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# **RECORD: a new software platform to model and simulate cropping systems**

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## **INTRODUCTION**

In order to extend the use of simulation models for the design of innovative cropping systems, the French Research Institute INRA has launched the RECORD project for the development of a modelling and simulation software platform for crop scientists. The platform is now available and is currently evaluated on several cropping system modelling projects before its larger diffusion in INRA research laboratories.

RECORD is a platform designed for developing models of cropping systems, including crops, soils, pests, pathogens and farm managers, at different spatial and temporal scales. Scientists will use the RECORD platform to develop new models as modular components, to re-use and combine them in order to represent cropping systems and to share them with the community. In accordance with these specifications, the generic VLE (Virtual Laboratory Environment) simulation platform, an object oriented programming software based on the DEVS formalism, has been chosen as the simulation kernel.

The second objective of the RECORD platform is to allow scientists to work with this simulation models: designing simulation experiments for parameters estimation, sensitivity analysis, optimization. The solution proposed by RECORD consists in using generic or specific methods developed with scientific softwares like R, which are directly linked with VLE.

## **DEVS MODELS AND VLE**

The Modeling and Simulation (M&S) theory (Zeigler et al., 2000) addresses major issues of computer sciences, from artificial intelligence to model design and distributed simulations. The DEVS discrete event formalism of the M&S theory is a common framework (formal and operational) for the specification of dynamical systems. DEVS defines an atomic model as a set of input and output ports and a set of state transition functions. Every atomic model can be coupled with one or several other atomic models to build a coupled model. This operation can be repeated to form a hierarchy of coupled models. The set of atomic and coupled models and their connections forms the structure of the model.

The VLE Virtual Laboratory Environment (Quesnel et al., 2009) is an original framework that can be used to model, simulate, analysis or visualize dynamics of complex systems. It is a free and open source software and its API (Application Programming Interface) that provides C++ libraries which support multimodeling and simulation by implementing the DEVS abstract simulator. VLE is oriented toward the integration of heterogeneous formalisms like ordinary differential equations, difference equations, finite state automata, cellular automata, etc. Furthermore, VLE is able to integrate specific models developed in most popular programming languages into one single multi-model.

## **BUILDING MODELS WITHIN RECORD**

The model construction of a specific cropping system is conducted through a three-steps approach. First, the systemic analysis of the cropping system allows to define the different atomic or coupled models to implement, their hierarchical organization and their granularity. Then, atomic

models are implemented as VLE components. Finally, these components are linked in order to define the whole cropping system model.

Atomic components can be built in different ways. Models based on various formalisms, e.g. differential equations, difference equations, state automata, cellular automata, decision rules, can be either described directly at the modelling language level or using the C++ API of VLE. Models originally developed outside the platform can be easily adapted and included within RECORD. The crop model STICS (Brisson et al., 1998) was thus recently included within RECORD after several adaptations: the time and the spatial dynamics was delegated to the VLE simulation engine, the procedure of model initialization was modified, and the program was encapsulated.

The linkage of components can be done through *gvle*, the graphical interface of VLE. With this interface, modellers can visualize the whole model at its different hierarchical levels. Atomic or coupled submodels can be included for building the whole model. The persistence of the linkage work is provided by an xml file (extension *vpz*) which is automatically generated by saving the work within *gvle*.

## WORKING WITH MODELS

People working with RECORD are modellers, model linkers, and model users. RECORD provides functionalities adapted to their specific requirements. For modellers, a wide range of API classes and numerical libraries cover the needs for cropping systems modelling. A repository of validated and well documented models allows model linkers to “pick up” existing components. The *gvle* interface of the platform can be used to plan model simulations and to specify the type of needed outputs. Users can also work directly from the R statistical software, or run simulations on a distant server through a web-interface.

## PERSPECTIVES

For some months, several models, e.g. crop rotations (Dury et al. 2009), TNT2 (Beaujouan et al., 2002), STICS (Brisson et al. 1998), and statistical methods ( Quesnel et al. 2009) have been developed or reimplemented within RECORD/ VLE. The platform is planned to be launched in spring 2010 (see *record.toulouse.inra.fr*).

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