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Toward a new approach for plant modelling

J.-C. Soulié^a, D. Luquet^a and F. Michel^b

^aCIRAD, UMR AGAP, F-34398 Montpellier, France

^bLIRMM, Université Montpellier II - CNRS, Montpellier Cedex 2, France

Email: jean-christophe.soulie@cirad.fr

Abstract: Understanding the processes governing plant growth and response of the latter at different stress (water, heat or drought, ...) are fundamental in order to improve and better adapt plant in their fluctuating environment (mainly rice, sorghum, sugar cane and oil palm in our case).

Modeling and simulation of such plant complex models allow testing, *in silico*, different assumptions about the processes controlling plant growth. There are already many models of plants that all have their strengths and weaknesses. These include, for example: STICS, GreenLab, APSIM, DSSAT, Sunflo, SarraH, EcoMeristem, In these models, behaviors, or reactions, were activated, typically by functions (or equations) with thresholds which allow trigger behavior with greater or lesser intensity levels. For example: destruction of a sheet, carbonaceous material reallocation, etc.

Now it appears (according to knowledge given by ecophysiological expert) that in natural systems, this analogy is not always true. Indeed, these systems, a plant for example, are constantly in a steady state while trying to reach their final goal that is growing on order to produce. Due to these facts, one can realize that there are always adjustments between the different organs of the plant. Unfortunately, the above conventional approaches used so far does not allow to take into account this fact, let alone implement them.

Also, the objective of this work is to try to fill this gap in our plant models. To do so, we should focus on the elementary bricks (or organs) within a plant: leaves, between node axis, tiller, etc. and describe individual behavior and interactions. Naturally enough, one can imagine that the multi-agent systems, from distributed artificial intelligence, are a good candidate to represent these phenomena.

To do this, we decomposed the plant into six agents: culm, root, leaf, internode, panicle, and peduncle. Then the plant is seen as a society of such agents. The *culm* agent's behavior is to stand the other agents defined below. The first culm is called *mainstem* and the others one are called *tiller*. The *root* agent's behavior is to catch assimilation and water into the ground. The *root* agents is seen as a single bulk compartment and is no more sophisticated. The *leaf* agent's behavior is to growth up to predefined length and then to start the senescence process that, at the end, destroy the leaf. It intercepts the light coming locally from the sun so that it produces assimilation. The *internode* agent's behavior is to start elongation and store starch in its tank. The *panicle* agent's behavior is almost the same than the internode one. The *peduncle* agent's behavior is to create spikelets and then filling grains (according to a potential sterility) in the case of rice for example.

At the society level, the agent plant's behavior is to maintain the plant state. These states can be (in the biological order): morphogenesis, elongation, panicle initiation, flowering, end filling, and finally maturity. These state are managed by an oriented finite state automaton. The transition between two states at a given state t is a function that combined the state at $t - 1$, the thermal time, the plastochron, and the stock.

Moreover, the organ topology is represented by a network of acquaintances between them. There are different levels of networks according to the different levels of topology. As we have to manage at least two types of environments (network, physical), we decided to use the "mind-body" approach. An agent is decomposed in one conative system (the mind) and this conative system has multiple physical representation in the multiple environments. It means that one body is plugged in one environment (network or physical). It embeds captors to catch information from the environment and actuators to act on the environment. As an example, the *leaf* agent has a body in the environment that produces the air temperature, the radiance, and the evaporative demand; and a body in a graph that links the leaf with its internode.

All this model will be implemented within the TurtleKit platform: www.madkit.net/turtlekit. TurtleKit is able to use the multiple environments approach and provide GPGPU acceleration in order to manage environmental data.

Keywords: Plant modelling, Multi-agents system, environment, GPU