CITS4403, Computational Modelling

Percolation and forest fires

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Task

Implement the following probabilistic CA model rule proposed in [1, 2] to model forest fires:

Each site is occupied by either a tree, a burning tree or is empty (e.g. burnt site). The state of the system is parallel updated (i.e. synchronous) according to the following rule:

1. A burning tree becomes an empty site
2. A viable tree becomes a burning tree if at least one of its nearest neighbours is burning
3. At an empty site, a tree grows with probability p
4. A tree without a burning nearest neighbour becomes a burning tree during one time step with probability f (e.g. lightning).

Simulate the CA model on a square lattice with periodic boundary conditions and investigate the following:

- **Percolation:** simulate first the situation $p = 0$ and $f = 0$ with an initial configuration where each lattice site is a tree with probability q, and empty with probability $1 - q$. Ignite a small patch of trees in the center of the lattice. Show that if q is low enough, the fire dies out.
  (a) Can you find an estimate of the critical value of q above at which the fire 'percolates'? Show examples of initial configurations in which fire will percolate, others in which it won't.
  (b) What is the effect of the overall lattice size (number of cells in each direction) for this problem?

- **Forest fires:**

  1. With $p = 0.3$ and $f = 6 \cdot 10^{-5}$, track the total number of burning trees, empty sites (burnt trees) and viable trees as a function of time.
  2. Is the system evolving towards a 'steady-state' qualitatively independent from the initial state (for at least most of them) and from the random seed?
  3. Modify p and f simultaneously, but such that the ratio f/p is constant. Can you describe the effect of f/p on the final state qualitatively and quantitatively? Experiment this with increasing lattice sizes.
  4. Explain the concept of *self-organised critically* in this context. See Ref. [2].
  5. With $f = 0$, investigate the propagation of fire in a relatively dense forest starting with different initial patches under fire (e.g. circular patch, linear patch, etc.). How does the shape of the patch under fire evolve in time? Does this evolution resemble the propagation of a real fire front?

- **Extension:** Discuss the appropriateness of the model to simulate real-life forest fires.

  1. What essential component(s) of real forest fires is (are) missing in the model?
  2. Extend the model above to include this (these) component(s). Explain how you formulate your new rules.
  3. Repeat some of the simulations done before to show differences of your new model, in particular the evolution of burning patches with $f = 0$. Interpret and discuss your results.

References

[1] Bak P, Chen K, Tang C (1990) A forest-fire model and some thoughts on turbulence, *Phys. Lett. A* **147**, 297–300

[2] Drossel B and Schwabl F (1992) *Self-organized critical forest-fire model*, *Phys. Rev. Lett.* **69**, 1629–32