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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 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 types of models. The platform implements a specific behavioural design pattern called Mediator, defining how objects interact with 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 presented in figure 1, is organized around three main functions:

- Systems' states**:** This function deals with the state 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.
- Cycle synchronisation: 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. This component also manages the priorities of the different interacting models according to their cycle durations (the fastest has a priority over the slower) or according to user controls.

- 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.

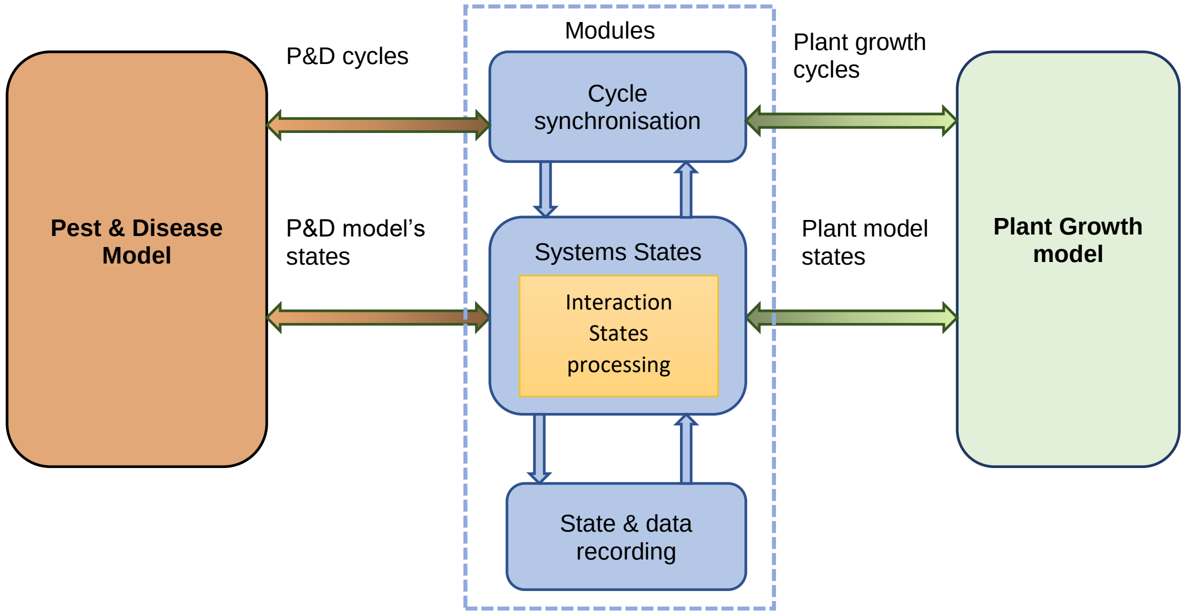

***Figure 1:** Interaction structure Schematics of P&D model and a plant growth model.*

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 modeller 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 frame between Coffee Berry Borer (CBB) attacks and Coffee trees models, calibrated from Indonesian data and tested on Latin America data. The platform aims to host other P&D models on Robusta species issued from experiments conducted in Uganda.

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