



Forest Fire Model and its Self-Organized Criticality

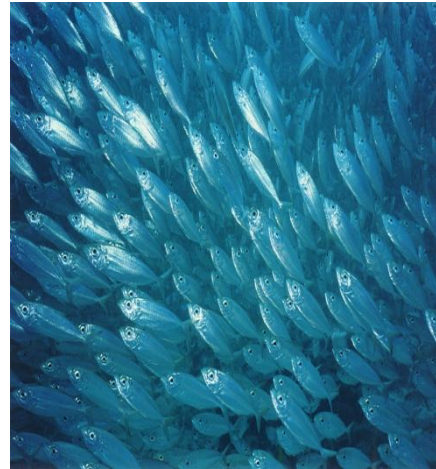
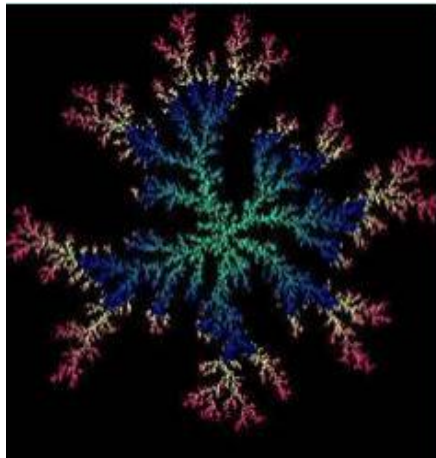
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Outline

1. Motivation
2. Introduction
3. Simulation results
4. Conclusion and Outlook

1. Motivation

Self-organized criticality can be seen in various systems:



Forest fire is one of the systems

Predict the behavior of a dynamic system (SOC)

Risk assessment and hazard protection

2. Introduction

2.1 Forest Fire Model (FFM)

Forest:

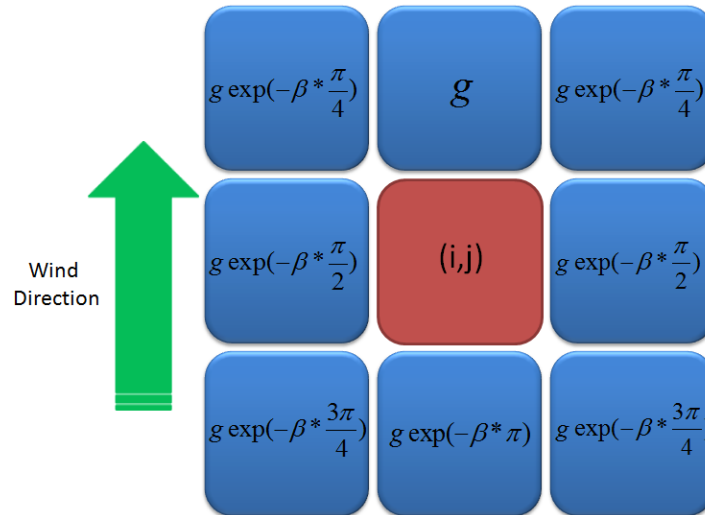
n*n grid
Empty site-0
Tree-1
Burning tree-2

Rules:

- (1) A tree can be ignited by lightening with a probability f
- (2) A burnt tree will become an empty site
- (3) A tree can grow in an empty site with a probability p
- (4) A burnt tree will cause fire in its neighboring tree with same probability g

Weather conditions:

$$P_w = P_{0w} \exp(-\beta \theta_f)$$



Parameters:

size-n
probLightening-f
probGrow-p
problgnite-g
density-d
wind- β
rain-r
step-N

2. Introduction

2.2 Self-Organized Criticality (SOC)

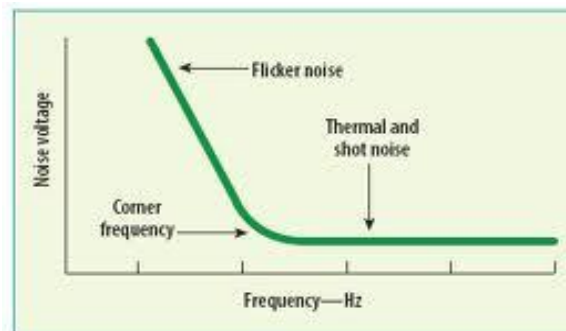
Definition:

A dynamic system can evolve into a **non-equilibrium steady state** **without tuning its parameters.**

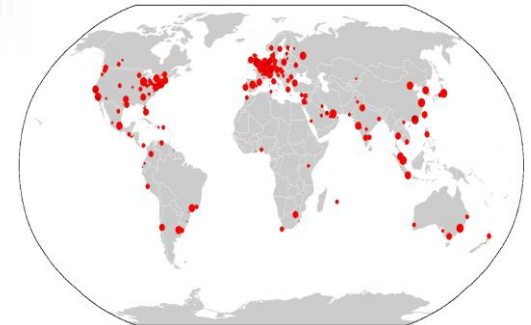
Properties:

- i) Long scale temporal fluctuations
- ii) Size-frequency distribution satisfies power-law
- iii) Flicker noise

$$\sim 1 / f^{\alpha}$$



Flicker noise is low-level semiconductor device noise that increases as a function of inverse carrier frequency, or $1/f$.



3. Simulation Results

3.1 Evolution of forest fire

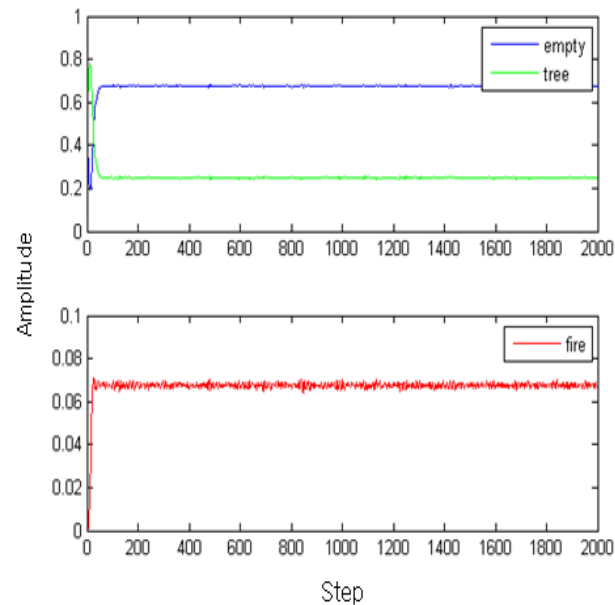
video

3. Simulation Results

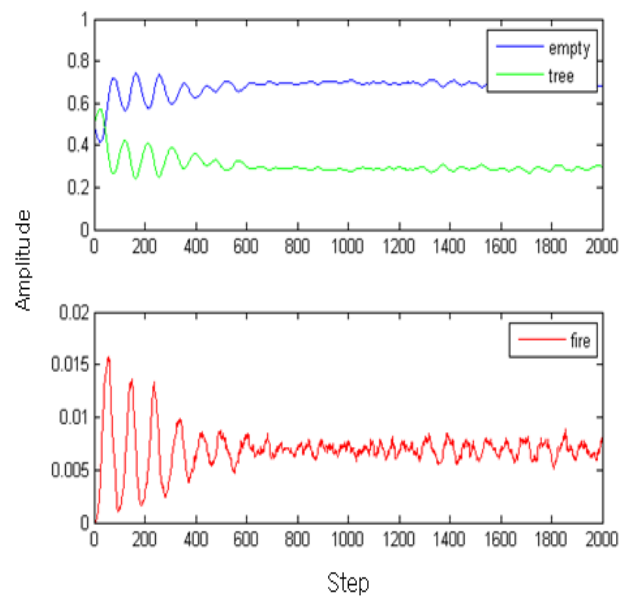
Reminder:
size-n
probLightening-f
probGrow-p
problgnite-g
density-d
wind- β
rain-r
step-N

3.2 The regime of SOC

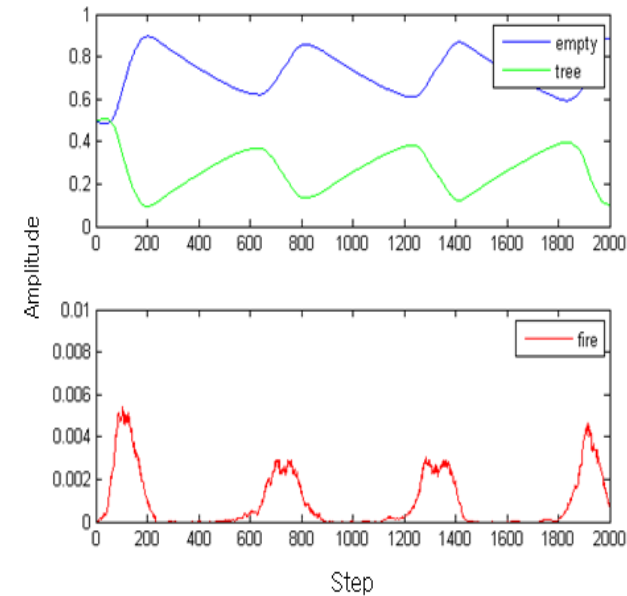
i) Keep $p/f = 10^3$, $n=500$, $d=0.5$, $g=1$, change p



$p=0.05$



$p=10^{-2}$



$p=10^{-3}$

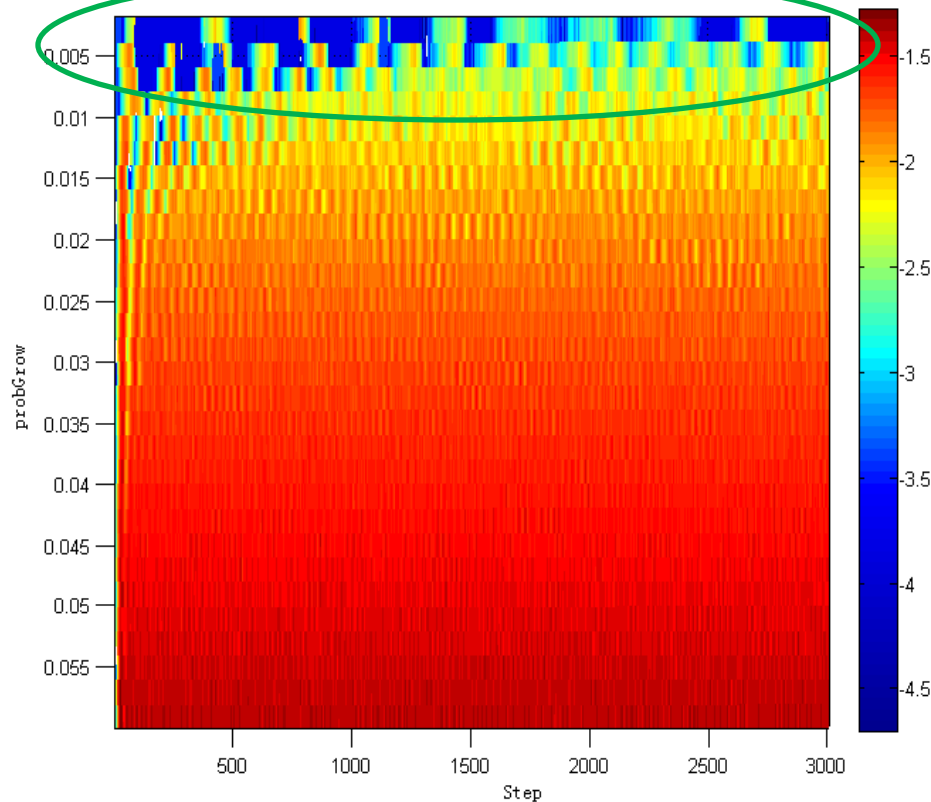
3. Simulation Results

Reminder:
size-n
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problgnite-g
density-d
wind- β
rain-r
step-N

3.2 The regime of SOC

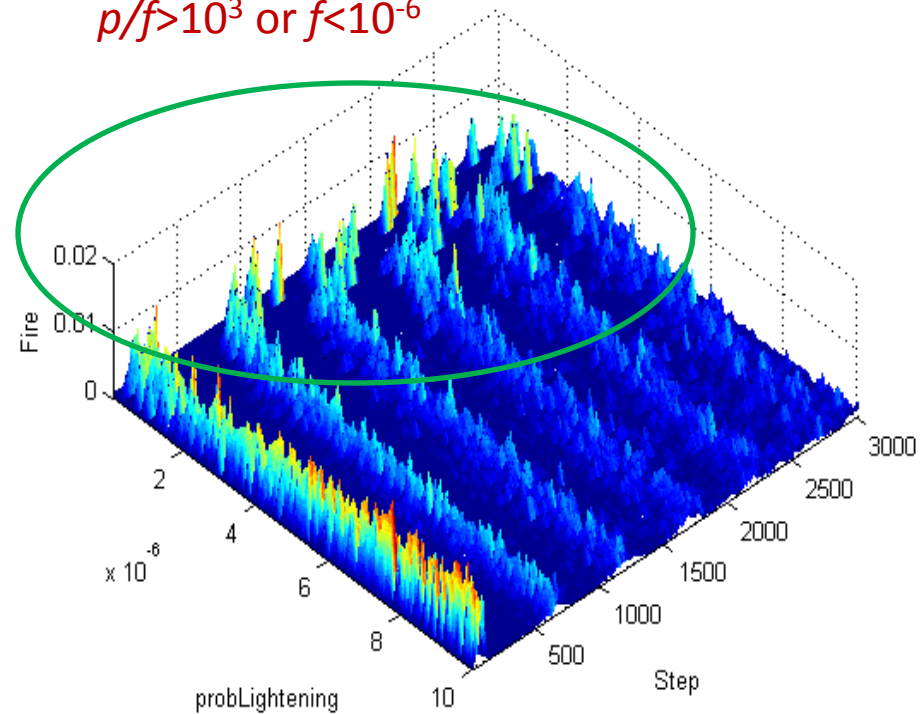
ii) Keep $p/f = 10^3$, $n=300$, $d=0.5$, $g=1$, scan p

$p < 0.01$



iii) Keep $p=0.001$, $n=300$, $d=0.5$, $g=1$, scan p/f

$p/f > 10^3$ or $f < 10^{-6}$



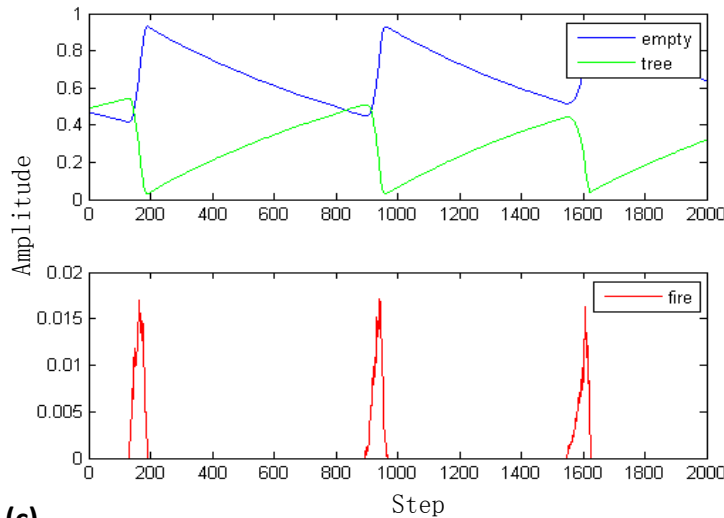
3. Simulation Results

Reminder:
 size-n
 probLightening-f
 probGrow-p
 probIgnite-g
 density-d
 wind- β
 rain-r
 step-N

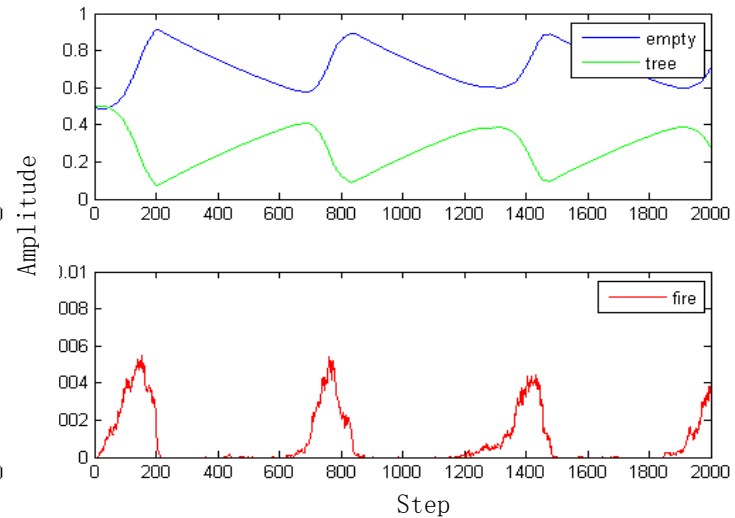
3.3 Effect of forest size

Keep $p = 10^{-3}$, $f = 10^{-6}$, $n = 500$, $d = 0.5$, $g = 1$, change n

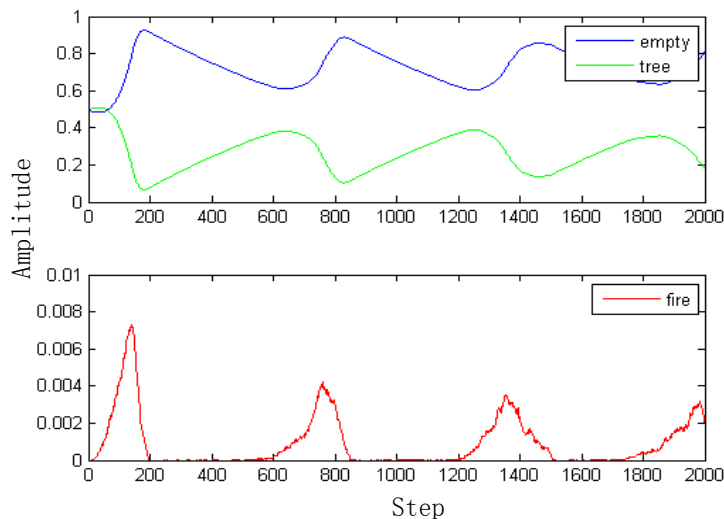
(a)



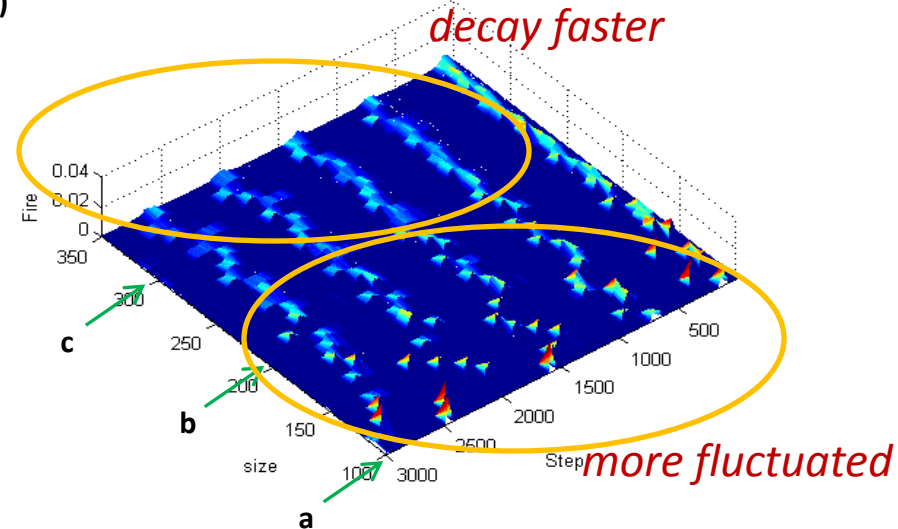
(b)



(c)



(d)



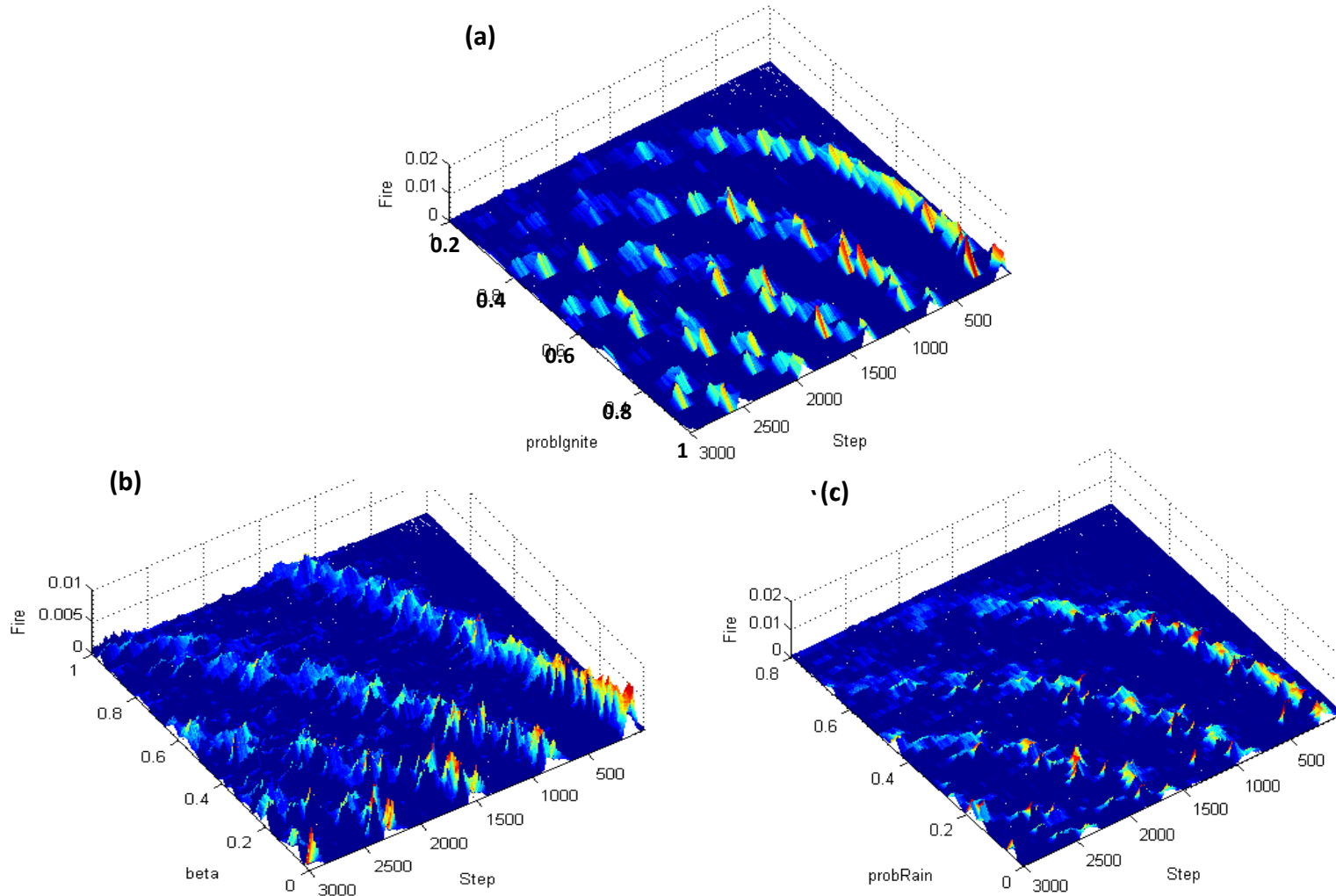
3. Simulation Results

Reminder:

size-n
probLightening-f
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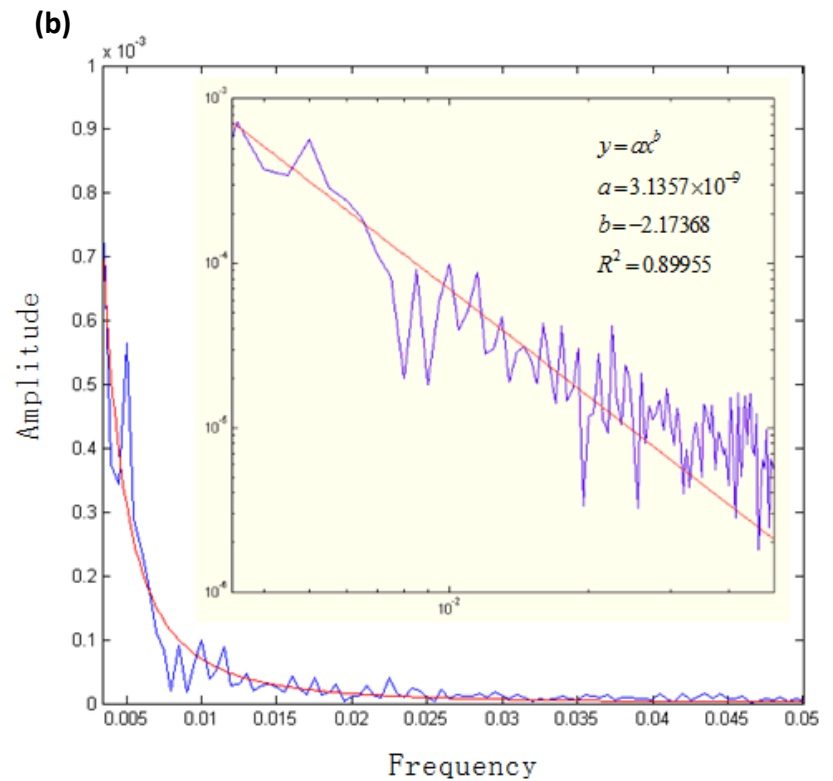
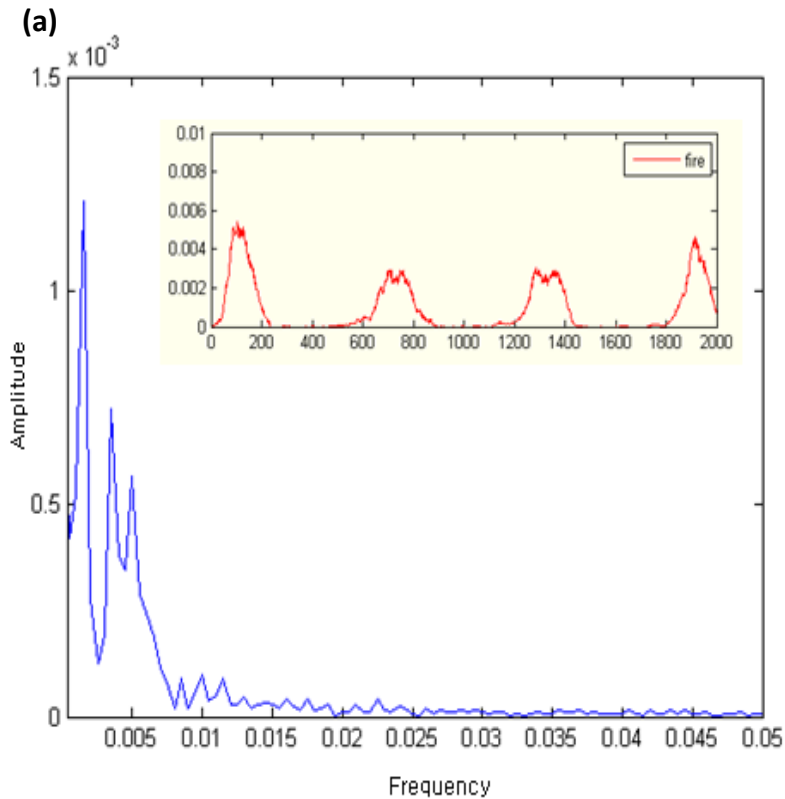
3.4 Scan other parameters

Keep $p = 10^{-3}$, $f = 10^{-6}$, $d = 0.5$, $n = 300$, scan g , β , r



3. Simulation Results

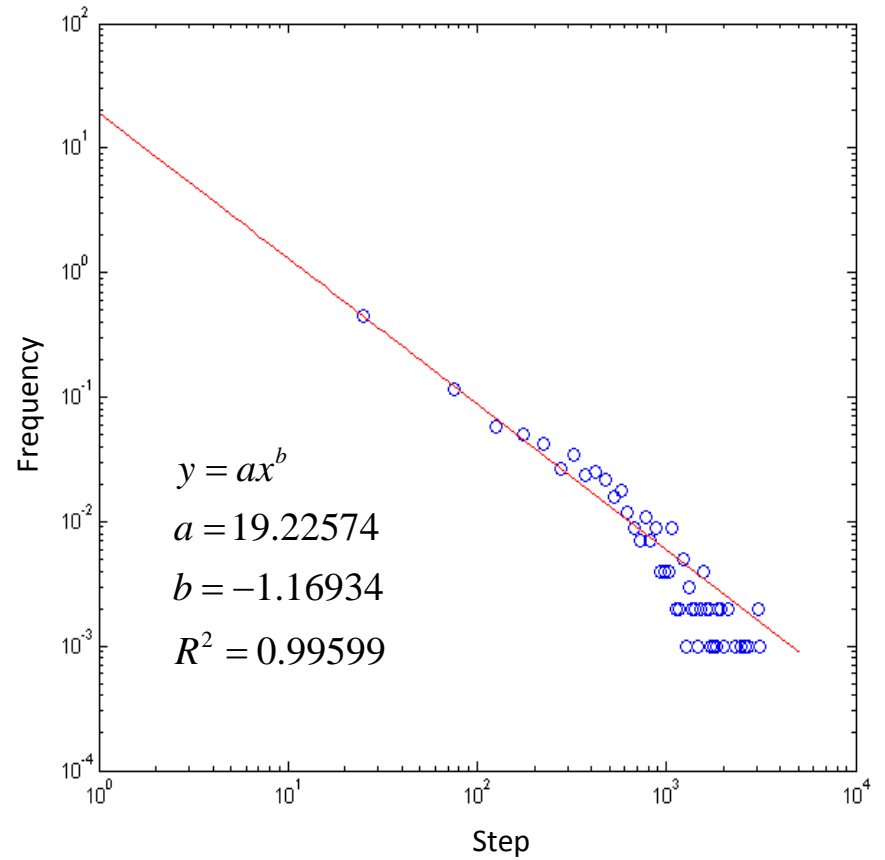
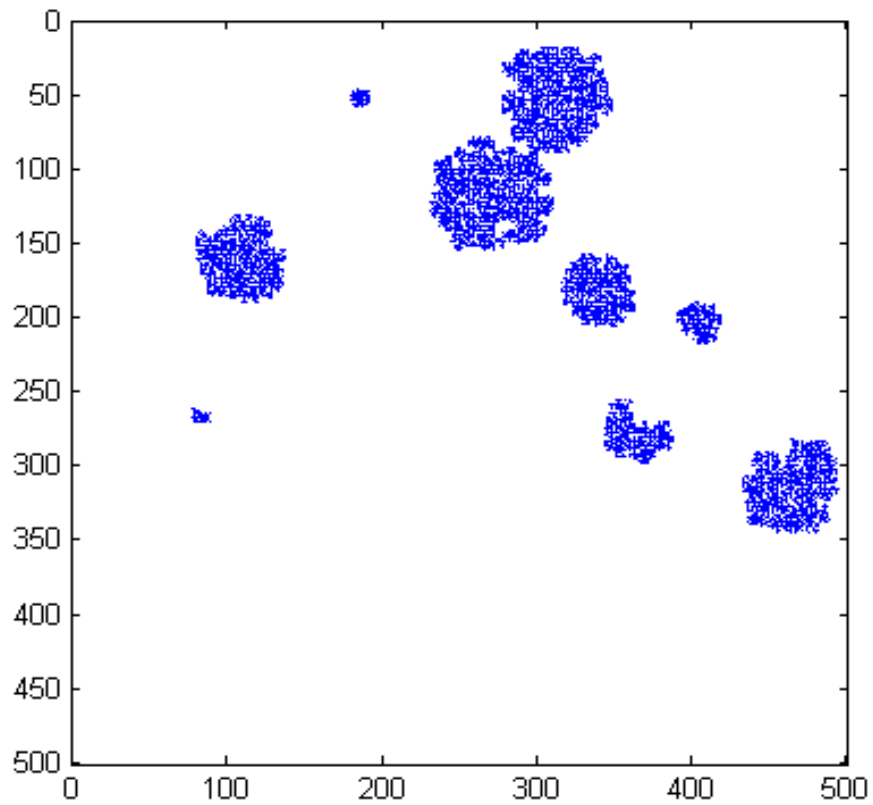
3.5 Flicker noise



Noise spectrum $\sim f^{-2}$

3. Simulation Results

3.6 Size-frequency distribution



4. Conclusion & Outlook

In this project:

- 1) We build a FFM based on CA
- 2) We scan different parameters to characterize our FFM
- 3) We observe the long scale temporal fluctuations of SOC states
- 4) We observe the 'flicker noise' in the noise spectrum
- 5) We show size-frequency distribution of fire clusters in our FFM satisfies the power-law

More things in the future:

Study larger forest within longer time scale

Consider more factors: landscape, species of tree

Scan power spectrum with different parameters

Understand the physical background behind the 'flicker noise' and the power-law distribution

Take-home message:

- 1) SOC='self-organized' +' critical'
- 2) SOC can be found everywhere. FFM is one of the systems.
- 3) 3 main properties of SOC

Thanks for listening!