Coupling plant growth models, application on pest & disease models: an interaction structure proposal

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When a plant is attacked by a pest or a disease, different effects can be observed on the yield and/or on the different organs that have been affected by the pest. In order to represent and simulate these effects, different works were done on the interaction between the plant growth model and its environment, or plant-pathogen (Qi *et al*., 2009), plant-climate or plant-plant (Gaudio *et al.*, 2021). The literature on plant-pathogen coupling is poorer regarding combined biotic and abiotic stress dynamics (Louarn *et al*., 2020). A classic way to approach model interactions is to test them within each other, but this approach is specific to each use-case and difficult to generalize (Garin *et al.*, 2014). Here, we propose to develop a formalism allowing to highlight all the coupling effects on the dynamics of all the models involved. over a large timescale (theoretically, throughout the plant's lifespan). The proposed framework thus inherits the model coupling approach of (Siad *et al.*, 2019).

We define an interaction platform structure as a model interaction framework, flexible in terms of number of models and type of models. The platform implements a specific behavioral design pattern called Mediator, defining how objects interact witha each other. Mediator promotes loose coupling by preventing objects from referring to each other explicitly, and allows their interaction to vary independently (Gamma *et al.*,1995). The interaction platform structure, as shown in figure 1, is organized around three main functions, as follows

- <u>Systems' states</u>**:** This function deals with the states variables of the interacting models and the platform states. The relevant states of the models involved in the interactions are collected and "translated" into platform states (dedicated to the interaction). When executing the interaction models maintained in the platform, the function potentially alters the platform states. Conversely, these platform states are "translated" into the state variables of the linked models.
- <u>Cycle synchronisation:</u> The platform defines and manages a scheduler because the temporal scales of each model can differ regarding its nature (e.g. calendar

time, thermal time) and/or length (e.g. days, weeks …). This function launches the linked models, and of course, between two model calls, launches the interaction process updating the system states within the platform.

- State recording and Storage: This function ensures the integrity of interacting models and platform states. It also manages data and other dynamics that are not required for interaction but are requested by the user for observations. The storage of states and variables thus ensures a secure simulation, allowing stop & go.

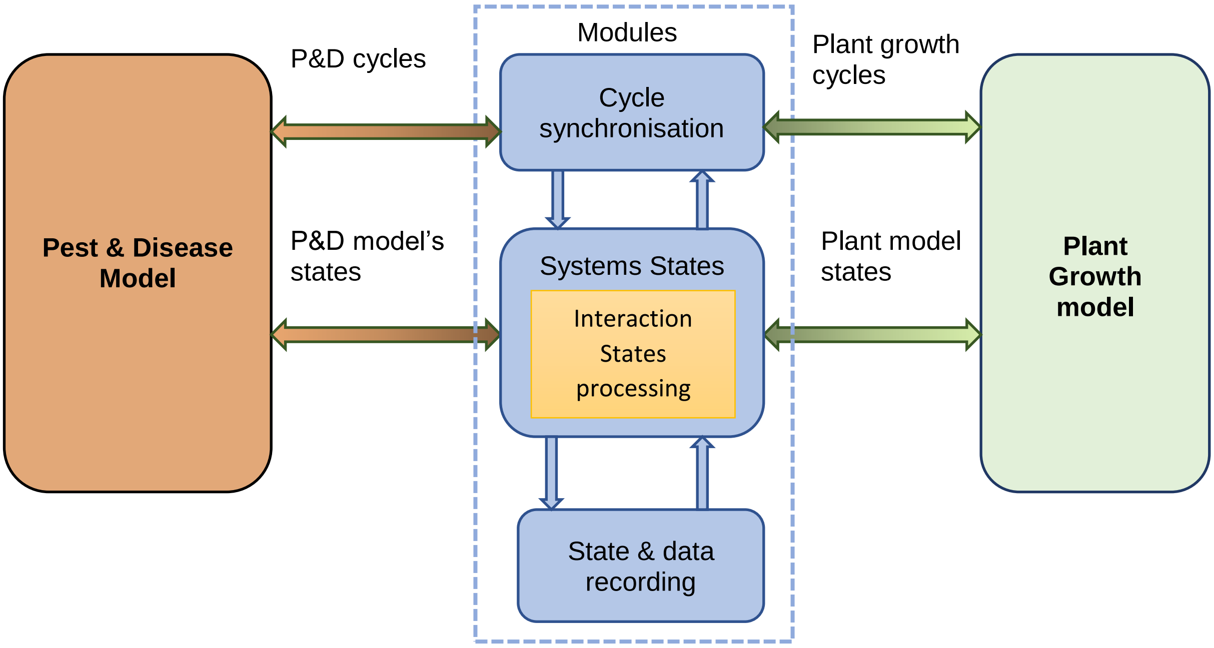

Figure 1: *Example of the schematics of the interaction structure between a Pest & disease model and a plant growth model.*

When setting up an interaction, few modifications are generally necessary on the models, which are supposed to be operational with a stop-and-go implementation. Moreover, the modular structure of the platform is designed to be easy to understand and to customize the low-level interactions descriptions: the user modeler defines how the state variable of the interface interacts, not the states of the models. This is an advantage during development, each module is independent and we can modify each one independently, still guaranteeing the execution of the platform.

We are currently applying and developing this interaction structure frame between Coffee Berry Borer (CBB) attacks and Coffee trees models.

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