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Efficient stochastic Functional Structural sympodial Shrubs Modelling based on structural hierarchy. Application to Guayule

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Introduction

Functional structural modelling of shrubs, especially aromatic plants, confronts with a fine consideration of their structures, often complex and with many reiterations, especially for sympodial plants. The models and their simulations are therefore complex and costly to use for the selection and definition of crop routes. Here we propose alternative solutions suitable for sympodial plants that do not show neoformations, by reducing the structural complexity to that of a monocaul plant.

Material and methods

The conceptual framework used is that of GreenLab, in its most extensive formalism, applicable in particular to the stochastic modelling of rhythmically growing trees (Wang et al., 2012). In our case, sympodial plants erect axes composed of modules. First, in the absence of neoformations, the succession of phytomers per module is replaced by a meta-phytomer (Jaeger et al. 2016), each module materializing a development cycle. We extend this work to the functional properties that inherit from those of the phytomers: we substitute the binomial probabilities at the phytomer scale by distributions reflecting mean and variance at the module scale. In a second step, we linearize the representation of the structure as follows: we represent an axis of theoretical development including the succession of meta-phytometers, from the initial module (unique, it is the oldest) to the last (the youngest). This representation is thus similar to that of a monocaul plant, except that we substitute a cohort of meta-phytometers instead of each phytomer. Under these conditions, we can use a simple version of the model dedicated to single-stemmed plants, StemGL (Ribeyre et al. 2018), after taking into account several phytomers per age along the trunk, with particular impact on the distribution of secondary growth biomass. The approach is applied to the Guayule, a plant of increasing interest for latex production (Snoeck et al., 2015).

Results and discussion

In our application on the Guayule, stochastic structures were generated by the explicit phytomer approach and the meta-phytomer approach where we show that the number of organs generated is reduced by a factor close to $(N-1) \cdot b^a$ where N represents the mean number of phytomers per module, b the mean branching factor and a the age.

Similarly, the linearization of the structure allows a substantial reduction of time (by a factor of 7 for age 4 and up to more than 1000 for age 8) while obtaining the same biomass distributions in simulation and the same values in the estimation of the model functional structural parameters. The lack of geometric instantiation is open to discussion. In our implementation

under StemGL, the visualization of simulated plants is based on functional representation [Jaeger et al. 2018]. It does not take into account geometrical features such as height, but allows the materialization of biomass variations and the number of meta-phytomers per cohort (C and D in the figure).

Conclusion

An approach well adapted to a context requiring numerous simulations and experiments. The gain in complexity brought is major and becomes the only possible alternative for important ages (the complexity remaining linear in age and not polynomial). It is exploitable on stochastic models and on a large number of species showing sympodial growth, with a single physiological age.

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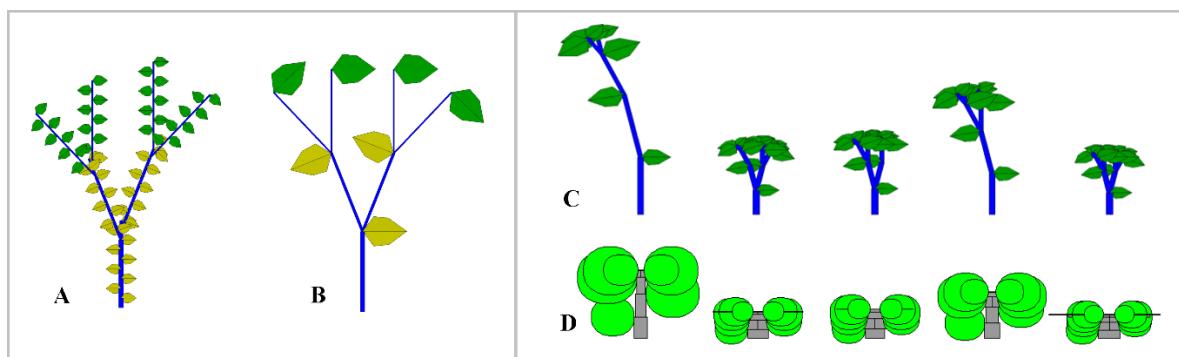


Figure: Reducing geometrical and topological complexity in FSPM illustrated on the Guayule. A: An explicit structural model simulation at age 3. B: the same structure simulation with meta-phytomers. C and D: Five instantiations of a functional structural stochastic simulation hold on the guayule at age 5 with meta-phytomers; the upper row simulates explicitly the plant geometry and topology, while the lower row performs the simulation without geometrical computations.

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