



Using Flexible Time Scale to Explore the Validity of Agent-based Models of Ecosystem Dynamics

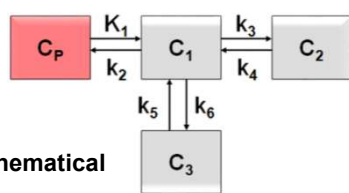
Application to Simulation of a Wild Rodent Population in a Changing Agricultural Landscape

Jean Le Fur and Moussa Sall

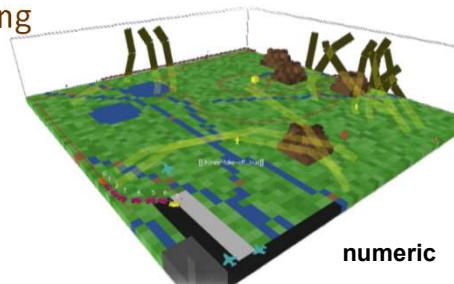


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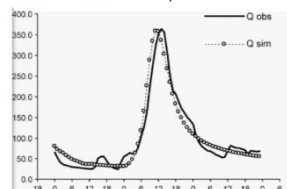
CALIBRATION : Identifying models' parameters value is a major issue in model engineering



mathematical



numeric



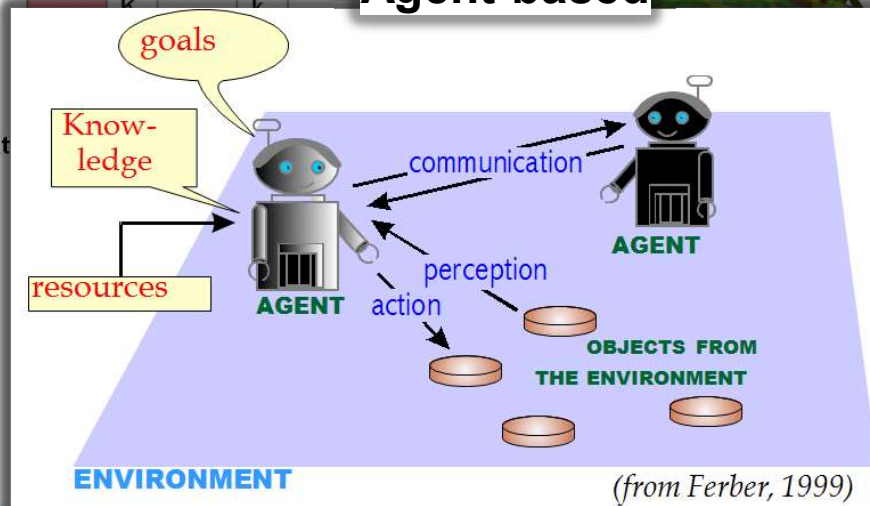
physical



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Identifying models' parameters value is a major issue in model engineering (cf. Watts, 2016)

Agent-based



SimMasto

physical

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Calibration in agent-based models

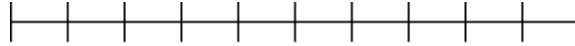
- Calibration question differs from one formalism to the other, from one use case to the other
 - e.g., in agent-based models:
 - Discrete Time Simulations
 - Discrete Event Simulation

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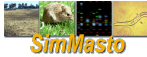
Discrete time simulations (DTS)

- Discrete time agents sequentially perform deliberation/actions once each time step



Process Simulation has uniform step sizes

- As a general use, DTS time step is fixed to one realistic value, given the use case, when other parameters may change.
- However, time step choice may have impact on models' outcomes
(Buss and Roawei, 2010, Kuo, 2015)
 - it is often difficult, if possible, to **determine if one agent has to process the selected scheme once each second, two seconds, minute, hour, day or the like**



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Aim of the Study

- Configure a discrete time agent-based model of a rodent population
 - Model's target: perennial rodents' population (*i.e.*, long term lasting)
- Configure the model to be run at several time scales
 - ➡ Design and conduct a sensitivity analysis of the model to time scale
- Evaluate the optimal time step duration



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Summary

- Introduction
- Use case overview
- Presentation of the model
 - Simulation Outputs
- Time scale sensitivity analysis
 - Time scale dependencies
 - Protocol selected
- Result
- Discussion



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Use case overview

Agent-Based Model of a Rodent
Population in the Wild



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Presentation of the case study

France, Poitou-Charentes region

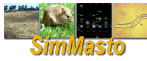
Landscape of plains and open fields
(spring, winter, alfalfa, grassland cereals)
in which rodents evolve



Question: use of agricultural land by rodents?

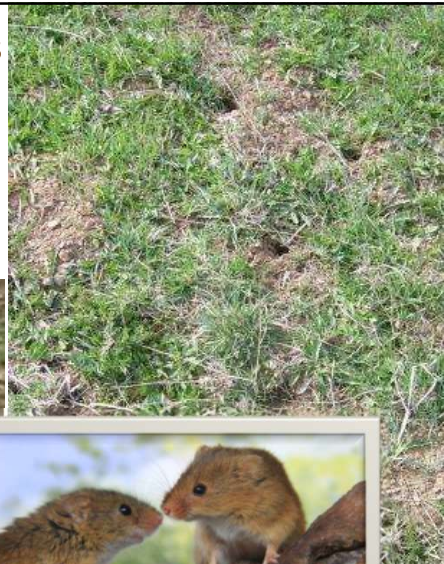
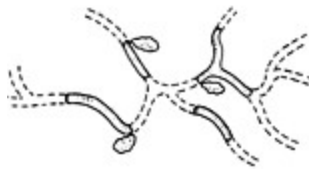


Common vole (*Microtus arvalis*)



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Burrow systems of voles colonies



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APPROACH: Mechanistically rich agent-based modelling(*)

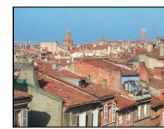


Observed dynamics come from the combination of various phenomena

Include: abiotic, trophic, physiological, behavioural, social, demographic and environmental mechanisms, landscape dynamics.
- each the most parsimonious way -

Outcome: formalize the dependency of each causal chains and produce global patterns.

Consequence: complex patterns that cannot be systematically interpreted but can be studied by modifying the model's logic or parameters.



(*) Uchmanski and Grimm, 1996, De Angelis and Mooij, 2003, Topping et al., 2010)

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Model Presentation

- **Dynamic habitats**
- **Rodent agents**
- **Simulation outputs**

Le Fur, Mboup & Sall (Simultech 2017)
*A Simulation Model for Integrating
Multidisciplinary Knowledge in
Natural Sciences*



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Simplified representation of the habitats variety

Habitats encountered in the field :



hedges



(5)



meadows



fields and roads



(1)



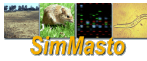
motorway



(0)

simplification

(rodent affinity for the habitat)



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Simplified representation of the habitats variety

Habitats (rodent affinity for the habitat)



hedges



meadows



fields



houses and roads



motorway

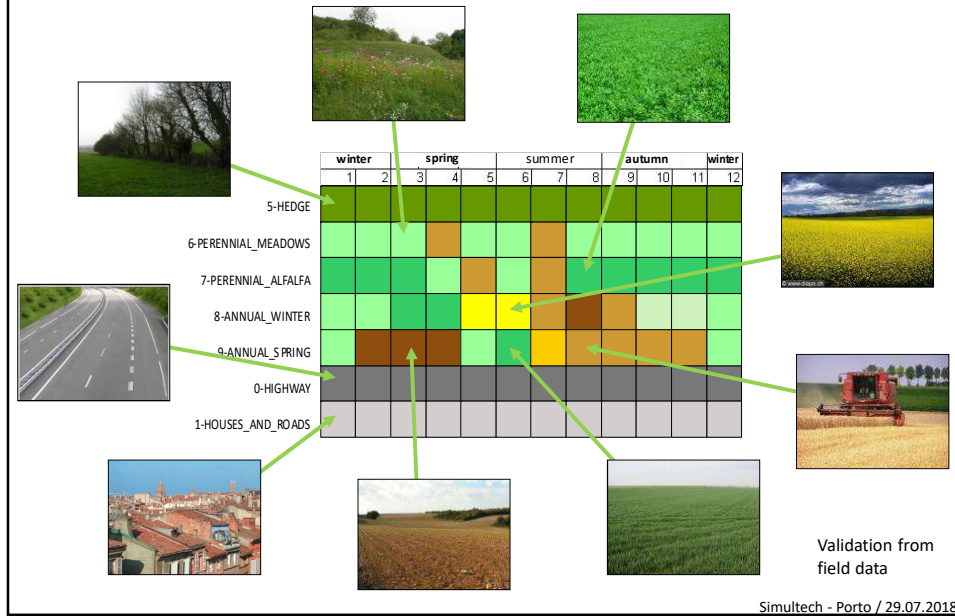


Technical operations



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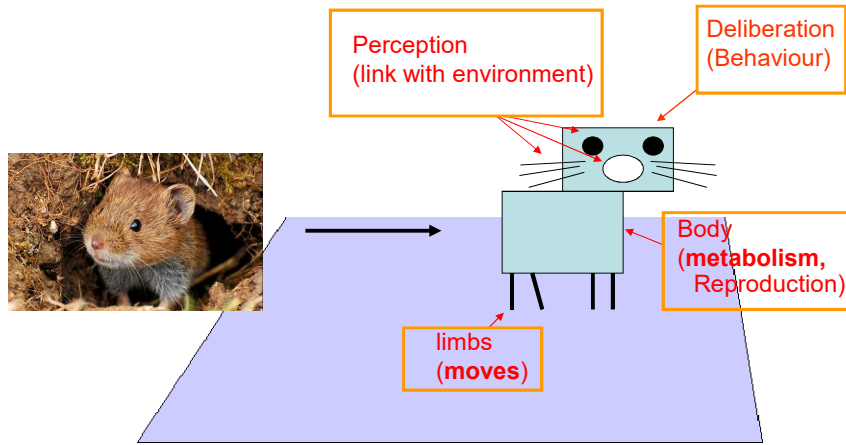
Technical operations (annual dynamics of the landscape)



Resulting landscape dynamics on a theoretical grid



Rodent Agents Competencies

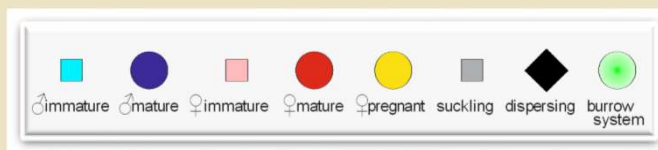


... within a changing landscape

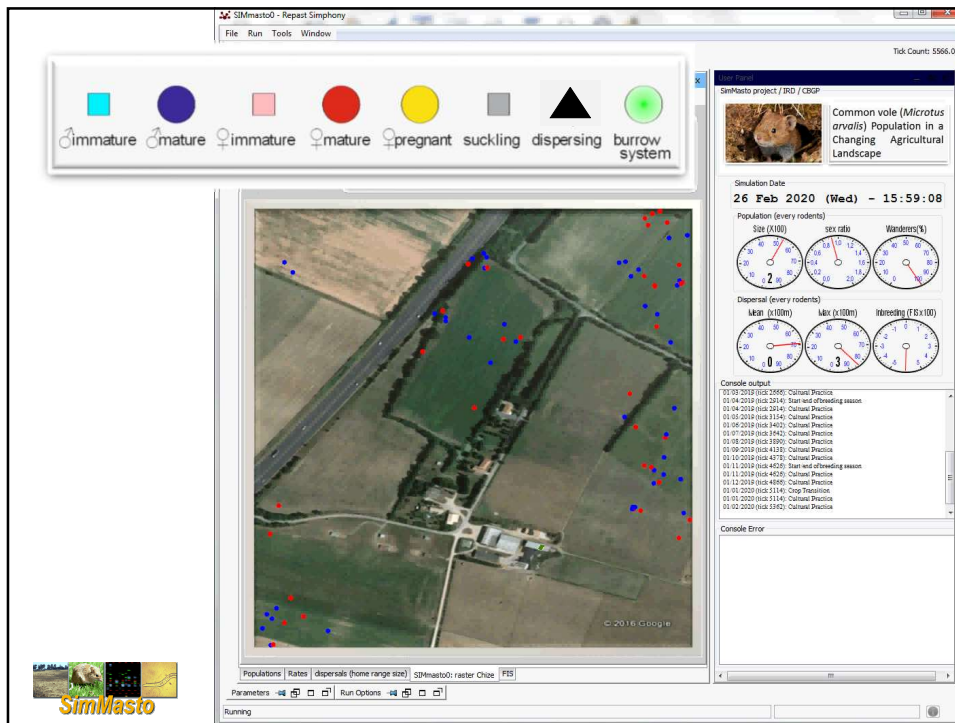


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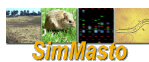
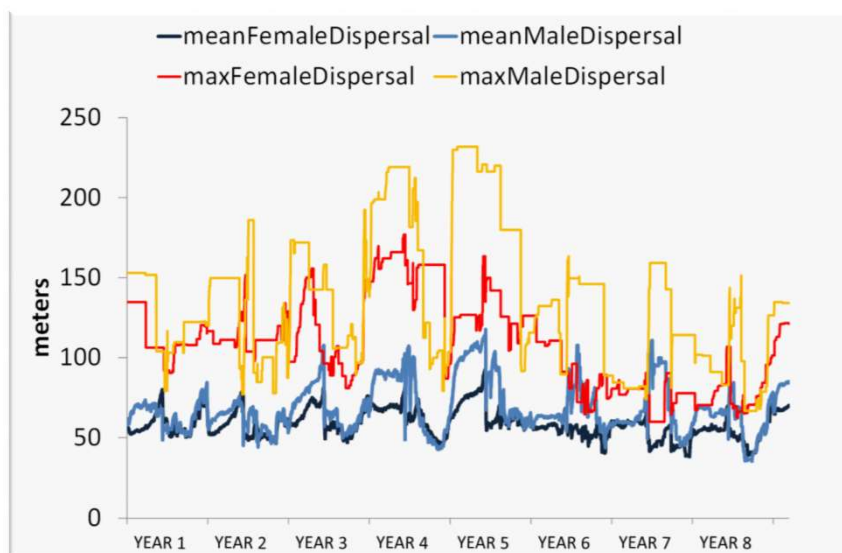
Simulation outputs



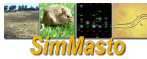
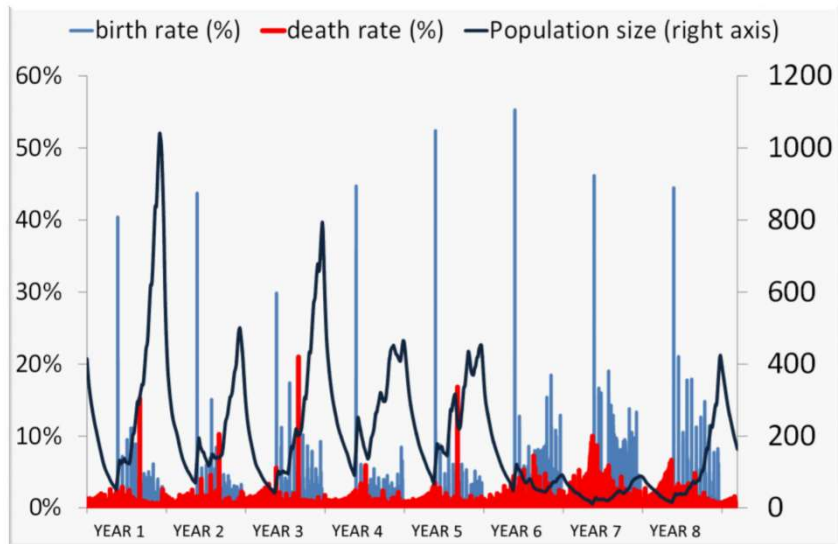
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Overall result for agents' dispersal



Overall result for population



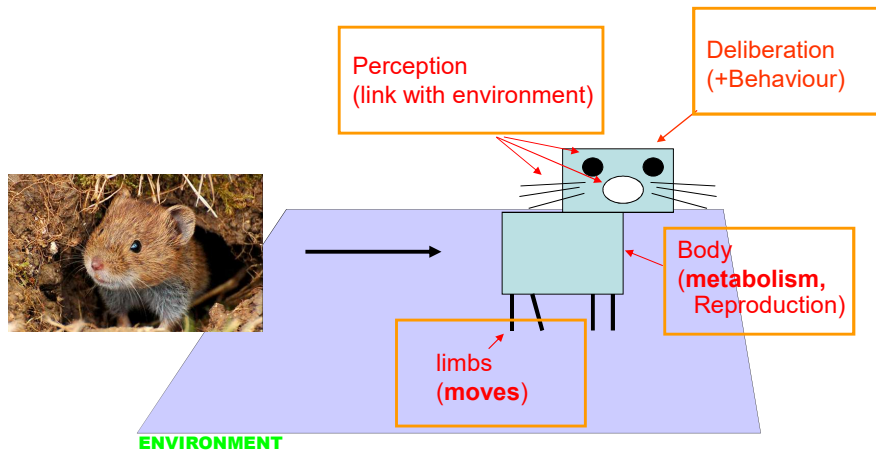
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Conducting a time scale
sensitivity analysis



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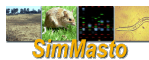
1./ Relative conversion of time-related mechanisms



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2/ Sensitivity Study Protocol

- Simulations are run using three ranges of time steps:
 - 1) from 5 min to 90 min each 5 min,
 - 2) from 90 min to 48 hours each 10 min and
 - 3) from 48 hours to 9 days each 30 min.
- Three constraints imposed to stop simulations.
 1. maximum population of 6.000 individuals (signing a pullulating population)
 2. No female remains (signing a collapsing population)
 3. If none of the above:
Stop at 3 years simulation duration
 - Simulations are stopped at the beginning of the reproduction season where rodents' population is at its lowest.



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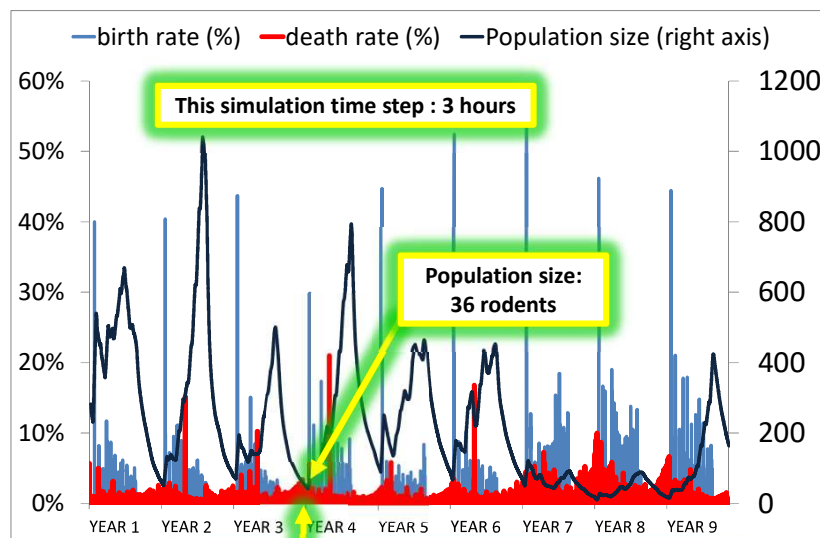
Results

Time step sensitivity analysis



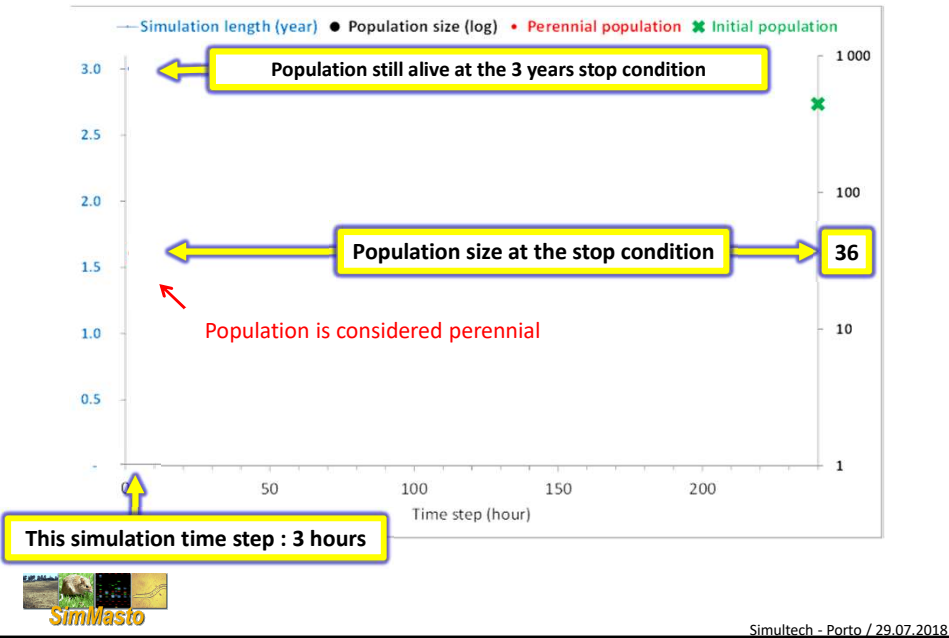
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Building the graph

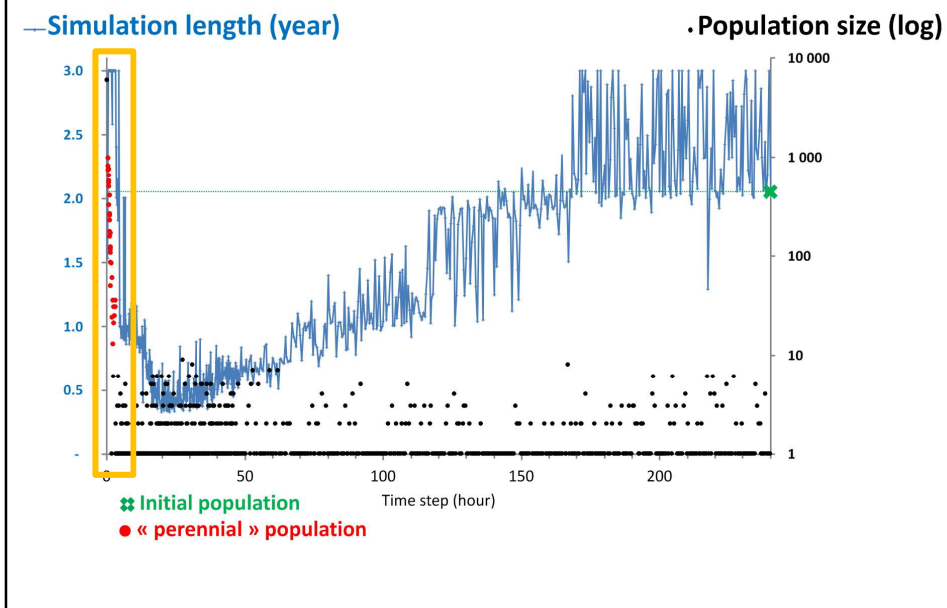


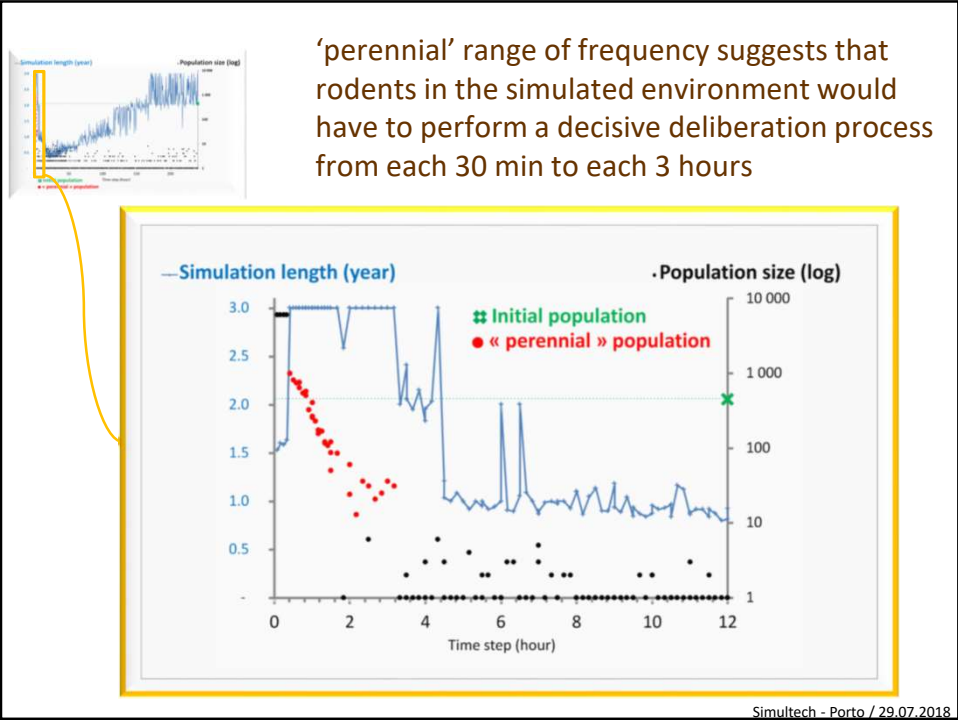
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Building the graph



Selected output indicators of the time step sensitivity analysis





Discussion



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CAUTION, results are indicative

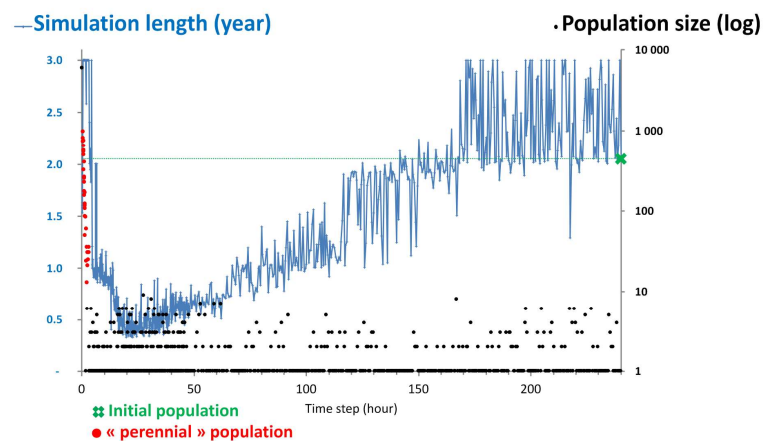
Single parameter sensitivity analysis

Results obtained "all other things being equal otherwise"



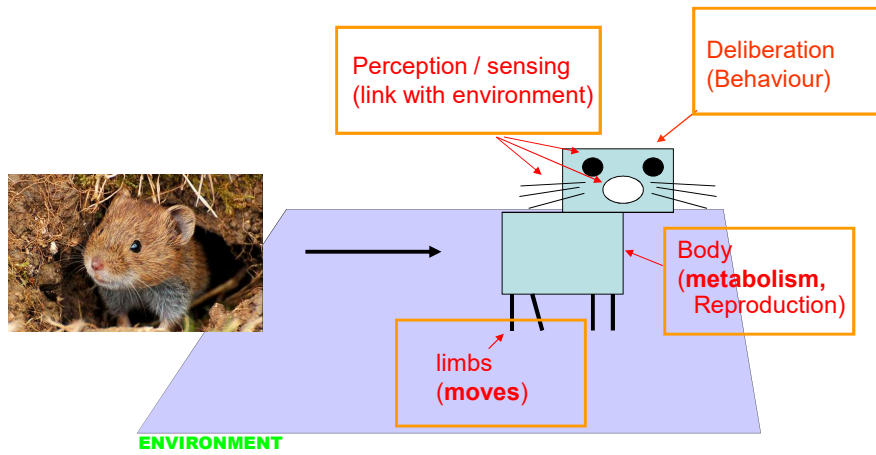
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Q: In an ideal scheme, the simulated population dynamics and indicator values would remain unchanged whatever the time scale chosen



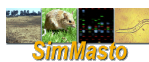
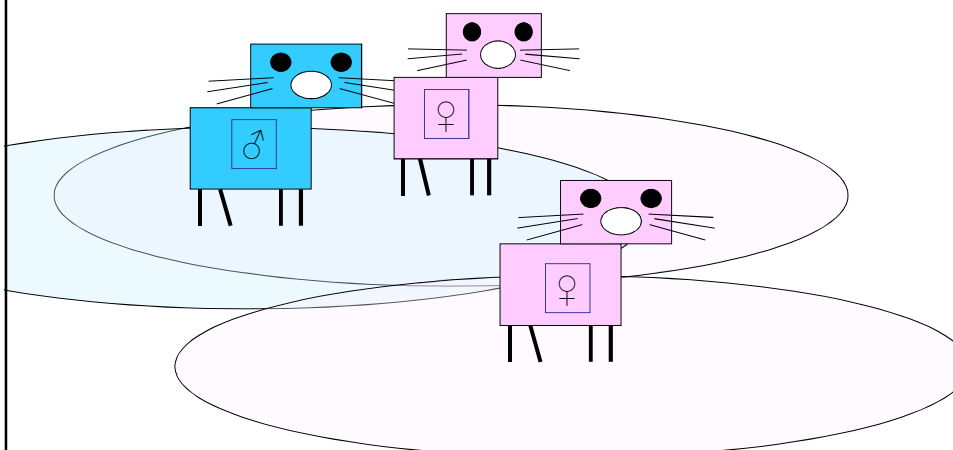
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Sources of discrepancies/biases - Time-related mechanisms



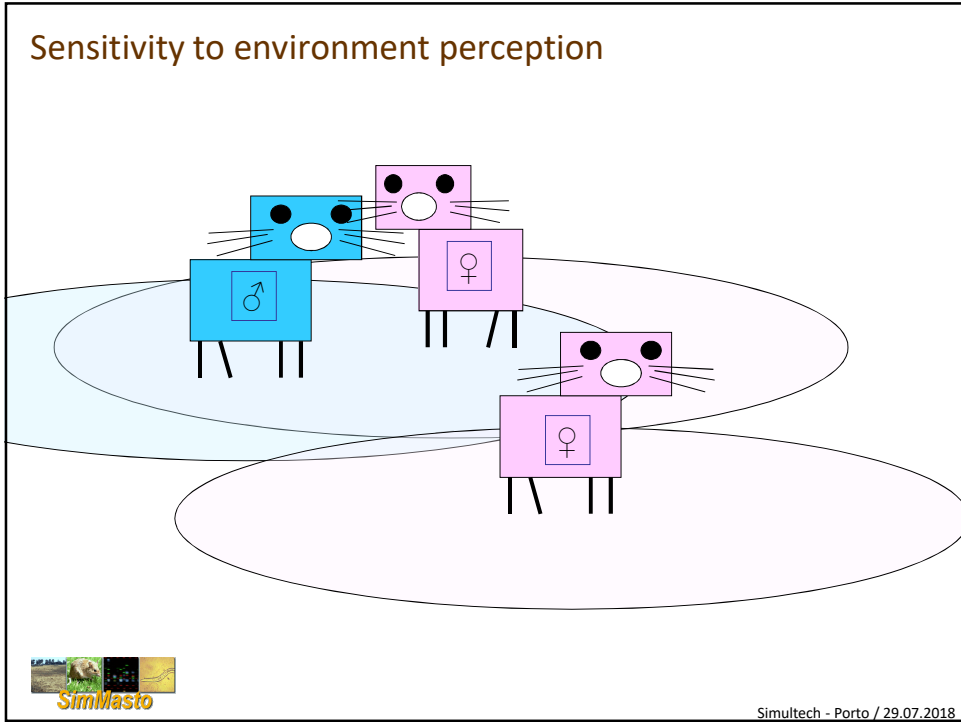
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Sensitivity to environment perception

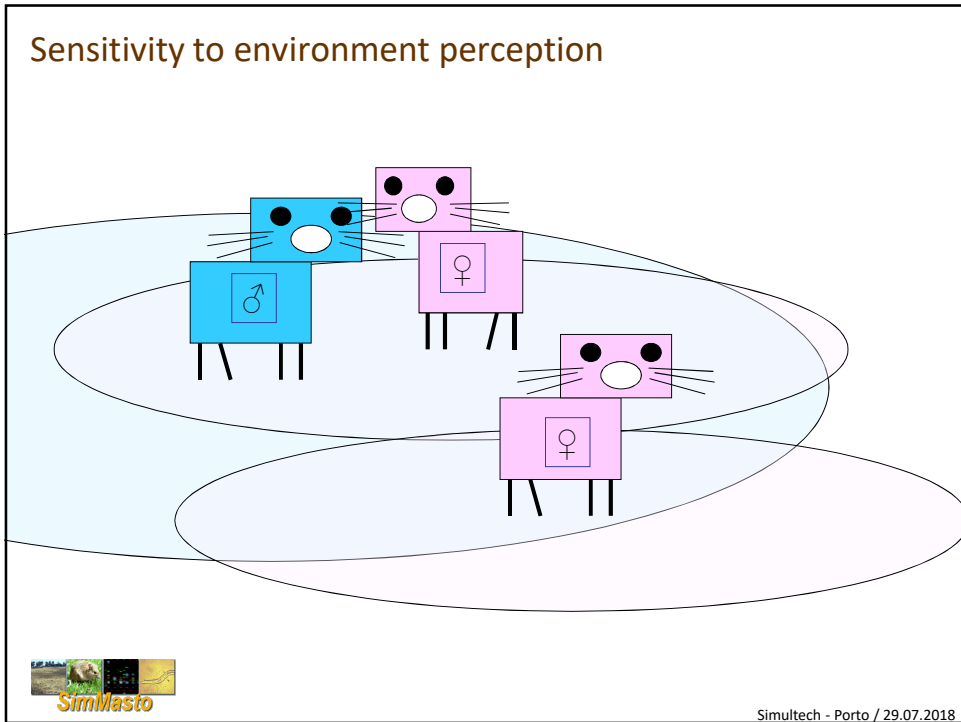


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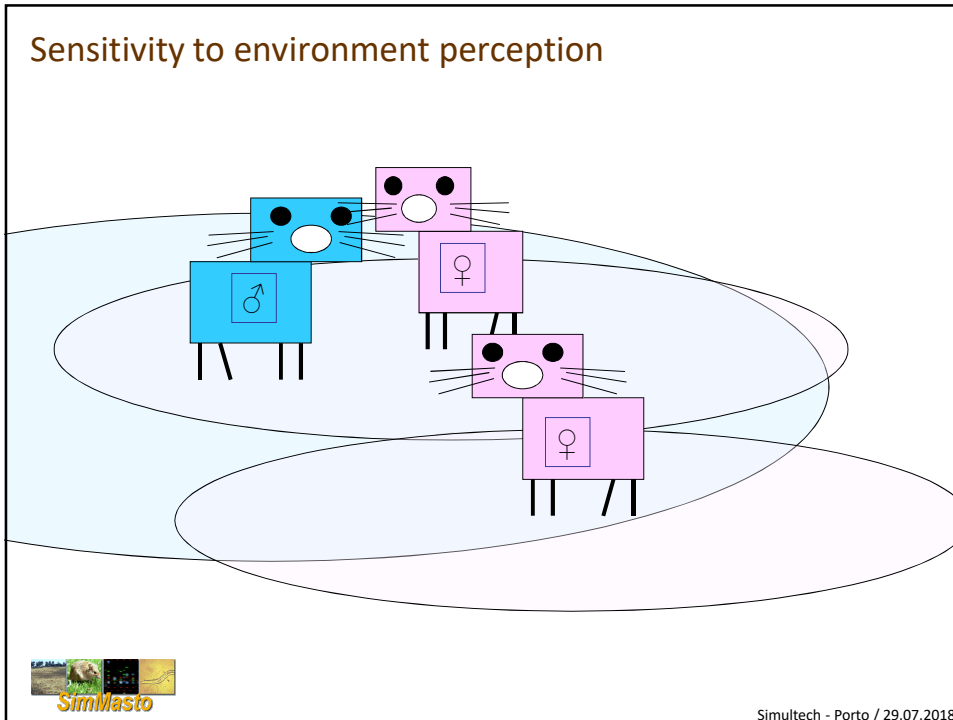
Sensitivity to environment perception



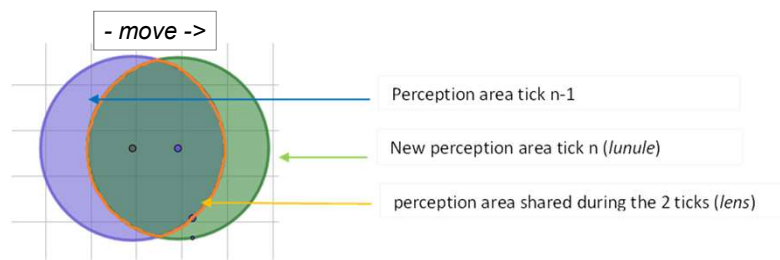
Sensitivity to environment perception



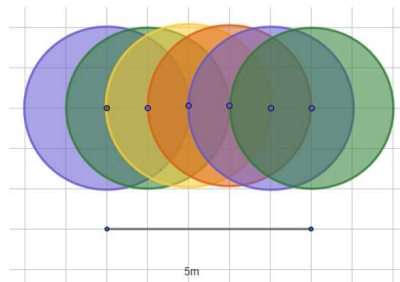
Sensitivity to environment perception



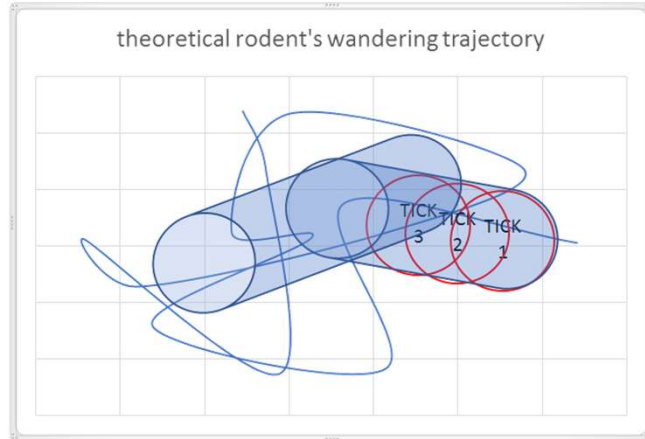
Is computing sensing as a function of perception circle radius is appropriate ?



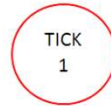
In simplified straight line move
The cumulative sum of sensing areas is greater than the corresponding one at a larger tick



However, rodents' trajectories are seldom linear

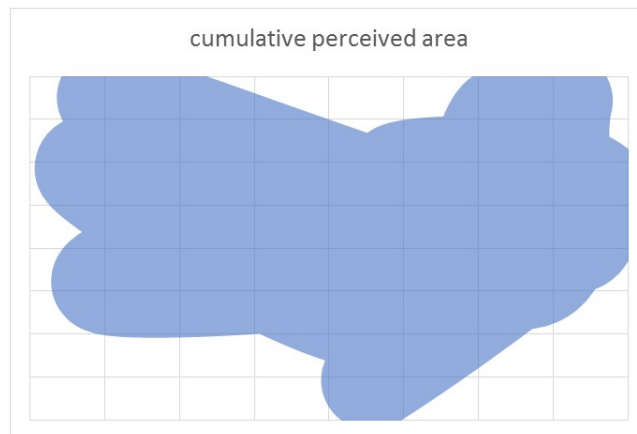


Perception area within the first tick



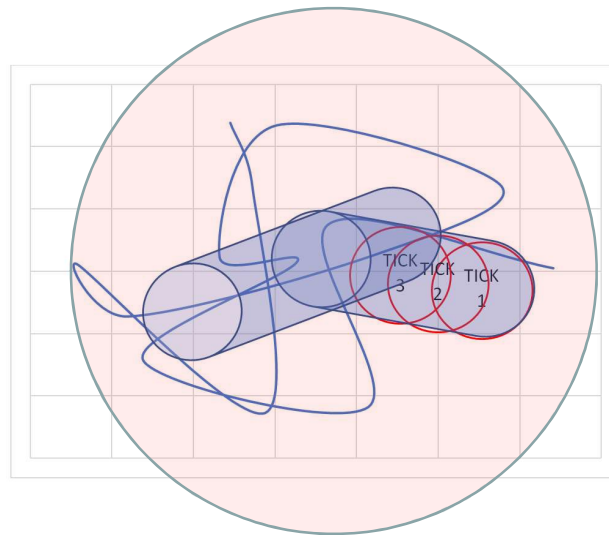
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Travelled area then decreases and converges toward the same order of magnitude that the integrated circle



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In any case, perception depends on the rodent's trajectory



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Conclusion

What is the convenient time step for such model ?



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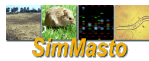
Use case example :

What is the convenient time step for one model ?



Situation after only 1500 steps (6 months)

Time step :
180 min
(3 hours)



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What is the convenient time step for one model ?



Use case example:

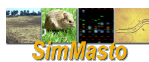
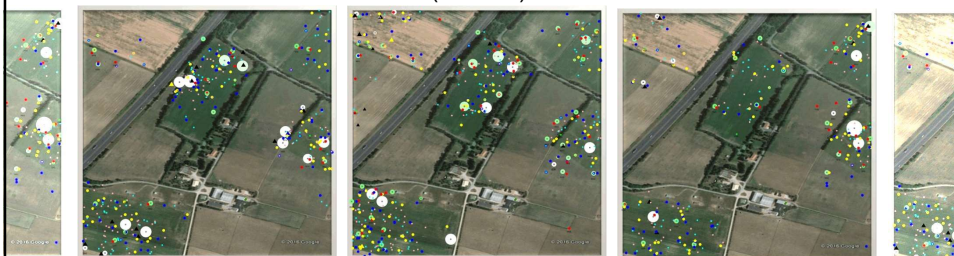
Situation after only 1500 steps (6 months)

Time step :

179 min

180 min
(3 hours)

181 min



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Thank you for your kind attention

