A Real Space Cellular Automaton Laboratory (ReSCAL) to analyze complex geophysical systems

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Abstract
The Real Space Cellular Automaton Laboratory (ReSCAL) is a generator of 3D multiphysics, markovian and stochastic cellular automata with continuous time. The objective of this new software released under a GNU licence is to investigate the dynamics of complex geophysical systems and develop interdisciplinary research collaboration.

ReSCAL key features
• Stochastic process for transition of neighboring cells (doublets).
• Setting physical environments and boundary conditions.
• Computation of the physical length and time scales.
• Detection of solid surfaces and steepest slopes.
• Avalanche dynamics (segregation and stratification).
• Localized control and forcing of the transition rates.
• Optional coupling with a multispeed lattice gas automata.
• Real-time rendering and light shading.

Stochastic cellular automaton
Our cellular automaton consists of a discrete dynamic system within a 2D or 3D grid of cells with a finite number of states. The evolution processes are defined in terms of stationary or non-stationary transition rates between the various possible states of the doublets (e.g. Poisson process).

Model #1: Roughness of the core-mantle boundary

Lattice gas coupling
Optionally, a 2D fluid flow can be computed from the discrete motions of particles along 8 directions, according to a set of collision rules. Numerical methods provide the mean velocities for the local modulation of transition rates. Thus we obtain a permanent feedback between the topography and the flow.

Model #2: Dune morphodynamics

Algorithm
creation of the cellular space; initialization of the lattice gas; surface topography; time scale;
while end.of.simulation = FALSE do
  if elapsed.time > lgca.delay then
    lattice gas collisions;
    lattice gas propagations;
    interpolation of the velocity field;
    end
  probability distribution;
  stochastic transition of doublet cells; time evolution;
end

Conclusion
Our modular approach can be applied (and developed) to analyze various complex geophysical systems with reasonable numerical efficiency.

Structured data
• Cross referenced arrays of cells and doublets, providing direct access to the cellular space location.
• Polymorphism of the cells.

Optimization
We implemented dynamic arrays of active doublets with automatic defragmentation. Thus we obtain contiguous memory pools for each kind of active doublets.

Execution speeds
• up to $10^9$ transitions/min. without lattice gas.
• up to $10^7$ transitions/min. and 1000 cycles/min of lattice gas.

Supplementary informations
Sources available online via http://www.ipgp.fr/~rozier/ReSCAL/rescal-en.html

References

Numerical simulation of the core-mantle boundary with 20000x500 cells

Dune figures by Deguo Zhang.