APP PHY 157 WFY-FX-2

LAB REPORT 10

Complexity Science: Cellular Automata

[Source code here!](https://github.com/lovelyandeo/AP157-Computational-Analysis-and-Modeling-in-Physics)

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Background

Complexity science is an emerging field that offers a fresh perspective on traditional scientific inquiry by focusing on the study of complex systems and employing novel tools and methodologies. Unlike traditional reductionist approaches that break down systems into their individual components, complexity science seeks to understand the behavior and properties of complex systems as a whole. Cellular automaton is one of its fundamental concepts which we will explore in this report.

Objectives

In this activity, we aimed to:

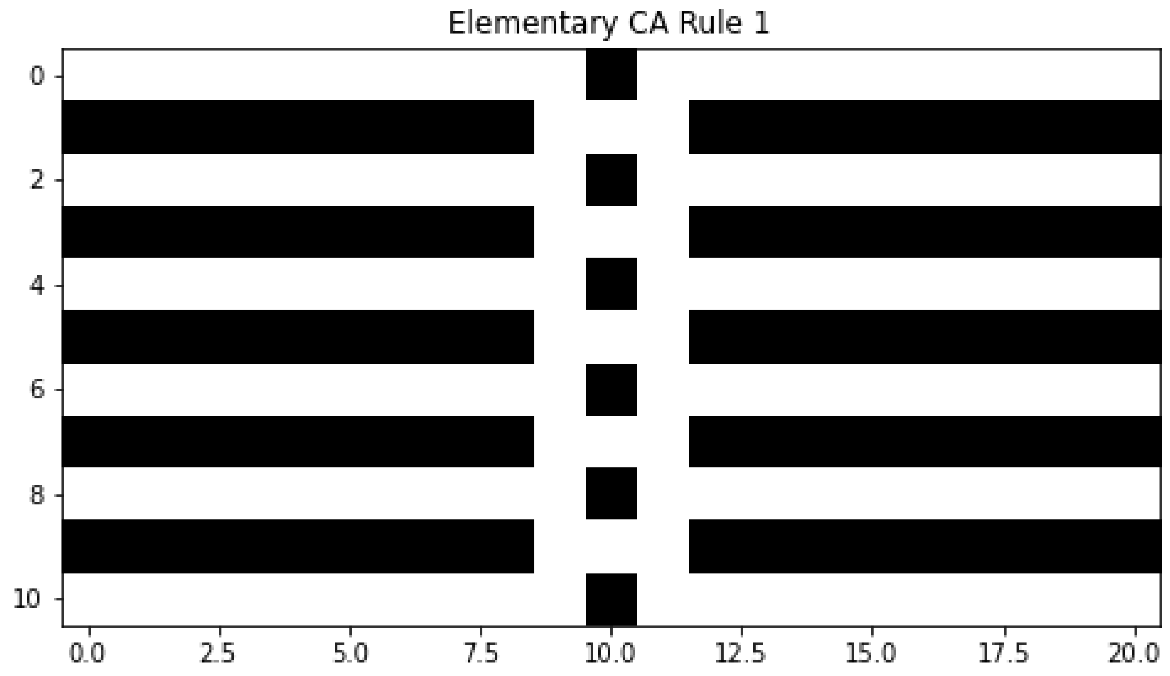
1. Define a cellular automaton.
2. Demonstrate Wolfram's 1D CA models.
3. In the context of CA, discuss determinism, randomness, and universality.

Results and Analysis

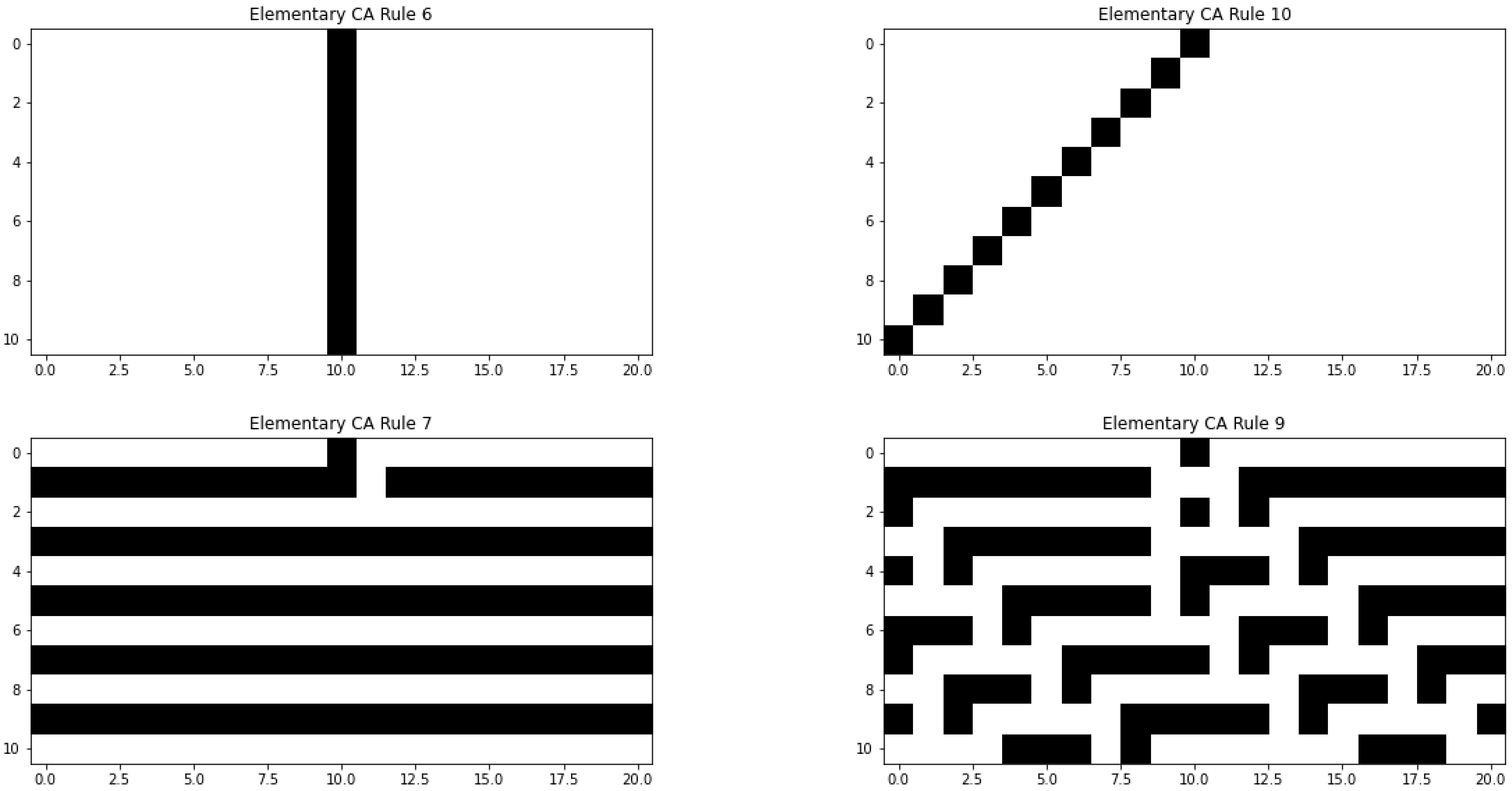
A **cellular automaton CA** is a computational model that operates on discrete units or cells. It performs computations by updating the state of these cells based on predefined rules. The evolution of the system occurs in discrete steps, with each cell's state changing according to the specified rules over time. In this report, we will be exploring the evolution of these cells and pattern using different models and rules.

The class of 1D cellular automata is referred to as **elementary CA**. In this class, the cells can have only two possible values, either 0 or 1. It operates in a fully deterministic manner, meaning that the future state of each cell is solely determined by the current state of the cell and its neighboring cells. Hence it does not incorporate randomness as part of its transition rules. Additionally, it is not universally capable, meaning it has limitations in terms of its computational power and pattern simulation abilities. Specifically, elementary CA is limited to a set of 256 transition rules, and it cannot simulate arbitrary or complex patterns beyond this predefined set.

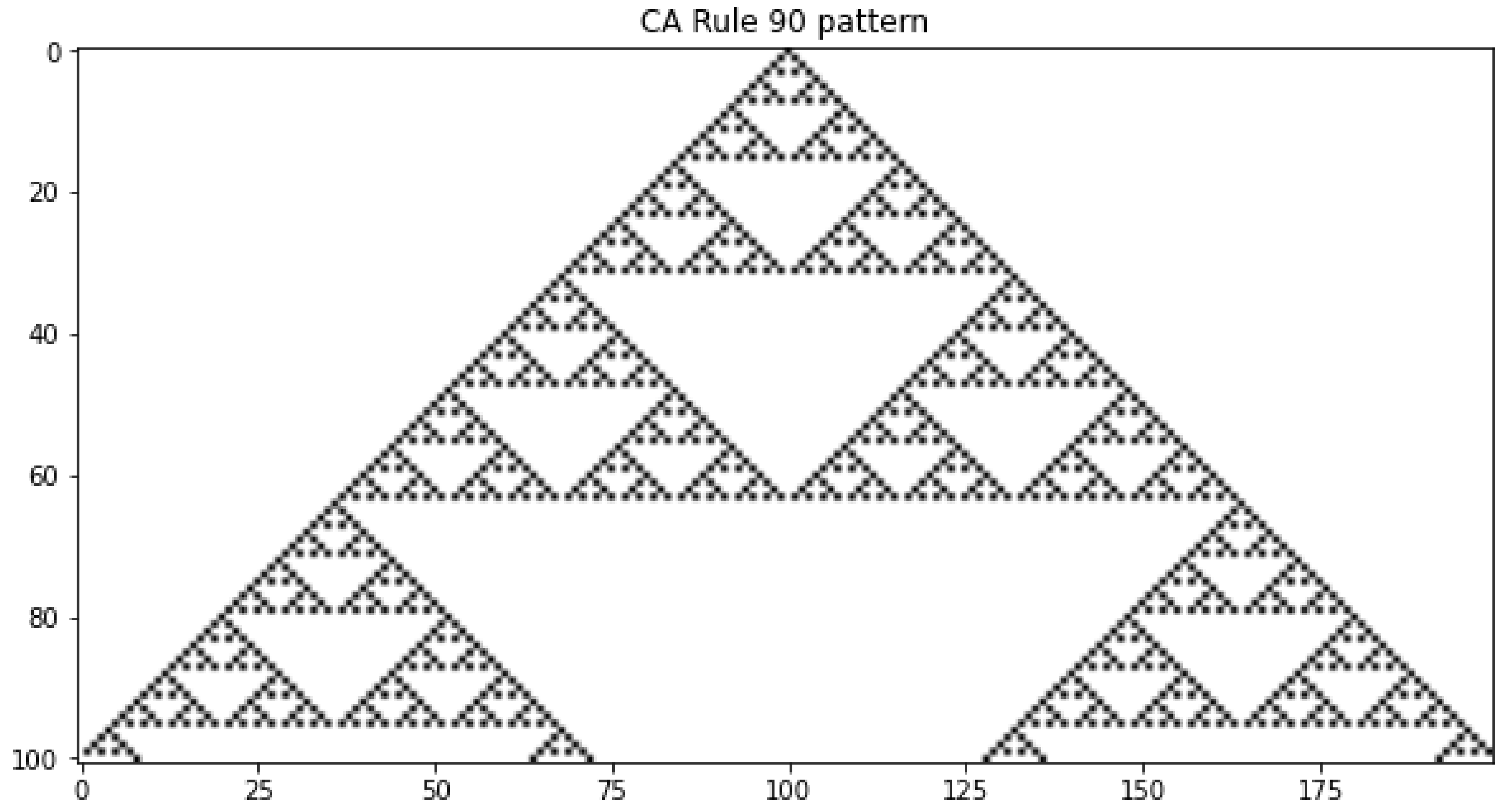
On the right image, we can observe a pattern formed using transition rule 1 of the elementary CA. In the subsequent slide, we also explored different patterns that emerge by applying various transition rules within the model.



Elementary CA


Elementary CA Rule 6
Elementary CA Rule 10
Elementary CA Rule 7
Elementary CA Rule 9
0
2
4
6
8
10
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0

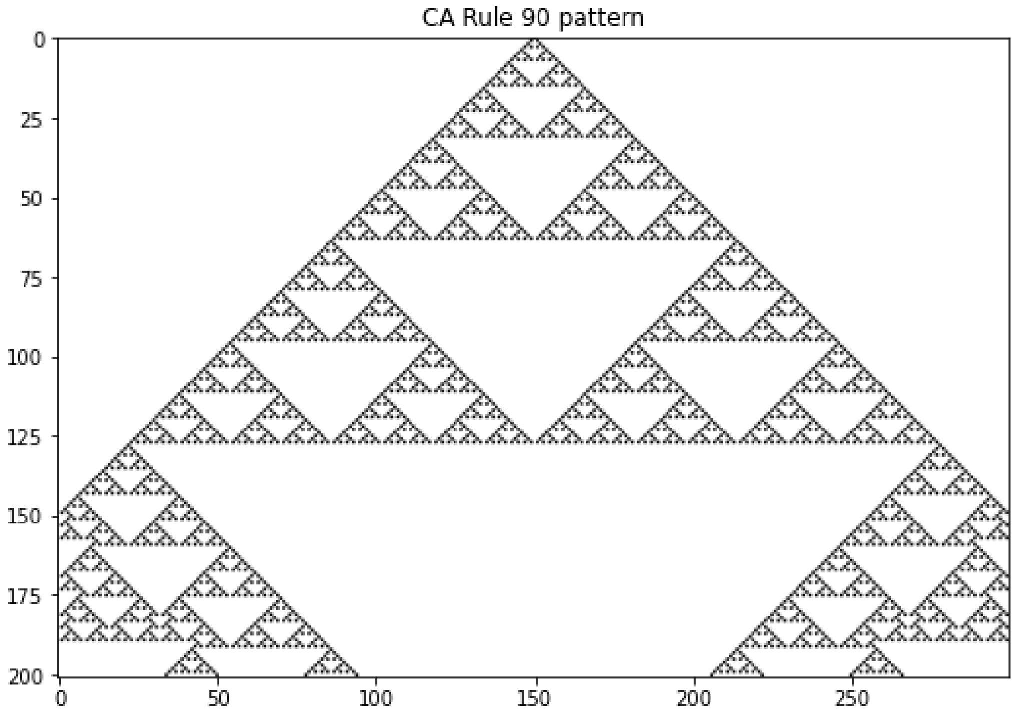
Rule 90

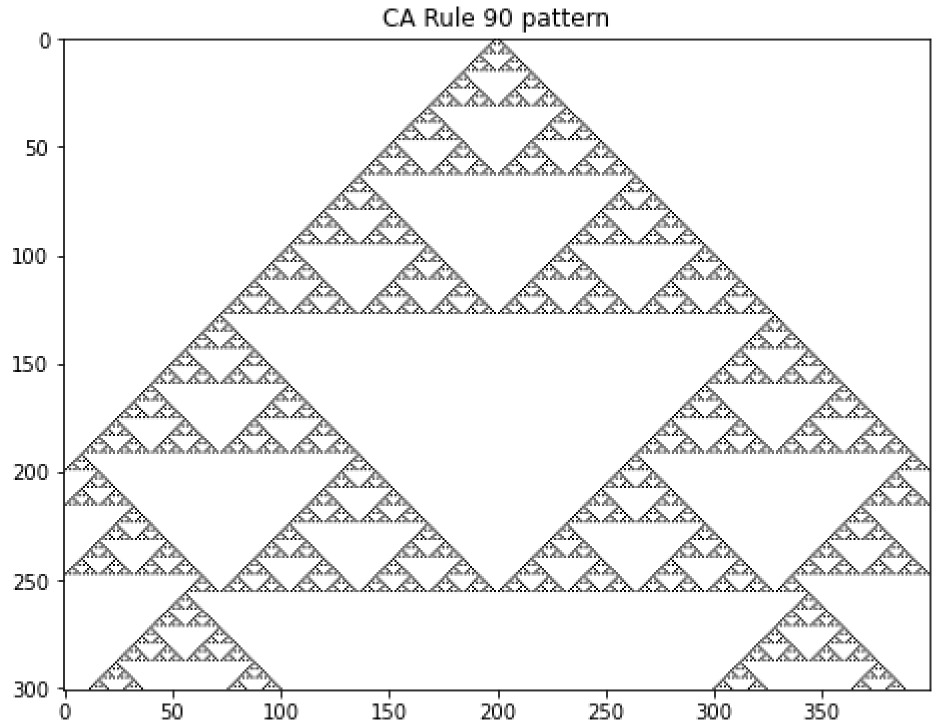


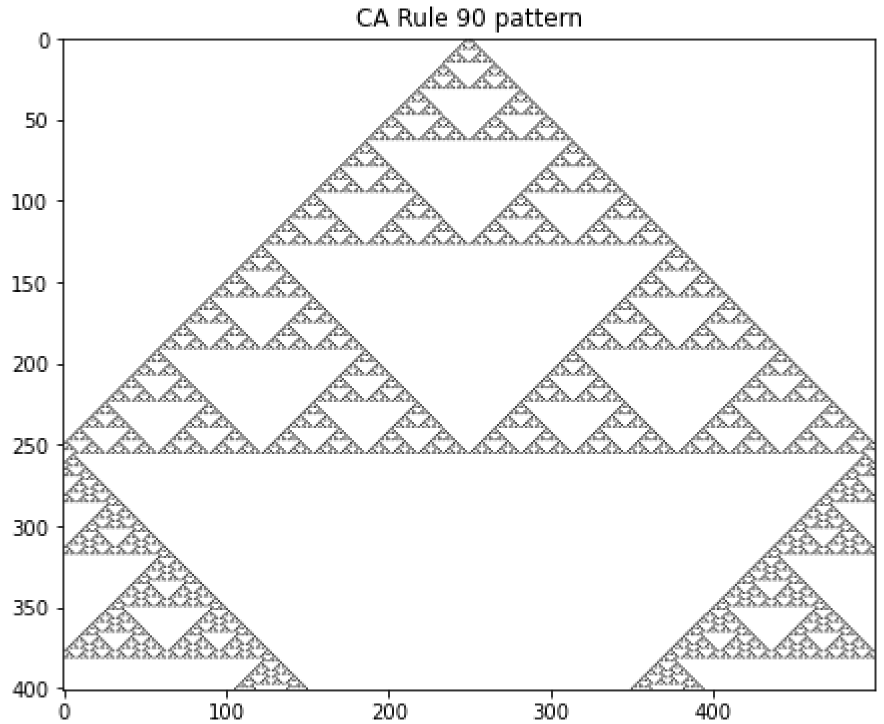
Rule 90 is a specific rule within the elementary cellular automaton (CA) model. In Rule 90, the next state of a cell is determined by applying the exclusive OR (XOR) operation to its neighboring cells. This rule operates in a fully deterministic manner, meaning that the future state of each cell is solely determined by the current states of its neighbors.

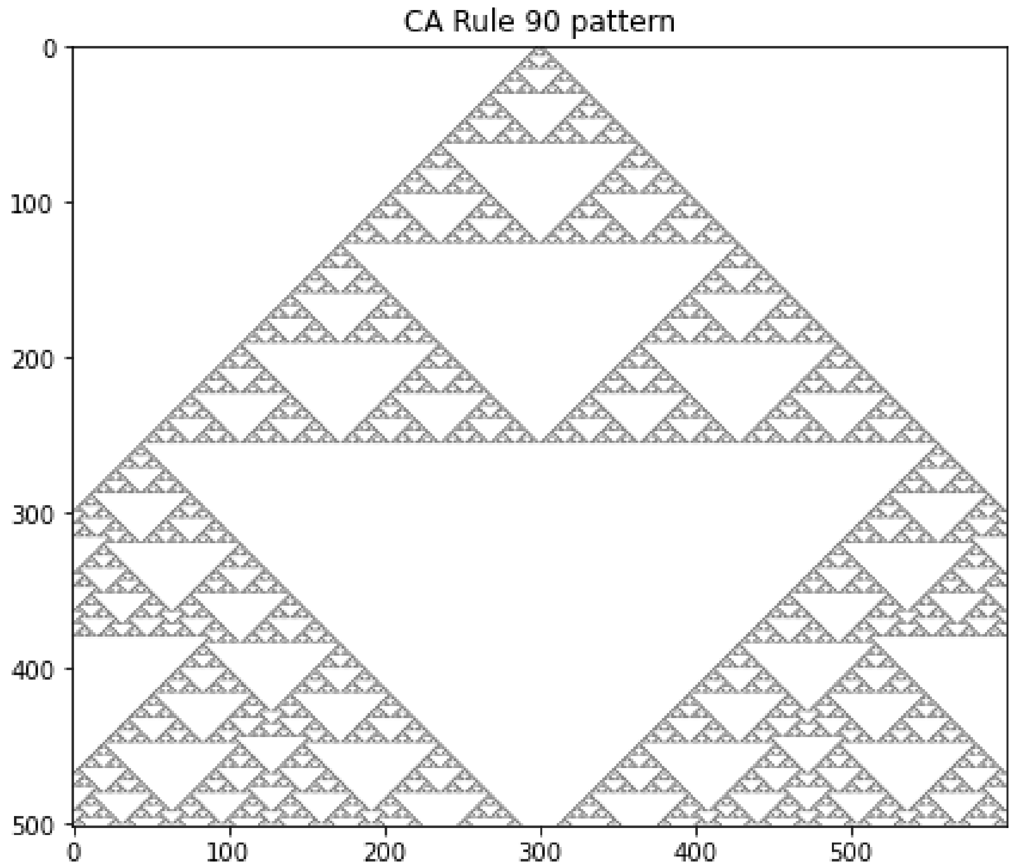
When Rule 90 is applied, the resulting patterns exhibit repetition and similarity to Pascal's triangle, as shown in the image on the left. These patterns are observed to have a symmetrical and structured nature.

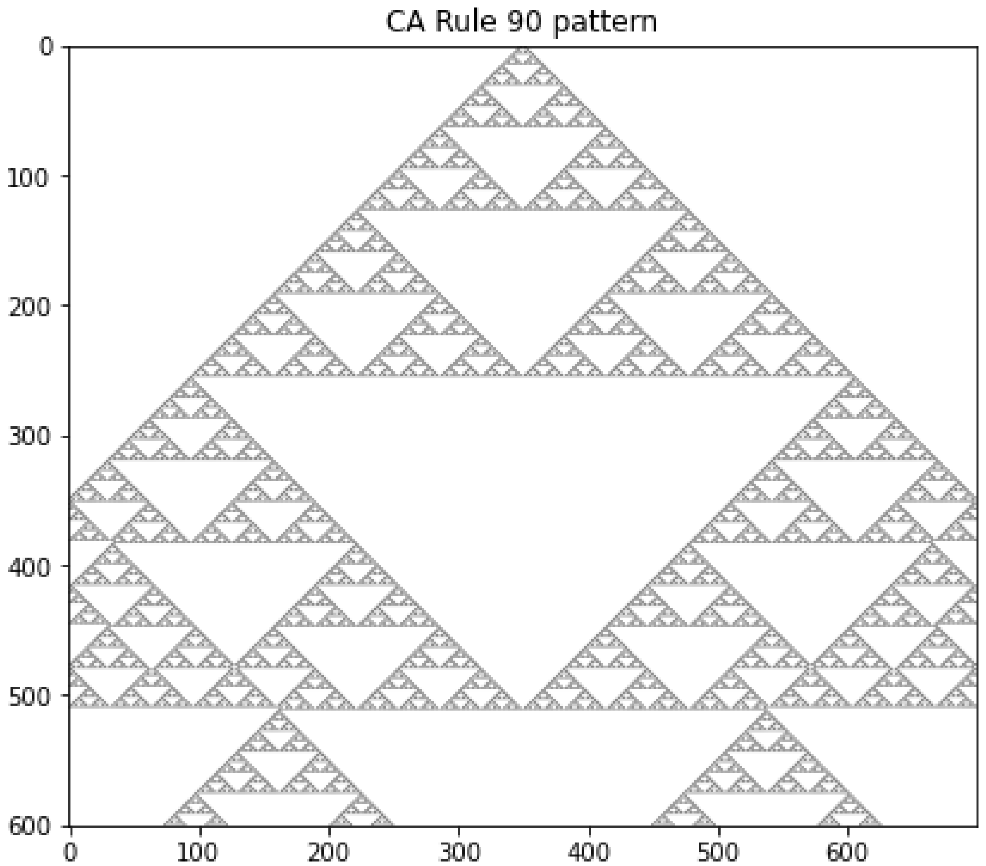
In the next slide, we explore the behavior of Rule 90 by gradually increasing the number of steps or cells along the axis. As we do so, we observe the pattern receding, revealing a clearer view of the repetitive structure and symmetrical nature of Rule 90 CA. This progression allows us to witness how the pattern evolves and extends as we expand the size of the CA grid.

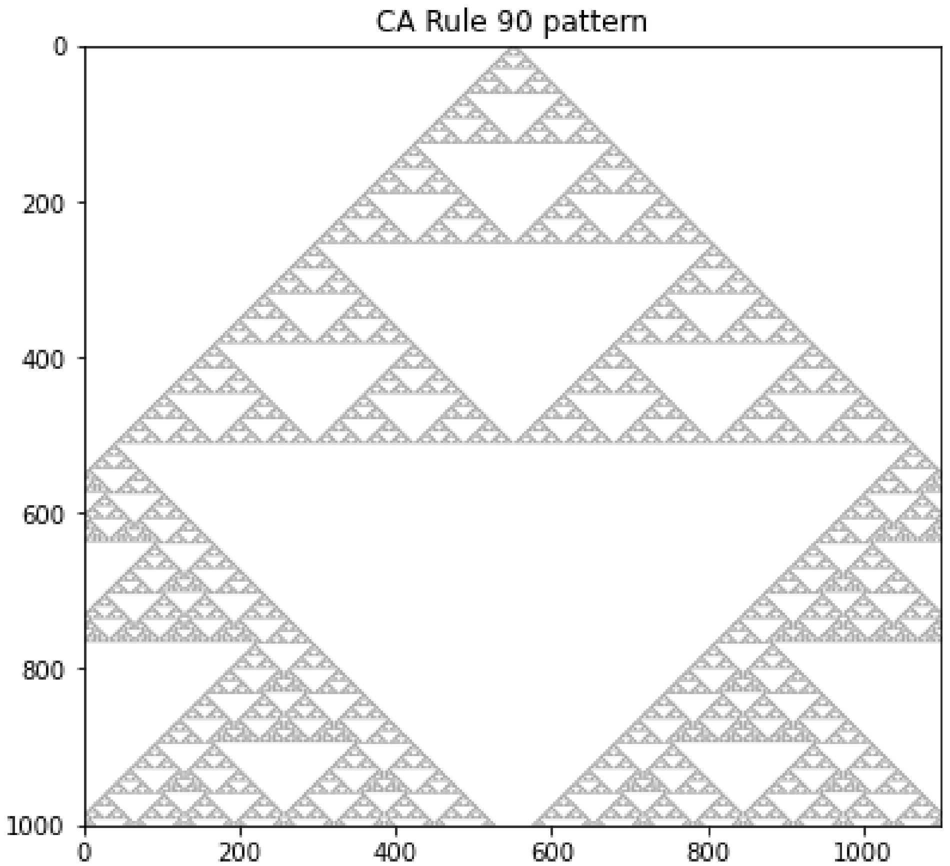

CA Rule 90 pattern
0 25 50 75 100 125 150 175 200
0 50 100 150 200 250


CA Rule 90 pattern
0 50 100 150 200 250 300
0 50 100 150 200 250 300 350


CA Rule 90 pattern
0 50 100 150 200 250 300 350 400
0 100 200 300 400


CA Rule 90 pattern
0 100 200 300 400 500
0 100 200 300 400 500

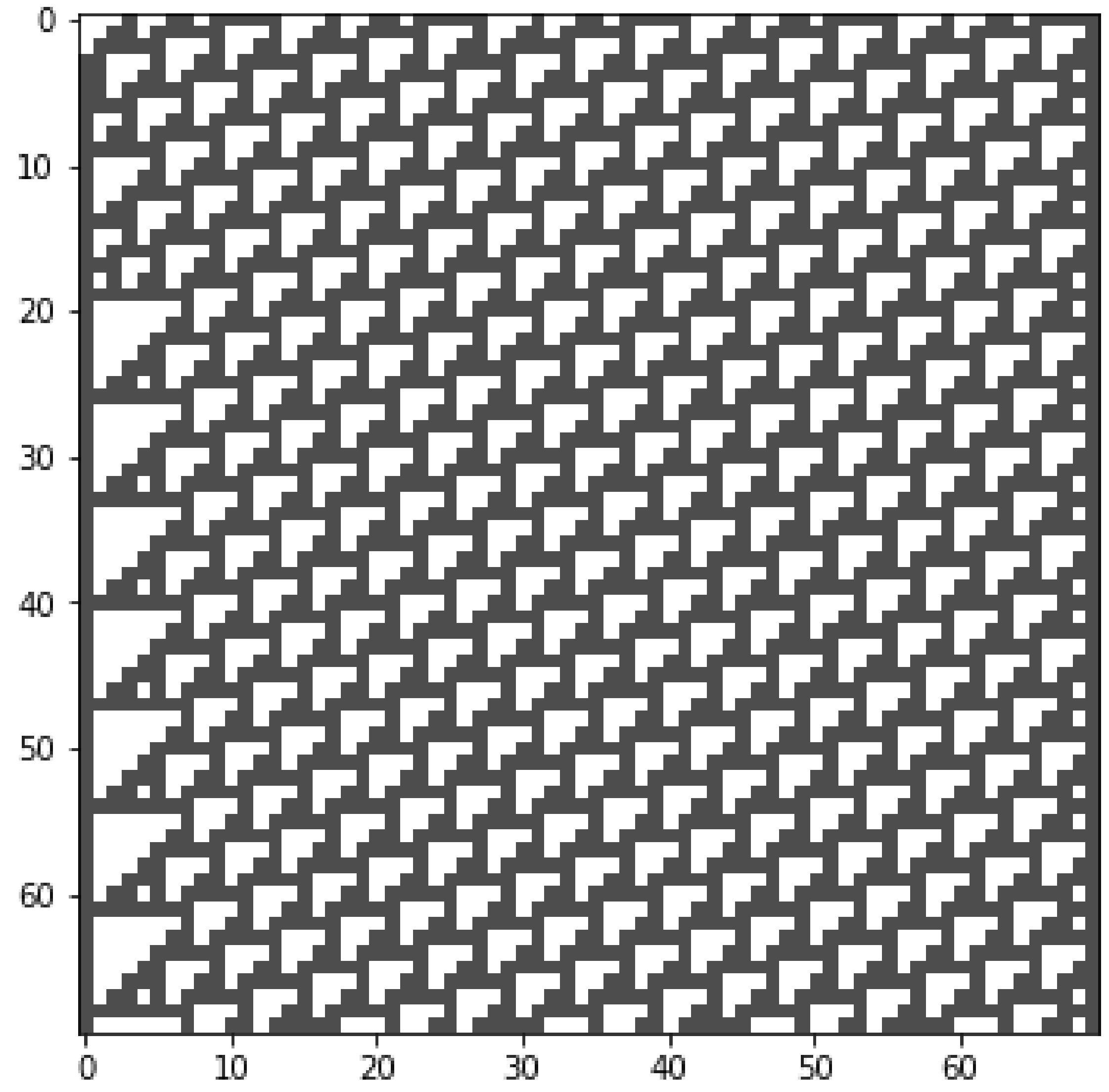

CA Rule 90 pattern
0 100 200 300 400 500 600
0 100 200 300 400 500 600


CA Rule 90 pattern
0 200 400 600 800 1000
0 200 400 600 800 1000

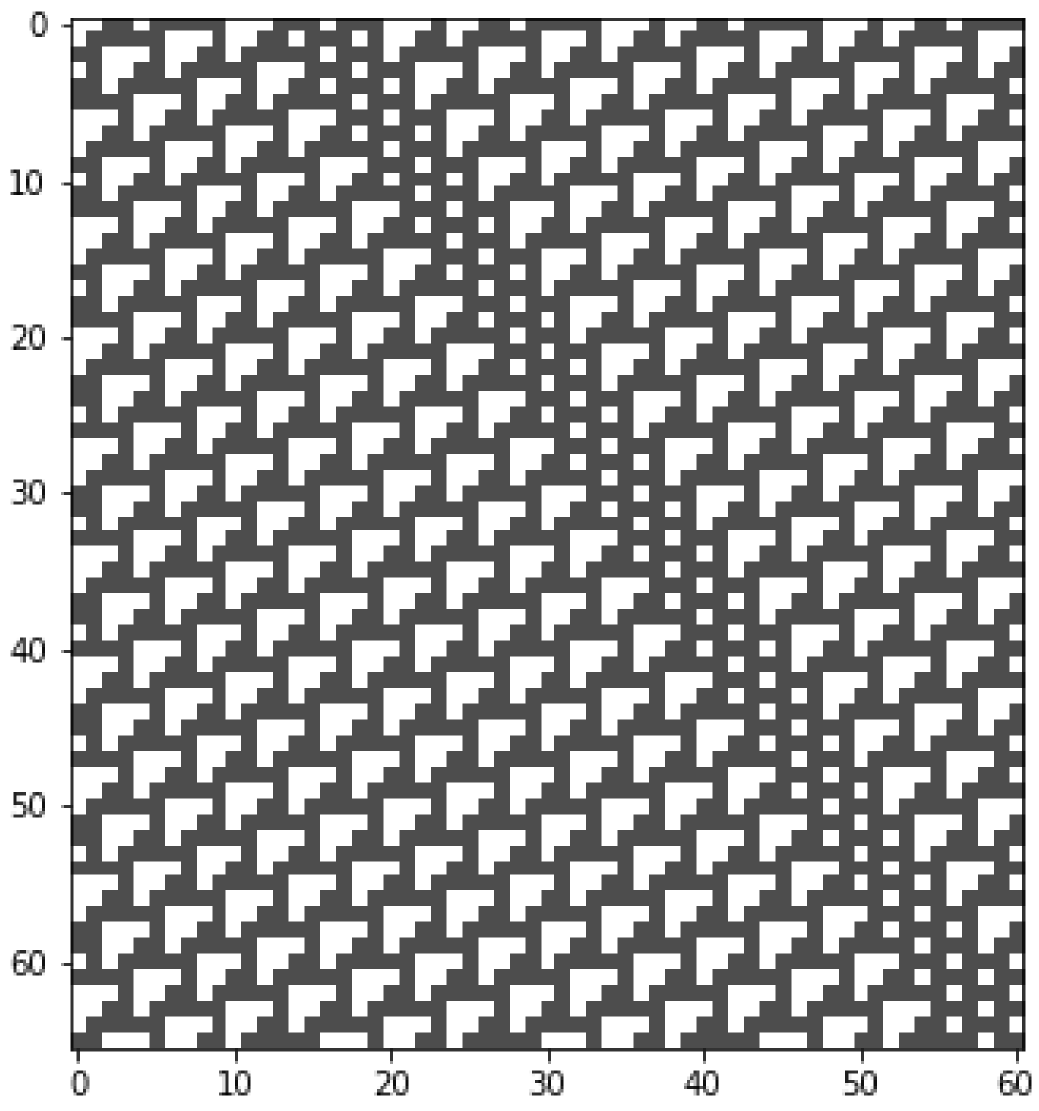
Rule 110 is another well-known rule in the elementary cellular automaton (CA) model. Unlike rule 90, it is recognized for its computational universality and exhibits a more intricate and non-linear transition rule. This rule considers specific combinations of states in the cell's neighborhood to determine the next state. Similar to rule 90, it does not incorporate randomness into its transition rules.

Rule 110 holds great significance in the field of cellular automata due to its computational universality and its ability to simulate arbitrary computation. It generates intricate patterns that captivate researchers and enthusiasts alike.

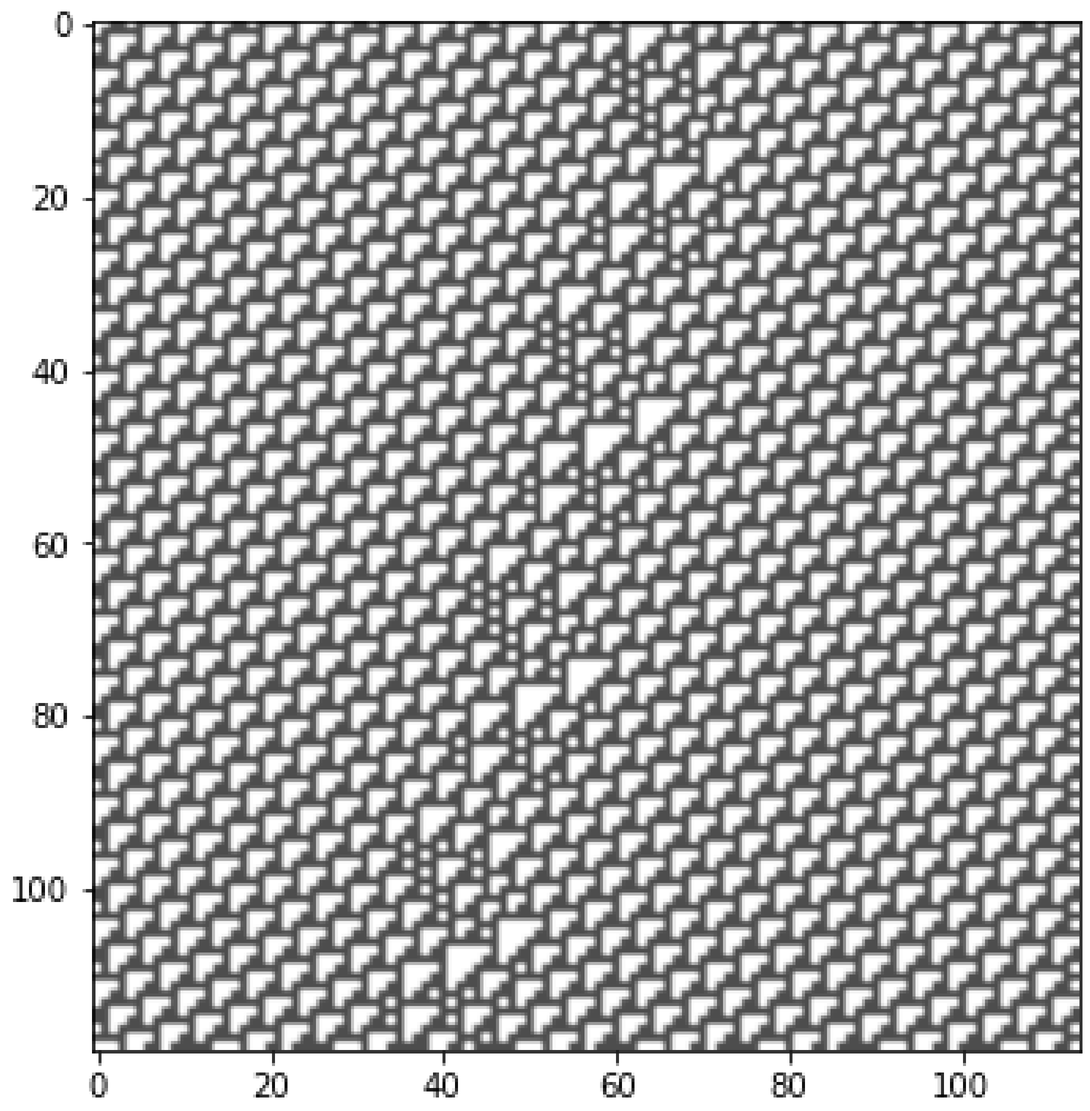
In the next slide, we delve into the exploration of spaceships in Rule 110. These spaceships represent moving structures within the automaton. We investigate the intriguing phenomena that occur when these spaceships intersect with one another.



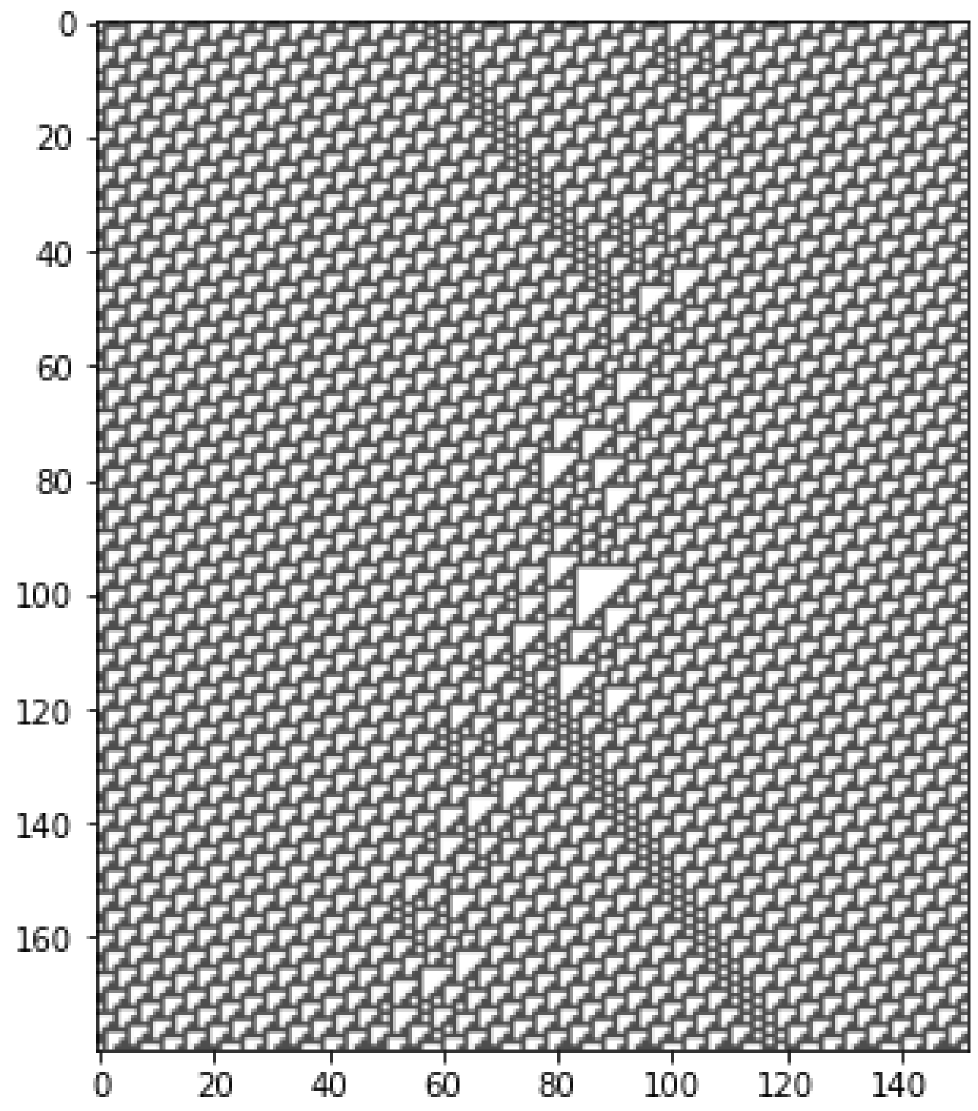
Rule 110



Spaceship that translates right



Spaceship that translates left



Intersecting spaceships

Key takeaway

- Different rules within the elementary or 1D cellular automaton model offer unique characteristics
- Various rules within the model dictate its degree of determinism, randomness, and universality

Reflection

At first, I have to admit, it was a bit intimidating! Trying to grasp which rules and concepts belong to which models took some time. But as I delved deeper, I discovered the incredible versatility of cellular automata and how they allow us to represent systems using cells in so many fascinating ways. Although I've only scratched the surface with elementary cellular automata, I'm thrilled to continue learning and exploring other classes like totalistic and probabilistic CA. Hopefully, there will be more chances to do so in the future.

This is the last lab report for this semester! Can't believe I survived :') Tysm po for a fun semester <3

Self-evaluation

100/100

I believe I was able to deliver what was required for this lab report.

References

Here are the materials I used as guide to accomplish this activity:

Downey, A. (2016). Think Complexity.
https://uvle.upd.edu.ph/pluginfile.php/892120/mod_resource/content/1/thinkcomplexity2.pdf

Downey, A. (2016). Think Complexity - Chapter 5 notebook.
https://github.com/AllenDowney/ThinkComplexity2/blob/master/notebooks/chap05.ipynb