CoSMoS scale simulations and the path towards scientific validation

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1. Individual-based models in Ecology

Advantages

- Realism and relaxation of assumptions
- Cross-scale simulations
- Experimental parameterisation
- Observable, spatial, emergent

Disadvantages

- Computational resource requirements
- Limited scale of simulations
- Result interpretation
- Validity not straightforward

Implications

- Pragmatic
- Paradigmatic

2. The CoSMoS approach

CoSMoS – **Co**mplex **S**ystems **Mo**delling and **S**imulation – seeks to develop a methodology and a toolset for creating models and simulations of complex systems that provide *arguments of their scientific validity*. It is a case study oriented research that looks at systems ranging from robotics to the immune system and plant ecology.

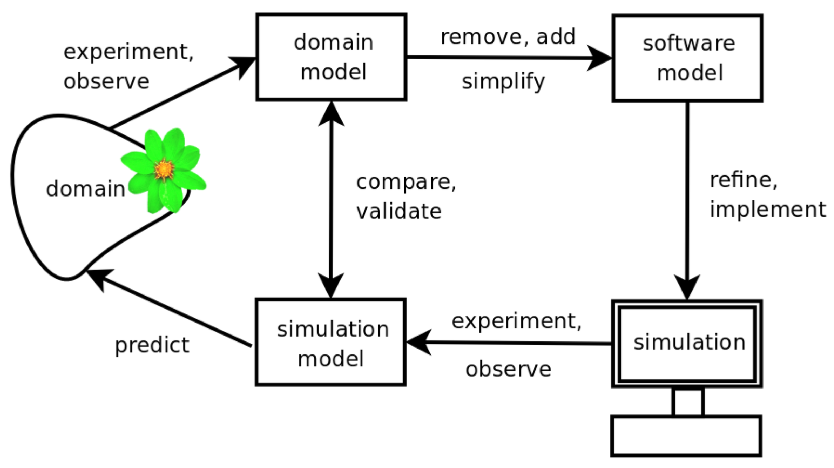
Combining software and critical systems engineering approaches, efforts are made for:

- properly *documenting* both the studied domain, models and simulations
- generating *arguments* of validity and expressing them formally.
- bringing simulations closer to the *scale* of real-world, complex systems.

3. CoSMoS infrastructure

Research methodology

- multidisciplinary inspiration
- deliverables are its documented models and the explicit argument of validity



Process Oriented Programming (Occam-π)

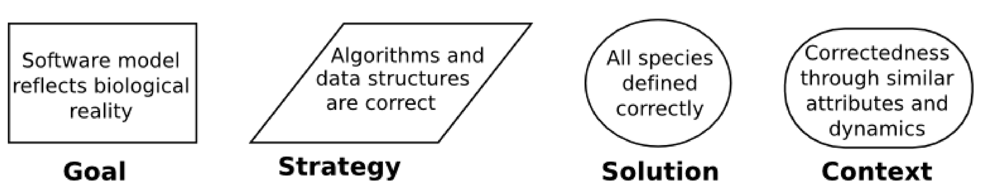
- straightforward concurrency of processes
- millions of processes running on a single PC
- distribution across computer networks

Process reengineering

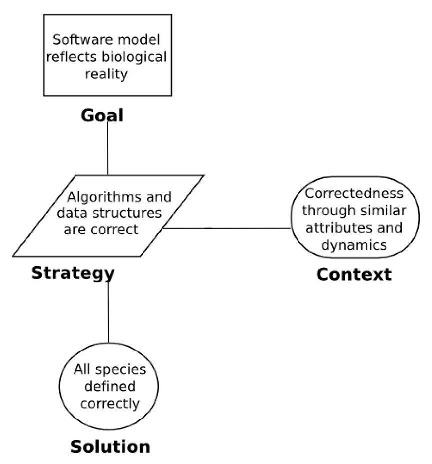
- addressing limitations of previous research
- a paradigm shift, from objects to processes
- patterns may be extracted and reused for further studies

Formal argumentation

- simulations of complex systems need to provide arguments of their validity
- argument definition with GSN (Goal Structuring Notation)



GSN components



GSN example

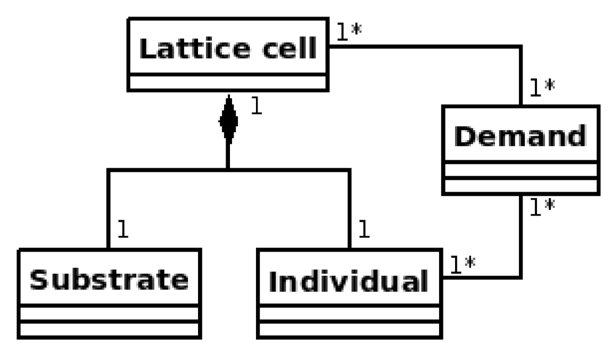
4. CoSMoS and plant ecology

Aim

Revamping a C based plant ecology simulator in order to obtain a drastic increase in simulating capacity. In turn, this allows testing hypotheses in more realistic setups, while enabling CoSMoS to refine its methodology and toolset.

Approach

- models are defined in a formal language (e.g. UML)
- all assumptions are recorded and exposed

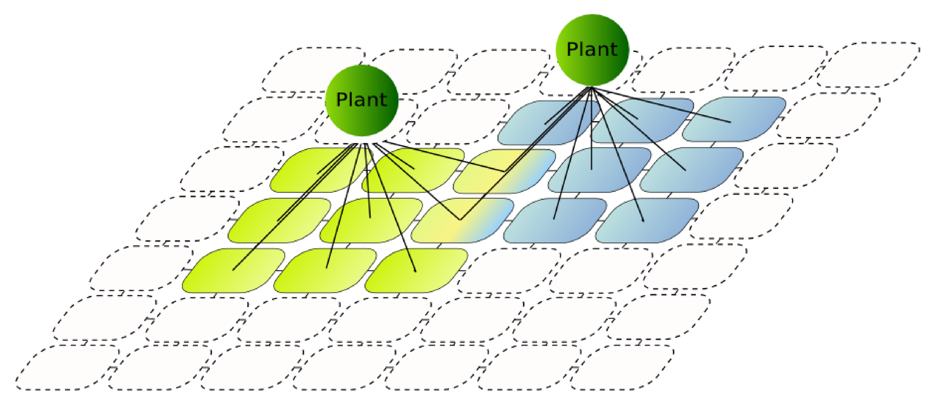


UML high-level model of a simulation

1.Environment	
1.1	resource release and replenishment rates are constant
1.2	the environment is 2D and each grid cell can hold only one plant
1.3	the maximal level of resource is homogeneous across the lattice
2.Individual	
resource uptake and allocation	
2.1	requested uptake is homogeneous for the same distance from the plant
2.2	resource allocation to the structural compartment and structural store has a fixed ratio
2.3	the uptake area varies homogeneously and is not affected by neighbouring competitors
development and survival	
2.4	germination is instantaneous (takes only one time step)
2.5	plant developmental stages are discrete
2.6	plants develop "unhindered" if having necessary resources
2.7	plant fully release their resources when they die

Assumptions list

- Occam-π implementation, scaling to 10^6 individuals
- both plants and environment are processes
- space is discrete, but continuity can be implemented



- argument of validity built using GSN

5. Conclusion

✓upscaling of simulations is within reach, that is
✓ecologies of millions of plants can be studied
✓validation and argumentation techniques are essential
✓CoSMoS is a multi-track project, aiming to contribute to complex systems research

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Find out more at www.cosmos-research.org