UNIVERSITEIT VAN AMSTERDAM

SOC of Financial Dynamics with Bak-Sneppen Model

Group 8

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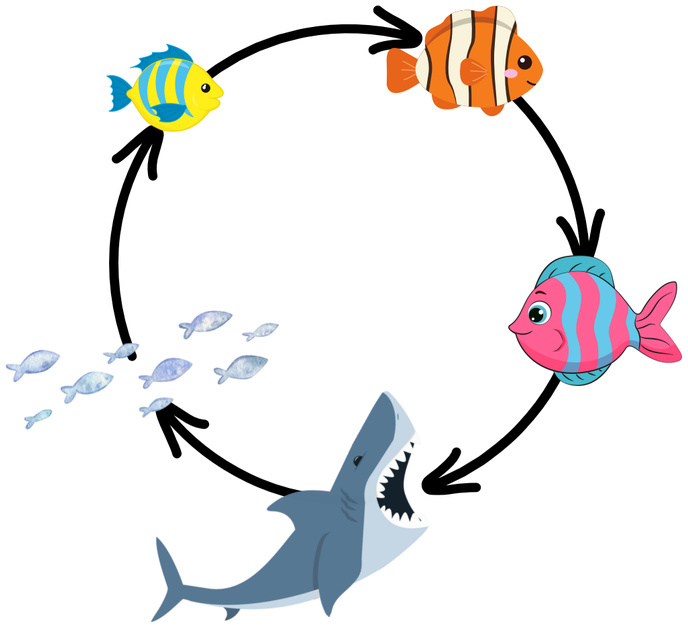
01.

INTRODUCTION

Motivation
Hypothesis

Introduction



Motivation： The financial market ecosystem resembles a biological world, where market can be potentially influenced by the fluctuation of participants.

- The Bak-Sneppen model -- a simple model of co-evolution between interacting species.
- Study the contagion effects in financial markets, how the dynamics of participant propagate among the market, potentially leading to significant systemic shifts.

Research question

-- How does the 2D Bak-Sneppen model, focusing on its self-organized criticality, quantitatively describe the dynamics of financial markets, specifically in terms of scale invariance?

Hypothesis

- **Hypothesis 1:**
  Market disruptions are scale invariant and follow a power law distribution with the Bak-sneppen model.

- **Hypothesis 2:**
  The system is robust by introducing small perturbations (random events) and showing that the system behavior remains scale-invariant.

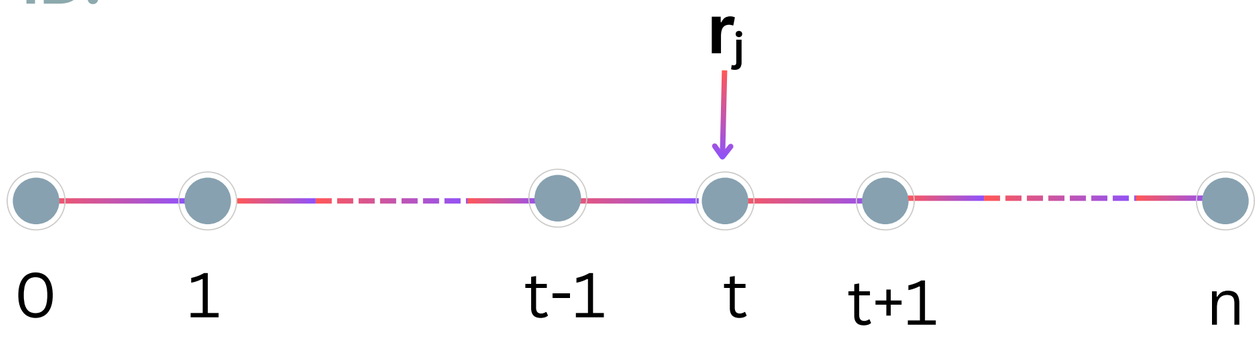
02.

METHOD

The Lattice Geometry
The Bak-Sneppen Model
Avalanche

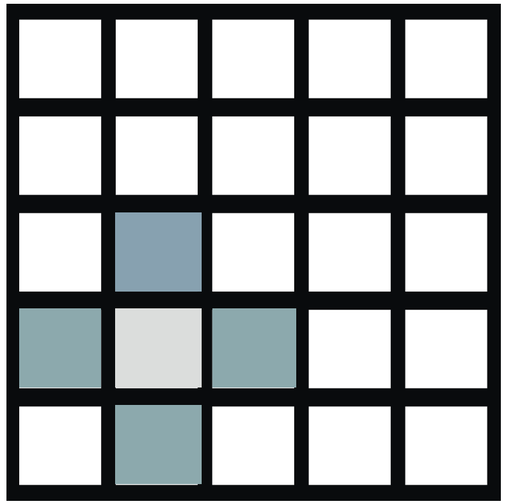
The Lattice Geometry

1D:



- select periodic boundary conditions with period n + 1, such that $r_{n+1} = r_0$ and $r_{-1} = r_n$.
- discretized time t = 0...n ➡ every trading day
- fitness value rj ➡ stock price/company profit performance

2D:



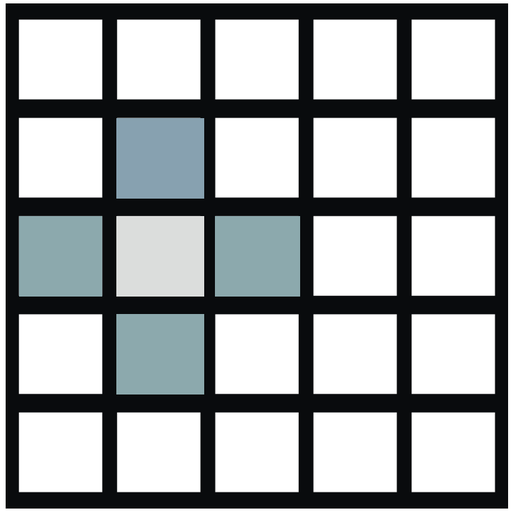
- In two-dimensional grid, each grid g_{ij} can represent the market participant/one company in the market.
- Each participant has a "fitness" value, r_{ij} ➡ performance or health in the market.
- Initial values are distributed follow a uniform distribution: $r_{ij}^0 \sim U(low,high)$

The Plan

- To give the grid some dynamic behavior, draw inspiration from the well-known evolutionary model.
- Create a computer simulation for a returns field that exhibits self-organized criticality (SOC).

Bak-Sneppen Algorithm:

- Find the (least adopted) worst r_{ij} ;
- Update r_{ij} and neighbors $r_{i\pm1,\, j\pm1}$ with random number ~ U(0,1);
- Leads to a self-organized critical system, observes dynamics for avalanche.



Avalanche

Definition -- a series of cascading updates happened when the value of an element of the grid below specific adaptive threshold. If an update is triggered, the avalanche length is added by one until no more elements fall below the fitness threshold

Eg. a rapid, large-scale sell-off event triggered by a disturbance that cascades through the market, affecting a significant number of stocks, sectors, or even the entire market.

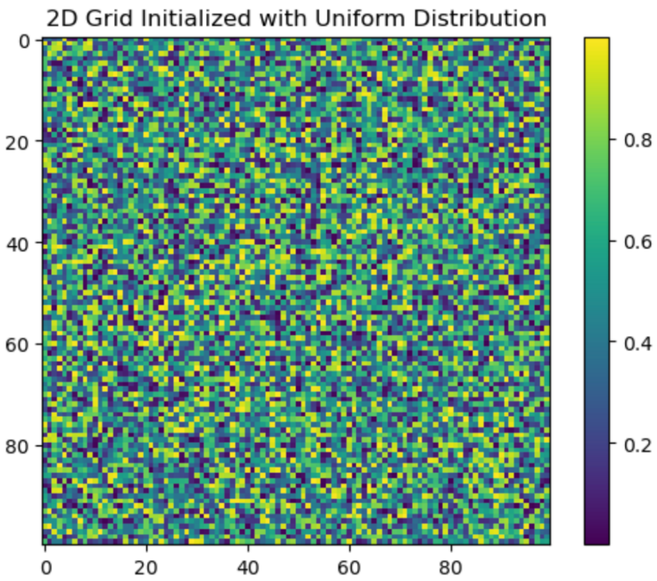
- **Happen**
- **Propagation**
- **Avalanche Size**

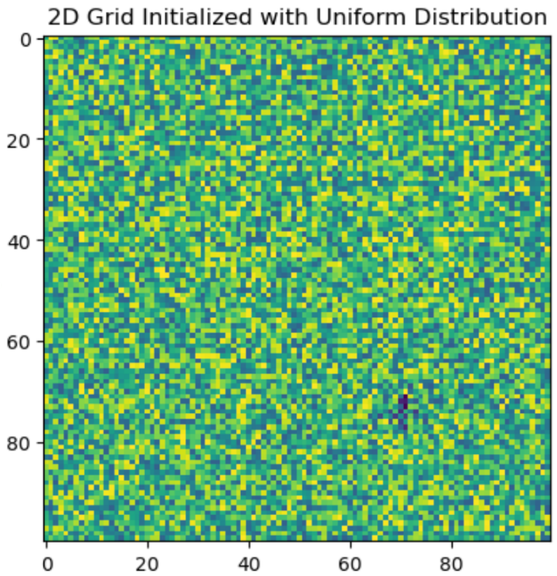
03.

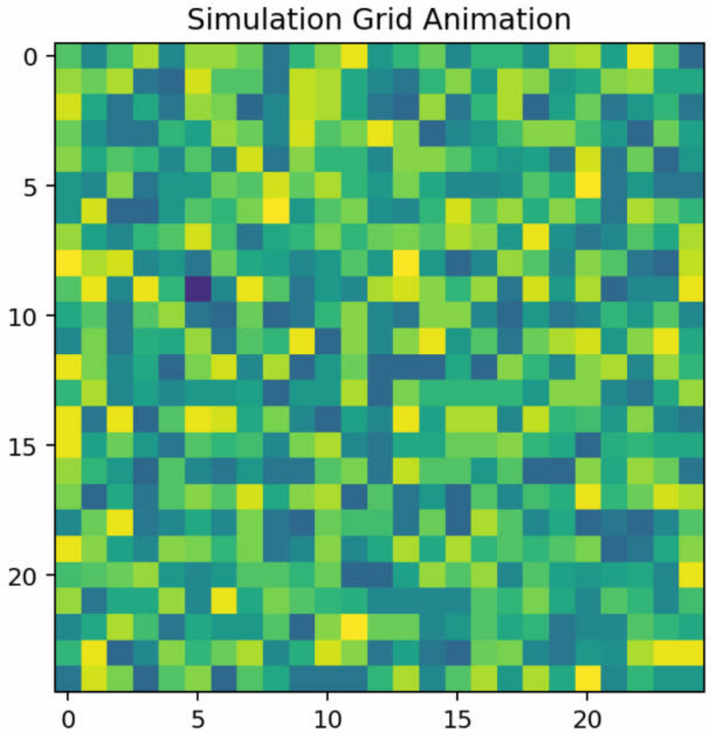
SIMULATION & RESULT

Simulation

Initialization → Find minimum fitness value grid → Update fitness value (itself and its neighbor) → Avalanche



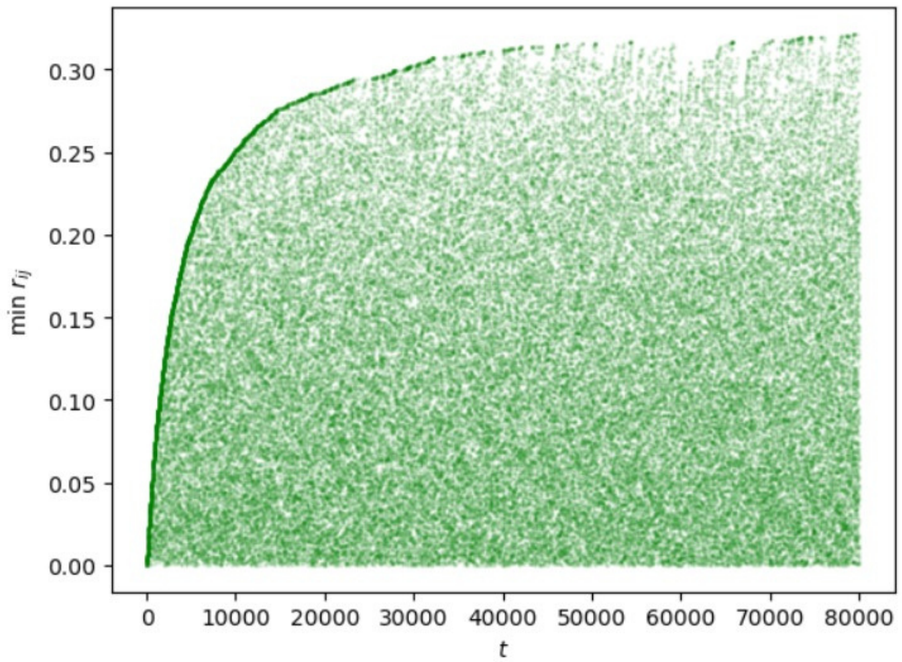




Result

Initialization → Find minimum fitness value grid → Update fitness value (itself and its neighbor) → Avalanche

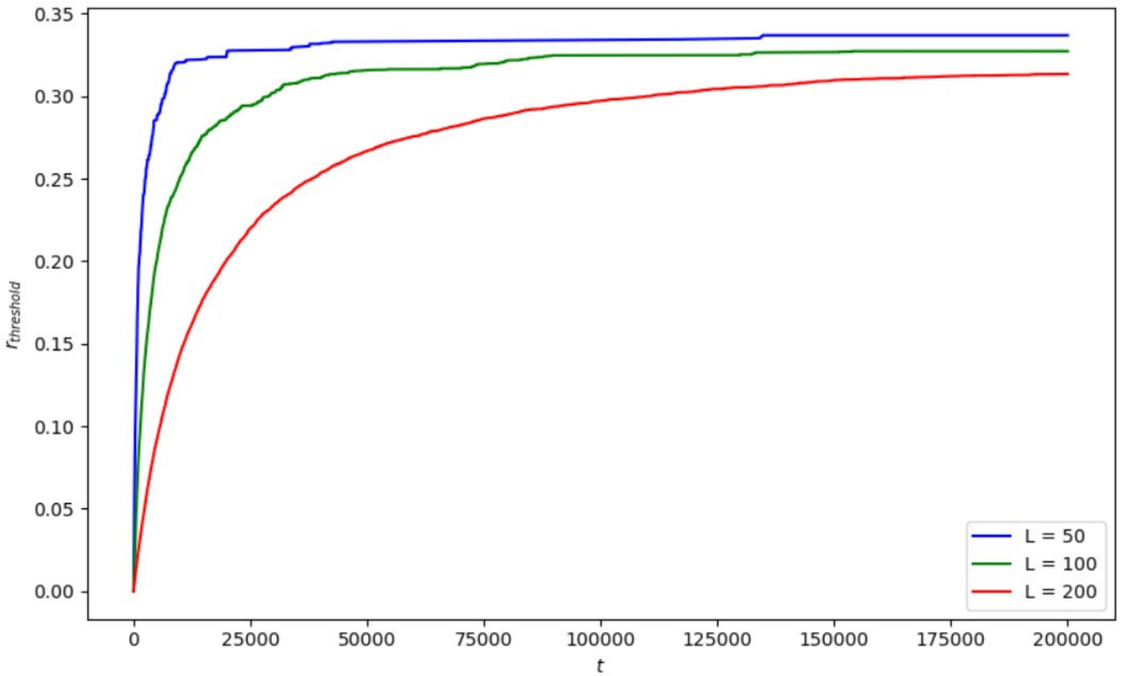
Scatter plot of lowest fitness value



Fitness Values

- Increase rapidly at first
- Reach a relatively stable state

Convergence for grid size L

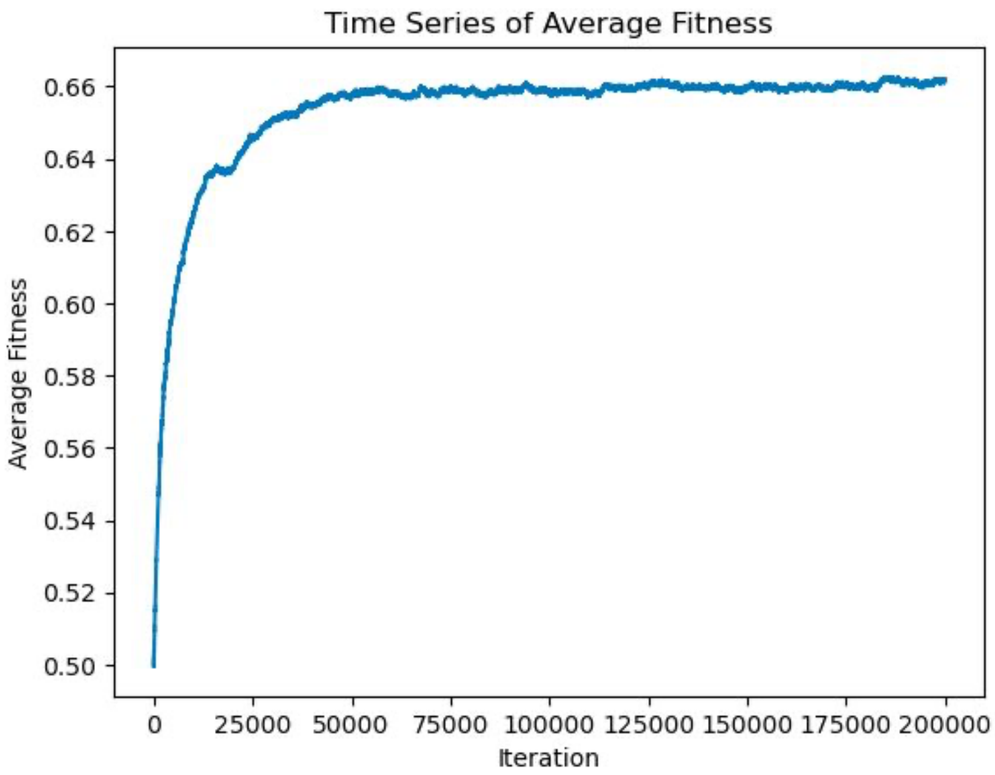


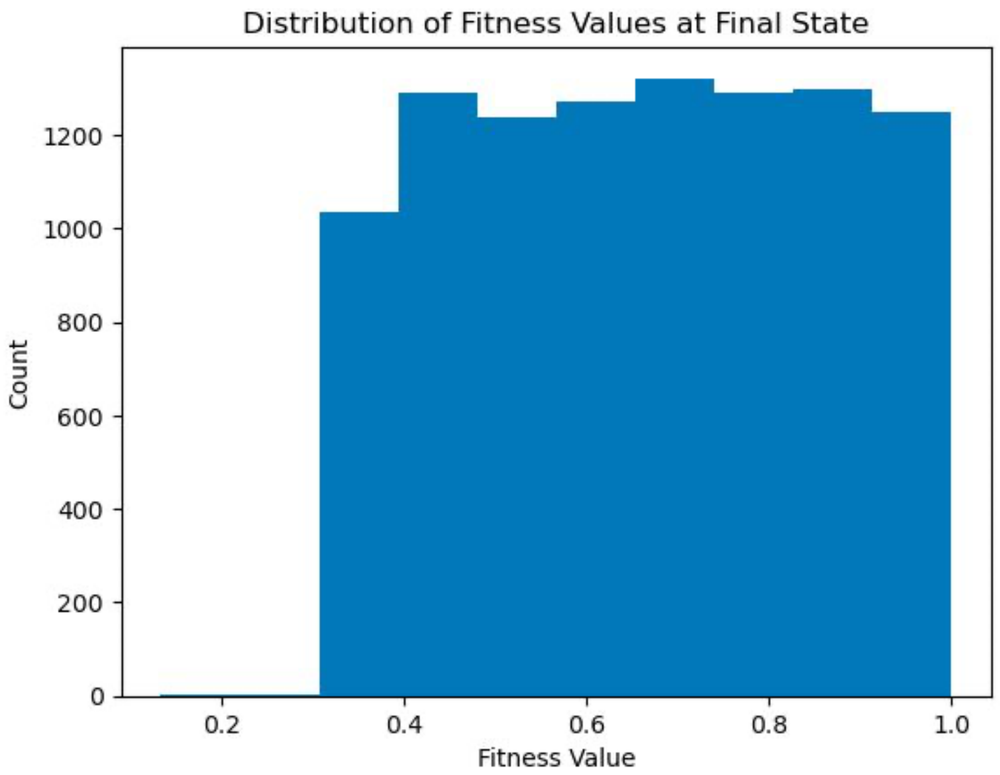
Convergence for grid size L

- Smaller size of grids – faster to convergence
- All turns to SOC

Result

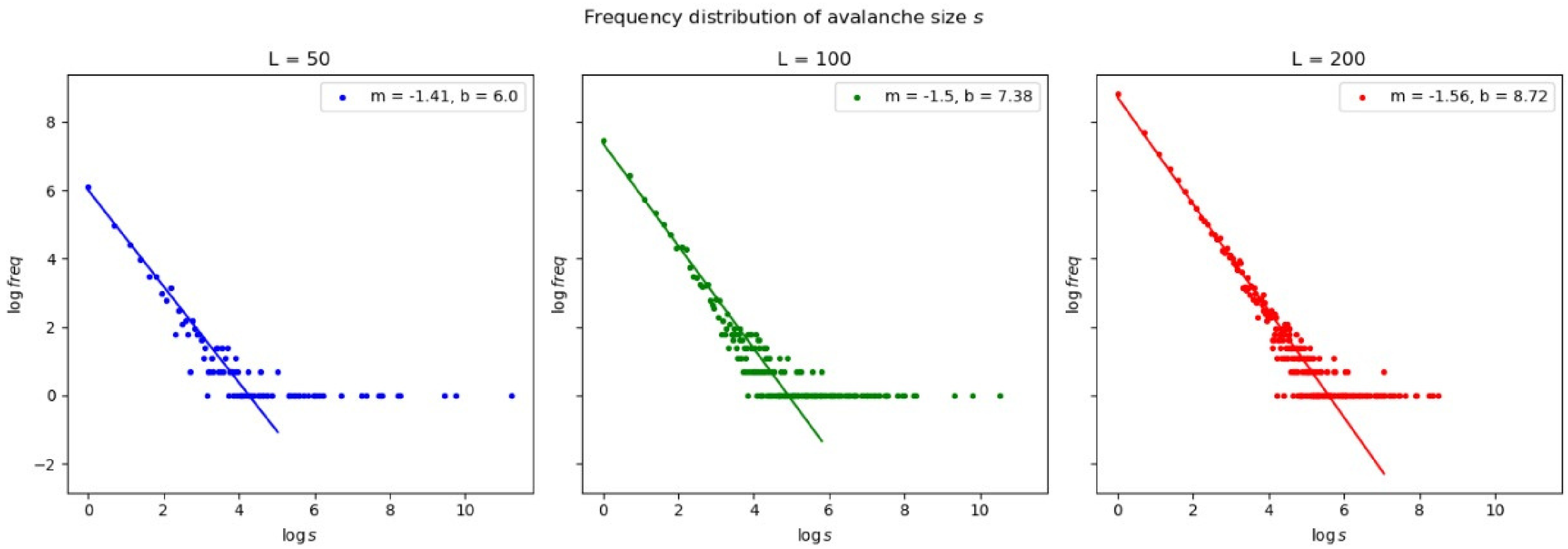
Initialization → Find minimum fitness value grid → Update fitness value (itself and its neighbor) → Avalanche





Result

Initialization → Find minimum fitness value grid → Update fitness value (itself and its neighbor) → Avalanche



log-log

04.

INNOVATION

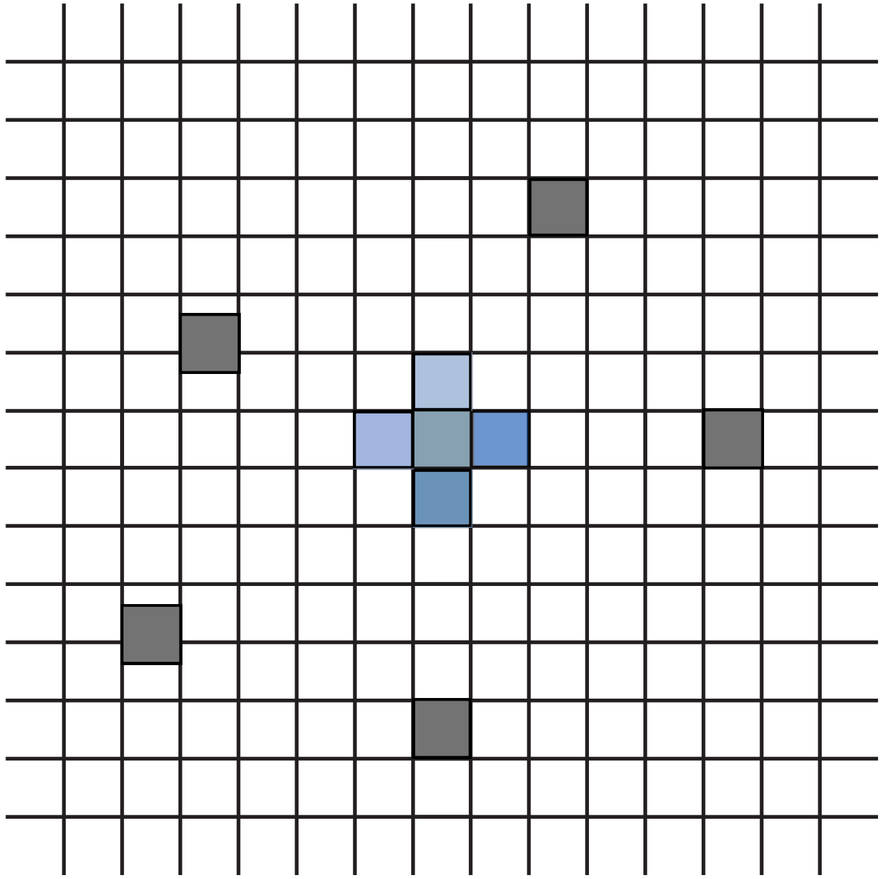
Innovation and Result Analysis

Innovation I

-What would happen to market if there are insider tradings?

Add random events in the model:

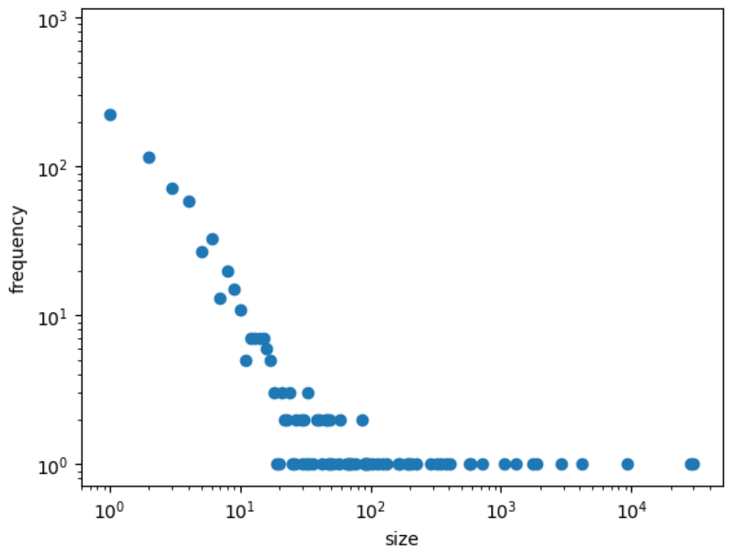
1. In a random timestep: On average, every λ timestep there is one insider trading – followed by Exponential distribution
2. Update the minimum fitness value grid and its 4 neighbors as we did before (basic model)
3. <u>Inside info:</u> choose a random number ~ (10,20) of random grids
4. Update their fitness value (with random noises)

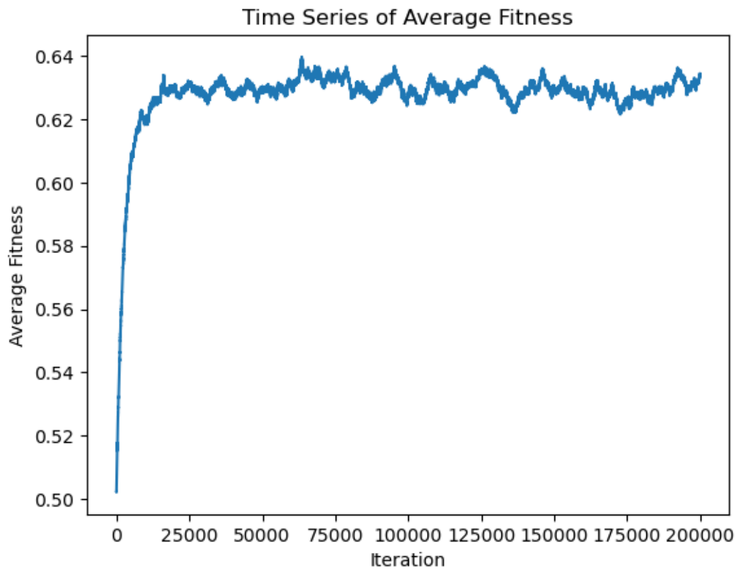


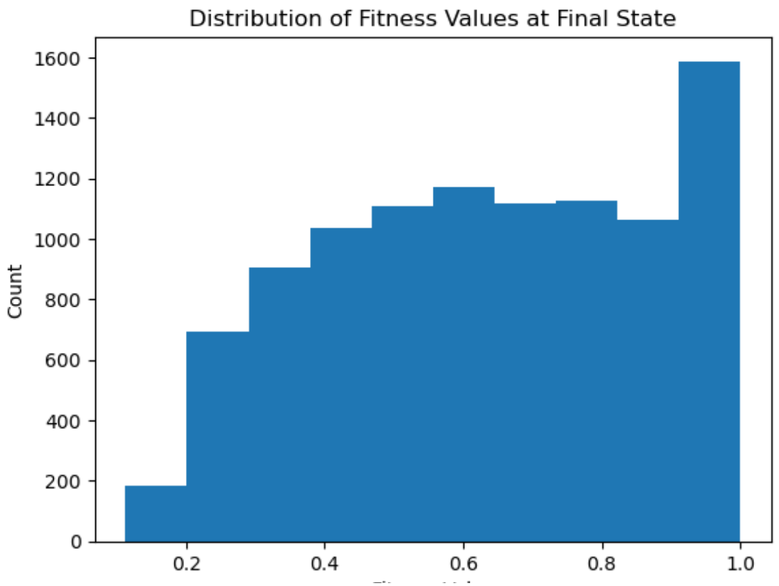
one certain timestep

Innovation I Result

λ = 0.5, noises strengh = 0.2







Avalanches frequency

- Efficiency and stability

Convergence

- Subtle fluctuation

Distribution

- Changes in market structure

Innovation II

-- Is it a risk or an opportunity to the neighbour?

Add weight of the neighbors

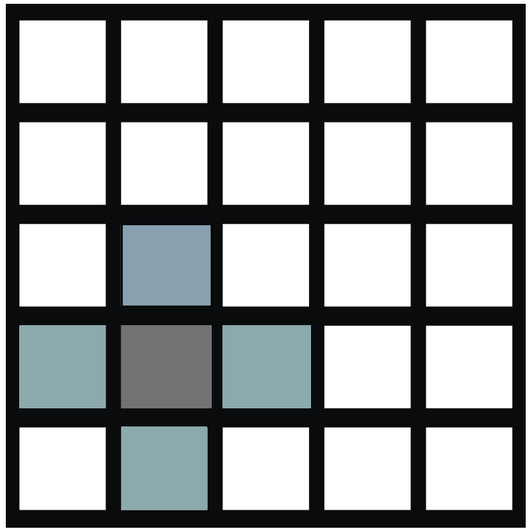
Change update rule:

- Find the minimum value grid and its 4 neighbor
- Update Value Procedure:

1. Central grid: randomly sample from U (0,1)
2. Update 4 neighbors with weight function:
   with weight w ~ U (0,1), direction d, tendency bias coefficient k

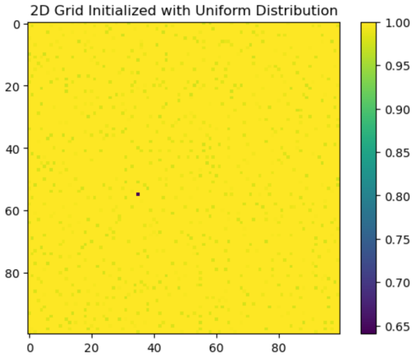
Initial value + w × Initial value × d

where: $d \begin{cases} 1, \text{ if } rand() < (0.5-k); \\ -1, \text{ otherwise} \end{cases}$ $k \sim (-0.5, 0.5, 10)$



Innovation II Result

biased result



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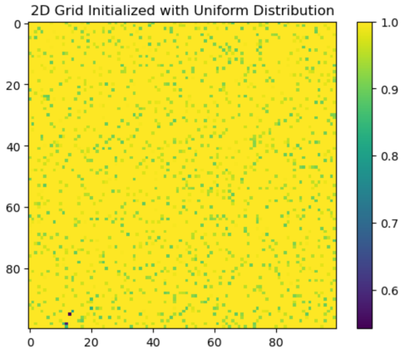

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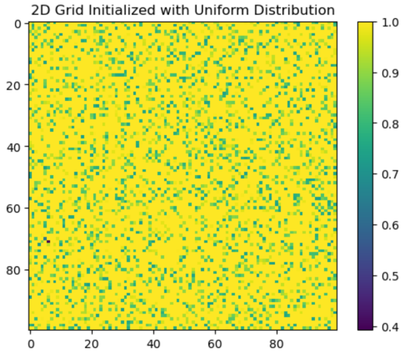

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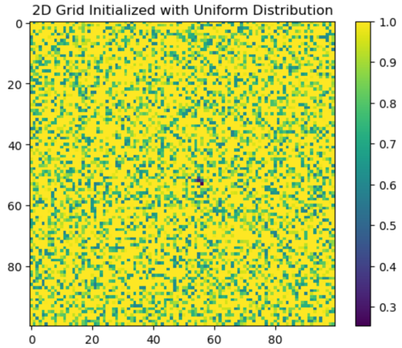

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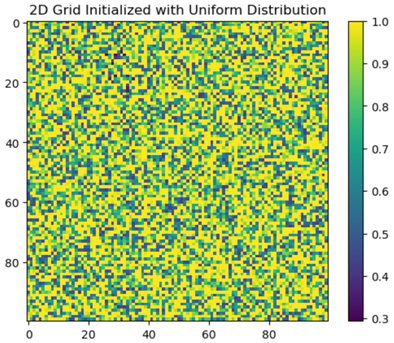

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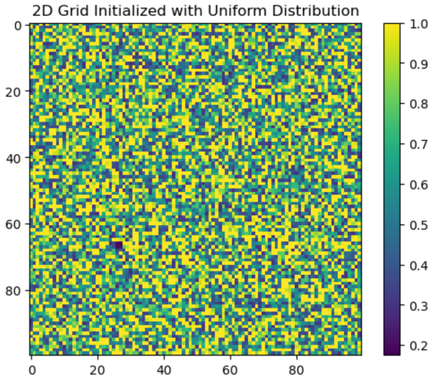

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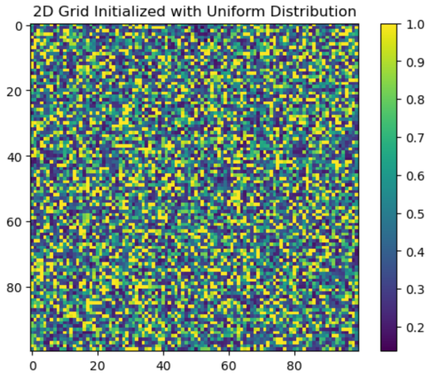

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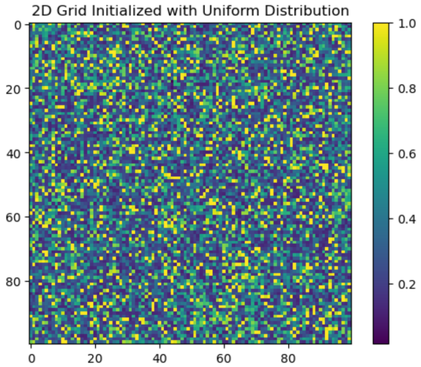

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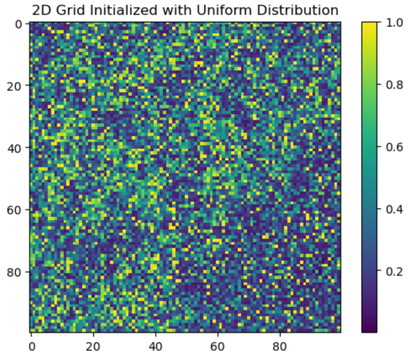

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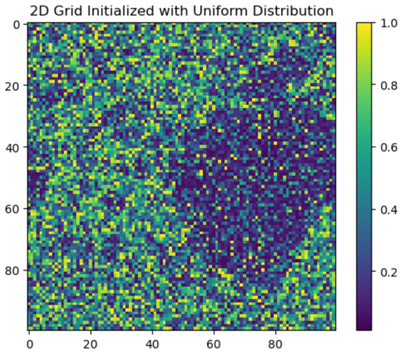

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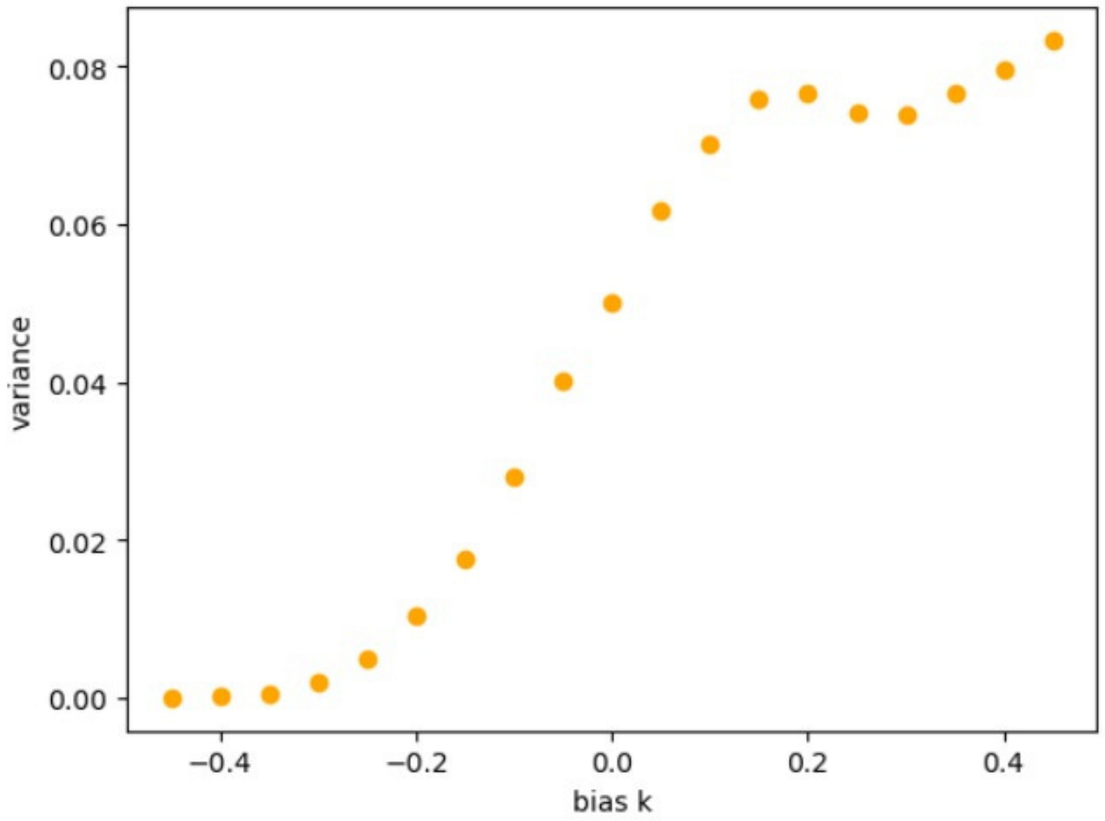
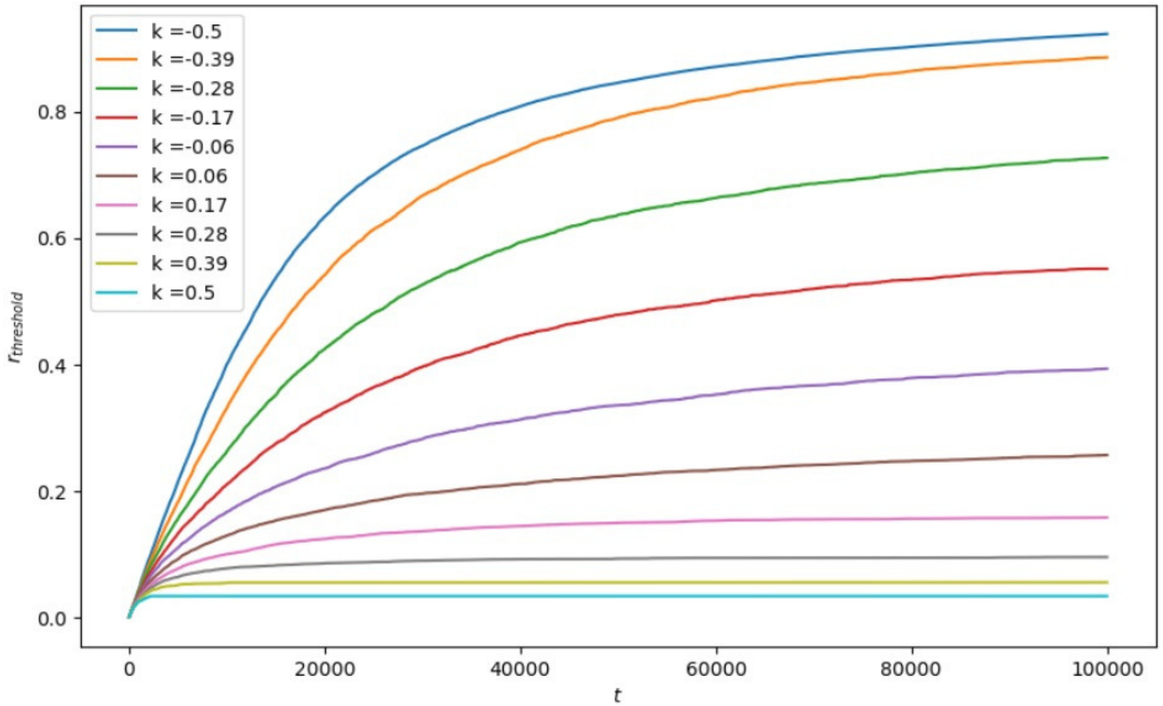
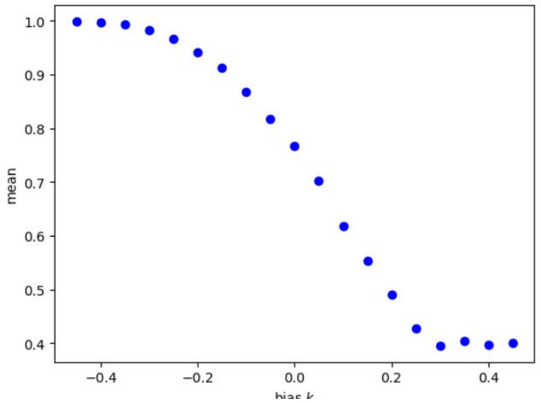
Innovation II Result

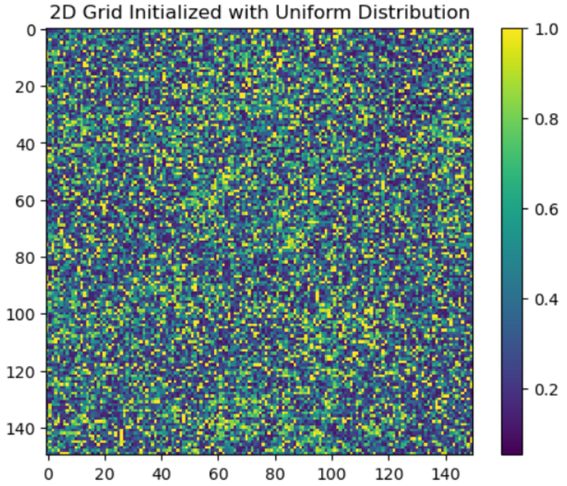






fitness threshold chages with different bias value

K = (0.25 – 0.40)


2D Grid Initialized with Uniform Distribution
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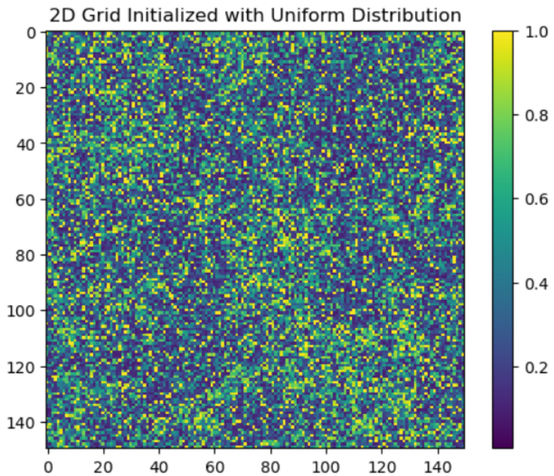
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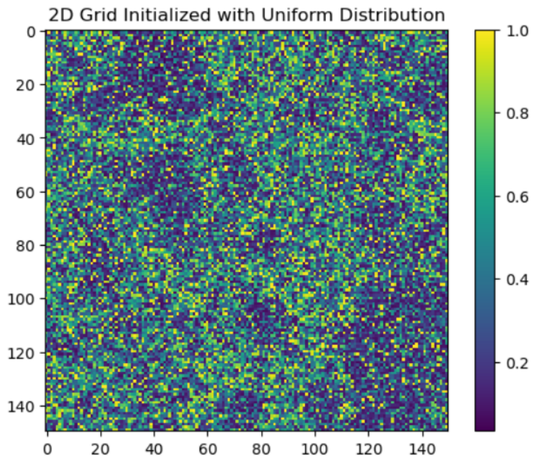
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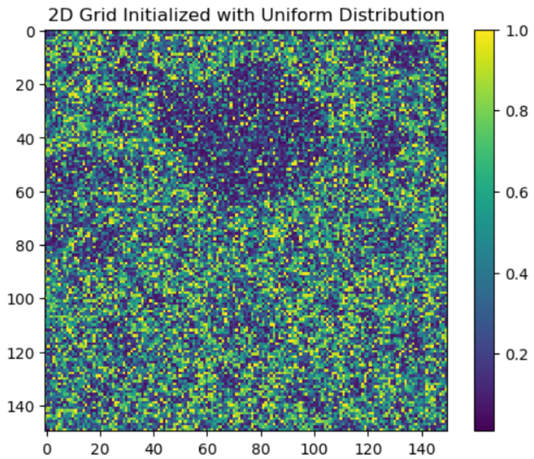
2D Grid Initialized with Uniform Distribution
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05.

CONCLUSION

Conclusion

The experiment successfully demonstrates the Bak-Sneppen models' ability to capture complex financial market dynamics, as shown through simulations and the exploration of innovative approaches. It highlights the importance of parameters such as noise strength and bias values in affecting market behavior and efficiency.

Future work

- The prospect of using these models for fitting the real financial data is expected （Nasdaq）, offering a valuable tool for forecasting market trends.
- Although we have introduced several interconnections within the grid, it may be helpful to introduce more complexity to the models by including more variables and interconnections.

Reference

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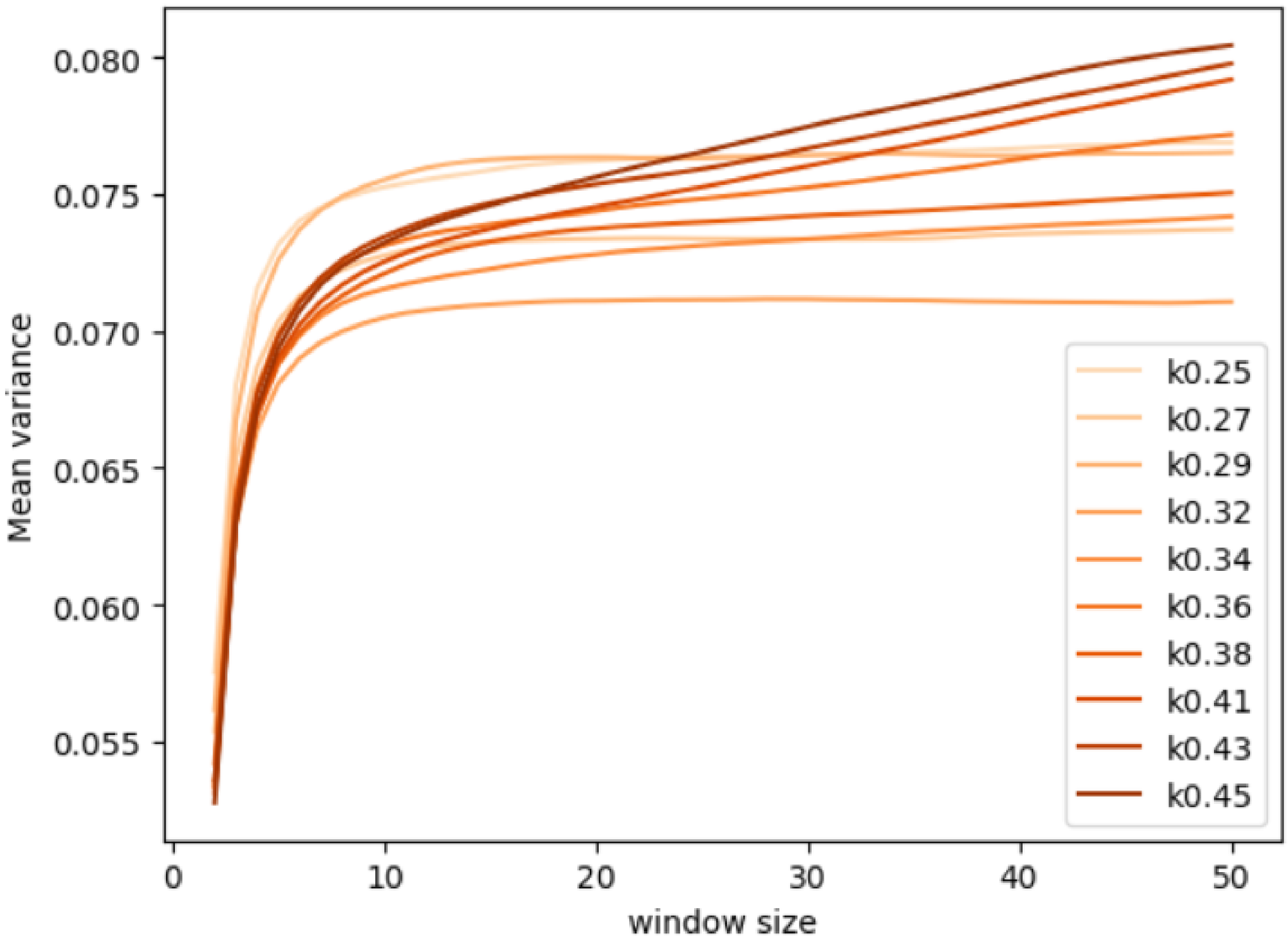
THANK YOU

Have any question?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