

Exploring the outcomes of a simulation model : Collective action in the Village of Diohine



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Model exploration in a paradigm shift

By answering the question “How do we get to...? ?” rather than “What if... ?”

Note : c'est le passage du plan complet à l'algorithme générique, qui change la place de l'observateur.

Families of exploration methods via HPC

$$M : \text{Inputs} \rightarrow \text{Outputs}$$

- Calibration : $\operatorname{argmin}_{\text{Inputs}} (\text{fitness}(\text{Outputs}))$
- Sensitivity Analysis : $\frac{\Delta \text{Outputs}}{\Delta \text{Inputs}}$
- Pattern Space Exploration : $\sim \text{Image}(M)$

Focus on PSE

- look for the **diversity** of reachable model outcomes
- Genetic Algorithm engine + novelty search based heuristics
- available on OpenMOLE platform

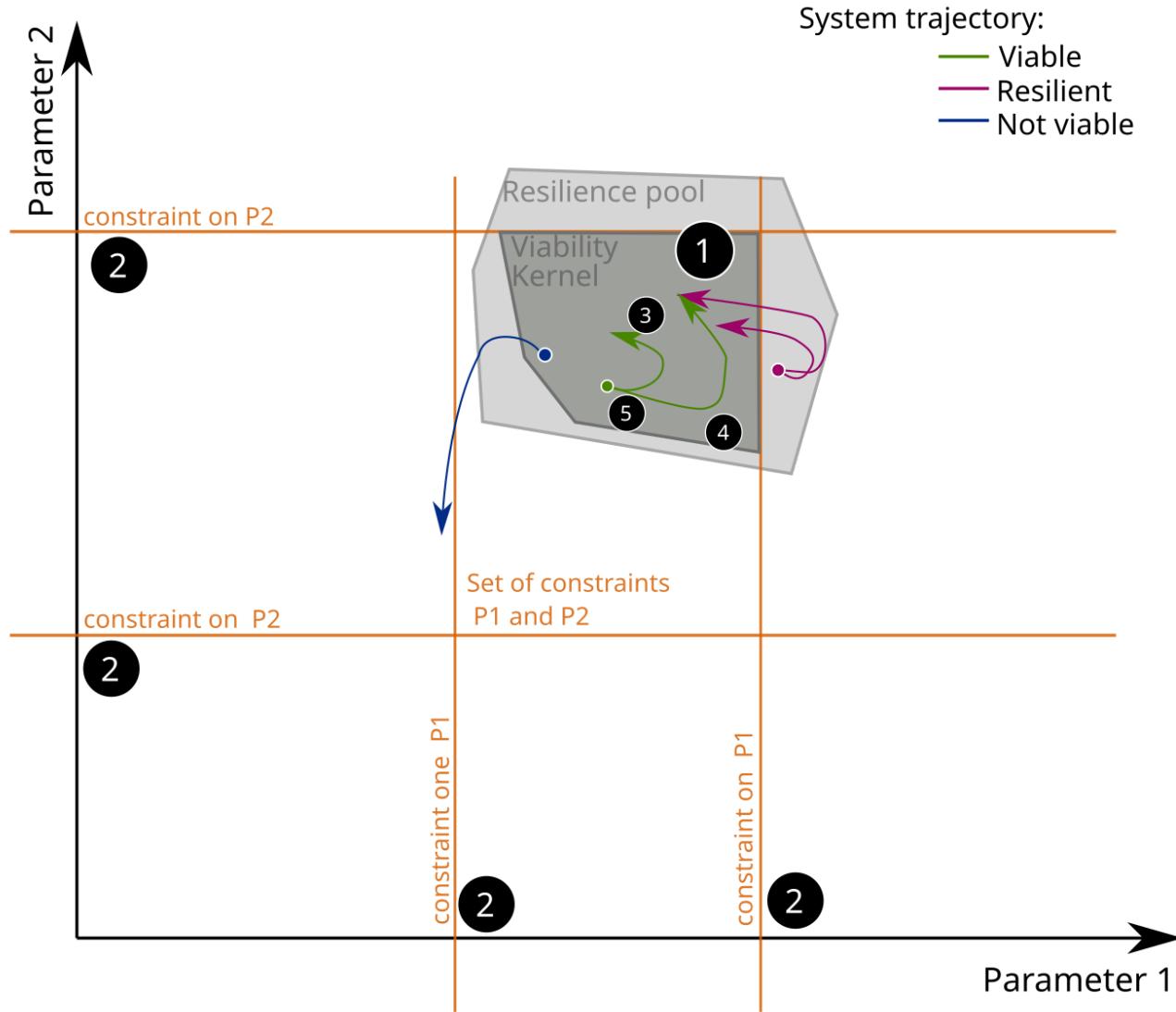


Chérel G, Cottineau C, Reuillon R (2015) Beyond Corroboration: Strengthening Model Validation by Looking for Unexpected Patterns.
PLOS ONE 10(9): <https://doi.org/10.1371/journal.pone.0138212>

What is viability theory ?

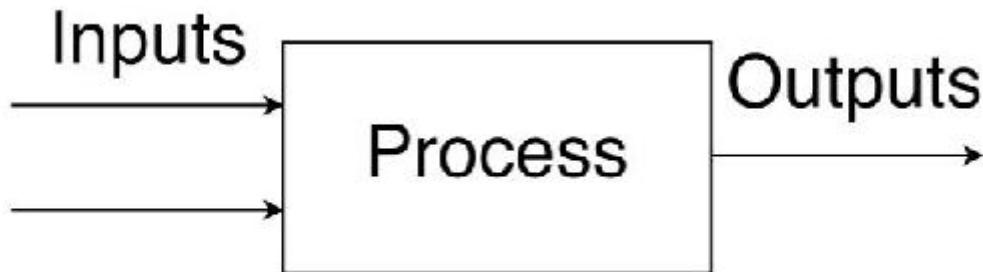
- mathematical concept of viability theory (Aubin 1991)
- The important thing is not only to identify the best solutions as in the case of the search for Pareto optimums, but to identify all the **viable** situations.

In the cases that interest us regarding the common “identify management strategies that avoid future crises without penalizing the current generation” (Sabatier et al. 2023)



Viability theory applied to simulation models

- Simulation Models can be seen as *functions*
- model transform inputs into outputs : $\{Output\} = M(\{Input\})$
- no mathematical closed form, no calculus
- Properties investigated by computation (DoE)



PSE : Pruning trajectories

which tools to use ?



Pruining trajectories



Some trajectories make no sense !

e.g. Control on population size set to 10 during 29 years and set back to the nominal size at the 30th year .

To filter out the useless trajectories, we need to re-simulate (and qualitatively assess) them.

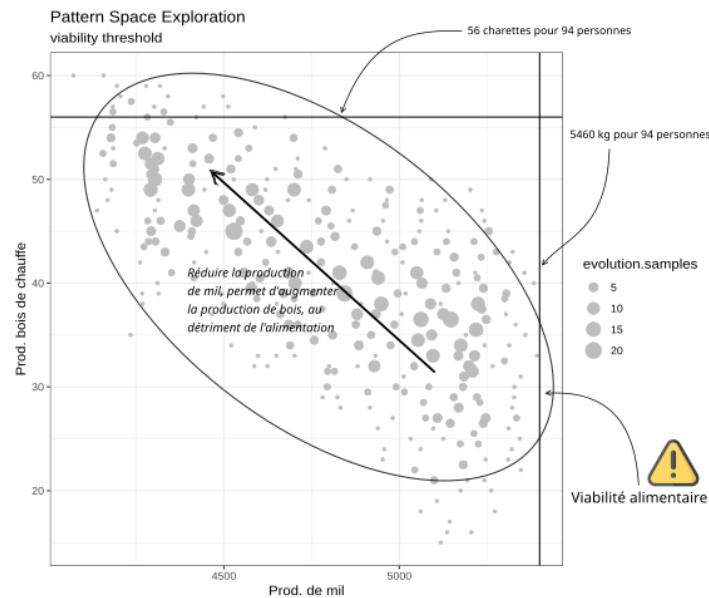
PSE on Faidherbia Forest Management

- Some inputs stand for management strategies
- PSE give the final states of potential **trajectories** regarding outputs
- Viability theory as an **inspiration** to classify/assess trajectories in the Output Space
- Combine potential trajectories mapped with management space to get insights about evolution of commons

An example in Diohine

The SAFIRe model : Simulation of Agents for Fertility, Integrated Energy, Food security, and Reforestation.

one dot = the exit point of 30 simulated years



First step towards viability assessment

PSE gives a mapping between possible practices and their outcomes

This is a first step to approximate viability kernel by delineating candidates trajectories enveloppes

From final stat results to trajectories

For a given solution in the viability kernel , we need a method to find all the possible input that led to it.

This is what the OSE (Origin Space Exploration) method tries to achieve (W.I.P)

Then : resimulate the trajectories to get insights on what make them viable and the **effect of controls**

Perspectives / ToDo List

- redefining input **ranges** : some of them may be mathematically possible, but make no sense for the Actors / socially unacceptable
- modeling the **effects** of a control on an input : intensity and frequency of the input value modification
- Use violation of theses constraints as a **reject clause** in the GA sampling step

Final Roadmap outline

Given a simulation model, we use HPC to :

1. identify the trajectories leading ultimately to the viability kernel (PSE)
2. get the origins of ultimately viable trajectories (OSE)
3. filter out the “not-always-viable” trajectories to delineate viability kernels in the **input space**

