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STUDYING CROPPING SYSTEM MANAGEMENT BY SIMULATION: THE RECORD PLATFORM PROJECT

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Introduction

The pressing need in adapting and improving farming practices has motivated research efforts to extend the classical analyses of soil-crop-climate systems to considerations of their management at field, farm and regional scales. For the specific question of analysing and designing innovative cropping systems, INRA (French National Institute for Agricultural Research) has launched the development of a simulation modeling platform called RECORD. This modelling platform is intended to ease complex model development and to promote model reusability. The platform will also offer common methods for estimating model parameters, analysing simulation outputs and optimizing management policies. In the following, we first present the main functional requirements of RECORD. We then present some preliminary choices concerning the platform architecture.

Modelling and simulation of cropping systems

The RECORD platform has been designed as a modelling and simulation software platform where researchers can build, assemble and couple their own pieces of model to pre-existing ones, and can simulate the resulting models. Analysing and designing cropping systems by modelling and simulation require to consider the interactions between agronomical, environmental and socio-economics components. In particular, both biophysical models like crop models, weed models, bioaggressor models, and decision models, for tactical decisions, strategic management, must be integrated if needed, and a key feature of the project is to put the management of cropping system on an equal foot with biophysical aspects. In order to open widely the platform to all the models, we chose to make no restrictions on the type of biophysical and decisional models that will be developed or plugged in our environment.

Modelers often encounter problems when they have to deal with temporal or spatial aspects in modelling work. The temporal granularity may be heterogeneous in cropping system models, from hours to years, with a time horizon going from weeks to several years and including cumulative aspects. Concerning the spatial aspects, the granularity is defined through elementary spatial units which are, most often, the agricultural parcels. The spatial horizon that has to be considered is rather wide, from fields to small agricultural regions.

The RECORD modelling environment will thus have to facilitate the implementation of heterogeneity and interactions between different kinds of spatial dynamic models, at different scales. These models can be either deterministic or stochastic, and are described within different modelling formalisms like difference equations, differential equations, partial differential equations, cellular automata for biophysical models, discrete events models or agent-based models for decision models.

Another key feature of the platform concerns the different services it will offer for the simulation activity (Wallach et al., 2006). They concern three major issues: the management of data, the statistical analysis of output data and some essential tools for the design and optimization of innovative farming systems. Simulation models may require a lot of input data and produce a large amount of output data of various types (time series, probability distribution, action chronicles, maps...). This is particularly true when user wants to perform wide range multi-simulations. So, the platform has to provide services concerning the management of these data. It is also important to offer an interface between models and some well-known databases available to agronomical researchers, such as soil databases for example. In order to analyse the output data, different statistical tools like *R* software will be available from the platform, and RECORD will provide special support on some statistical methods used for example for sensitivity analysis. The scientific

purpose of the RECORD project is to analyse and design innovative farming systems in a context of climate change and sustainable development. Methods in simulation optimization, multicriteria decision analysis and data mining will have to be integrated to the platform.

The platform architecture

We identify three main issues to consider in the definition of the platform architecture.

First, the main contribution of the framework should be to encourage modelers to adopt a systemic approach when they model cropping system. For that, we propose to provide a convenient way to design clearly hierarchically structured models, and to make available to users all the mechanisms for easily defining systems and subsystems through their interactions, their states, their inputs and outputs and their dynamics. We see this systemic approach as a way of enhancing model intelligibility and reusability, by allowing a clear identification of component boundaries, and by easing their extraction in the process of elaborating new models.

This systemic approach is clearly suitable but must be accompanied with capabilities to adapt existing model components. Some specific features might need to be added, enriched or removed. Facilities for modeling by composition are important but the possibility to create brand new components and models is fundamental as well. The object-oriented paradigm and the incorporated ideas of polymorphism, inheritance, interface-based communication are offering clean and efficient means in the modeling process. In other words, the object-oriented representation should ideally be embedded with the systemic structuring approach.

Second, the framework has to provide flexibility, extensibility, and compatibility. We already saw that cropping system modeling could require the use of different modeling formalisms that have to be simulated all together. The architecture of the framework should then clearly separate the layer dedicated to the scientist user, based on representation languages directly related to the modeling formalisms used by modelers, from the layer that realizes integration of these different modeling formalisms. We must then consider that there are two specific levels for describing frameworks; the modeling level and the implementation level (Van Evert, 2005). The underlying requirement of this architectural design is then the need of strong theoretical basis and existing algorithms to address the required formalism heterogeneity through these two levels.

Third, the framework should support the co-existence of different types of coupling between several model components. To build a new model, components might be associated in a very loose way. In that case the idea is to manage parallel simulation of different models, with some data exchange at run time between these models seen as communicating components. This is the kind of solution developed for instance in the OpenMI framework, used for integrated water management modeling (Gregersen and Blint, 2004). When several models need to be closely connected and require frequent synchronizations, sophisticated protocols are required in order to avoid inefficiency problems. In this case, it seems preferable to have a single simulation machinery and to force all models to conform to a common implementation-level formalism. Such a formalism should be able to deal with a large range of simulation models, either continuous or of discrete event type. DEVS (Zeigler et al., 2000) is typically in this category.

Perspectives

We intend now to evaluate the VLE modeling and simulation environment (Quesnel et al., 2007), which supports the DEVS formalism, as a basis for the development of the RECORD platform. The main issues will concern the development of the modeling formalisms that fit the needs, in particular for the spatial and decision making aspects. See <http://record.toulouse.inra.fr> for more about this project.

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