MaBoSS Ecosystem

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Outline

1. What is MaBoSS
2. MaBoSS with WebMaBoSS
3. MaBoSS environment with unix
4. MaBoSS with Jupyter notebook
   - UPMaBoSS for population modeling
   - Ensemble models
5. PhysiBoSS for agent-based spatial population modeling

What is MaBoSS? Markovian Boolean Stochastic Simulator

A(nother) tool for pathway modeling

Boolean:

Boolean node state: 0 or 1 for node *i*.

Boolean network state: vector of Boolean node state for a given network. For each node *i*, $\vec{S}$.

Stochastic:

Probability space over network state space (not on Boolean state): give a probability for each network state.

Stochastic process: time dependant probabilities.

$$P(\vec{S},t) \in [0,1], \sum_{\vec{S} \in \Sigma} P(\vec{S},t) = 1$$

What is MaBoSS? Markovian Boolean Stochastic Simulator

Markov:

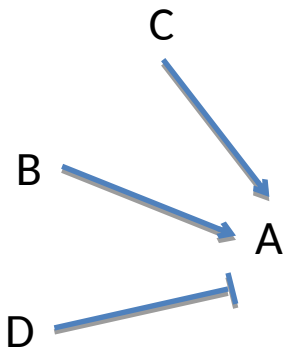
Markov process: stochastic process defined by

1) Transition rates: In MaBoSS, define rate value (time^{-1}) and condition for activation and inhibition of nodes

```
Node A {
    rate_up = (C AND B OR NOT D) ? 1.0 : 0.0;
    rate_down = (C AND B OR NOT D) ? 0.0 : 4.5;}
```

2) Initial condition:

p[(A,B,C,D)=(0,0,0,0)]=0.7
p[(A,B,C,D)=(1,0,0,0)]=0.2
p[(A,B,C,D)=(1,1,1,1)]=0.1



What is MaBoSS? Markovian Boolean Stochastic Simulator

Simulator:

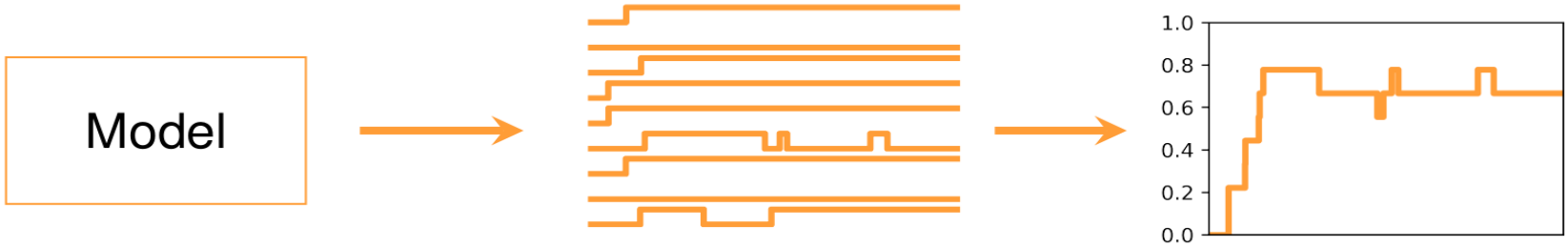
Simulation algorithm (Gillespie algorithm) for estimating probabilities from transition rates and initial condition.

Simulation parameters: time length, number of trajectories.

C++ software:

- Inputs: *bnd* (Boolean Network Descriptor) file and *cfg* (Configuration) file
- Outputs: csv files for probabilities and asymptotic states.

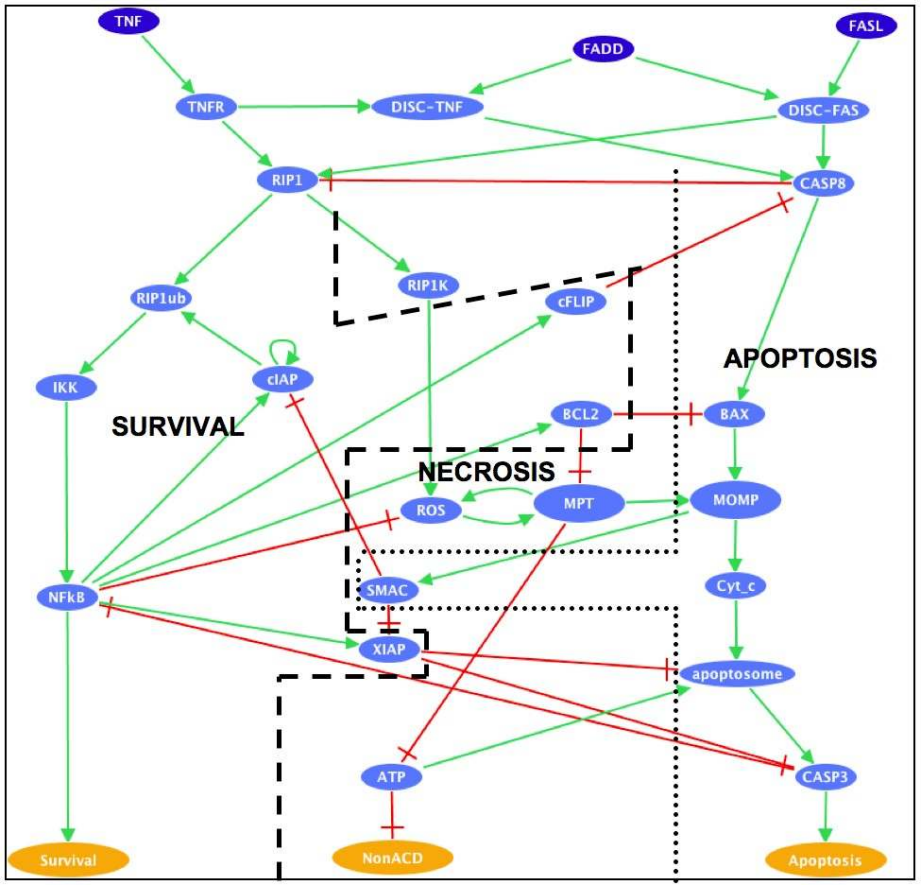
What is MaBoSS? Markovian Boolean Stochastic Simulator



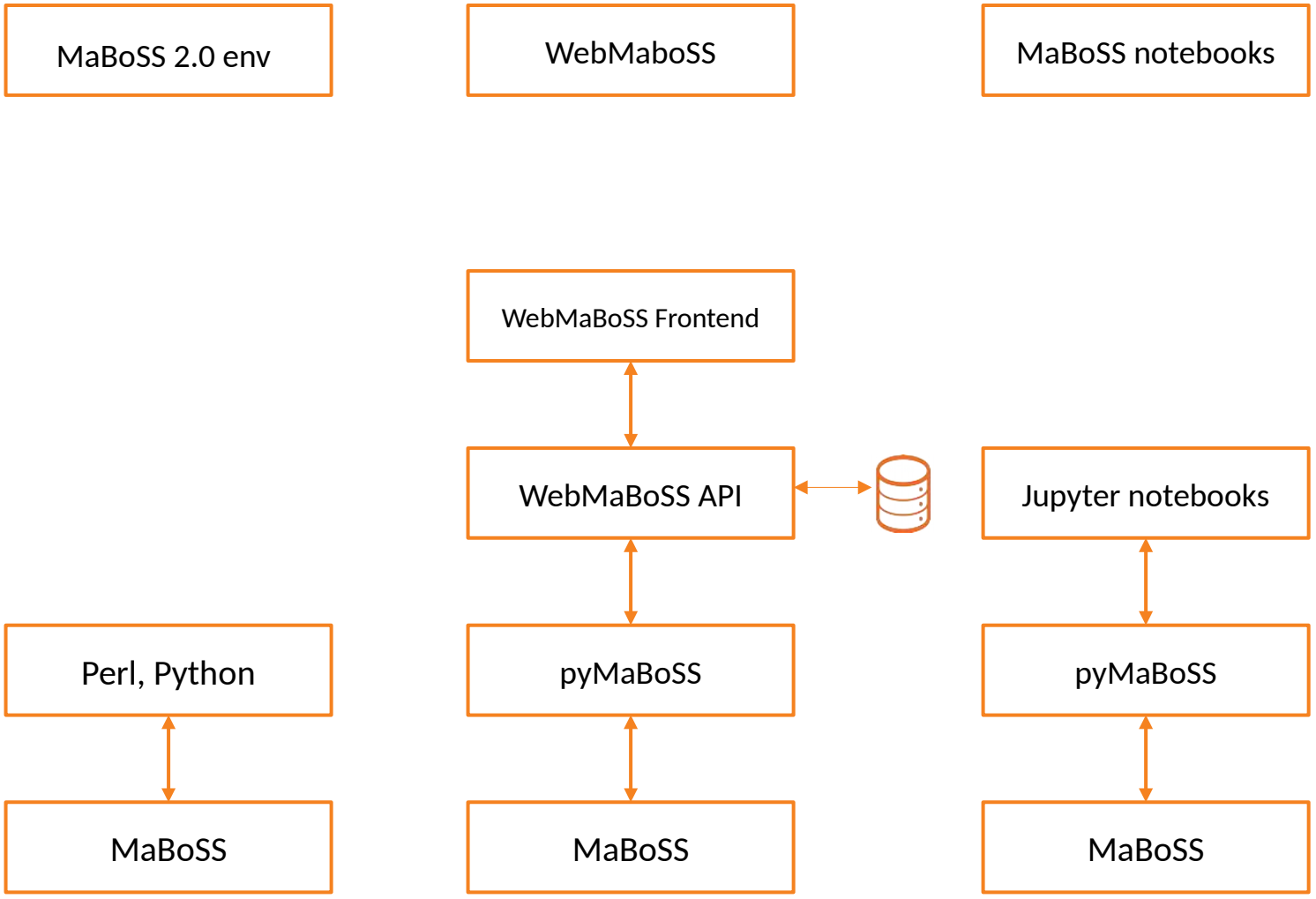
- Uses logical model skeleton to simulate dynamical models
- Produces stochastic trajectories
- Allows population interpretation
- SBML package being developed (annotations !)

Example with TNF -> cell fate

Use published cell fate model (GINsim/MaBoSS), available on MaBoSS web page, https://maboss.curie.fr

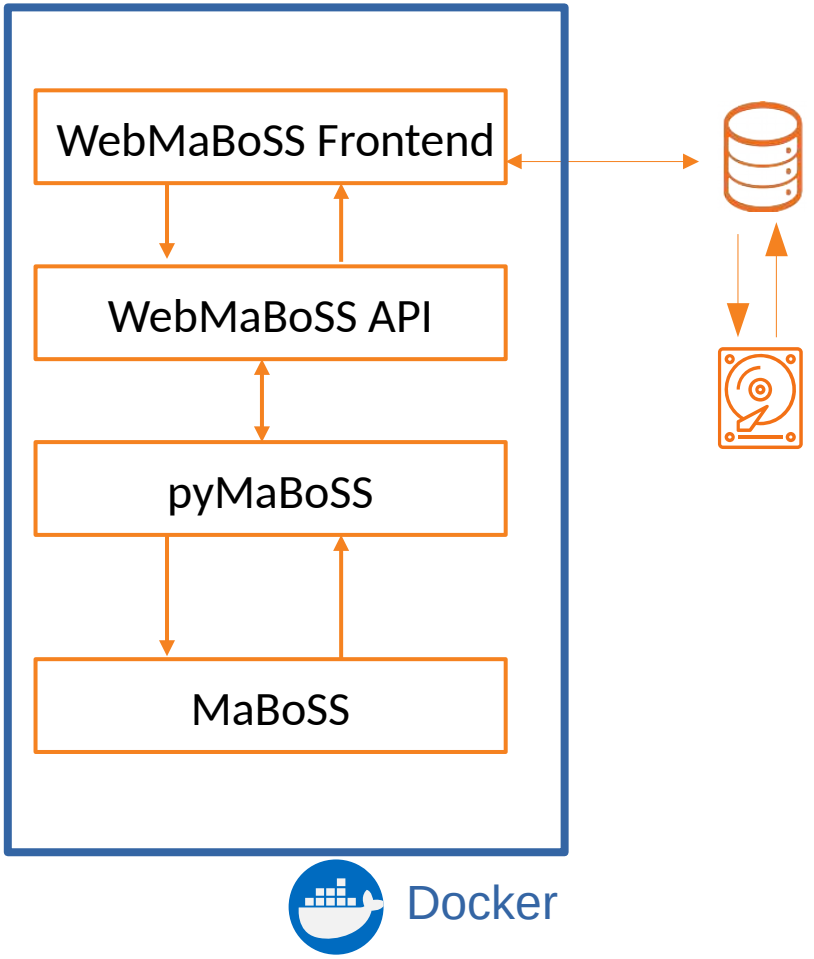


Different MaBoSS environments



WebMaBoSS

User friendly, no need to fully understand MaBoSS inputs-ouputs, interactive figures



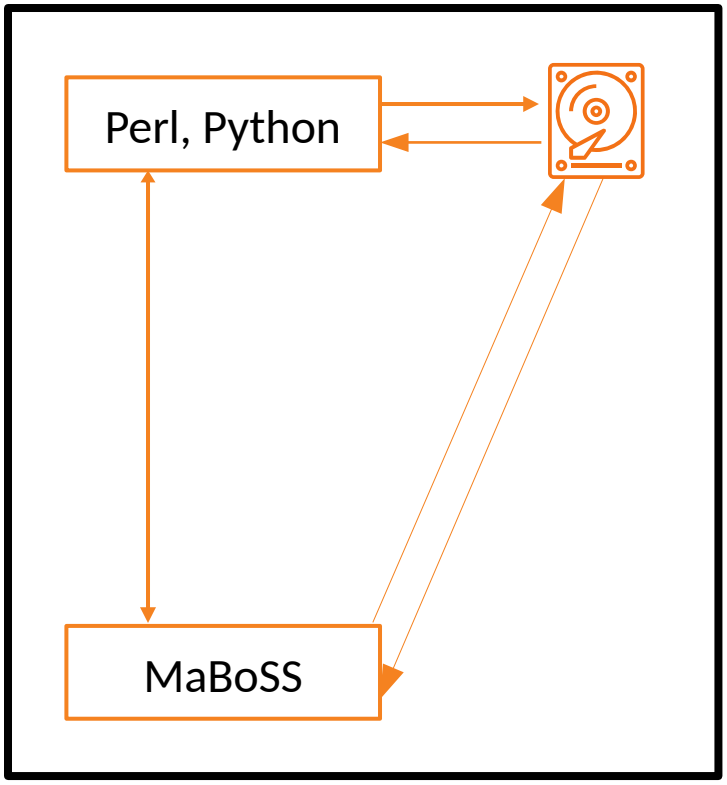
- Web interface (remote computation)
- Database to store models/results
- Multiple pipelines implemented (eg mutations)

Demo version available at :

https://webmaboss.vincent-noel.fr

MaBoSS 2.0 environment

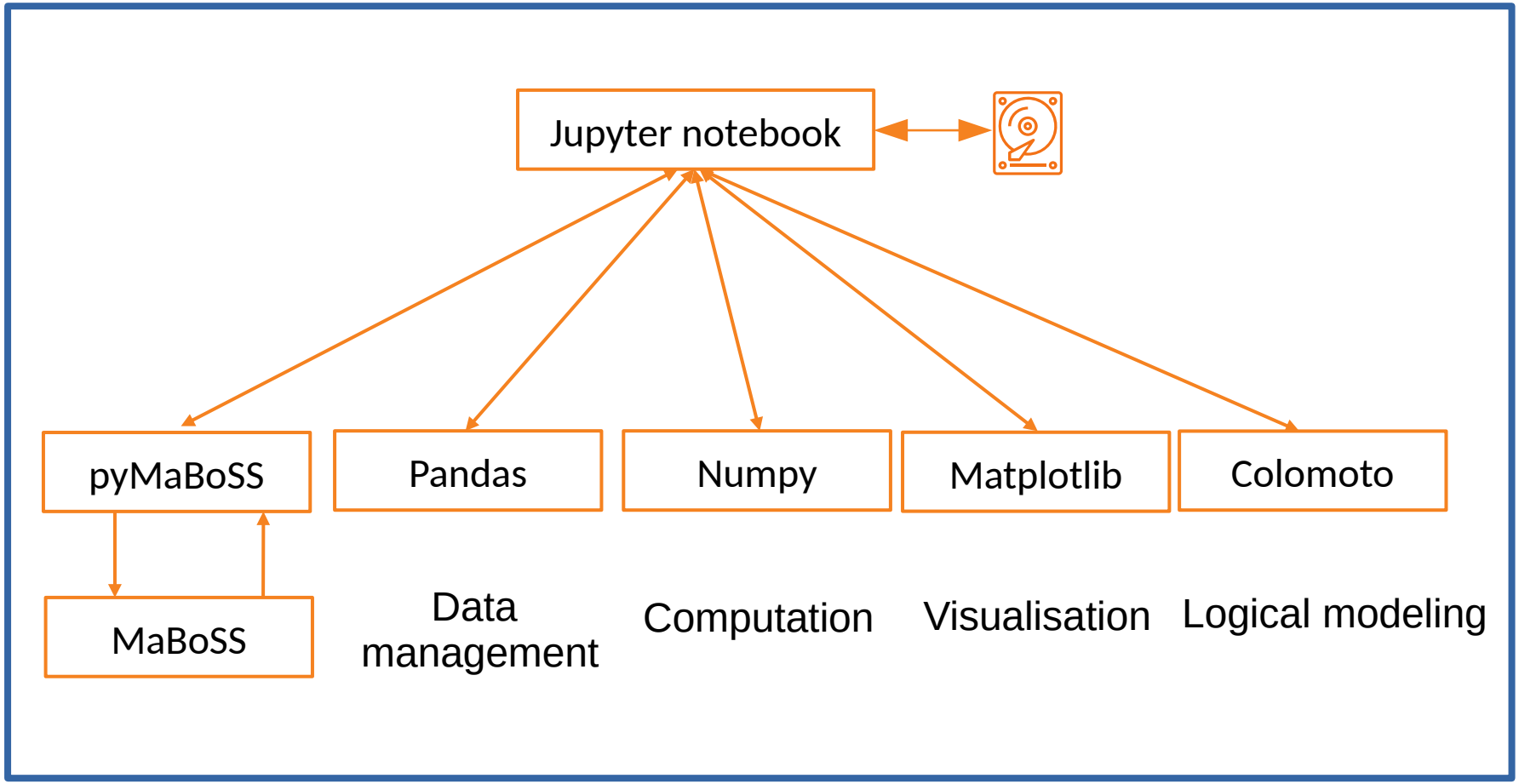
Light to install, multiple batch processing, computation on server



- Multiples post-processing scripts (plotting, analysis, ...)
- Multiples batching scripts (sensitivity analysis, mutations, ...)

MaBoSS notebook

Reproducible data analysis, multiple simulation within python coding,
with access to a variety of libraries



Docker or Conda

UPMaBoSS

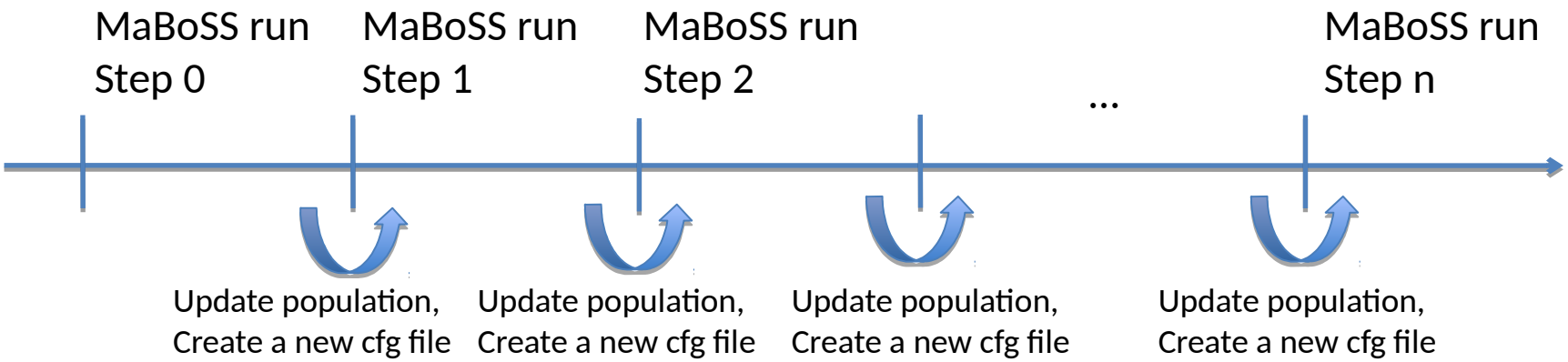
Use a signalling pathway(s) inside each cell -> MaBoSS model.

Specify, in the new *upp* file

1. Node for cell death,
2. Node for cell division,
3. Inter-cell communication (ligand -> receptor for instance), by defining update of external variable(s) according to probabilities and population size

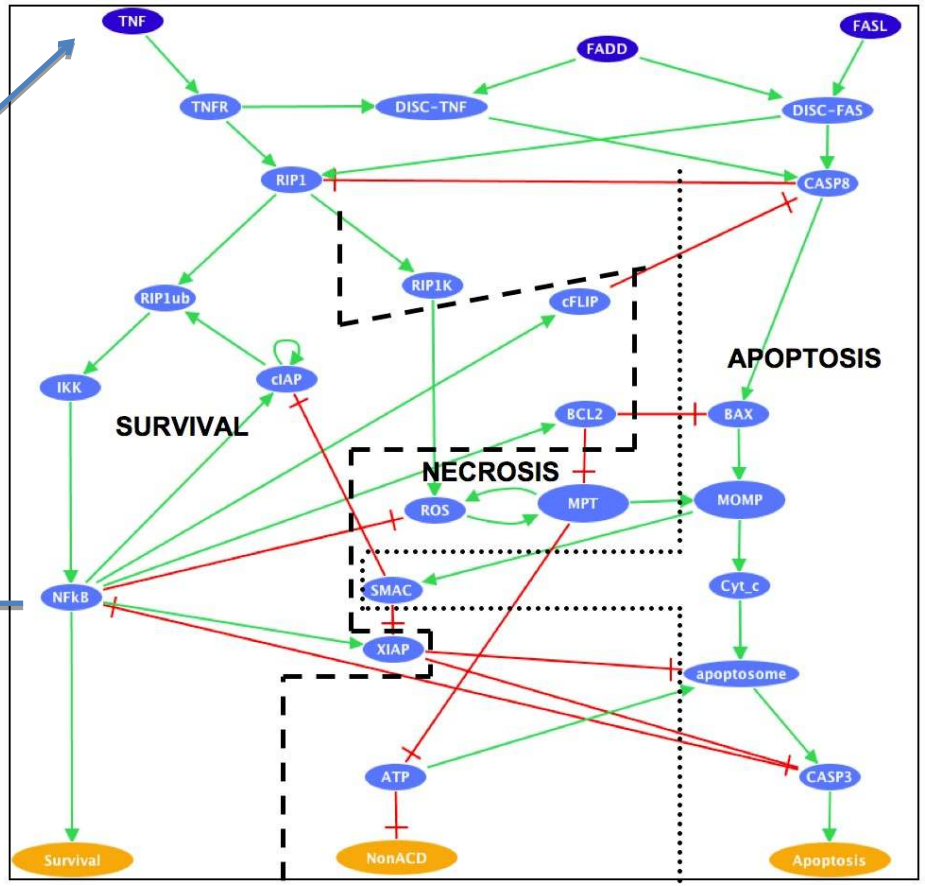
Outputs:

- size of cell population over time,
- probabilities of “network states” over time



Example with TNF -> cell fate

Use published cell fate model (GINsim/MaBoSS), available on MaBoSS web page, https://maboss.curie.fr



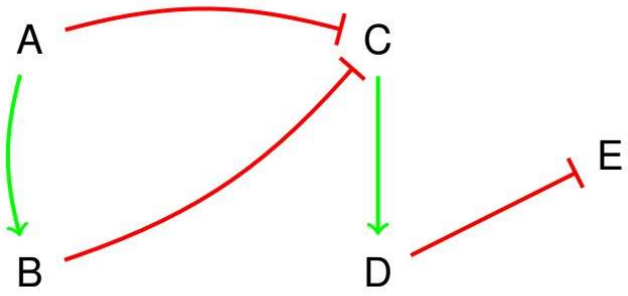
Production of TNF induced by NFkB

Cell Division / Proliferation

Cell Death

Ensemble models

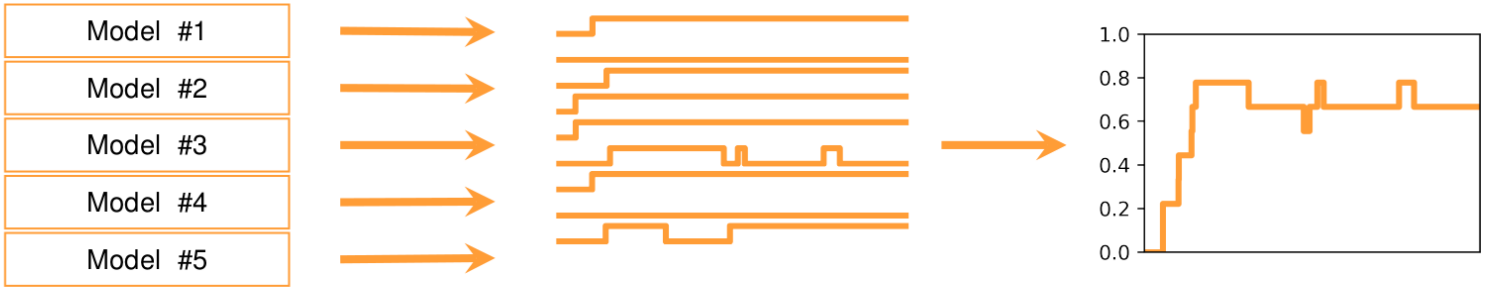
From a set of constraints, produces a set of valid models,
and treats them as an ensemble of models.



+

Constraints :

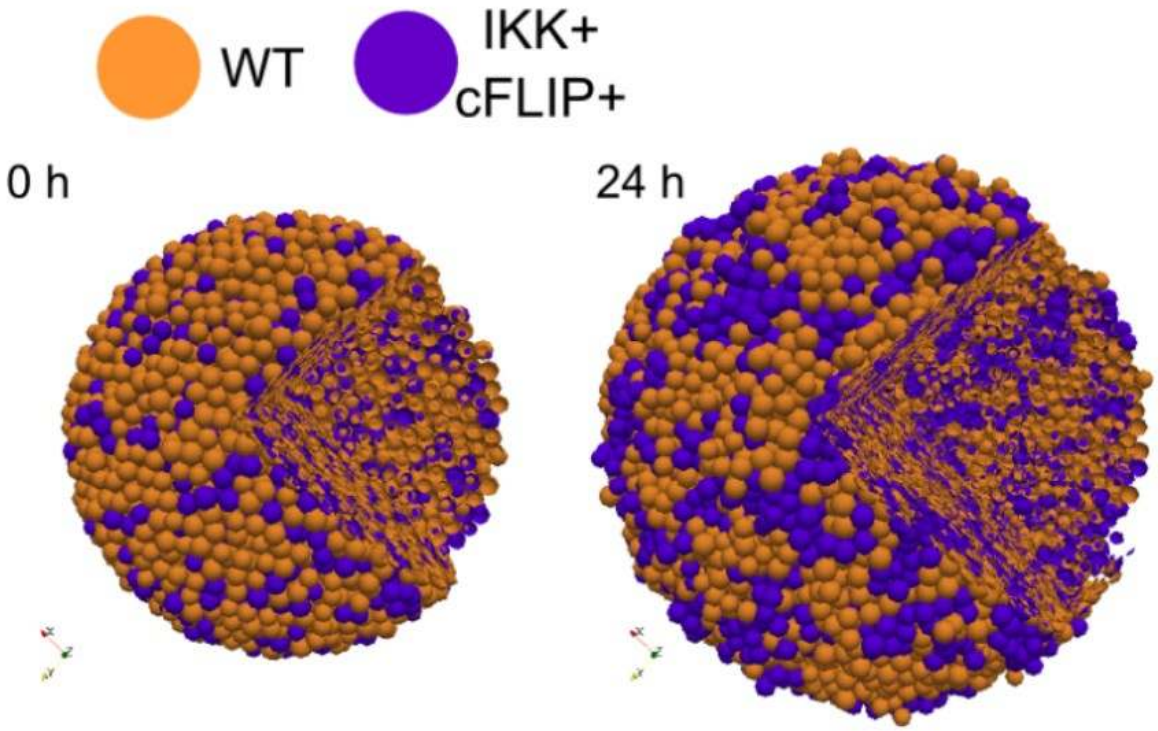
- Fixpoints
- Reachability
- Biological knowledge



-> Allows diversity of mechanisms within the model, to represent single cell variability, modeling uncertainty.

PhysiBoSS

Flexible and computationally efficient framework
to study heterogeneous cell population growth



=> Agent-based model, with every cell running a MaBoSS model. Allows cell-cell communication, diffusion.

Acknowledgments

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sysra
OBJECT & PERSISTENCE

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https://github.com/vincent-noel/MaBoSS-Ecosystem
https://maboss.curie.fr
https://webmaboss.vincent-noel.fr