Equation-free analysis of agent-based models: Fire spreading in a Forest

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1 The Model: An Overview

This model is available in the NetLogo [1] model library and simulates the spread of fire through a forest represented by a 2D lattice where the fire is started on one side of the forest [2], see Fig. 1. The model contains only one parameter, the density of trees in the forest. How far the fire spreads depends on the density, but also has a dependence on the (randomly) initialised location of the trees. Here a fire dies out rapidly in sparse forests, or burn the majority of trees in a dense forest. In this model a fire can spread in any direction in the 2D lattice, but assumes there is no wind, so a fire can only spread from one tree to another unburned tree.

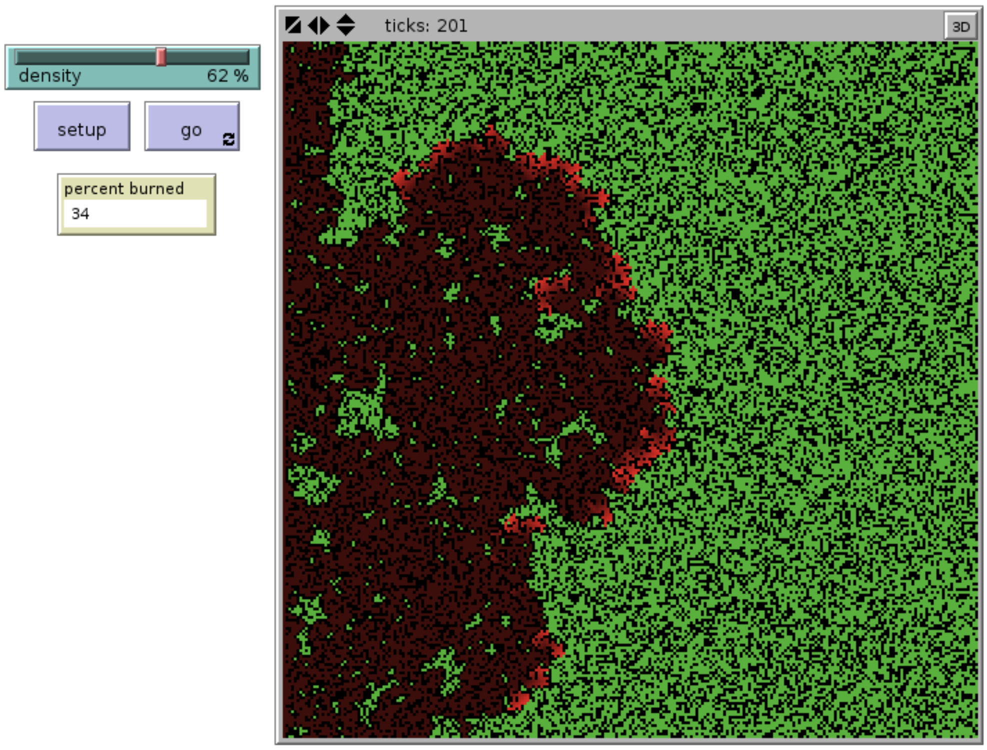

Figure 1: *NetLogo Interface for the Fire model. The only tunable parameter is forest density.*

2 The Model: Details

The density of the forest, ρ, is the only controllable parameter in this simple model. The level of noise in this model is low, however the number of trees burnt for a given forest density will vary between runs. We analyse the equilibrium state in this model between initial density ρ in the forest and the percentage of trees burnt,

$$F(\rho, \kappa^*) = \kappa^* \ , \tag{2.1}$$

where κ is the ratio of burned trees after τ and initial number of trees.

3 Requirements of the User

The user defined settings in the input file are given below.

```
String NetlogoFile = "netlogo/Fire.nlogo";
String[] systemParameters = {"set density"};
double[] param = {10.0};
String[] Measure  = {"(burned-trees / initial-trees) * 100.0"};
String[] LiftOperator = {"set density"};
double[] Initial  = {10.0};
boolean isSystemInitialised = false;
```

Here the continuation parameters is the density of trees in the forest after each ensemble has been simulated the measure of the system us the percentage of tress burned from the initial population.

4 Outcome of Equation-free Analysis

The results of the continuation are shown in Fig. **??**. This illustrates the existence of a critical parameter with a non-linear threshold, a common feature in complex systems [2]. Moreover this threshold is over a narrow range of forest density, which can be set between 0 and 100. Investigating this model by simply running simulations could easily observe a linear dependence due to a coarse interval in ρ or due to the noise in the system which is largest during the transition, see Fig.

5 Further Reading

The following table contains a reference list for further reading on the topic contained in this method and example.

Topic	Reference
Introduction to bifurcation analysis	[3]
Introduction to continuation	[4–7]
Introduction to equation-free methods	[8–10]

Acknowledgments

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References

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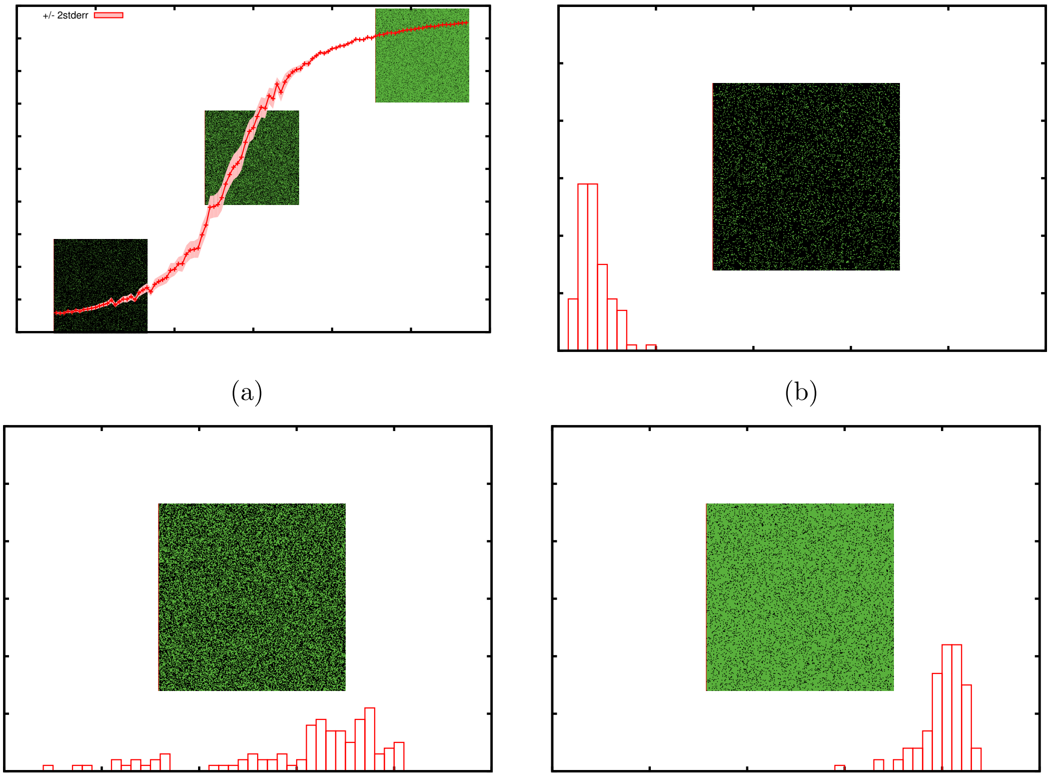

(a) (b)

(c) (d)

Figure 2: *Continuation of the NetLogo Fire model [2] with (a) parameter dependence curve and (b)-(d) distribution of realisations after simulation.*

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