An open-source software environment for modelling fluxes in landscapes

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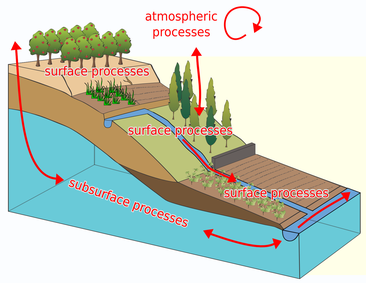
Context, concepts and simulations

Landscapes are complex systems where many processes interact in time and space. In agro-ecosystems, these processes are mainly physical processes, including hydrological-processes, biological processes and human activities. Modelling such systems requires an interdisciplinary approach, coupling models coming from different disciplines, developed by different teams.
In order to support collaborative works, involving many models coupled in time and space for integrative simulations, an open software modelling platform is a relevant answer.
OpenFLUID is a software framework and an operational platform for integrative modelling and simulation of landscapes functionning. It allows to build spatial simulations based on i) pluggable models which are coupled, ii) a digital representation of the landscapes.

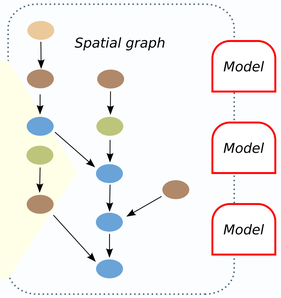
Real landscape



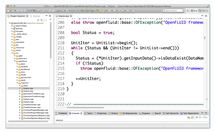
Landscapes are represented as a hierarchical graph where nodes represent the spatial units (fields, ditches, roads, rivers, ...) and can embed rich information (geometry, physical properties, simulation variables,...). Edges represent the connections (from-to, child-parent) between these spatial units.

Spatial processes are represented as one or many models. These models simulate the dynamics of processes by computing data attached to every node of the graph, and can rely on rich information embedded by nodes and edges.
The spatial coupling of models is based on controlled data exchanges over the spatial graph.

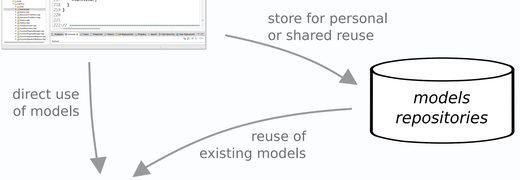
OpenFLUID modelling



Models development and sharing



The pluggable models can be easily developed *de novo* or encapsulate existing models using the dedicaded development environment. They are written in C++ or compatible language (C, Fortran, ...)



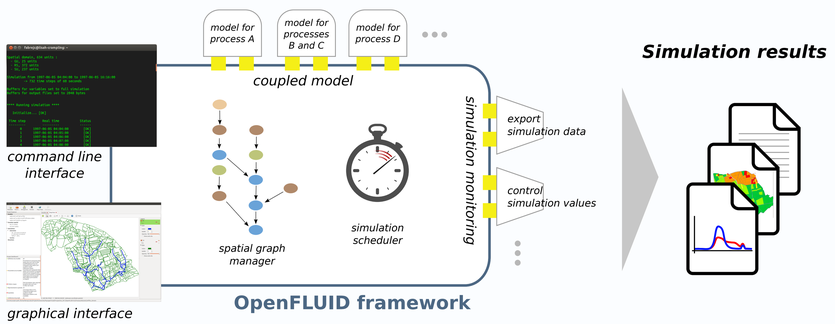
Simulation execution

OpenFLUID simulations can be run either using the command line interface or the graphical user interface.
During simulations, the plugged models compute and exchange variables and events attached to every spatial graph node. The plugged observers can monitor the simulation continuously, for exporting data, controlling values, or for performing any non intrusive operation. The data storage and exchanges over the spatial graph for the model coupling is managed by the platform engine.

Input dataset

digital landscape representation, coupled model configuration, monitoring definition, ...

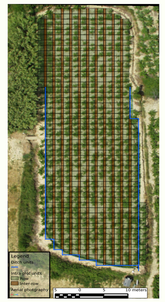
The input dataset can be built by hand using text editors or GIS environments, or using specifc tools such as GeoMHYDAS (Lagacherie et al, 2010)



Simulation results

Modelling application examples using OpenFLUID

Runoff pathways at field scale



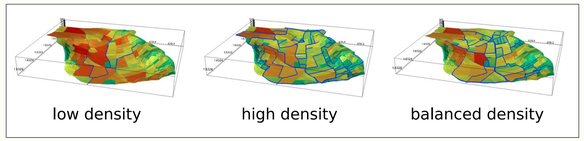
Objectives: 1) studying the effect of intra-field variability on the runoff generation and flow pathways, 2) comparing different implementations of the same hydrological process.
Methods: A 1200 m² vineyard field (Roujan, France) is divided into more than 1000 surface units. The coupled model is made of a rainfall-runoff model and three surface transfer models which are interchanged for implementations comparison.

Risk analysis of water contamination by pesticides

Objectives: Studying the impact of agricultural practices changes and buffer zone implanting on pesticide transfer to surface water.
Methods: Puissalicon catchment (100ha, France) is divided into 190 surface units (fields, roads, banks, buffers) and 40 reach segments (ditches, pipes, rivers). The coupled model is made of hydrological models and fate-and-transfer pesticide models.

Hydrological network topology effects

Objectives: Studying the impact of hydrological network density on erosion and surface water accumulation.
Methods: 8000 simulations using a rainfall-runoff-transfer coupled model, with differents hydrological networks densities and topologies (Levavasseur et al. 2012).



Simplified modelling of traffic on Manhattan streets

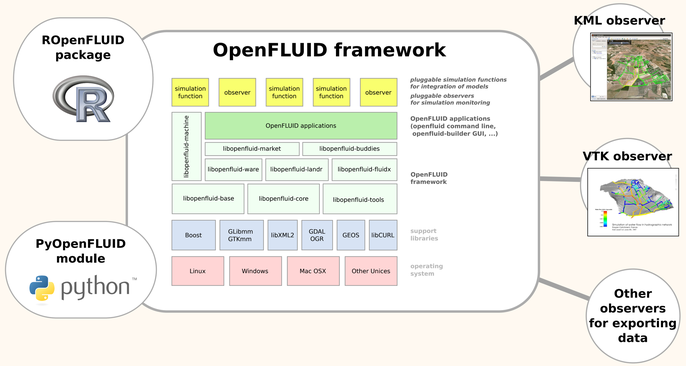
Objectives: Using OpenFLUID in a very different context of usual applications, demonstrating its abilities in modelling various types of spatial fluxes.
Methods: A simplified coupled model of road traffic transfer and traffic lights switching, applied to a spatial representation of streets in a urban context.

An open-source layer cake with candies

OpenFLUID relies on many open-source libraries for the core architecture and functioning (Boost, GLib, libXML2, libCURL), the management of GIS data (GDAL, OGR), the spatial algorithms (GEOS) and the GUI features (GTK).
All of these libraries licenses allow a non-restrictive reuse.

OpenFLUID is licensed under the terms of the GPLv3 license, with a special exception.
This special exception allows to plug and distribute models which are not compliant with the standard GPL license.

The OpenFLUID framework can be embedded into the Python language using the PyOpenFLUID module, or into the GNU R statistical environment using the ROpenFLUID package.



OpenFLUID uses a collaborative approach either for its development and the scientific applications. OpenFLUID make the sharing of knowledge and source codes easier.
OpenFLUID software, documentation and collaborative support are available on the web site: http://www.openfluid-project.org
OpenFLUID source code is available on the GitHub open-source hosting platform: http://github.com/OpenFLUID/

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