Expanded Parameters in the Self-Organized Critical Forest Fire Model

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Introduction

The forest fire model has been used as an analogy to test the theory of Self-Organized Criticality as a model of complexity. The goal is to search for scale invariance in randomly generated forest fires using a computer simulation. In a previous model by B. Drossel and F. Schwabl, power-law behavior was seen when the nearest neighbors to a tree on fire catch on fire, and it has been assumed that if further neighboring trees also catch on fire, then it will still exhibit self-organized criticality, showing scale invariance. Testing this assumption aids to the exploration of the applicability of self-organized criticality because the model is the most useful when it applies to a large range of systems, as closely related to nature as possible.

Self-Organized Criticality (SOC)

Self Organization: Larger system shows order due to small scale interactions, this order being *scale invariance* in the *power law behavior.*

Critical State: The point in which a system is no longer in equilibrium.

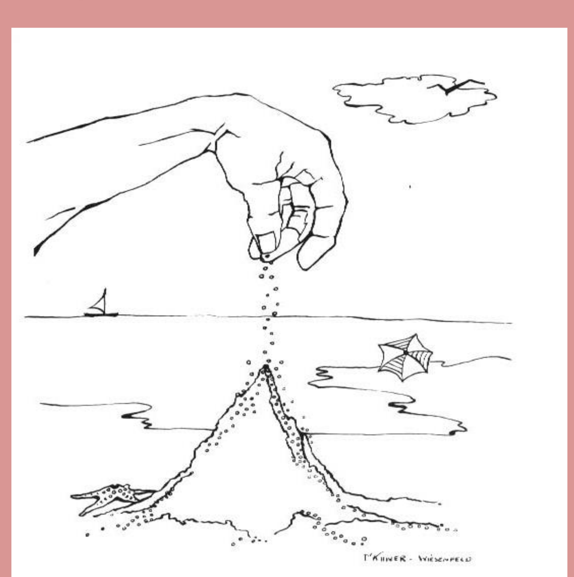


Figure 1. Physical representation of the sandpile model.

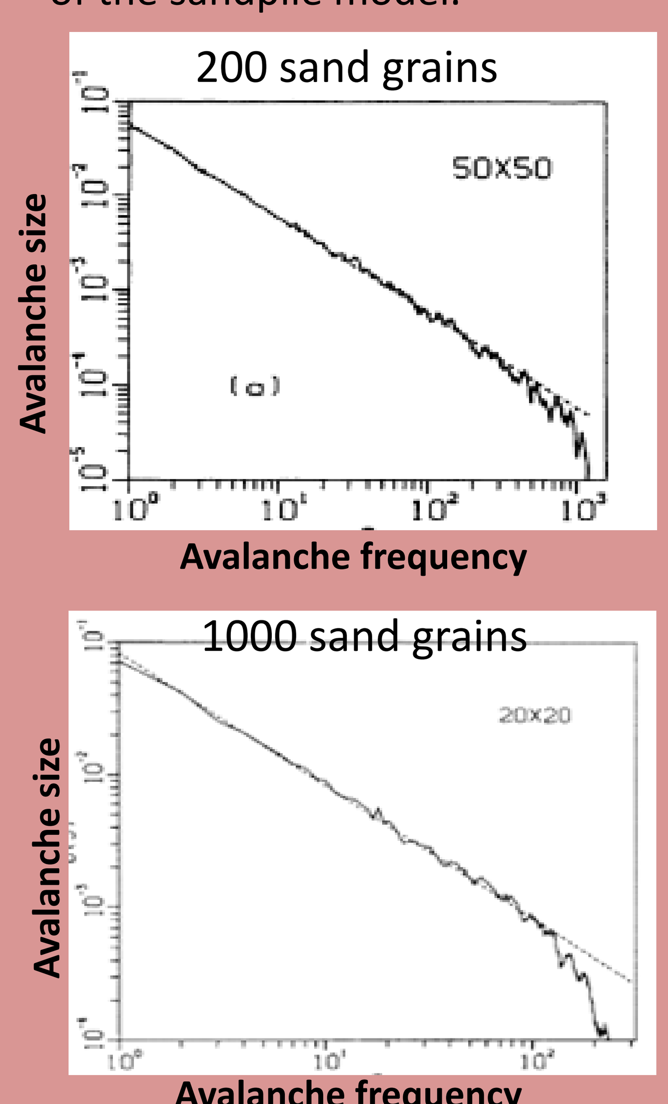


Figure 2. Power-law behavior for 200 grains and 1000 grains of sand.

Sand Pile Model:

- First model used to explore SOC
- Grains of sand are added to the pile one by one
- Eventually avalanches randomly occur
- Avalanche size and avalanche frequency shows "power-law" behavior

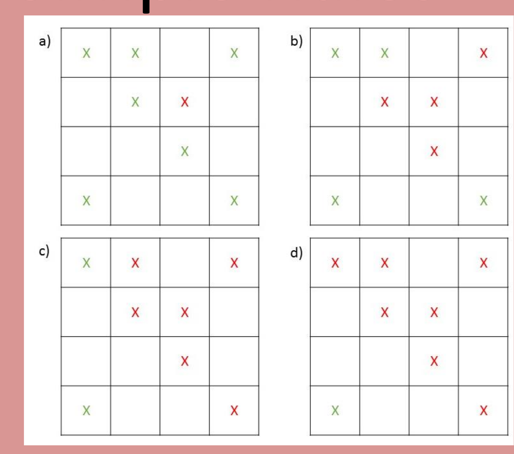
Power Law Behavior:

- Relative change in one quantity shows a proportional relative change in another
- Smaller avalanches are more frequent than larger ones
- Power-law equation: $s = \frac{1}{f^{\propto}}$
  - $\propto$ is the slope on a log-log scale

Scale Invariance:

- When changing the lattice size, the slope does not change
- 200 grains of sand and 1000 grains of sand show the same slope in their power-law relationship

Simple Rules



- Lightening strikes random tree
- Fire spreads to nearest neighbors
- Left with clusters of trees still alive

Figure 3. Small scale forest fire model.

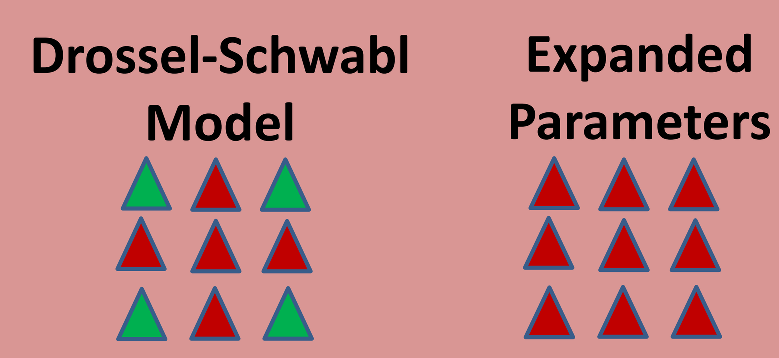


Figure 4. Representation of expanded parameters

- Drossel-Schwabl model spread to the four nearest neighbors
- Claimed that if it spread further we would see scale invariance, supporting the presence of SOC

Methods

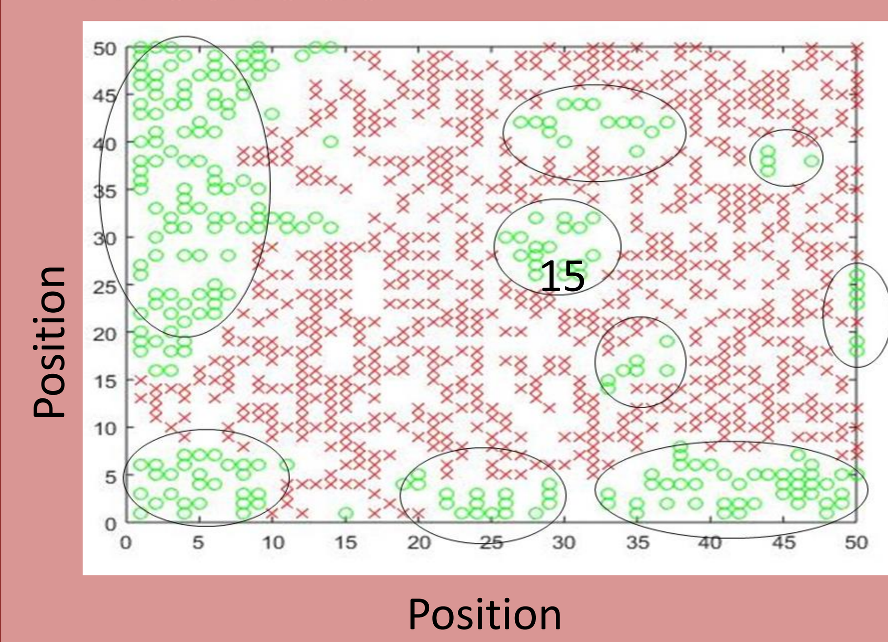


Figure 5. An example of a time-step in the forest fire simulation.

- Each circle represents a "cluster"
- Cluster Size (s) is the number of trees in a cluster
- Number of clusters R(s)
- Radius of the average number of trees R(s)

Results

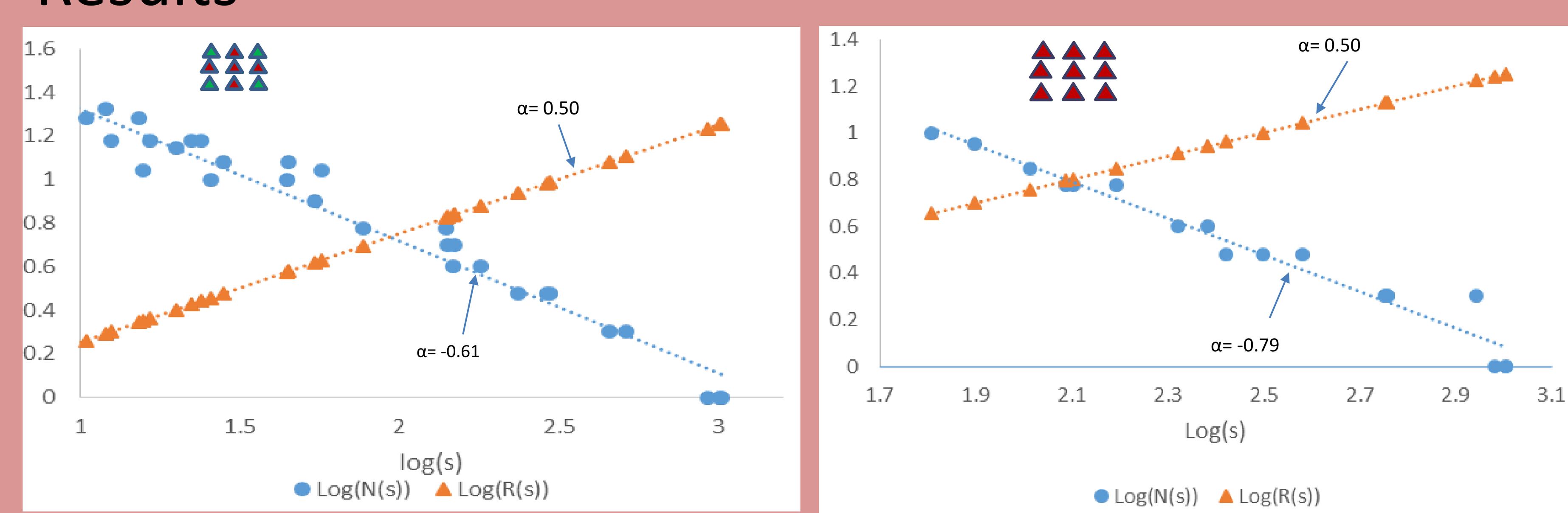


Figure 6. Number of clusters and cluster radius as a function of cluster size for the original model (Left) and the expanded parameters (right).

Analysis

- Power-law still present with the expanded parameters
- Scale Invariance was shown for R(s) because of the same slope, but not for N(s).
- In order to fully prove or disprove self organized criticality, both fires must be tested at different lattice sizes.

Future Work

- Test different lattice sizes
- Expand different parameters such as lightning frequency and forest density
- Refine counting algorithm in code

References

[1] P. Bak, C. Tang, and K. Wiesenfeld, Phys. Rev. Lett. 59, 381 (1987).
[2] B. Drossel and F. Schwabl, Phys. Rev. Lett. 69, 11 (1992).

Acknowledgements

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