities than the computer programming languages to build domain specific tools and portable graphic user interfaces.

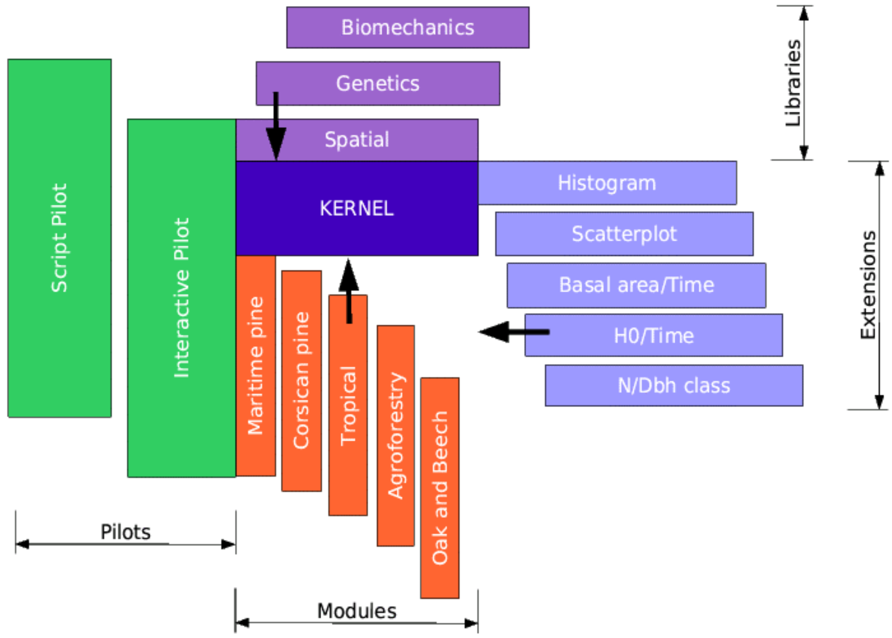

Figure 1. The Capsis architecture.

A domain dependent tool with a common methodology but accepting models with different data structures, simulation steps and evolution methods can be an intermediate, quite efficient but still open option. Capsis has such an open software architecture (Fig. 1) arround a stable kernel, augmented with applicative and technical libraries. The models are integrated into as many modules and a lot of tools can be added at every time inside evolutive extensions. The platform is usable in interactive context to explore possibilities or non interactive context to run long or repetitive simulations.

3. THE CO-DEVELOPMENT METHODOLOGY: AN EFFICIENT WAY OF WORKING

Development is expensive. A reasonable economic model of development should care to require few developpers for a great number of modellers. Efficiency invloves to avoid development bottlenecks : modellers should have a great level of autonomy. Last, the general validity is the greatest when everyone works at his level of competence: the computer scientists should deal with technical aspects and modellers should deal with their models only.

The Capsis co-development methodology keeps everyone autonomous and at his level of competence by learning modellers to become development-beginners. This was made possible only by choosing appropriate tools and languages: combining performance and ease to use. Our choice was the Java language, which is clean enough to be accessible for non developpers, and also a very powerful language.

The co-development choice involves a serious training session for the modellers at the beginning. Such courses are organized once a year and more if needed, immediately followed by a co-design session together with the modeller. After some days, the modeller can go back home with everything on its computer and go on working alone, with the assistance and support of the Capsis developper only when needed. A set of simple and free tools are installed on the modeller's machine and a central network versionning system helps sharing all the source codes between all the partners of the project.

Working together on software does not mean only technical problems. The Capsis Charter explains clearly the roles and rights of each actor in the project. The main point is that the modeller is in charge of the development of its model in Capsis. In return, he will be able to get help from the developper when needed. The charter also explicitly mention respect of the intellectual property of all partners. These points are important because all the source codes are shared between the modellers and developpers of the project, composing the Capsis co-developpement community.

Every component developed inside Capsis except the Capsis modules (i.e. the models implementations) are freely distributable under the Lesser General Public Licence, meaning that the core application is usable by everyone, including every extensions. For the modules, the author can decide when they want to choose a licence, free or not, and to distribute them outside the community. This framework eases the partnerships (no need for contracts to work together in these conditions) and relies on mutual confidence.

4. RESULTS

The current release of Capsis, named Capsis4, has been developped in the AMAP laboratory since 1999. It now contains about 25 empirical models (Fig. 2) of different types : mainly distance-independent tree models and individual tree models, but also mixt models.

Model name	**Kind / Species**	**Corresponding author(s)**
mountain	Spruce	B. Courbaud (Cemagref)
selva	Tropical, genetics	S. Gourlet-Fleury, G. Cornu (Cirad)
ventoux	Heterogeneous	Ph. Dreyfus (INRA)
pnn	Pinus nigra nigricans	Ph. Dreyfus (INRA)
eucalypt	Eucalyptus in Congo	L. Saint-André (Cirad)
pp3	Maritime pine	C. Meredieu (INRA)
laricio	Corsican pine	S. Perret (Cemagref)
sexi	Tropical	G. Vincent (IRD), D. Harja (ICRAF, Indonesia)
hisafe	Agroforestry, STICS	I. Lecomte (INRA)
ventouG	Heterogeneous, genetics	Ph. Dreyfus (INRA)
fiesta / nrg	Pinus halepensis	Ph. Dreyfus (INRA)
bimodal	Continuous	A. Franc (INRA)
qs1	Quercus petraea	J.-F. Dhôte, Ph. Dreyfus (INRA)
fagacees	Oak and Beech	J.-F. Dhôte, P. Vallet (INRA)
alisier	Sorbus torminalis and Oak	S. Oddou-Muratorio (INRA)
regelight	Regeneration	A. Piboule (ONF)
ca1	Cedrus atlantica	F. Courbet (INRA)
mangrove	Mangrove	Ch. Proisy (IRD-AMAP)
samsara	Spruce, Fir, Broadleaved	B. Courbaud (Cemagref)
luberon	Cedrus atlantica, genetics	F. Courbet, F. Lefevre (INRA)
quercus	Quercus petraea, genetics	S. Gerber (INRA)
bidasoa	Fish dynamics, genetics	J. Labonne (INRA)
presage	Forests in Quebec	S. Turbis, D. Mailly (MRNFP, Canada)
pradiata	Radiata pine	D. Pont (Forest Research, New Zealand)
sylvestris	Scots pine	S. Perret, T. Perot (Cemagref), C. Meredieu (INRA)
transpop	Transitionnal populations	Sylvie Oddou-Muratorio (INRA)
cytisus	Scotch broom, grass, sheep	Estelle Chambon-Dubreuil (INRA)
paletuviers	Avicennia, Rhizophora	Patrick Heuret (INRA-AMAP), Marilyne Laurans (Cirad-AMAP)

Figure 2. The capsis models, chronological order of integration, since 1999.

Distance-independent tree models manage diameter or girth distributions : the tree is a representative for a class of size and the model calculates new distributions at different dates. Individual tree models manage individual trees considering optionnaly their location : competition can then be based for example on light. Some of these spatially explicit models deal with a spatial environment description (slope, regeneration at the ground level, zone of influence of the tree, seed flows...). These models all deal with stand growth and may also process mortality and regeneration.

In all cases, the outputs are numerous dendrometrical variables like basal area, height or dbh for the dominant trees or the mean tree, volumes, biomass, crown variables, distributions, many scatterplots and stand tables to watch the results of the simulation. Thanks to the extension compatibility mechanism in Capsis, the list of outputs can be completed for each model by the author who can decide himself to develop a new graphic or export format.

Capsis4 also contains several applicative libraries in the fields of spatial structures generation and analysis, biomechanics inside the trees, genetics with genotype descriptions for individuals and groups, or economics. These libraries provide data structure and algorithms as well as interactive dialogs to get parameters when needed. They can be used in the modules to generate input data, study trees internal constraints or run analysis on the model's output variables.

Connecting the Capsis models with other software is possible for various reasons : get data from a Geographical Information System, simulate crop production outside Capsis from an agroforestry model, feed an architectural simulator with stand level data to get in response information about the branches, polycyclism or growth units of the trees. Such connections have already been implemented, including the STICS (Brisson et al., 1997) crop model, the ForestGales (Gardiner et al., 2000) wind risk model, the SVS 3D vizualization software, itself part of the USDA Forest Vegetation Simulator (Van Dyck, 2000) and the AMAPsim (Rey et al., 1998) architectural simulator. These connections are always built in a manner requiring only few changes to be reusable from other Capsis models.

CONCLUSION

Capsis is now under exploitation, models are regularly being added by new partners who accept the Capsis charter. It was open enough to accept heterogeneous and agroforestry models. An experiment was even done with a fish dynamics model, it suceeded and helped make the Capsis framework more generic. The grouping system can now act on groups of every kind of individuals and not only trees or cells in the ground description, enhancing the outputs system by allowing the comparisons between different groups.

Capsis is support for various projects in the forestry and agroforestry fields and extensions to other scientific fields are discussed at the present time with all the partners.

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