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# The SOC in cells' living expectations of Conway's Game of Life and its extended version

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ABSTRACT

In self-organized systems such as Conway's Game of Life (CGL). Wikipedia, Conway's game of the life, https://en.wikipedia.org/wiki/Conway%27s_Game_of_Life., though whether the single cell will survive or die seems unpredictable, the log–log distribution of all cells living frequency satisfies the 1/f linear law, thus meets the Self-organized Criticality(SOC) rule, which not only proves that CGL is a self-organized system, but more significantly, that the chance of living for each cell is spatial heterogeneous, and is statistical fractal.

After carried out CGL, the specified iterative period which begins with a random initial condition and ends when it reaches the homeostasis, add up all the states which the living cells are marked by 1s, and the dead are marked by 0s. The resulted sum picture consisting of cells having its gray level representing the living times during the iterative process. By plotting the gray level distribution of the sum picture on log–log scale, the graph indicates the spatial living expectations distributions. Then we find the curve of the graph satisfies the Self-organized Criticality(SOC) rule, showing its linear feature in the intermediate zone, which also has name of 1/f feature.

To examine its universality, we designed a more complicated self-organized cellular automata with each cell having five possible states thus the rule table becomes more complicated. As expected, the consequence shows the similar feature, and the linear feature is even more obvious when the similar experiments are carried out.

To conclude, it is a new discovery of SOC from a new perspective. And with the self-organized systems expanding to other different rule tables, this feature may still be satisfied.

More further, considering the natural self-organized systems of living creatures, the spatial living expectations of different phenotypes may satisfy the 1/f law, too. Though we regard this as an inspirational orientation, the supposition needs more designed experiments to prove.



## 1. Introduction

Since the SOC concept was raised by Per Bak, Chao Tang and Kurt Wiesenfeld(BTW) in 1987 [2], lots of studies have been done in numerate fields, which can be mainly divided into parts of biology, physics, and society. In the SOC most related field, biology, the rule has been found in the dynamics of brain functional networks [3], and more specular study has been carried out of human brain network synchronization [4], which can be viewed as arising from the complex neural system. In physics, a

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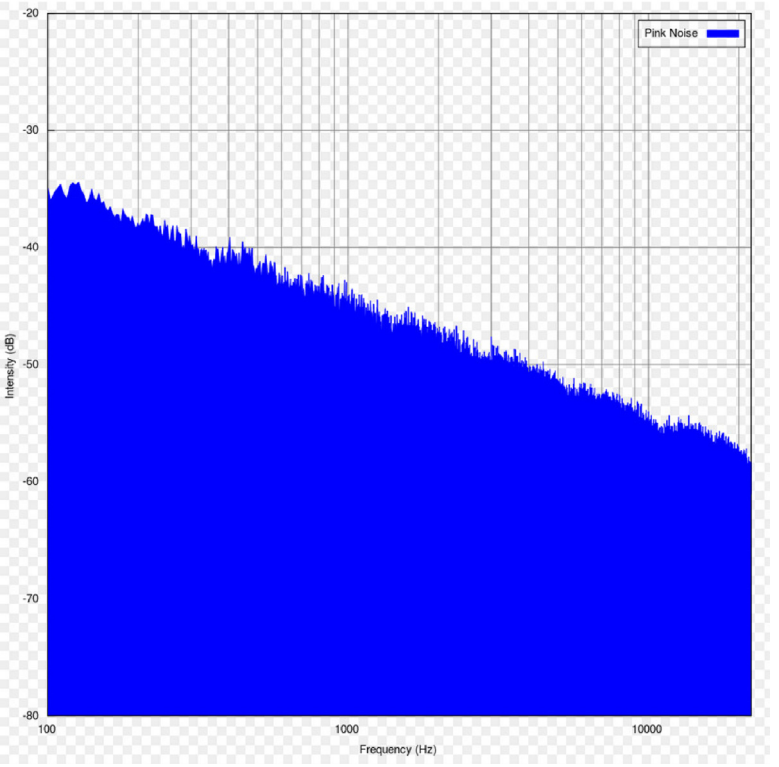


**Fig. 1.** Pink noise spectrum by Warrakkk on Wikipedia-Pink noise. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

research shows that the plastic deformation of ductile metallic glasses can evolve into a self-organized critical state characterized by the power-law distribution of shear avalanches [5]. As for social behaviors, the development of urban systems has long been described as self-organized, the statistical evidence can also be found [6].

Because the feature is statistical, and the scale of events can be specified in different situation, its application can be so widespread. So we think that as a self-organization system, CGL may have other undiscovered SOC features.

According to BTWs sand pile model, during the process which begins with disturbances on the self-organization system and ends when it comes back to the homeostasis, the events frequency distribution on Log–log scale should satisfies the 1/f power law [1]. On the basis of this definition, we designed the experiments showed in this paper and find that cells' living times of each possible state satisfy the 1/f power law, thus satisfy the SOC.

In CGL and its extended version in which each cell has five possible states, the features are similar, no matter what the initial condition. It can be considered a new discovery of SOC in CGL, and may be generalized to other cellular automata or natural systems.

## 2. Background

Before SOC was raised by BTW, the scale-invariant behavior has been noticed, and the 1/f power law has been found in earthquakes much like Gutenberg–Richter law [7]. Then SOC connects these behaviors to the self-organized systems, make many people focus their research on the self-organized systems and the relationship between self-organization and natural phenomena.

The concept of 1/f power law we refer here comes from the 1/f noise, or pink noise. 1/f noise is a signal or process with a frequency spectrum such that the power spectral density is inversely proportional to the frequency of the signal [8]. Its spectrum approximation on a log–log plot can be linear, like it shows in Fig. 1 [9].

## 3. The frequency distribution of Conway's Game of Life

### 3.1. Experiment design

We choose MATLAB to carry out the experiments. The steps and the specifications of the experiment procedure are as follows:

A. The size is 128*128. Each cell has two possible states, live or dead. The initial condition is generated randomly. And the neighborhood type is the Moore neighborhood, which includes eight adjacent cells.
B. The rule table is CGL's.
C. The iterative process begins with random initial condition and ends when it reaches the homeostasis. Because the periods of all possible circulation of local graphs are two or three, so the judgment condition is whether the current state is the same as the state two or three iterative times before.