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Expertise of the scientific community
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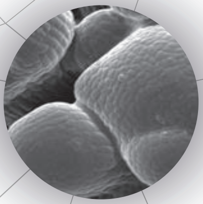
COMPLEX SYSTEMS

From biology to landscapes



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Probabilistic models and statistical inference methods – identification of developmental patterns in plant phenotyping data

Recent advances in agronomy are a spinoff of the genomic revolution combined with technological advances that enable the acquisition of novel plant phenotyping data at various scales. New approaches are needed to characterize plant developmental processes from tissue to whole plant scales. Robotized phenotyping platforms produce high-throughput spatiotemporal plant development data and enable studies on the effects of environmental and genetic factors on plant development in a renewed context. Plant phenotyping data analysis methods are changing rapidly due to the availability of low cost big data, increased computing power and the emergence of new mathematical paradigms at the crossroads between probabilistic modelling, statistical inference and pattern recognition. Phenotyping data are intrinsically structured (spatiotemporal, multiscale), thus necessitating the development of dedicated probabilistic models and inference methods for their analysis.

This new paradigm for analysing such data is characterized by:

- Data structured in sequences, time series, tree structures, graphs, 2D and 3D images.
- Integrative models that combine response, explanatory and latent variables to model structures at different scales (e.g. development stages or growth phases). Complex dependencies between these variables, often indexed by a time series or tree structure, can be represented by probabilistic graphical models.
- An extended inference framework concerning not only parameter estimation but also model structure (using model selection techniques) and latent structures (e.g. segmentation into development stages or growth phases).

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Plant structure-function models

Greater insight into how plants function and develop is needed to address societal calls for more ecological and sustainable agriculture in a global climate change setting. To this end, an approach that explicitly takes the plant structure into account to simulate the complex interactions with processes that govern plant growth has been developed in recent years—the so-called functional structural plant model (FSPM). This transdisciplinary approach at the crossroads between biology, computer science and physics is designed to incorporate plant morphology and function knowledge in the form of a dynamic 3D model. It can be utilised particularly to study the role of plant structure on different ecophysiological processes such as light interception or disease proliferation with regard to above-ground parts, as well as root/soil relationships. It therefore requires assembling the various disparate tools and models developed by the scientific community, e.g. using methods proposed by the OpenAlea platform. The Virtual Plants team (INRIA/CIRAD) is involved in the development of many tools for simulating growth and different ecophysiological processes, including mechanical ones, light capture, carbon allocation, etc. The team is also involved in the development of a number of tools for the simulation of growth and various ecophysiological processes. Moreover, it develops or collaborates in the construction of different FSPM models, representing above-ground or underground parts, and ranging from herbaceous crops (wheat, maize, sorghum) to fruit trees (mango, apple). The ongoing challenges related to these issues are to facilitate online use of these complex tools for web-distributed simulations, as well as the standardization of a number of tools for simulating ecophysiological processes. From an application perspective, future challenges include the integration of these models at different scales into crop models so as to take both genetic variability and spatial heterogeneity of simulated populations into account.

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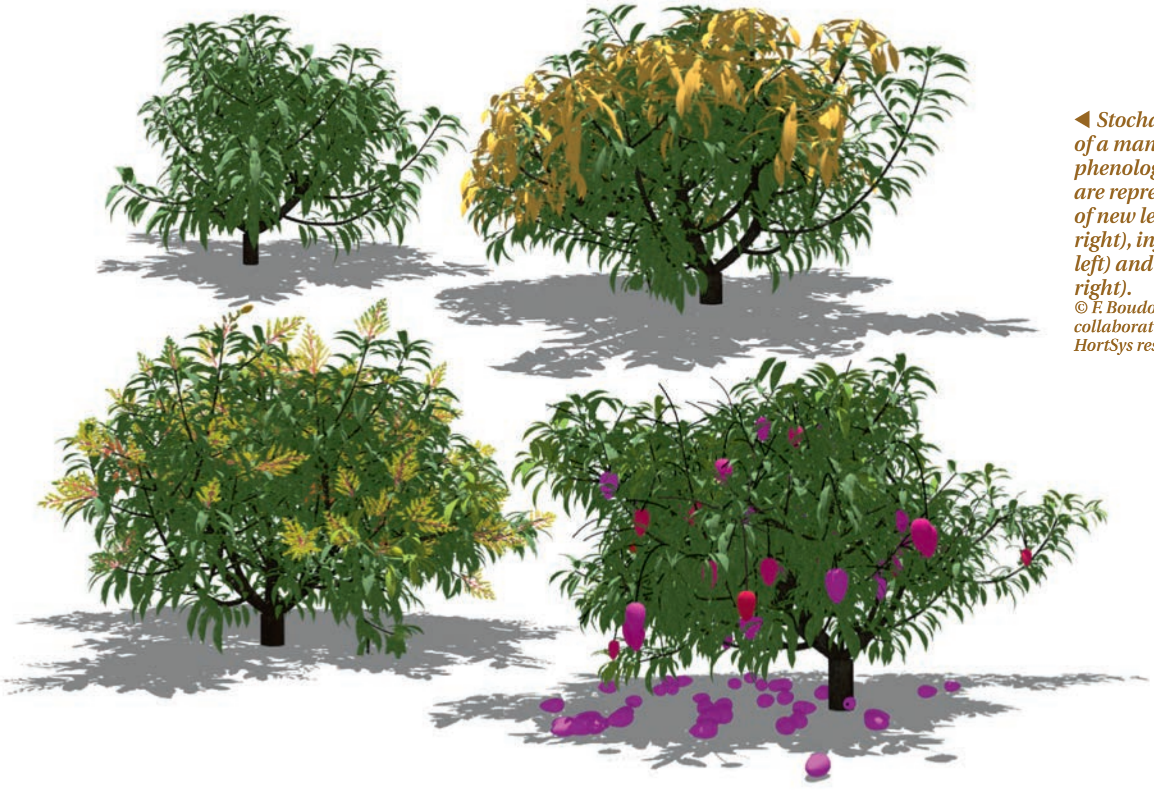

◀ Stochastic simulation of a mango tree. Different phenological stages of growth are represented with the onset of new leafy shoots (upper right), inflorescences (lower left) and fruit growth (lower right).
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