Title: Cellular Automata based Modelling of Stock Market

Name: Krishnendu Dasgupta

Mentor: Dr. Souvik Roy

Paper Referred:

1. Stochastic Cellular Automata Model for Stock Market Dynamics
   (By **Marco Bartolozzi** and **Anthony William Thomas)**

<u>Abstract</u>:
In this work, it has been tried to showcase the **Dynamics of the Stock Market** with the help of a **2D Cellular Automata**.

The **Active Traders** are characterised by the states **+1(*Buying Stocks*)** and **-1(*Selling Stocks*)**.

The **Inactive Traders** are characterised by **0 State**.

Some Simulation Rules(For changing the State of the Traders from Active to Inactive and Vice Versa) are applied and the simulation is done.

Based on that Simulation, some Graphs are plotted.

After that, Simulation rules are Tweaked.
Instead of checking the Neighbours and keeping the condition on the basis of **at least 1 Neighbour** in the Simulation Rules, ‘K’ and ‘l’ Neighbours are respectively checked for the Rule(1) and Rule(2) of Simulation where ‘K’ and ‘l’ are taken from the Set {1,2,3,4}.

Graphs are obtained and along with that some Drastic Changes are also observed in the Dynamics of the Market.

We witness the **Strictly Increasing** Graphs of the Simulation to become sometimes **Strictly Decreasing** when the ‘K’ and ‘l’ values are Increased.

In the later part of the analysis, we take The **Global Neighbourhood Condition** for the Simulation to resemble the Real Life Stock Market.

These Neighbours are **Fully Random** in nature.
Since, we are considering 512×128 Grid, so we have **65,536** cells and out of those cells, these Global Neighbours are **Randomly Chosen** and preferably they don’t collide with the Local Neighbours.

There we observe some Interesting Changes in the Dynamics of the Market.
The Graphs remain **Strictly Increasing** for a very long extent of time as compared to the Most Initial Model.

Basic Model

<u>Description of the Model</u>:

A <u>512×128</u> Grid is taken where each cell can have **3 states**, precisely, **0**,**+1** and **-1**.

- **0** indicates an **Inactive Trader** who is not involved in the Market.
- **+1** indicates an **Active Trader** who is **buying** some stocks.
- **-1** indicates an **Active Trader** who is **selling** some stocks.

Now, initially **a Random Configuration** is taken and then the simulation is continued for generations to get some Interesting Observations.

The **Initial Random Configuration** guarantees to have **not more than 27% of Active Traders**.
<u>Von Neumann Neighbourhood</u> is considered for the simulation.

<u>Rules of the Simulation</u>:

1. If a Cell is in **State 0** and **at least 1 of its Neighbours** is in **State 1**, then with **Probability P_H**, it gets converted to **State (+1 or -1)**.

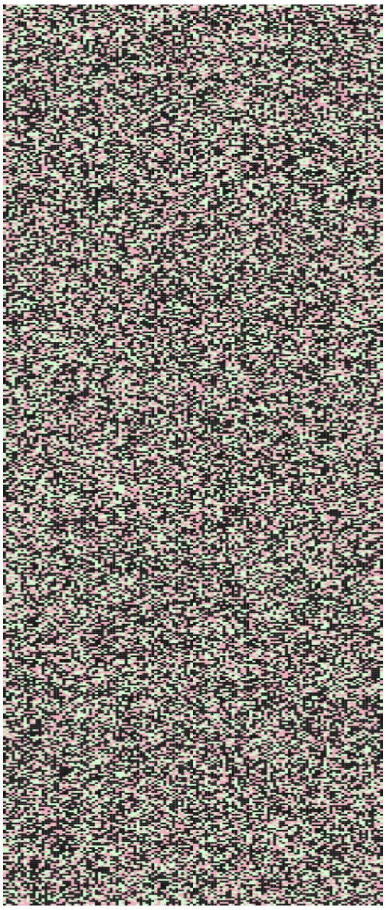
2. If a Cell is in **State 1** and **at least 1 of its Neighbours** is in **State 0**, then with **Probability P_D**, it gets converted to **State 0**.

3. If a Cell is in **State 0**, then with **P_c Probability**, it gets converted to **State (+1 or -1)**.

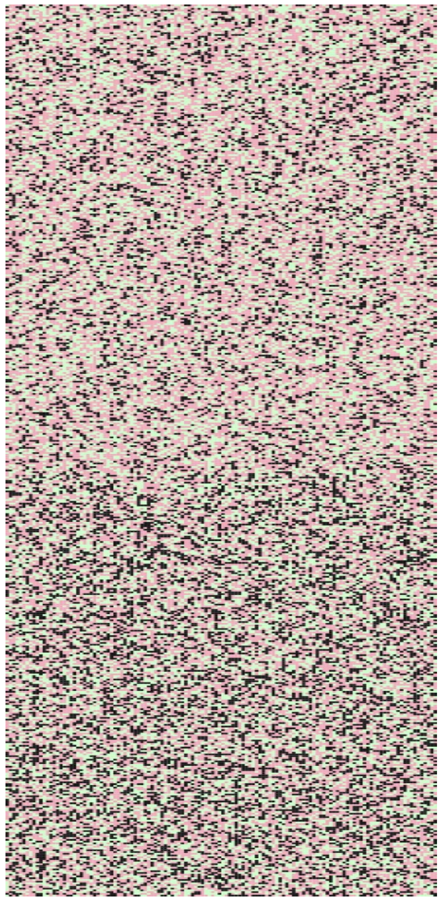
Simulation Pictures:

Below is the Diagram for $\mathbf{P_D = 0.5}$,$\mathbf{P_H = 0.6}$,$\mathbf{P_H = 0.3}$ and simulated for **1,00,000 Generations**.

N.B.: Here **Black Cells** represent **Inactive Traders** and **Non-Black Cells** represent **Active Traders**.



Initial State



Final State

<u>Graph of the Simulation</u>:

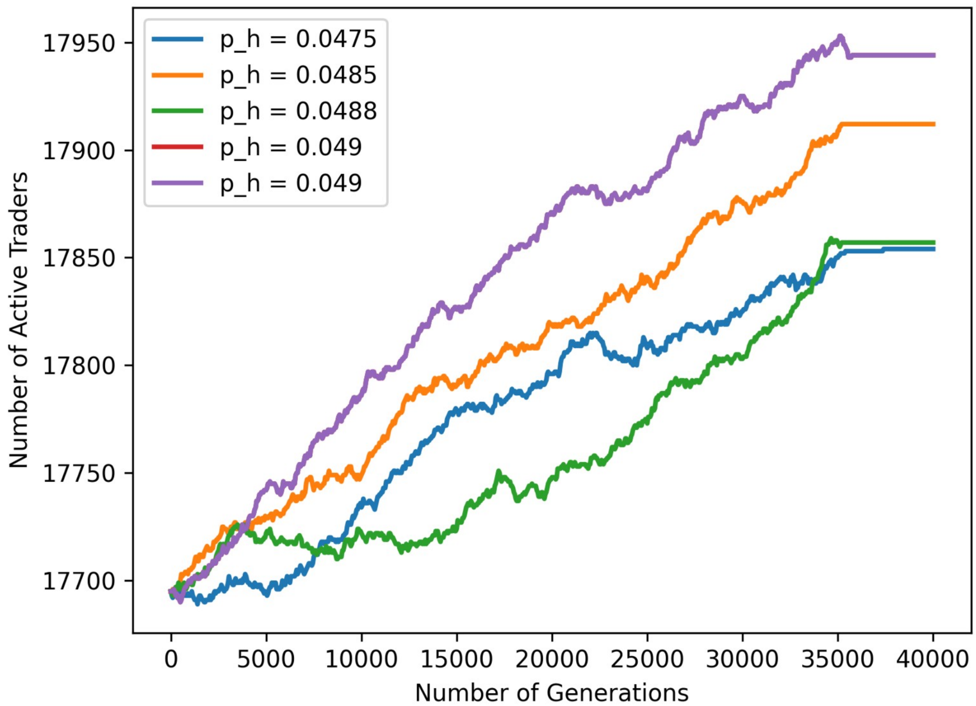
As per the Instructions and values given in the Paper, we do the fine Tuning of the Value of P_H.

We take Fixed values for <u>P_C = 0.0001</u> and <u>P_D = 0.05</u>.

Then we take 5 Different Values of P_H as
[**0.0493**, **0.0490**, **0.0488**, **0.0485**, **0.0475**].

Then we simulate using these values and plot the Graph between **Number of Active Traders(*Y-Axis*)** vs **Number of Generations(*X-Axis*)**.

The Graph obtained is Given Below:



<u>*Nature of the Graph*</u>*:* The Graph obtained is **Strictly Increasing** and finally settles and becomes almost **constant** within the range of **35,000** – **40,000**.

Extended Model – I

Changes In the Simulation Rules:

In the Previous Main Model, as per the **Given Conditions (1) and (2)**, only **1 Opposite Neighbour** can make the cell toggle from its state to another on a **certain Probability**.

But, if we changed that **quantity of 1** to **K** and **l** maybe respectively for the Rules, then a very Interesting Result comes in Picture.

Where K, l $\in$ {1,2,3,4}

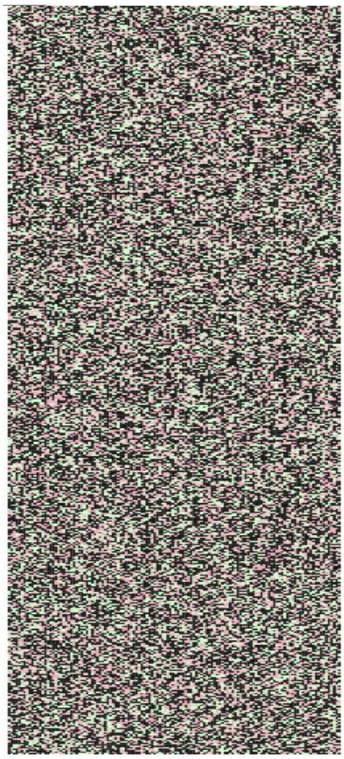
Revised Rule(1): If a Cell is in **State 0** and **at least 'K' of its Neighbours** is in **State 1**, then with **Probability P_H**, it gets converted to **State (+1 or -1)**.

Revised Rule(2): If a Cell is in **State 1** and **at least 'l' of its Neighbours** is in **State 0**, then with **Probability P_D**, it gets converted to **State 0**.

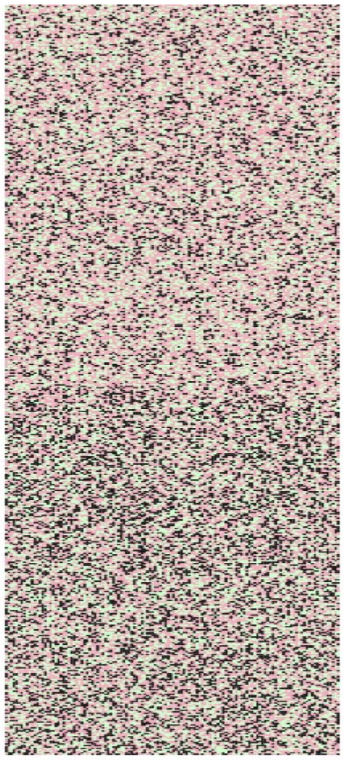
Simulation Pictures:

Below is the Diagram for $\mathbf{P_D = 0.5}$,$\mathbf{P_H = 0.6}$,$\mathbf{P_H = 0.3}$ (For **k = 4** and **l = 2**) and simulated for **1,25,000 Generations**.

N.B.: Here **Black Cells** represent **Inactive Traders** and **Non-Black Cells** represent **Active Traders**.



Initial State



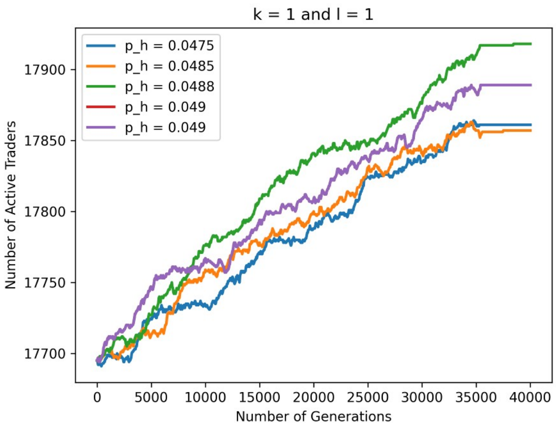
Final State

Graphs Obtained:

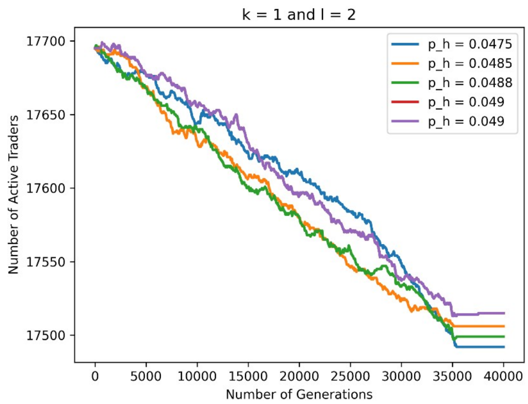
The Graph which was **Strictly Increasing** till now now becomes **Strictly Decreasing** for some cases like (K = 1 and l = 3), (K = 2 and l = 2), (K = 3 and l = 4), (K = 4 and l = 4) etc.

So, Clearly it can be inferred that on Increasing the values of K and l from 1, the **Rate of Increasing of Number of Active Traders decreases** and **sometimes it becomes totally Decreasing in Nature**.

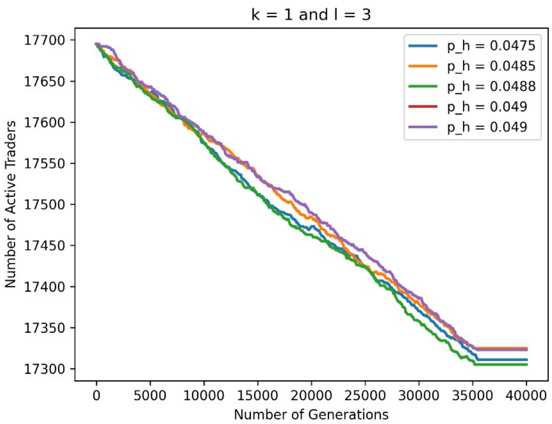
The Graphs are given as follows:



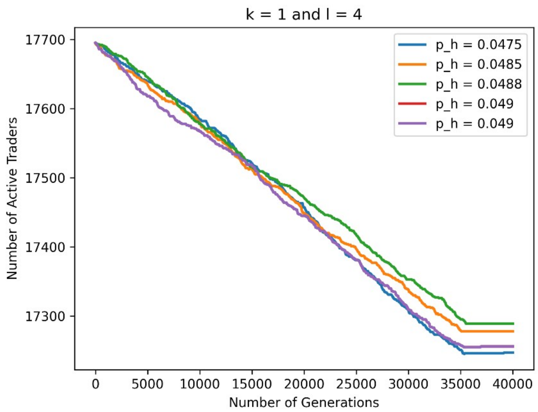
K = 1 and l = 1 (**Increasing**)



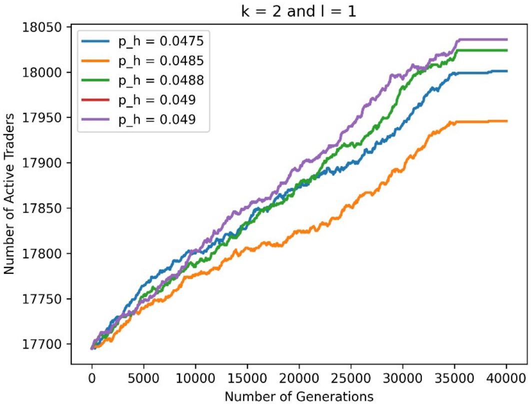
K = 1 and l = 2 (**Decreasing**)



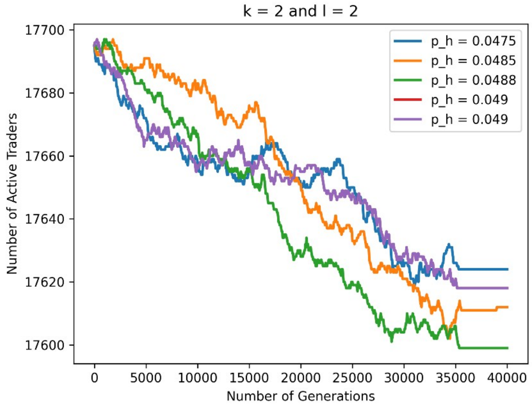
K = 1 and l = 3 (**Decreasing**)



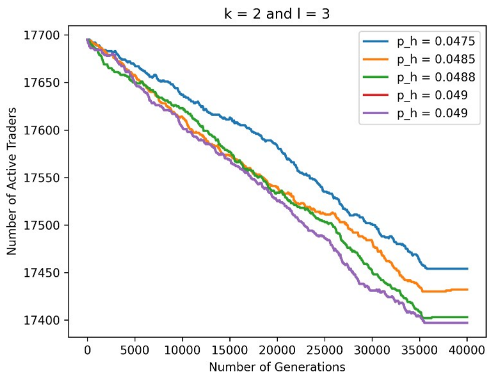
K = 1 and l = 4 (**Decreasing**)



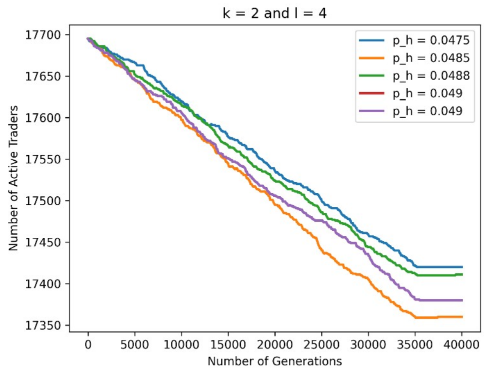
K = 2 and l = 1 (**Increasing**)



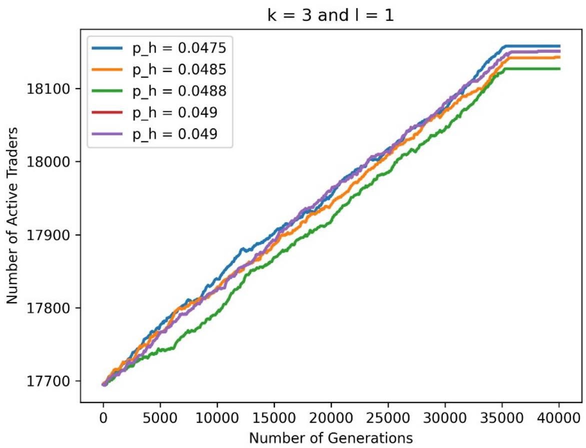
K = 2 and l = 2 (**Decreasing**)



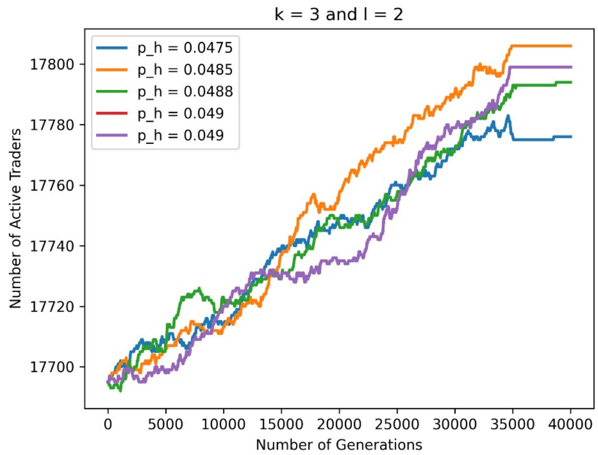
K = 2 and l = 3 (**Decreasing**)



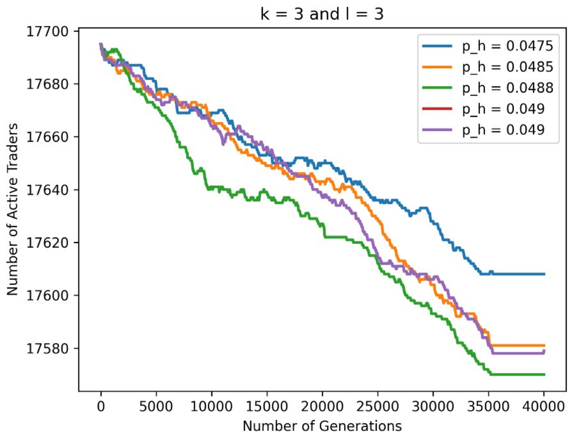
K = 2 and l = 4 (**Decreasing**)



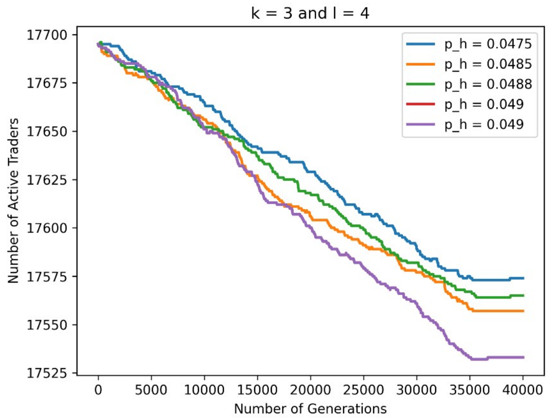
K = 3 and l = 1 (**Increasing**)



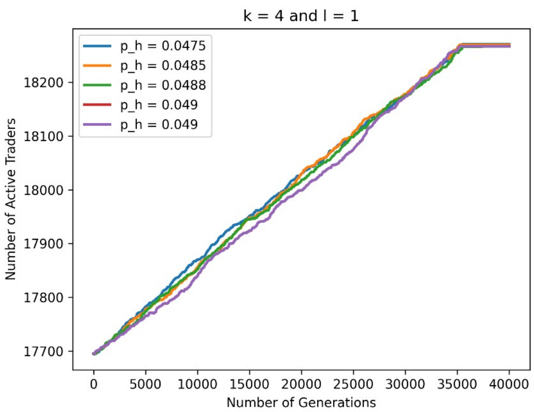
K = 3 and l = 2 (**Decreasing**)



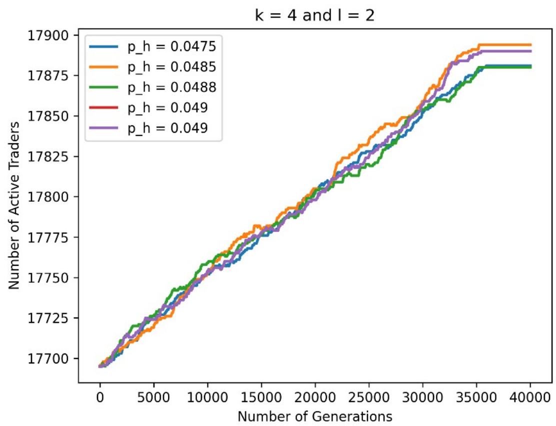
K = 3 and l = 3 (**Decreasing**)



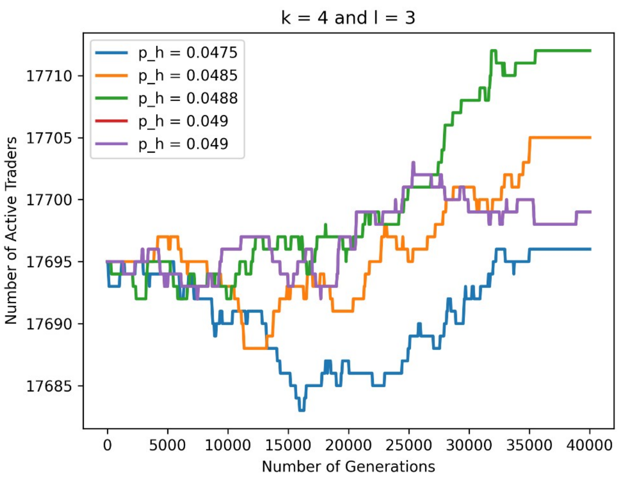
K = 3 and l = 4 (**Decreasing**)



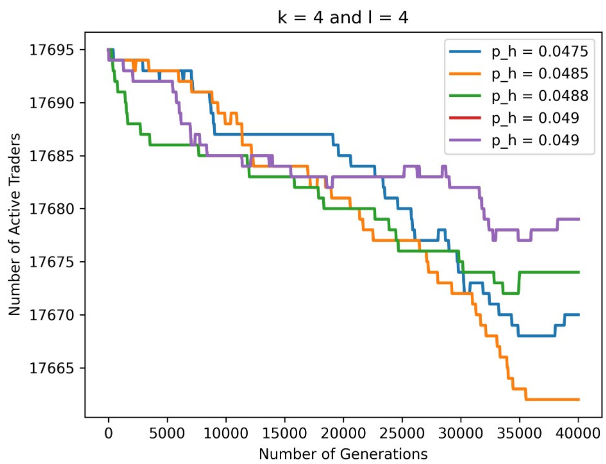
K = 4 and l = 1 (**Increasing**)



K = 4 and l = 2 (**Increasing**)



K = 4 and l = 3



K = 4 and l = 4 (**Decreasing**)

Here K = 4 and l = 3 has a very unique kind of Graph. At first it **Decreases** but then it **Increases** and then Stabilises around 35,000.

Extended Model – II

Changes In the Neighbourhood Conditions:

Till now, we have seen the Neighbours to be Local Von Neumann Neighbours to be considered for Simulation.

But in this second version of the Extended Model, **Global Neighbours** have been taken into picture so as to get some Insights about the Effect of the Market as a whole to a Particular Cell(A Trader to be precise).

But n **Real Life**, the Stock Market's Traders are **not only dependent on their Local Neighbours**, for being converted from **Active to Inactive** and **vice versa**, but also somehow dependent on the **Global Neighbours**.

Conditions for Choosing the Global Neighbours:
Since, we are considering 512×128 Grid, so we have **65,536** cells and out of those cells, these Global Neighbours are **Randomly Chosen** and preferably they don't collide with the Local Neighbours.

Final Neighbourhood Structure of the Modified Model:
Following are the two cases Considered with respect to Global Neighbourhood Condition:

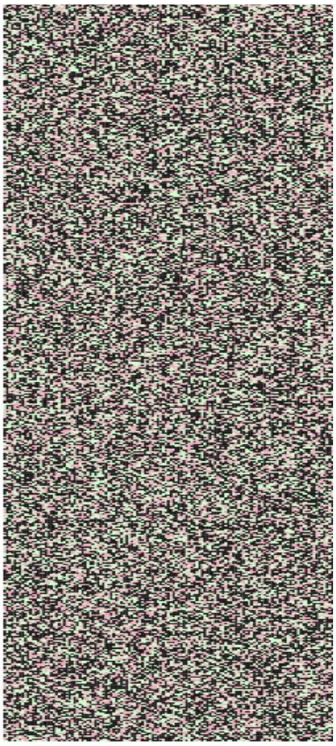
- **2 Local Neighbours**(Randomly chosen from 4 Von Neumann Neighbours) and **2 Global Neighbours**(Randomly chosen from the whole Board)

- **3 Local Neighbours**(Randomly chosen from 4 Von Neumann Neighbours) and **1 Global Neighbour**(Randomly chosen from the whole Board).

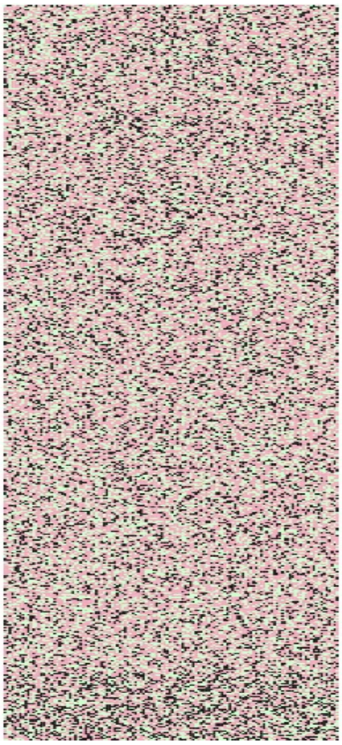
Simulation Pictures – I:

Below is the Diagram for **P_D = 0.5**,**P_H = 0.6**,**P_H = 0.3** and simulated for **1,25,000 Generations** for **2 Local Neighbours** and **2 Global Neighbours** Case.

N.B.: Here **Black Cells** represent **Inactive Traders** and **Non-Black Cells** represent **Active Traders**.



Initial State

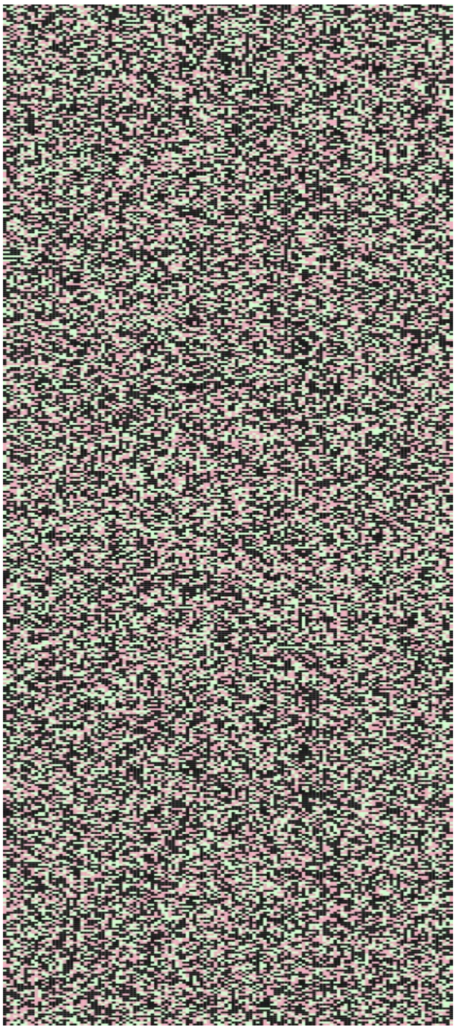


Final State

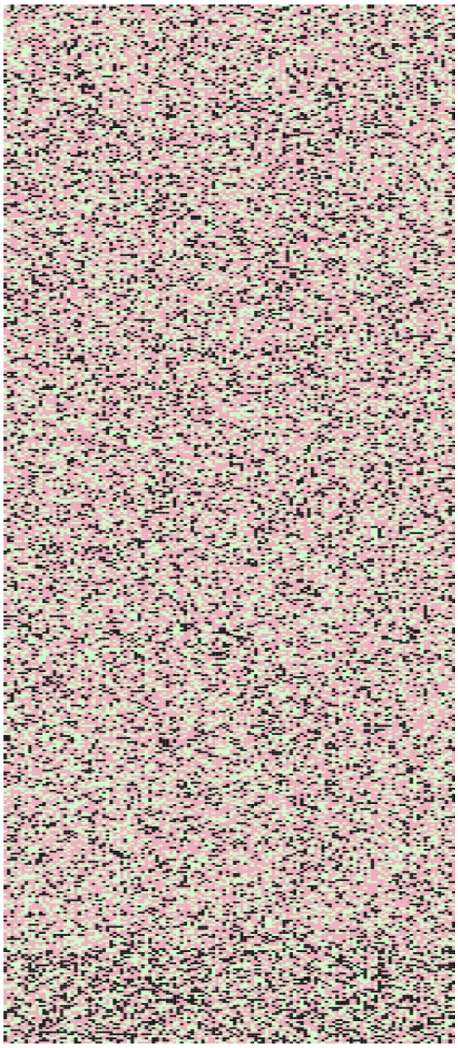
<u>Simulation Pictures – II</u>:

Below is the Diagram for $\mathbf{P_D = 0.5}$,$\mathbf{P_H = 0.6}$,$\mathbf{P_H = 0.3}$ and simulated for **1,25,000 Generations** for **3 Local Neighbours** and **1 Global Neighbours** Case.

<u>**N.B.**</u>: Here **Black Cells** represent **Inactive Traders** and **Non-Black Cells** represent **Active Traders**.



<u>Initial State</u>



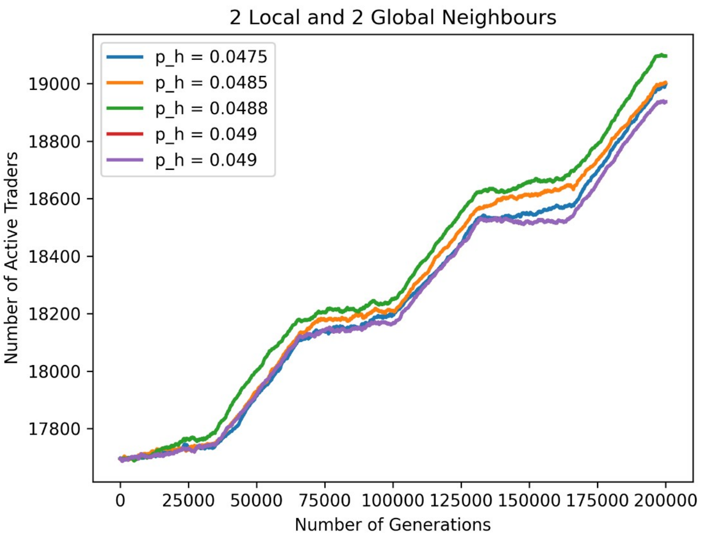
<u>Final State</u>

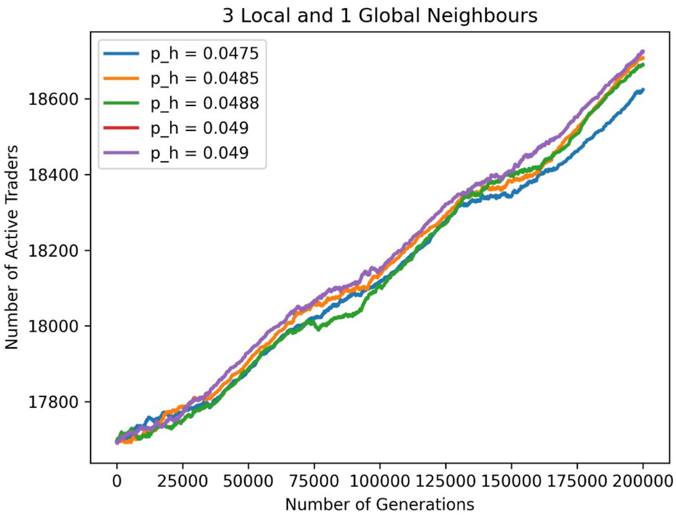
Graphs Obtained:

In the Previous Models, the Graph would **stabilise** almost between the Range of **36000-40000**.

But, here in Global Cases, the Graph **does not stabilise** at all **till 2,00,000** and keeps on increasing.

The key takeaway is that if we mix the Global Neighbours in the scenario, the **Number of Active Traders** keeps on increasing for a very large Number of Generations and does not necessarily becomes constant.





Future Scopes:

Through this Model, we have tried to emulate the **Dynamics of Stock Market** Trading starting from the most **Basic Model** and then adding Modifications to it making the Model more and more similar to the **Real World's Market Dynamics**.

Since, this Model simulates the Dynamics of a **Stock Market**, similarly it can be Extended easily to Simulate any type of Open Market like **Crypto Market** and further.