Year of CfP: 2008

Project No 0803-024 completed

Project title: Development of a tool box for the modelling and simulation of retroactions between plant growth and plant biomechanics

Units managing the project: AMAP, Botany and computational plant architecture (CIRAD, CNRS, INRA, IRD, Montpellier Supagro, UMII), LMGC CNRS, Laboratoire de Mécanique et Génie Civil

Project leaders: Thierry Fourcaud, AMAP (Thierry.fourcaud(a)cirad.fr), Tancrède Almeras LMGC

Countries involved in the project: China, UK

Sub-thematic axes: IPB-1 (Integrative Plant Biology 1: *Genetics and genomics, plant breeding, ecophysiology*)

Objectives:

The response of plants to mechanical stress is of major interest in number of research fields. Despite many experimental investigations already carried out on this phenomenon, the underlying physiological mechanisms are still poorly understood. This project aims at developing a library of biomechanical tools devoted to the simulation of retroaction processes between plant growth and its mechanical state at the individual scale.

This library will be developed in Java programming language (compatible with current growth models and platforms that are developed in other projects) based on previous studies carried out by the involved teams. It will be designed in order to allow the interactions with plant growth simulators to be easily performed via

- The stepwise extraction of structural information
- The stepwise modification of growth parameters (e.g. maturation strains, branching probabilities, sinks of assimilates, allometric rules) with regards to the current mechanical state of the plant.

The biomechanical model will be based on the beam theory and the solver derivate from the Finite Element Method. The toolbox can be split into several independent modules (mesh, beam section, material properties, biomechanical pre-stresses for woody plants, assembly of the stiffness matrix, assembly of the force matrix, solver of linear and non-linear systems for static and dynamic problems, field and history outputs, manager of cumulated field output, connections with plant growth parameters), which could be developed separately by different people.

Action carried-out and results obtained:

The project was divided into 4 main steps:

1 - Definition of the structure of the library: it was mainly to distinguish the different core modules (reference materials, beam cross sections, mesh, loads, scheduler, solver, post-GPU) and associated data structures (representation of the topology, list of applied constraints, list of events, functional links between the different modules).

2 - Implementing the library under the platform Scilab, evaluation tests and coupling with the plant growth simulator GreenScilab (http://liama.ia.ac.cn/wiki/projects:greenscilab:home). The Scilab toolbox is operational and can calculate the bending of growing stems as well as the field of mechanical stress (see internship report of Miss Yang Ming, Ecole Centrale Pékin), through the implementation of the transfer matrix method. It was used to evaluate the risk of tree breakage within a forest stand submitted to strong winds, according to the allometry of each individual. This

work was conducted in partnership with the Department of Wood Science and Forestry, Faculty of Forestry, Geography and Geomatics, Laval University, Quebec, Canada;

3 - Development of the library in Java and of a "stand alone" simulator with a proper graphical user interface (see report of William and Benjamin Surroca Train, and site development http://amap-dev.cirad.fr/projects / plantbiom / wiki).

4 - Interfacing with the software XPLO (http://amap-dev.cirad.fr/wiki/xplo), which is devoted to the representation of plant architecture, via the data structure Architree? This work is still underway as part of a TER M1 internship at the University of Montpellier 2. Meanwhile, the library PlantBioM was translated in C language and implemented within the simulation platform for plant growth Qing Yuan, developed by partners LIAMA in Beijing (see visit of Dr. Mengzhen Kang and internship of Mr Haoyu Wang).

A modeling work has been carried out ahead of this development work, as part of Thomas Guillon's PhD thesis. It was proposed a new theoretical framework to explicitly calculate the mechanical response of a growing beam by defining a virtual reference configuration. An article describing this framework and giving examples of calculation has been submitted to the journal "Biomechanics and Modeling in Mechanobiology.

Prospects for the future:

The project PlantBioM continues in the form of a MASTER internship in Computer Sciences, which would achieved the integration of the library in the software XPLO.

The prospects in the short and medium term are:

- Implementing Thomas Guillon's results in a new PlantBioM solver. An algorithm has already been developed in Java and tested for solving equations of biomechanics;

- Provide a tool for training and expertise for the management of urban trees, based on the software XPLO-PlantBioM. This tool will allow testing the impact of different types of intervention (pruning, bracing, etc ...) on the tree mechanical factor of safety.

- The above point should also be developed with the METLA (Finland) and the University of Gottingen (Germany). A thesis proposal is being drafted and should be submitted in 2011 as part of an ITN European project supported by INRA on Virtual Plants.

- The PlantBioM toolbox would be used as part of research partnerships with LIAMA, China, if the cPlant project (EU INCO-LAB) submitted in early 2011 is accepted. This research includes modeling the architectural plasticity of plants and in particular dynamic feedbacks between bending of stems and development of branching.

Total Agropolis Fondation funding: € 21,330 (travel expenses)

Funding categorie(s): Agropolis Fondation small grants (support for exploratory, risky and innovative projects)

Project duration: 1 November 2008 – 31 December 2009

Keywords: modelling – simulation – plant – biomechanics – growth