MaCS4Plants: A mathematic & computer science network for FSPM

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Introduction

Since the early 90's, AMAP lab (Montpellier, France) has developed multiple software applied to plant architecture modelling. AMAPstudio embeds models and applications to simulate the structure (AmapSim, RoCoCau), the function (ARCHIMED), and visualize (Xplo, Simeo, Scan) plant architecture and functional outputs (e.g., light interception, carbon assimilation). These tools were first developed in collaboration with researchers doing in-field traits and architecture measurements, for plants species studied in natural forests, agroforestry systems and crops. More recently, AGAP Institute developed the OpenAlea platform (Pradal et al., 2008) to answer the growing need for computational resources coming from the increasing complexity and scale of applications of plant models, and for data analysis associated to new data acquisition techniques such as high-frequency phenotyping platforms or LIDAR measurements. Both AMAPstudio and OpenAlea are designed for providing modelling tools for the FSPM community, they share common formalisms for plant representation (*i.e.,* MultiScaleTreeGraph, mtg; Godin et Caraglio, 1998) and similar 3D edition and visualization tools. However, these tools have largely diverged for multiple reasons: language source code, integration in different platforms, plants with different architectures studied for specific research topics but also different laboratories with distinct needs and directives. Therefore, although many human and financial resources were mobilized, they were organized in an inefficient way that led to a duplication of work and hindered the tackling of important scientific questions and upcoming challenges mobilizing the FSPM community.

Materials and Methods

In this context, researchers and engineers specialized in mathematics and computer science from AMAP and AGAP decided to gather their expertise into the Mathematics & Computer Science (CS) network For multiscale functional structural modelling of Plants within their agroecological systems (MaCS4Plants). This network aims at providing an extensive library of generic functional models (*e.g.* Albasha et al., 2019, cf. also Vezy et al., 2022, talk in this conference) as well as tackling scientific problems in the math and CS domain applied to agroecological transition and resilience to climate change: big data analysis, hybrid modelling, multiscale and structure-function studies or full plant modelling (*i.e.,* root and shoot). The technical objectives are: i) to offer a coherent and integrated modelling offer to the community based on OpenAlea platform, ii) develop scientific workflows to automatically and efficiently integrate, develop, test and distribute models, iii) provide an extensive documentation and a large set of example notebooks, from a short demo of a model to a full workflow for reproducible paper. The aim of these notebooks is to ease reproducibility and offer training material for FSPM modelling to young students, researchers and collaborators.

Results and discussion

In this study, we will present the first achievements of the MaCS4Plants network:

- An extensive catalogue of modelling software developed and their integration into OpenAlea (https://openalea.rtfd.io).
- The proposal of a standard format that integrates both topology and geometry at multiscale of plants, and the possibility to export it toward common 3D visualization software.
- A set of online didactic interactive notebooks on FSPM.

An example application with the PalmStudio project will be presented (cf. Fig. 1) to showcase a complex FSPM application integrating multiple models written in different languages (C++, Fortran, Python, Java, Julia), and interacting at different space and time scales. PalmStudio models shoot and root architecture development in interaction with the environment.

Conclusion

Finally, we advocate for the need to facilitate interoperability of models via easy integration into existing platforms but also via development of standard formats. Therefore, we emphasize the fact that this network is open to anyone willing to collaborate and aims to be a first step toward a similar initiative at international level.

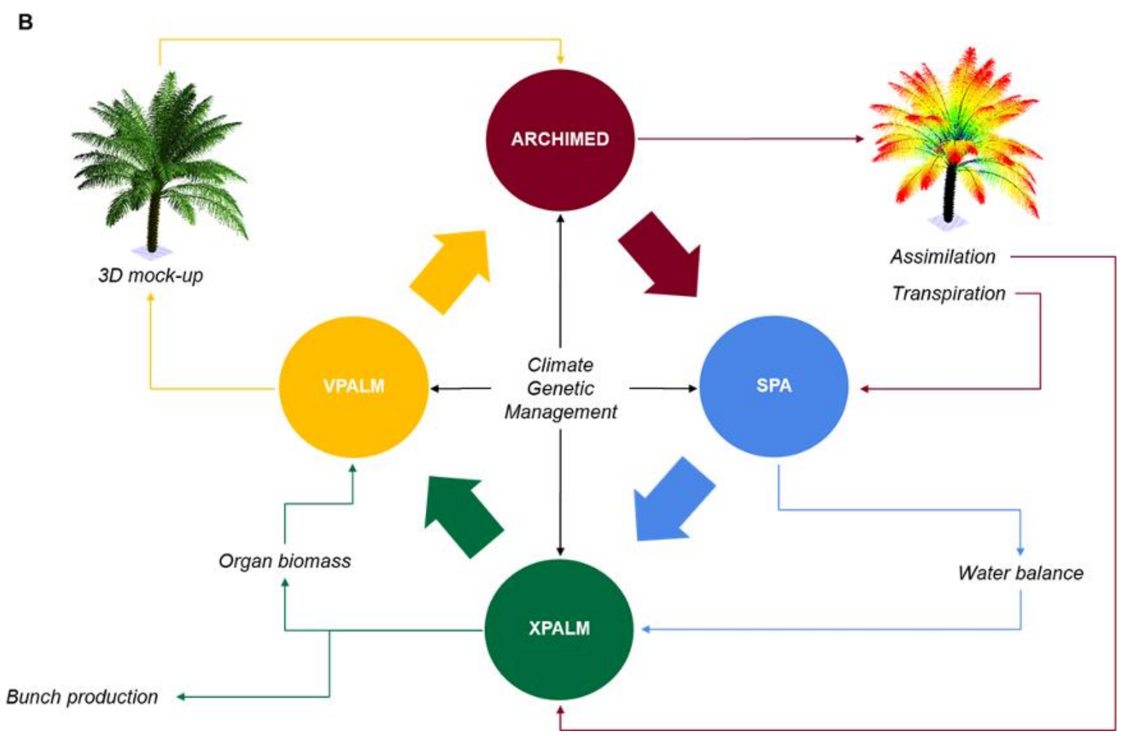

Figure 1: Diagram of the PalmStudio FSPM workflow. This final workflow aims at simulating the growth of palm plants, representing a realistic system based on in-situ architectural and geometrical measurements, and simulating biophysical processes such as light interception, energy balance, CO_2 and H_2O fluxes in interaction with the root system and the soil, and finally allocating assimilates for organs growth and development and eventually plant yield.

References

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