Map-Based Cellular Automaton

Project Description

This project is an interactive simulation that models how competing influences spread across a geographic map. Each pixel is treated as a "cell" in a cellular automaton, which evolves through multiple levels of influence. Over time, regions shift between neutral, red team, and blue team states depending on local interactions and propagation rules.

Technical Highlights

- Built in **Processing/Java** with efficient pixel-based updates to handle thousands of cells per frame.
- Implemented an **influence-propagation algorithm** using weighted neighbor sums and generational thresholds.
  Designed flexible **state-transition rules** to allow experimentation with different propagation models.
- Optimized rendering loop to support interactive visualization and smooth performance.

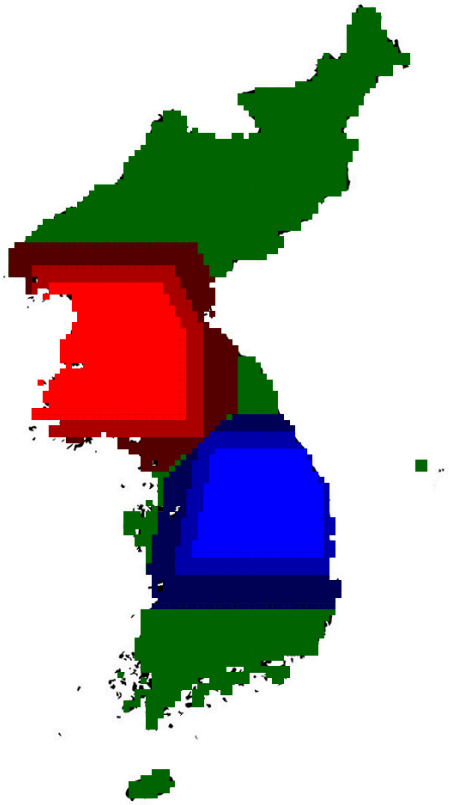
Applications

While framed here as "Red vs. Blue Team," this framework can be applied more broadly to simulate:

- Information or idea spread
- Competitive dynamics (e.g., product adoption)
  Territory control in strategy games
- Diffusion processes on irregular maps

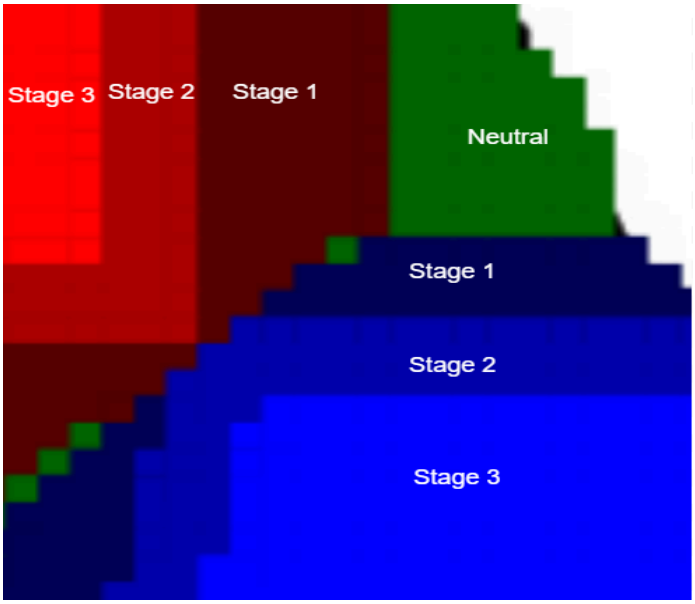
Possible States of a Cell

A cell can be in one of three states: Neutral, Blue team, Red team.



The Red and Blue regions will be further divided into three Stages, with Stage 3 meaning fully indoctrinated, Stage 2 being partially indoctrinated, and Stage 1 being somewhat indoctrinated.

The brighter the shade, the stronger the cell's ties to its teams, as well as its influence on nearby cells.



Key Features

- **Map Integration:** Any image map can be loaded as the simulation domain, letting the model adapt to real or fictional geographies.
- **Multi-Level Influence System:** Each cell has three progressive "strength" stages (1 = weak, 3 = fully entrenched), which determine both its resilience and its influence on neighbors.
- **Dynamic Evolution Rules:**

    - Neutral regions are highly susceptible to change.
    - Weakly aligned regions can shift allegiance under sustained pressure.
    - Strong regions act as stabilizing hubs that reinforce their surroundings.
- **Visualization:** Real-time rendering of influence spread, with color gradients showing relative team strength.

Evolution Rules

1. Each cell has a certain amount of influence to nearby cells in the next generation. The higher that cell's stage, the higher the influence.
   A Stage 3 cell has an influence of 3 on all nearby cells. Stage 2 has 2, and Stage 1 has 1. A cell can change its color if the total influence acting on it from its neighbours is high enough, as explained below.

2. For Stage 3 cells, if either the opposite team is favored OR both teams are favored, the cell has a 50% chance of turning into a Stage 1, 2, or neutral cell if it is influenced by a cell of the opposite team.

   For example, if a Stage 3 Red Cell is under the influence of a Blue cell, and Blue side is favored, the Red Cell has a 50% chance to turn into either a Neutral, Stage 1 Red, or Stage 2 Red cell.

3. If and only if the Stage 3 cell's team is favoured, it will not change state under any circumstances.

4. For Stage 1 and 2 cells, it does not matter if either team is favored. There are 3 possible influence states that this cell can be under.

   Opposite State Influence > Ally State Influence
   Opposite State Influence < Ally State Influence
   Opposite State Influence = Ally State Influence

5. In the case of a greater opposite state influence, the Stage 2 cells will turn into a Stage 1 if the cell reaches a threshold of 7 generations under the influence of an enemy state.

6. Similarly, a Stage 1 cell's Red/Blue influence will collapse, and will revert to a neutral state after 12 generations.

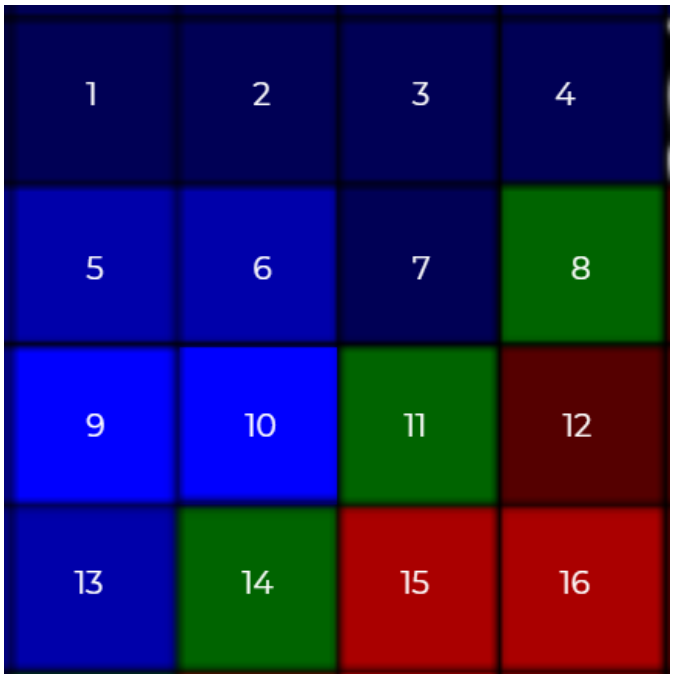
7. In the case of a greater allied state influence, the Stage 2 cell will turn into a Stage 3 cell after 7 generations. Similarly, a Stage 1 will turn into a Stage 2 cell after 12 generations. If there is an equal amount of influence, both states will slowly evolve towards their next Stage, albeit slower than it would

have if it were strongly influenced by an allied state.

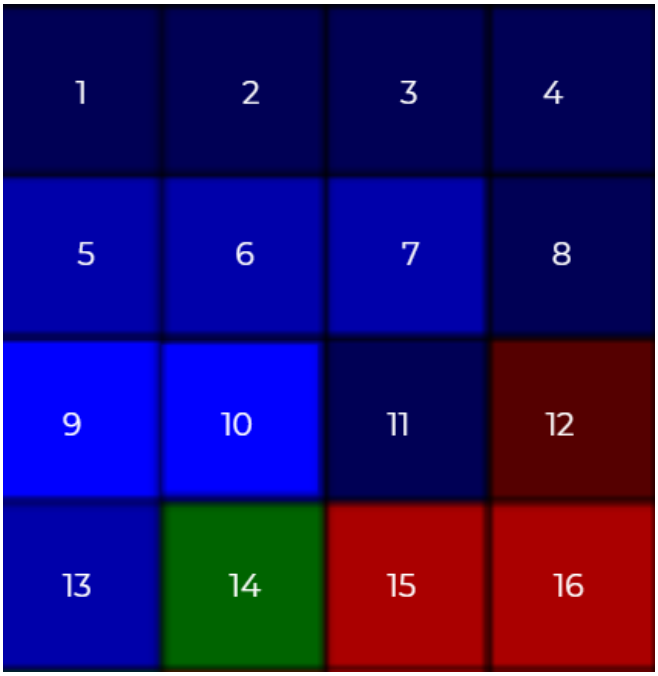
8. Neutral cells are very easily influenced. Only three generations are required to turn into a red/blue state. If there is an equal amount of influence from both red and blue states, the neutral cell will remain neutral.

Sample Evolution

First Generation:



Second Generation:



<u>In the first generation</u>
Cells 1, 2, 3, 4, and 7 are Stage 1 Blue team.
Cells 5, 6, 10, and 13 are Stage 2 Blue team.
Cell 9 is a Stage 3 Blue team.

Cell 12 is a Stage 1 Red team.
Cells 15, and 16 are Stage 2 Red team.
Cells 8, 11, and 14 are Neutral.

<u>In the next generation</u>
Three cells are changed. 7, 8, 11.

Cell 7, which is influenced by a factor of 7 (Blue) has been exposed to Blue team for long enough to advance to the next Stage (2).

The factor of 7 comes from the following.
3 (Cell 10) + 2 (Cell 6), + 3 (Cells 2,3,4) - 1(Cell 12) = 7.

Cell 8, which is influenced by a factor of 2 (Blue) has been exposed long enough to evolve into a Blue state.

Similarly, Cell 11 has evolved into a Blue state, as it is influenced by a factor of 1. (Blue).