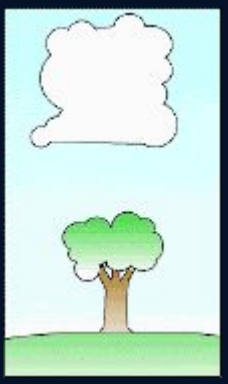
ZAPPED! Explaining lightning by simulating storm cloud charges using Cellular Automata

What it Models



Zapped! models the naturally occurring phenomenon of lightning in storm clouds. In nature, clouds form when water particles evaporate. As more and more particles accumulate, they circulate and collide with each other, exchanging electrons and generating charge. After gaining electrons and becoming heavier, negatively charged particles accumulate at the base of the cloud while positively charged particles accumulate at the top. A positive charge builds up in the ground because opposite charges attract, and once the potential difference in charge becomes great enough, a lightning bolt of energy bridges the gap between the clouds and the earth to discharge the electricity.

States of a Cell

- **Atmosphere** - treated as an empty space
- **Neutral Particle** - moves around and can collide with other particles to create electric charges
- **Positively charged particle** - spawned after a collision and travels to the top of the cloud
- **Negatively charged particle** - spawned after a collision and travels to the bottom of the cloud
- **Lightning strike** - cells turn white when a threshold is reached, simulating a lightning strike.

What a user can tweak

A user can tweak several aspects of the program, including:

- Grid Size & Frame Rate
- Lightning Threshold (how many charges must accumulate at the bottom of the cloud for a strike to occur)
- Particle Concentration (the number of particles that initially start off in the cloud)
- Charge Odds (the odds that when two particles collide a charge will be generated)
- int n = 80; //for best results, choose a number between 30 and 80
- Storm Severity (this number impacts the Charge Odds and the darkness of the cloud, meaning that it makes the storm cloud appear more severe while also causing lightning to strike more quickly).

Evolution Rules

In the first generation, **Neutral particles** are placed randomly in the **Atmosphere** and are assigned random directions to move in. All future cell states depend on the previous state of the cell, the state of its neighbouring cells, the direction particles are assigned, and whether or not the **lightning strike** threshold has been reached.

- **Atmosphere** cells remain **Atmosphere** cells until they are overwritten by another type of cell
- **Neutral particles** move in a constant, randomly assigned direction until they collide with other particles or collide with a wall.
- **Positively charged** particles always move upwards until they arrive at the top of the cloud, at which point they stay contained within the top 4 rows.
- **Negatively charged** particles always move downwards until they arrive at the bottom of the cloud, at which point they stay contained within the bottom 4 rows.
- If a user set threshold is reached, a **Lightning Strike** occurs, setting cells to white.

Types of collisions:

Neutral/Neutral OR **Neutral/Positive** OR **Neutral/Negative** :

Collisions occur when two particles are within one cell of each other (along diagonals and edges). If particles collide within the same cell, it is not considered a collision and they merge to become one particle in the next frame.

If a particle collision occurs, depending on the storm severity, there is a varying chance that that each particle will become a **Positive** particle or a **Negative** particle.

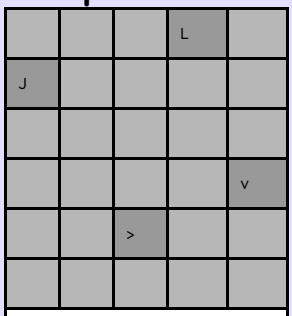
Positive/Positive OR **Positive / Negative** OR **Negative/Negative**:

The particles do not impact each other. In the frame after collision, both particles will continue in their respective assigned directions.

Any Particle and the edge of the screen:

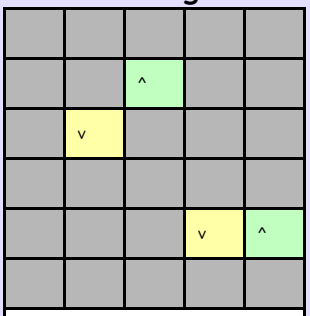
Any particle that collides with the edge of the screen will change directions and ‘bounce’ back into the centre of the cloud, where it can continue to engage in collisions.

Sample Evolution: Demonstrating what constitutes a collision (direction arrows shown)

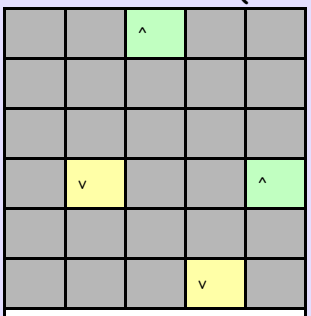


Neutral particles randomly placed within the cloud assigned to move in random directions.

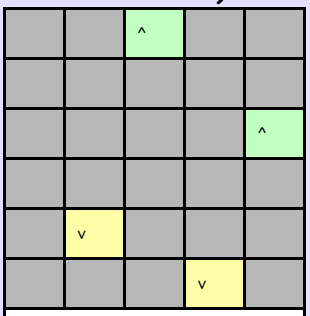
Neutral particles bounce off of walls (direction arrows shown)



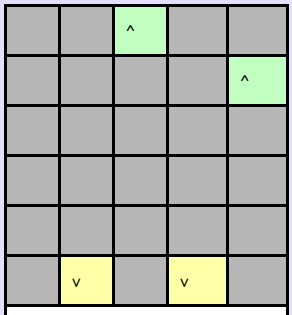
Two collisions occur. Each collision results in particles becoming **positive** ,**negative,** or remaining **neutral**. **Positive particles** move to the top of the cloud and **negative** particles move to the bottom.



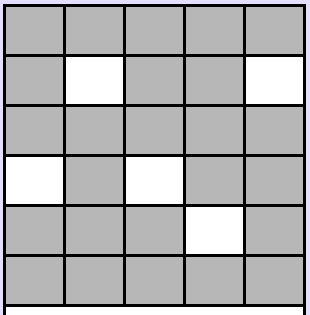
The **positive particles** travel to the top of the cloud. The **negative particles** travel to the bottom of the cloud.



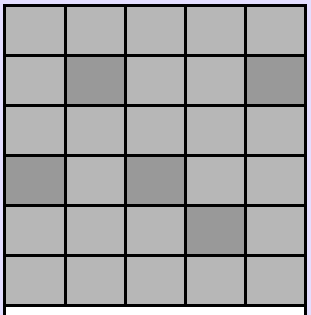
Particles continue to travel. Once reaching the top and bottom of the cloud, the **charged particles** move up and down within a confined area



A threshold of charge (specified by the user) is reached in the bottom of the cloud (in this example ,**2 charges**)



The cloud illuminates randomly scattered charges to simulate a lightning bolt once the threshold has been reached.



In the next frame, all charged particles return to neutral states and are rescattered randomly throughout the cloud (See frame 1)