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AMAPstudio: a 3D Interactive Software Suite for Plants Architecture Modelling

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Highlights: Plants architecture modelling results in building complex models. Turning them into simulators requires strong interaction between scientists and software developers. The AMAPstudio project adapts a methodology that has been successfully conducted in the forestry modelling field for 12 years. It focuses on a long-term supported software environment and a strong customized technical backing to help modellers integrate their simulators in highly 3D interactive software.

Keywords: Plants architecture models, FSPM, AMAPstudio, modelling software

INTRODUCTION

Plants architecture (Barthélémy and Caraglio 2007) includes the plant's structure at a given time and its past development. Reading finely the current structure of a plant reveals what happened in its history and can lead to a highly detailed multi-level description. These botanical observations can be coded and handled by software in Multi-scale Tree Graphs (MTG) (Godin and Caraglio 1998) for further studies.

The AMAP laboratory has been building plants architecture modelling software since the 80's, both for structure and architecture analysis (Godin et al. 1999) and for simulation (Barczy et al. 2008). Several other contributions have been proposed since then, including the L-Studio/Vlab software (Prusinkiewicz and Lindenmayer 1990), GroIMP (Kniemeyer and Kurth 2008) and L-Py (Boudon et al. 2012) to simulate plants based on L-Systems with a set of rewriting rules, and OpenAlea (Pradal et al. 2008), a component based framework aiming at easing the integration and interoperability of models from different disciplines. The *VPlant* sub-package of the latter is dedicated to plant development and its control at the genetic and molecular level.

In parallel since 1999, the Capsis platform has been developed in AMAP to integrate forestry growth or dynamics models (Dufour-Kowalski et al. 2012). The Capsis methodology (de Coligny 2007) has been built in a collaborative way with the forestry modellers and the platform now contains more than 60 models of french or foreign partners.

The aim of this contribution is to propose an adaptation of the Capsis approach to the modelling of plants architecture.

SPECIFIC DESIGN OPTIONS

In order to share the effort, we decided to split the problem in two, this is why AMAPstudio (Griffon and Coligny 2012) contains two main software. *Xplo* is dedicated to the single plant level while *Simeo* works at the level of a scene made of several plants. The two software have the same structure, they are both based on a multi-operating systems, multi-projects Capsis kernel and they share some key components such as a common project manager and a central schematic 3D view. Both software rely on a common implementation of the MTG to handle a plant multi-scale description including topology and geometry with all elements having any attributes.

Xplo and *Simeo* bring *interactive editors* with classical import / export capabilities and some specific features. For instance, *Xplo* has an Excel like central table browser to edit all plant elements and their attributes, synchronized in real time with the 3D view, it proposes a configurable geometry reconstruction tool to add geometry to the plant, based on specific attributes or additional rules. It also comes with a set of flexible extraction features to quickly select some elements of the plants by creating new columns in an extraction table, filter the values on the fly and compute simple statistics. The resulting data can be plotted directly in *Xplo* or exported to other software for further analysis. *Simeo* proposes a set of plugins to layout plants according to several patterns. The terrain where the plants are added can either be flat, with a single slope or rely on any height map. It is possible to select the plants and move them with the mouse, set their coordinates very accurately through an editor or enter angles to rotate them. The customized scene can be exported to external biophysical simulators with plugins and the results added in new plant attributes. These

features were made interactive to be usable by any scientist or student needing to make simple actions quickly (Fig. 1). Most of them can be managed by AMAPstudio's undo / redo system.

Besides these editors for the daily routine work of importing, checking, editing and exporting data, AMAPstudio software can host *simulators for plant growth models*, at the individual level in Xplo or at the scene level in Simeo.

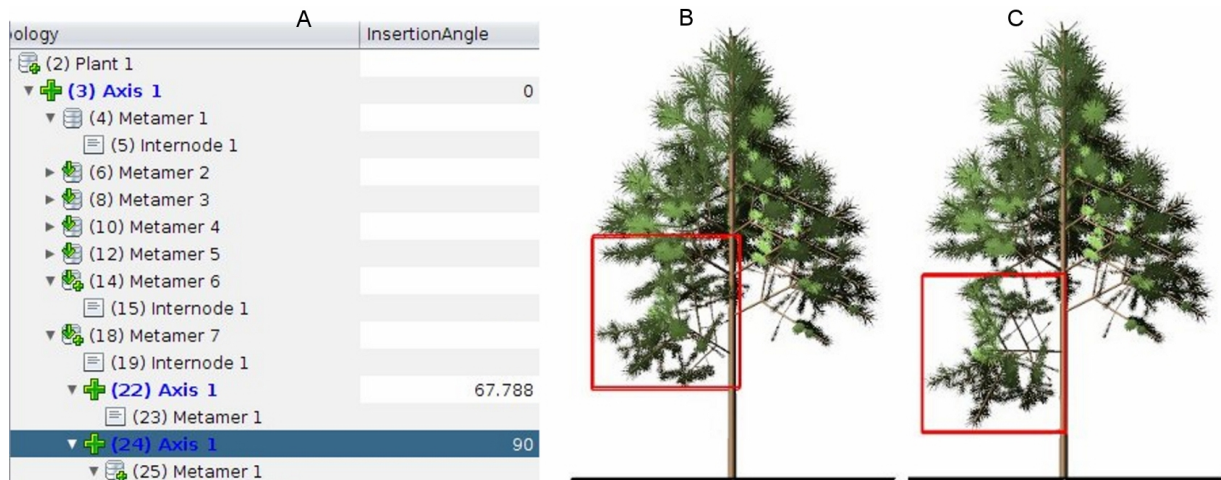


Fig. 1. Editing in the Xplo table view: (A) changing the insertion angle of the selected branch (B) of a juvenile Black pine tree is directly shown in the 3D view (C) when the on-the-fly geometric reconstruction is activated.

The modellers who decide to integrate their models in AMAPstudio have to read and accept the AMAPstudio charter describing the frame of the collaboration. Its main terms are the following: (i) the core software is distributed under the terms of a free license to make the partnerships easy, (ii) the modellers are in charge of the development of their models, (iii) they benefit from an initial training session, a customized starting stage and a permanent technical support, (iv) the ownership rules are clear: the models belong to their authors and they accept to share the source codes with all the other modellers adding their models into the project, (v) the charter also explicitly insists on the respect of each member's intellectual property.

Having a clear frame of rules facilitates the collaborations: each partner knows precisely from the beginning what investment he must make and what he can have in return. In particular, it is clear that the AMAPstudio developers - software engineers - will not help for the modelling work because they focus on the technical aspects for the modellers community: the scientists are the only authors of the models.

The project is based on the Java language which clearness and strictness help the scientists to develop with reasonable training and support.

Furthermore, its memory management makes it particularly convenient to build robust applications, its just-in-time native compilation features enable to get fast simulators.

The technical frame of the simulators comes from Capsis, there is no imposed modelling framework, the frame is about the minimal model usage: (i) initialisation of the departure situation and model configuration, (ii) parameters and stop criterion for the time loop. The model data structure is mainly a MTG in memory (or a MTG list) or any alternative plant description, the time step is free. The model evolution procedure calculates the successive states of the plant (or plant list) until the evolution limit is reached.

This loose framework can host very different models, including not exhaustively architectural models, functional-structural models, but also ecological models with environment interactions, including radiative balance or nutrients exchange with the soil.

All integrated models can be mixed with interventions or external events (e.g. pruning) to build scenarios and compare them. The simulations can be done with the interactive context or can be automated in specific scripts for long or repetitive tasks, concerning for instance heavy scenes with many highly detailed adult trees, running on dedicated calculation machines or clusters and writing their results in files for further analysis.

Because we know the importance of interoperability, AMAPstudio can import plant files through plugins, including MTG files, and all results can be exported the same way to MTG files or other standard formats to be reloaded in other applications.

CONCLUSION

AMAPstudio editors are used on a day to day basis by many students in the lab and by partners to load plant observations, check and edit them, reconstruct their geometry (Taugourdeau et al. 2010) and export extracted data to other software, e.g. Abaqus (Dassault Systèmes 2012).

Since late 2008, several plant level models have been integrated in AMAPstudio for various studies, including the aerial part of the plants: Greenlab (Feng et al. 2012), AMAPsim (Barczy et al. 2008), DRAFT (Taugourdeau et al. 2012), as well as the root part: DigR (Rey et al. 2011). Efforts are under progress to integrate libraries for radiative balance at the plant organ level (Dauzat et al. 2008) which can be used for ecological studies for a group of adult trees.

AMAPstudio is compatible with Windows, Linux and Mac OS, a web version can be downloaded on the project web site: <http://amapstudio.cirad.fr>.

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