Block Cellular Automaton – Exercise 1

Course: 80-512 / 89-512 - Computational Biology

Student Name: Elad Cohen

ID Number: 207252461

Department: Computer Science

Declaration:

We are aware of the attendance requirement in the course, and understand that those who do not meet it will not be able to pass the course.

Running the Code

Go to here and follow the steps in the README file.

Whether choose to use the exe file or to clone the repo the running the code is the same:

To run the simulation:

Inside the menu, you can:
- Run random initialization experiments (Q1).
- Choose predefined patterns (Q2 & Q3)
- Adjust settings: grid size, wrap-around, animation, etc.

(For adjusting the setting from true to false or false to true just pick the setting and it will invert the current state)

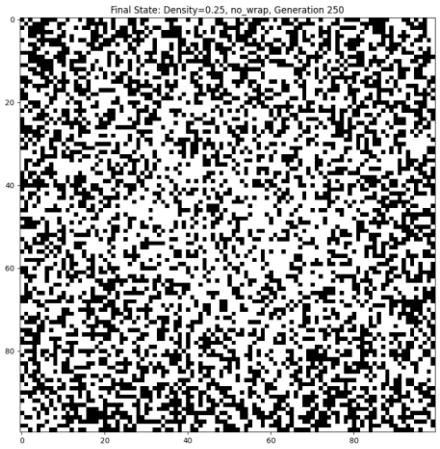
Automaton Rules

Each generation alternates between blue-aligned (even) and red-aligned (odd) 2x2 blocks.
Update rules per block:
- 2 live cells → no change
- 0, 1, or 4 → flip all values
- 3 → flip then rotate 180°

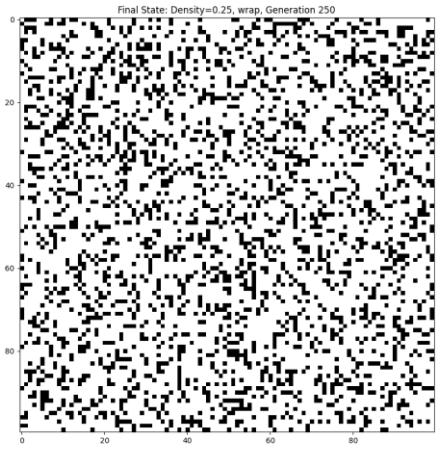
Wrap-around allows border cells to interact with the opposite side.

Question 1 – Random Initialization

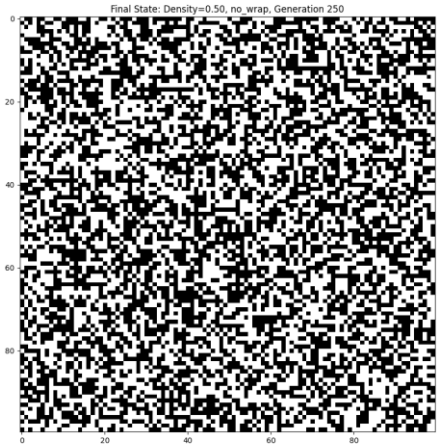
Experiments with initial live cell probabilities 0.25, 0.5, and 0.75 were conducted with and without wrap-around. Below are examples comparing the final state of each configuration.



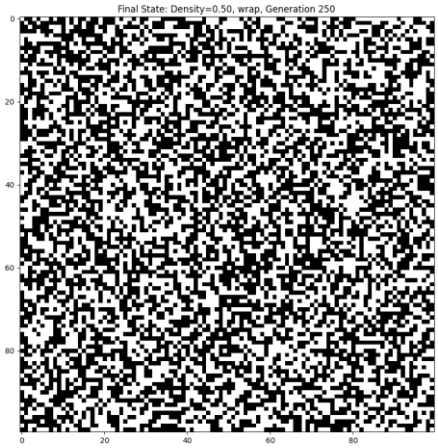
p=0.25 without wrap-around



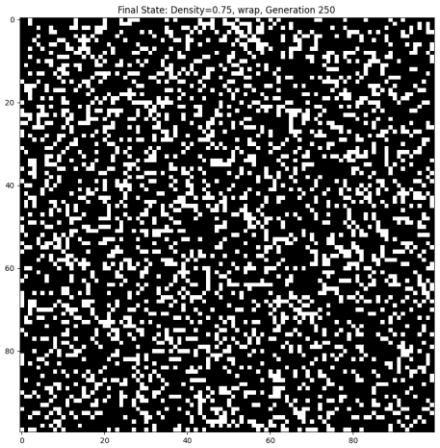
p=0.25 with wrap-around



p=0.50 without wrap-around



p=0.50 with wrap-around



p=0.75 without wrap-around

p=0.75 with wrap-around

Conclusion:

This experiment demonstrated how initial density and boundary conditions influence system evolution.

• With low density (p=0.25), both versions quickly stabilized or faded, but wrap-around allowed slightly longer activity thanks to edge continuity.

• At medium density (p=0.5), complex interactions persisted longer with wrap, while no-wrap decayed steadily, forming isolated stable patches.

• At high density (p=0.75), initial chaos was more sustained in wrap-around mode, while no-wrap led to earlier convergence into homogeneous blocks.

The results highlight how wrap-around prolongs evolution and increases pattern complexity, allowing for richer behavior through continuous space dynamics.

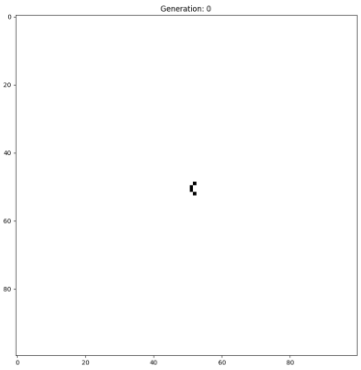
Question 2 – Gliders

A central glider pattern was tested. With wrap-around, the structure continued to move. Without it, it collapsed at the boundary.

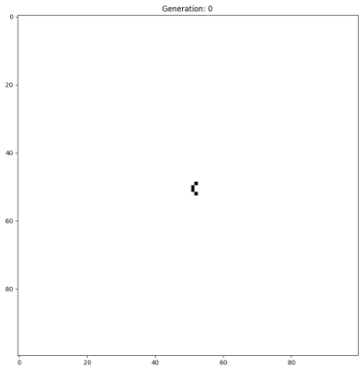
Additional generation snapshots for deeper insight:

Below are detailed observations at key generations for both wrap-around and non-wrap settings.

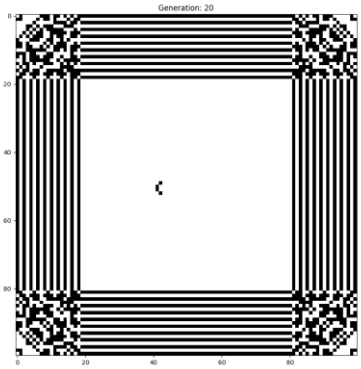
Glider template number 1:



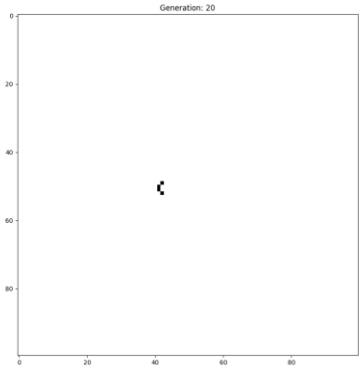
Gen 0 – No Wrap



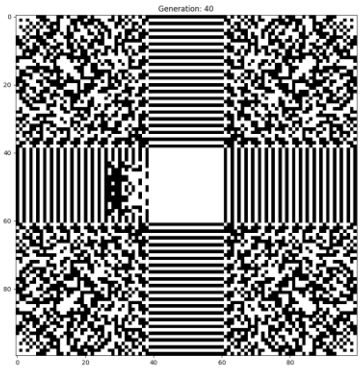
Gen 0 – Wrap



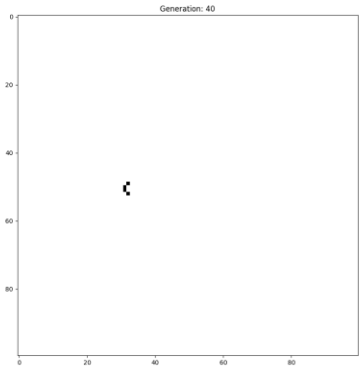
Gen 20 – No Wrap



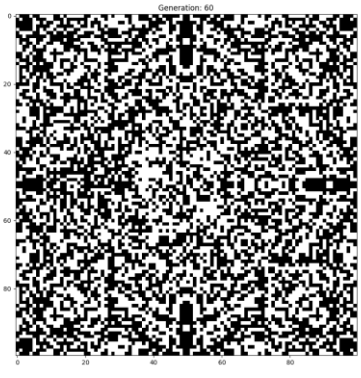
Gen 20 – Wrap



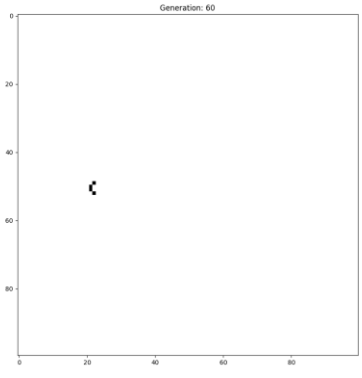
Gen 40 – No Wrap



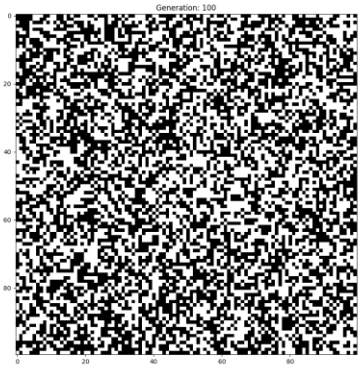
Gen 40 – Wrap



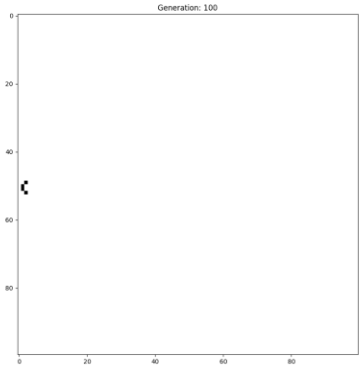
Gen 60 – No Wrap



Gen 60 – Wrap

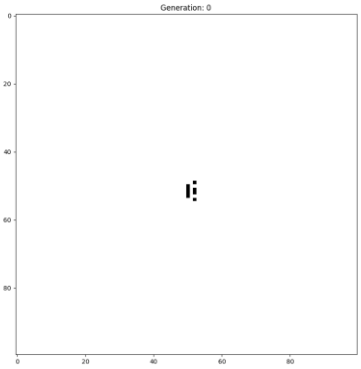


Gen 100 – No Wrap

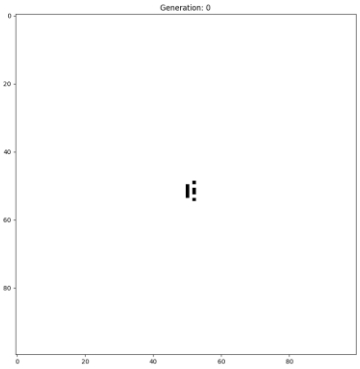


Gen 100 – Wrap

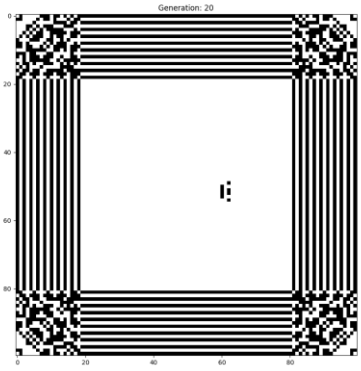
Glider template number 2:



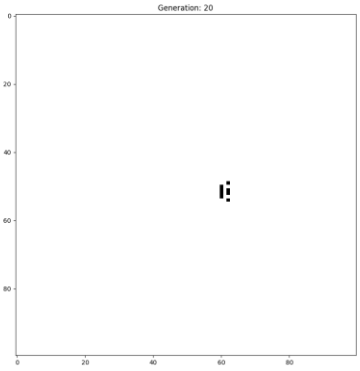
Gen 0 – No Wrap



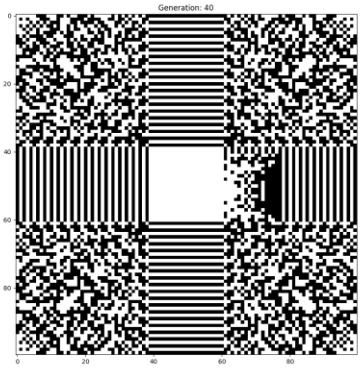
Gen 0 – Wrap



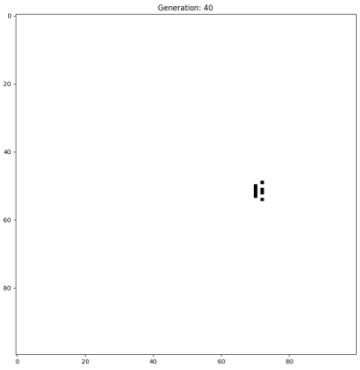
Gen 20 – No Wrap



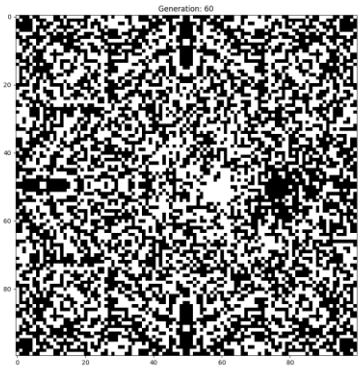
Gen 20 – Wrap



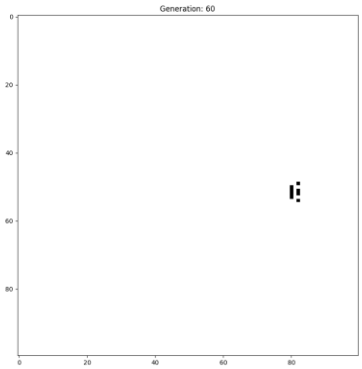
Gen 40 – No Wrap



Gen 40 – Wrap

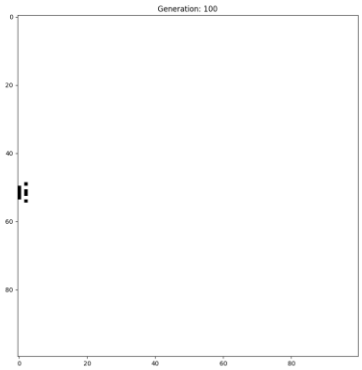


Gen 60 – No Wrap



Gen 60 – Wrap

Gen 100 – No Wrap



Gen 100 – Wrap

Conclusion:

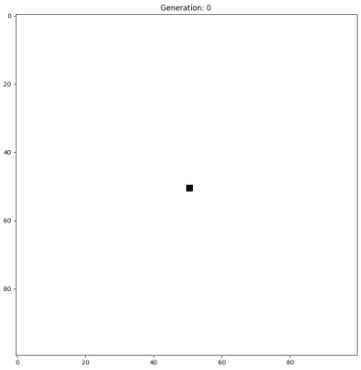
The glider pattern showed continuous horizontal movement under wrap-around conditions, maintaining periodic regeneration across boundaries. In no-wrap, motion was quickly halted at the edges, leading to collapse. This underscores how wrap-around is essential for supporting sustained directional propagation and glider dynamics.

Question 3 – Predefined Patterns

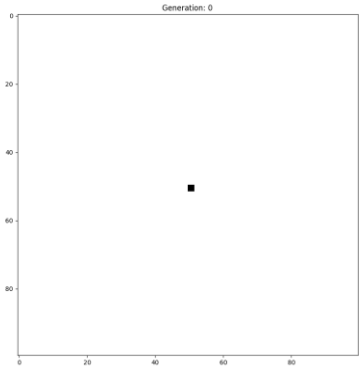
The following patterns were tested: blinker and traffic light.
Multiple snapshots below show their behavior under different settings.

Below are detailed observations at key generations for both wrap-around and non-wrap settings.

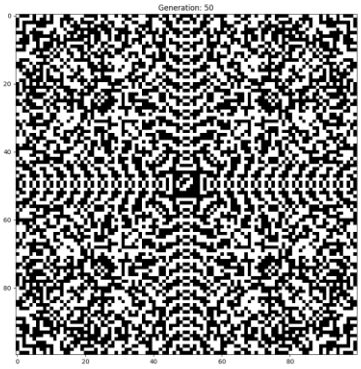
Blinker:



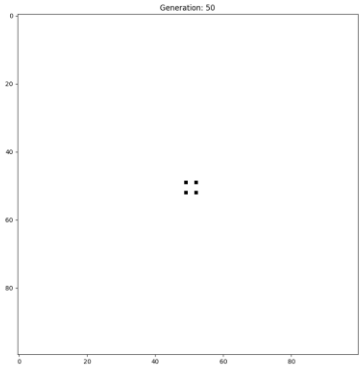
Gen 0 – No Wrap



Gen 0 – Wrap

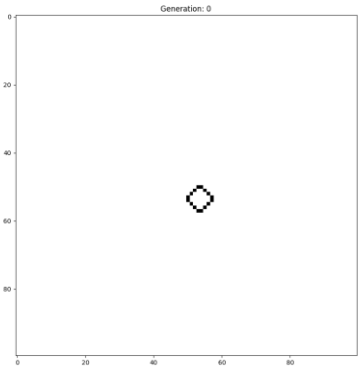


Gen 50 – No Wrap

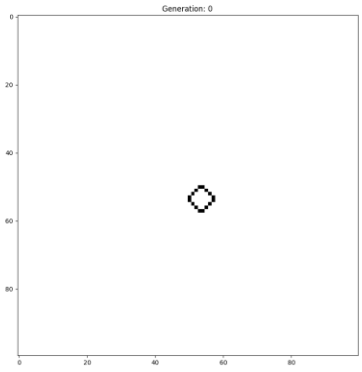


Gen 50 – Wrap

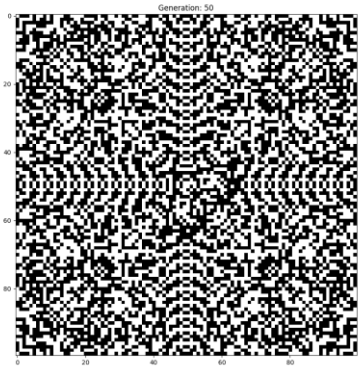
Traffic light:



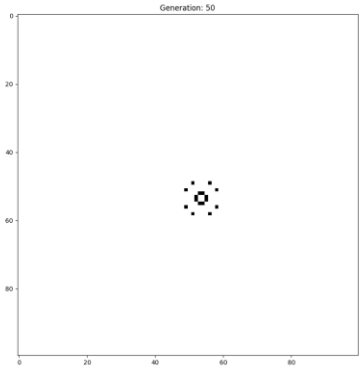
Gen 0 – No Wrap



Gen 0 – Wrap



Gen 50 – No Wrap



Gen 50 – Wrap

Conclusion:

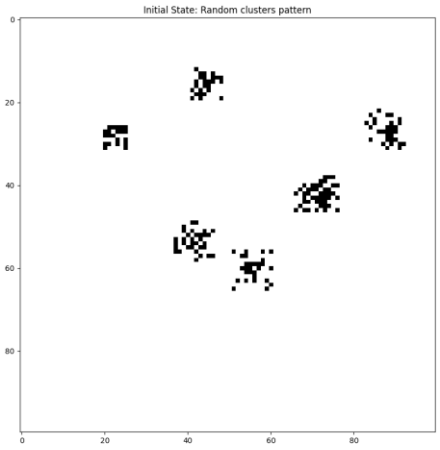
Blinker and traffic light patterns behaved differently under the two boundary modes. Blinker kept showing the same pattern in each two generations and the traffic light in about 20 generations. In wrap mode, both showed stable oscillations, while in no-wrap, damping and symmetry loss were common. Wrap-around thus supports temporal continuity and balanced behavior, preserving intended pattern functions.

Additional Observations – Experimental Patterns

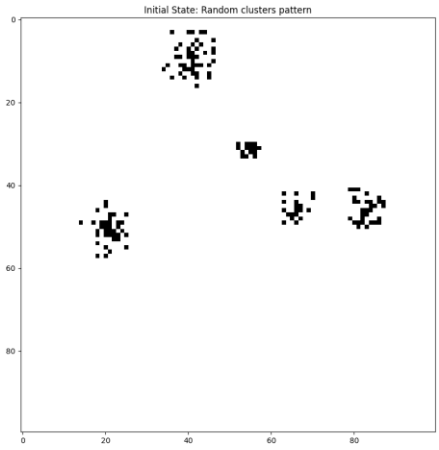
Random Clusters

The 'Random Clusters' pattern explores a unique behavior. It was tested both with and without wrap-around over 300 generations. Below are comparisons between both conditions and key frames showing their evolution.
This pattern begins with a scattered random distribution of live cells in small local groups. Without wrap-around, most clusters dissipate rapidly, leaving isolated static patterns. With wrap-around, the clusters interact across the borders, occasionally sustaining movement and oscillation over time. The system doesn't reach full stabilization within 300 generations.

Initial vs Final States:

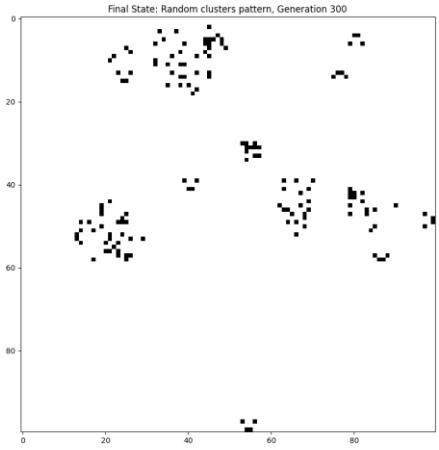


Initial – No Wrap



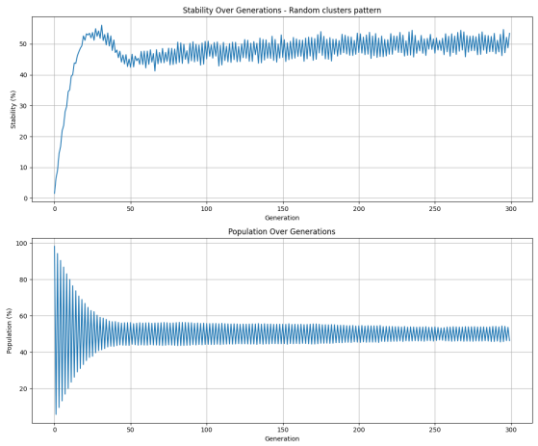
Initial – Wrap

Final – No Wrap

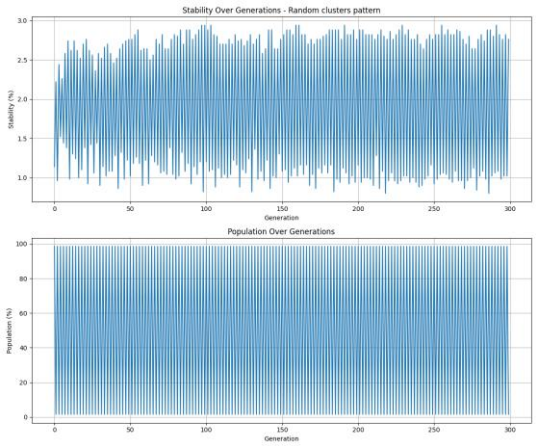


Final – Wrap

Metrics:



Metrics – No Wrap



Metrics – Wrap

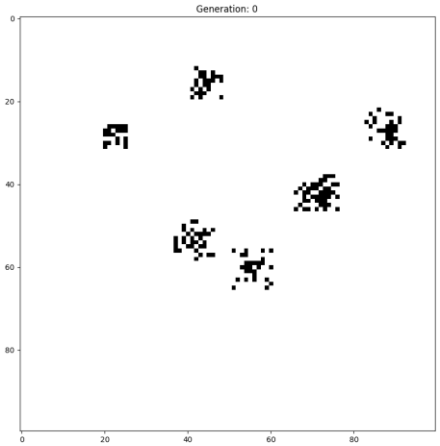
The stability graph in no-wrap rises rapidly, showing fast convergence to a static configuration. With wrap-around, stabilization takes longer due to ongoing activity from interacting clusters.

The population graph shows a steep decline in the no-wrap version, indicating that most initial clusters collapse quickly due to isolation. In the wrap version, the decline is slower, suggesting prolonged interactions across the edges that help preserve dynamic zones.

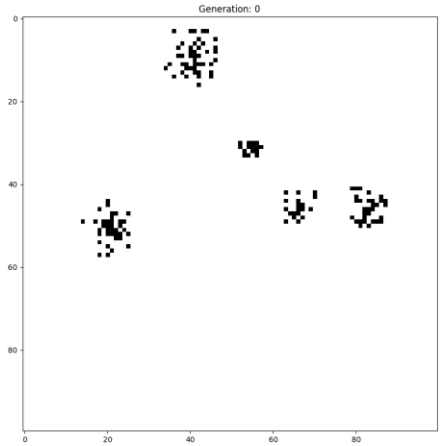
The stability metric in wrap mode oscillates as the glider progresses through space. In no-wrap, it levels off quickly as the system freezes.

The population curve stays nearly constant in wrap mode, since the glider keeps moving and regenerating. In no-wrap, population drops once the glider hits the boundary and collapses.

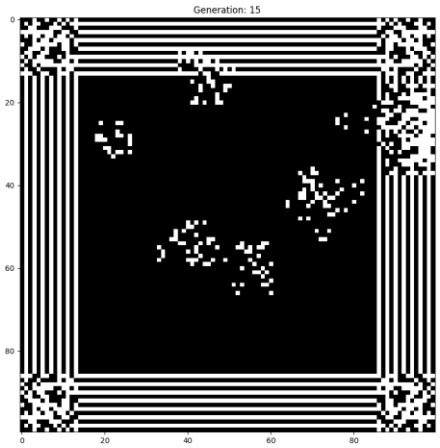
Evolution Snapshots:



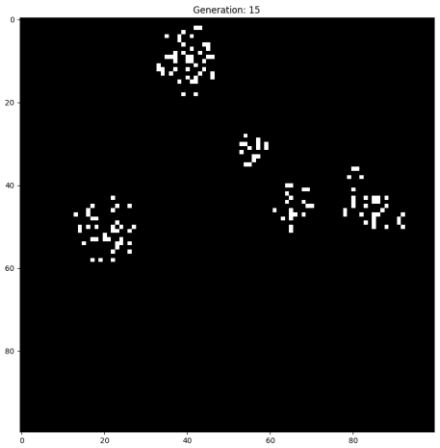
Gen 0 – No Wrap



Gen 0 – Wrap

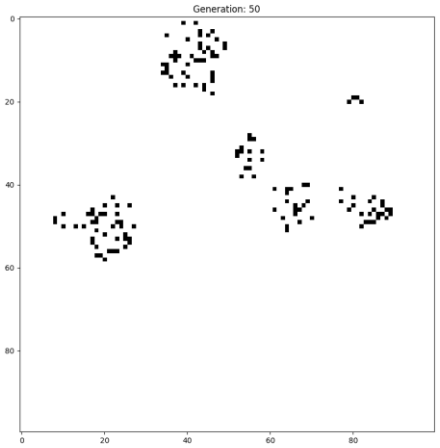


Gen 15 – No Wrap

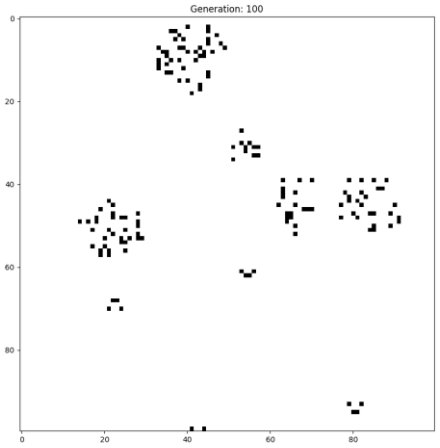


Gen 15 – Wrap

Gen 50 – No Wrap

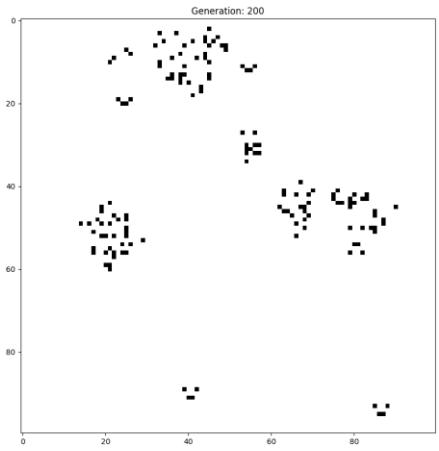


Gen 50 – Wrap



Gen 100 – No Wrap

Gen 100 – Wrap



Gen 200 – No Wrap

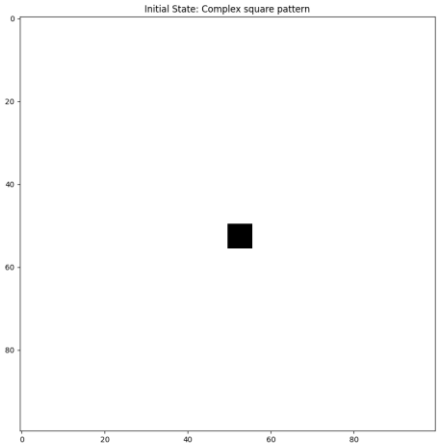
Gen 200 – Wrap

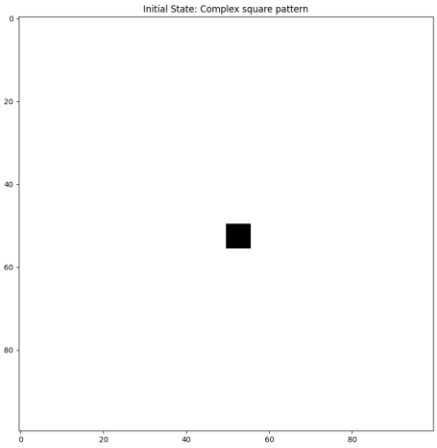
Weird / Chaotic Pattern

The 'Weird / Chaotic Pattern' pattern explores a unique behavior. It stated as an 8x8 square and through its evolutions gliders were created causing weird behaviors. It was tested both with and without wrap-around over 300 generations. Below are comparisons between both conditions and key frames showing their evolution.

This pattern starts with a non-symmetric arrangement leading to complex and chaotic behavior. In the non-wrap configuration, oscillations appear but fade over time into static islands. With wrap-around, chaos persists longer, with constant flipping activity and interaction across edges. This demonstrates sensitivity to boundary conditions and rich long-term dynamics.

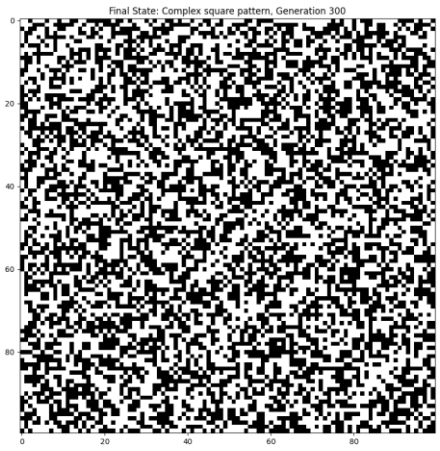
Initial vs Final States:

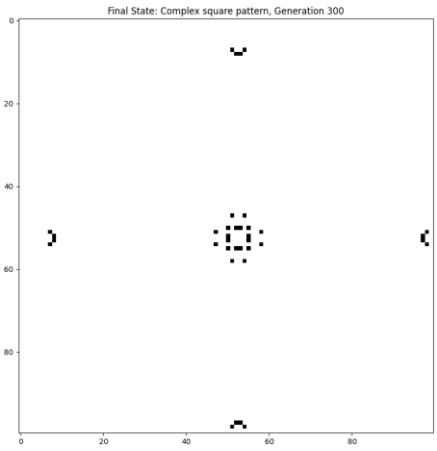




Initial – No Wrap

Initial – Wrap

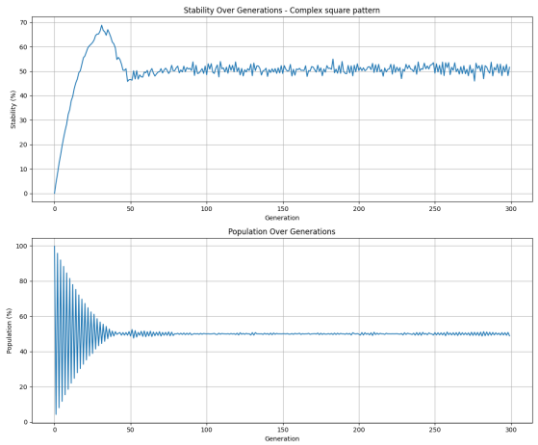


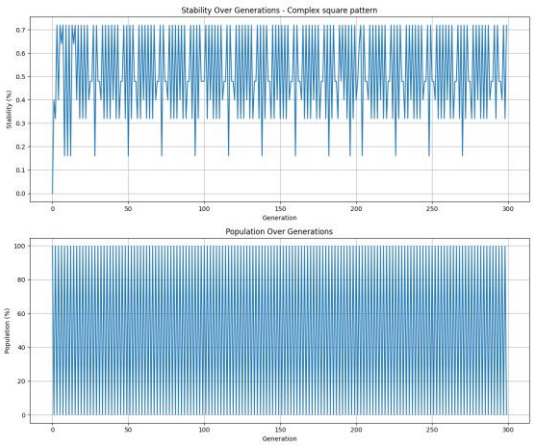


Final – No Wrap

Final – Wrap

Metrics:





Metrics – No Wrap

Metrics – Wrap

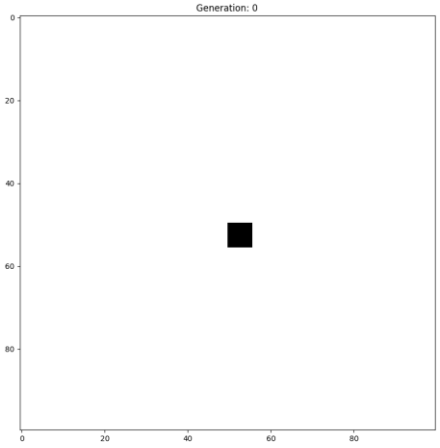
The stability metric in wrap mode oscillates as the glider progresses through space. In no-wrap, it levels off quickly as the system freezes.

The population curve stays nearly constant in wrap mode, since the glider keeps moving and regenerating. In no-wrap, population drops once the glider hits the boundary and collapses.

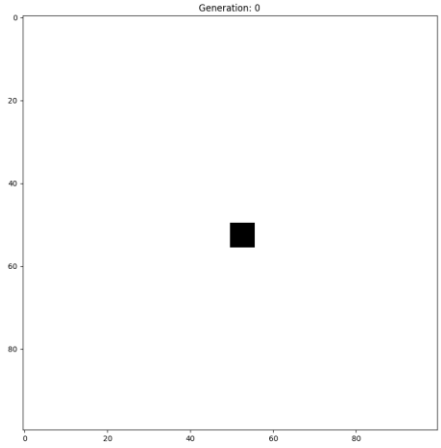
Stability grows slower in wrap mode, indicating rich ongoing evolution. The no-wrap graph shows faster flattening, consistent with fading activity.

This pattern creates chaotic local behavior. The population metric fluctuates for longer when using wrap-around due to persistent local oscillations. No-wrap shows earlier convergence as boundary effects suppress evolution.

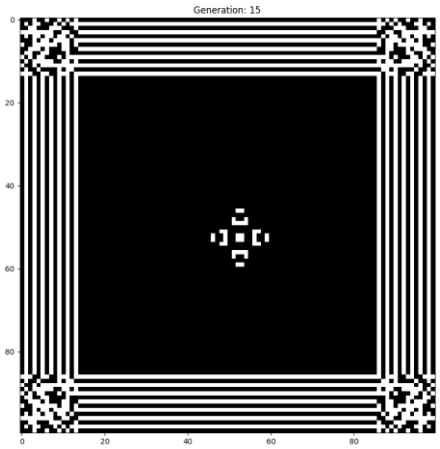
Evolution Snapshots:



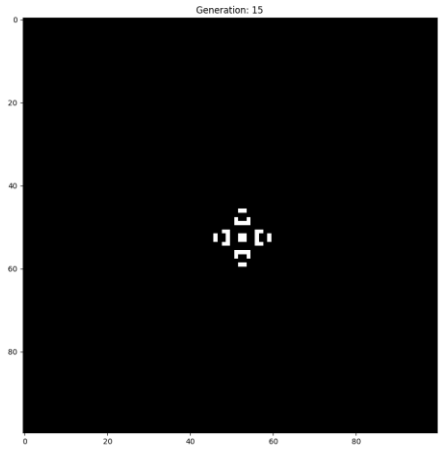
Gen 0 – No Wrap



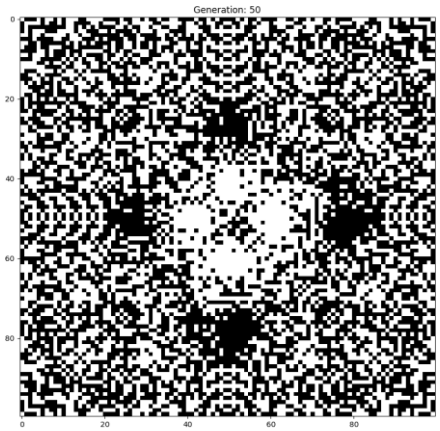
Gen 0 – Wrap



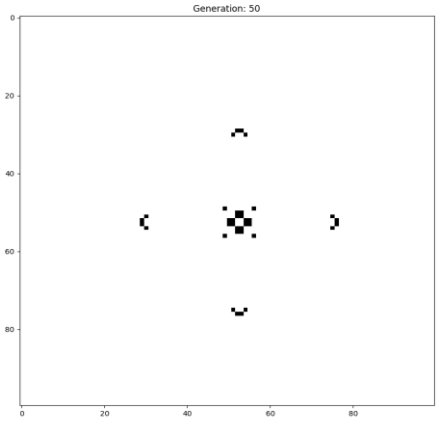
Gen 15 – No Wrap



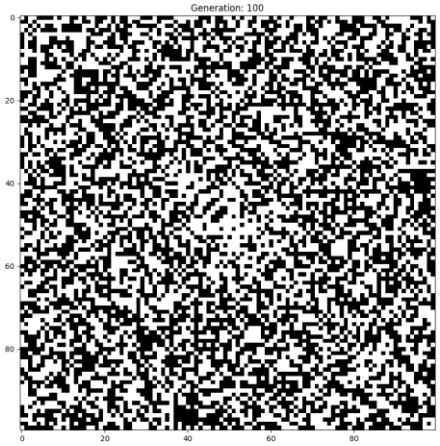
Gen 15 – Wrap



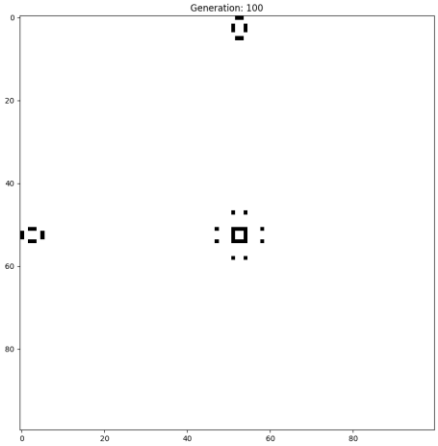
Gen 50 – No Wrap



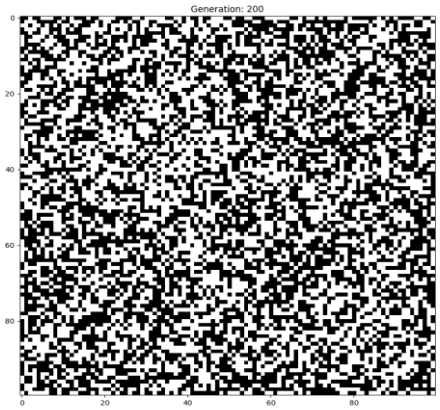
Gen 50 – Wrap



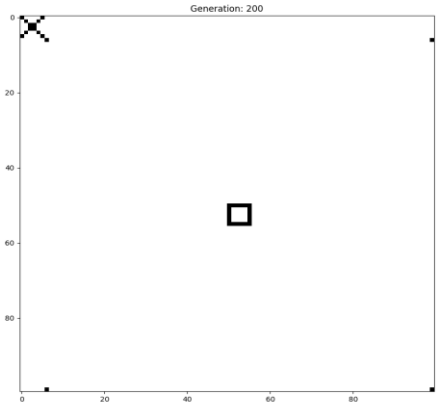
Gen 100 – No Wrap



Gen 100 – Wrap



Gen 200 – No Wrap



Gen 200 – Wrap

Final Conclusions

- Experiments show that wrap-around boundaries significantly enhance dynamic persistence, especially in patterns involving motion.
- Random cluster patterns tend to decay faster without wrap-around, while maintaining internal activity longer in wrap mode.
- Glider-like patterns demonstrate directional movement that is preserved only when wrapping is enabled.
- Weird patterns exhibit chaotic but rich oscillations. Their long-term behavior is highly sensitive to initial conditions and boundary effects.
- Across all cases, the automaton effectively models various behaviors: stabilization, propagation, oscillation, and decay.
- Metrics such as stability and population are consistent indicators of behavior convergence and activity.