# Virtual Genetics: Optimizing Population Growth in Conway's Game of Life

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## Motivating Questions

1. Can we design a Genetic Algorithm to favor high-growth starting boards?
2. Do factors like number of iterations and board size influence maximal starting states?
3. Are there some shapes which grow quickly but die off long term? Similarly, are there shapes with slow, stable growth?

## Methodology

Our project uses a Genetic Algorithm (GA) to find the most fruitful initial board state of the Game of Life using the following fitness function:

$$fitness(chromosome) = \frac{\#\ cells\ survived}{\#\ cells\ live\ at\ start}$$

Thus, fitness equals net growth rate.

Fixed Parameters:
- Board size: 25x25 cells (when the inner board has an odd side length) or 24x24 cells (otherwise), ensures inner board is centered
- Probability of crossover = 0.7
- Probability of mutation = 0.05

Manipulated Parameters:
- Side length of the inner board: 3, 4, 5, 6, 7
- Number of game iterations played: 5, 10, 25, 50, 100

We performed three trials at each inner board size and number of iterations and took the mean growth rate across the three trials.

## John Conway's Game of Life (GoL)

- Zero-player game played on a grid, simulates population growth
- Each space on the board is a "cell," cells can be living or nonliving

Rules:
1. Cells with <2 neighbors die from isolation
2. Cells with 2 or 3 neighbors survive
3. Cells with >3 neighbors die from overpopulation
4. A non-living cell comes to life with 3 living neighbors

## Results

| Game Iterations | Trial 1 | Trial 2 | Trial 3 | Avg |
|---|---|---|---|---|
| 5 | 2.0 | 2.0 | 2.0 | 2.0 |
| 10 | 4.0 | 3.83 | 5.0 | 4.27 |
| 25 | 10.17 | 10.17 | 10.33 | 10.21 |
| 50 | 16.33 | 15.71 | 16.33 | 16.12 |
| 100 | 17.3 | 17.3 | 19.0 | 17.9 |

Figure 1: Growth Rates for Inner Board Size: 3x3

| Game Iterations | Trial 1 | Trial 2 | Trial 3 | Avg |
|---|---|---|---|---|
| 5 | 2.75 | 2.78 | 2.75 | 2.76 |
| 10 | 5.71 | 5.71 | 5.71 | 5.71 |
| 25 | 11.17 | 12.2 | 12.2 | 11.85 |
| 50 | 16.57 | 19.33 | 19.33 | 18.41 |
| 100 | 16.9 | 16.9 | 12.8 | 15.5 |

Figure 2: Growth Rates for Inner Board Size: 4x4

| Game Iterations | Trial 1 | Trial 2 | Trial 3 | Avg |
|---|---|---|---|---|
| 5 | 2.73 | 2.75 | 2.56 | 2.68 |
| 10 | 5.0 | 5.0 | 4.57 | 4.86 |
| 25 | 7.75 | 10.0 | 8.86 | 8.87 |
| 50 | 14.67 | 9.8 | 16.33 | 13.6 |
| 100 | 13.5 | 15.4 | 12.3 | 13.7 |

Figure 3: Growth Rates for Inner Board Size: 5x5

| Game Iterations | Trial 1 | Trial 2 | Trial 3 | Avg |
|---|---|---|---|---|
| 5 | 2.06 | 2.29 | 2.43 | 2.26 |
| 10 | 2.91 | 4.44 | 5.0 | 4.12 |
| 25 | 6.89 | 6.89 | 6.10 | 6.63 |
| 50 | 12.22 | 9.38 | 8.46 | 10.02 |
| 100 | 10.7 | 10.9 | 10.2 | 10.6 |

Figure 4: Growth Rates for Inner Board Size: 6x6

| Game Iterations | Trial 1 | Trial 2 | Trial 3 | Avg |
|---|---|---|---|---|
| 5 | 2.0 | 1.95 | 2.0 | 1.98 |
| 10 | 2.62 | 2.30 | 2.36 | 2.43 |
| 25 | 4.09 | 4.60 | 4.0 | 4.23 |
| 50 | 5.95 | 5.76 | 5.21 | 5.64 |
| 100 | 6.7 | 7.7 | 6.8 | 7.1 |

Figure 5: Growth Rates for Inner Board Size: 7x7

## "The Butterfly"

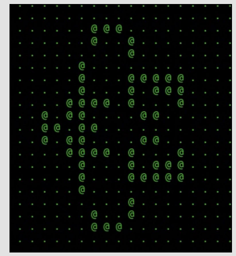

Figure 6: 4x4 starting board over 25 iterations

## Radial Symmetry

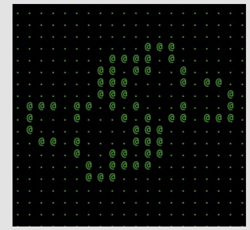

Figure 7: 4x4 starting board at 20 iterations

## Different Start, Same End State

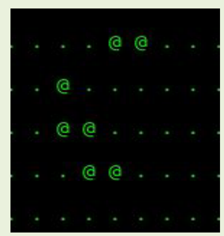

Figure 8: Best 4x4 inner square starting board for 50 iterations, trial 1

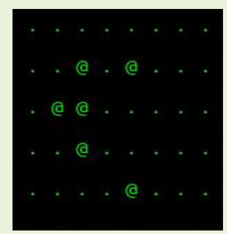

Figure 9: Best 4x4 inner square starting board for 50 iterations, trial 2

Figure 10: Best 4x4 inner square after 50 iterations, trial 1

Figure 11: Best 4x4 inner square after 50 iterations, trial 1

## Key Findings

- We confirmed that the GA favors high-growth start states
- Smaller inner board sizes tended towards higher growth rates
- Several unique start states led to identical end states, up to orientation
- Radial and bilateral symmetry frequently appeared in later iterations (>15)
- When run for >100 iterations, some boards had "offspring" behavior, where large shapes released smaller versions of themselves

## Future Directions

We would like to explore the imposition of more "real world" scenarios as parameters on GoL. For example, could we implement "sick" cells which spread their illness before dying off? If yes, then how does this affect the ideal starting shapes for such games? Additionally, we wonder if changing the rules of the game (say, raise the overpopulation standard to 5 neighbors) would have an impact on maximal initial states. Finally, we would like to look for populations which stabilize or survive long term, rather than having high net growth over a limited period of time.

## Acknowledgements

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