Multiscale functional-structural plant modelling at the example of apple trees

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Process-based crop models allow the prediction of the growth of plant compartments under homogeneous conditions and agricultural practices. They are less adapted to applictions where single plant organs are in the focus. Functional-structural plant models (FSPMs) were designed to overcome this limitation by representing 3-dimensional plant structure and physiological functioning with their mutual dependencies. However, when they include several processes and represent the plant at organ level, calculation times for FSPMs can become prohibitive, particularly for large plants. A further problem is caused by complexity: The necessary steps of parameter estimation and sensitivity analysis are nontrivial, due to the large number of parameters and the often non-linear dependencies between the modelled processes.
We will address these problems in a project of four teams, representing expertise in botany, horticultural crop modelling, mathematics and computer science. Our project will be devoted to two research foci: F1 – "Model development, calibration, analysis, and corresponding software tools", and F2 – "Case study: Modelling apple tree growth at organ, branch and whole-tree scale". In F1, we will build mathematical and algorithmic tools for bridging the gap between spatial and temporal scales (spatial: here organ – branch axis – individual tree – orchard; temporal: hour to year). Methods for upscaling, downscaling and maintenance of simultaneous plant representations (incl. processes) at several scale levels will be developed using the open-source simulation software GroIMP. Furthermore, a toolbox for parameter fitting, sensitivity analysis and validation for such multiscale models will be developed and implemented.
A further gap, closely related to that between scales, is that between mechanistic and empirically-based models. We will bridge this gap in the case study in F2, coming from both sides: An existing empirical, L-system-based model of apple tree growth will be fitted to different genotypes and environmental conditions. In parallel, a biophysically-based water flux and carbon transport model will be developed at the organ and branch scale, utilizing an existing tool in GroIMP for an easy specification and stable solution of differential equations on networks. This model will allow assessments of fruit quality under different water scenarios. In the end, both lines of work will be merged in an integrated, multiscale apple tree growth model with a hydraulic and a C transport component. It will be built, analyzed and validated using the tools from F1. At the same time, the continuous confrontation of the researchers in F1 with modellers' demands from F2 will guide the development of methods and tools and their integration in FSPM platforms.

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