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Forest Fire Simulation

Introduction:

My initial interest in this project partially came from the rising amount of forest fires and forest fire severity we have witnessed in recent years. I wanted to better understand what factors could be causing fires to spread the way we see in real life and if those conditions could be replicated in matlab to create a visual representation of a forest fire. After researching the topic, I was able to find other simulations for forest fires done in a variety of programming languages. While they share some characteristics of my simulation, they lacked the ability to change major factors and only seemed to generate patterns similar to each other.

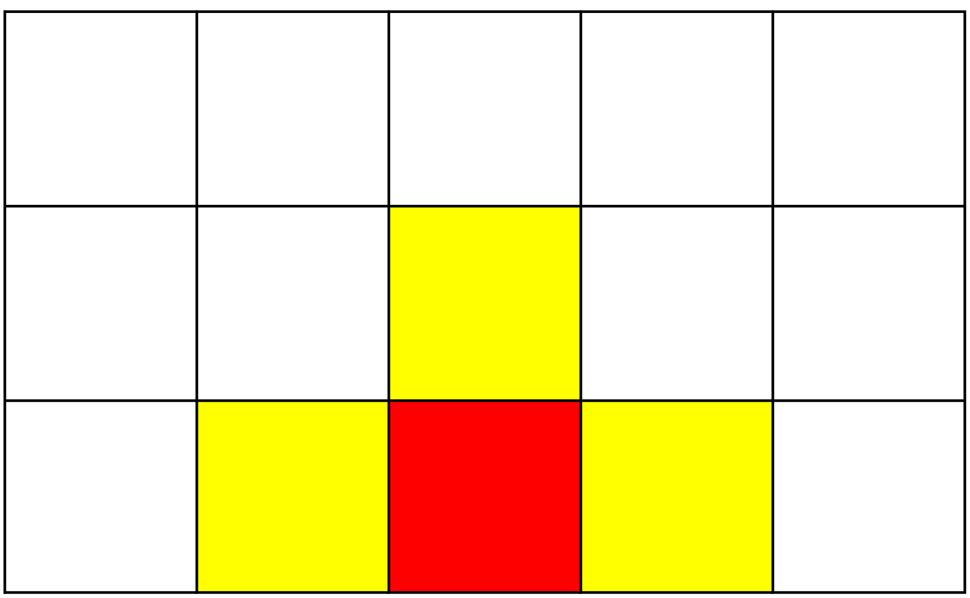
Methods:

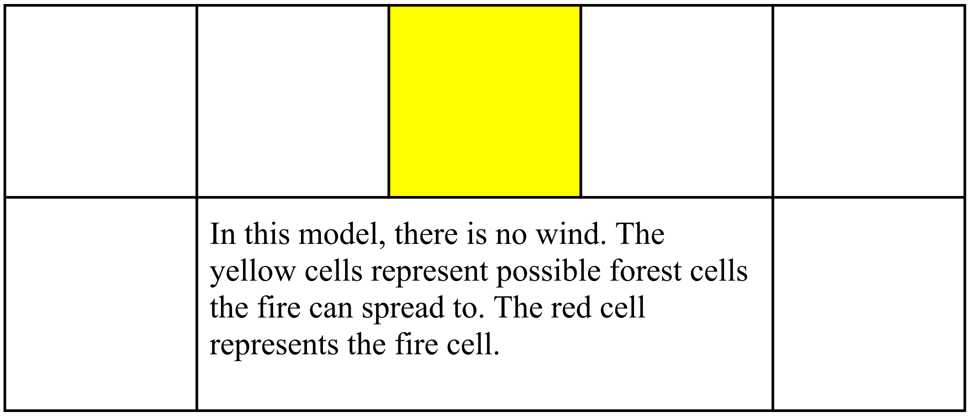
Assumptions

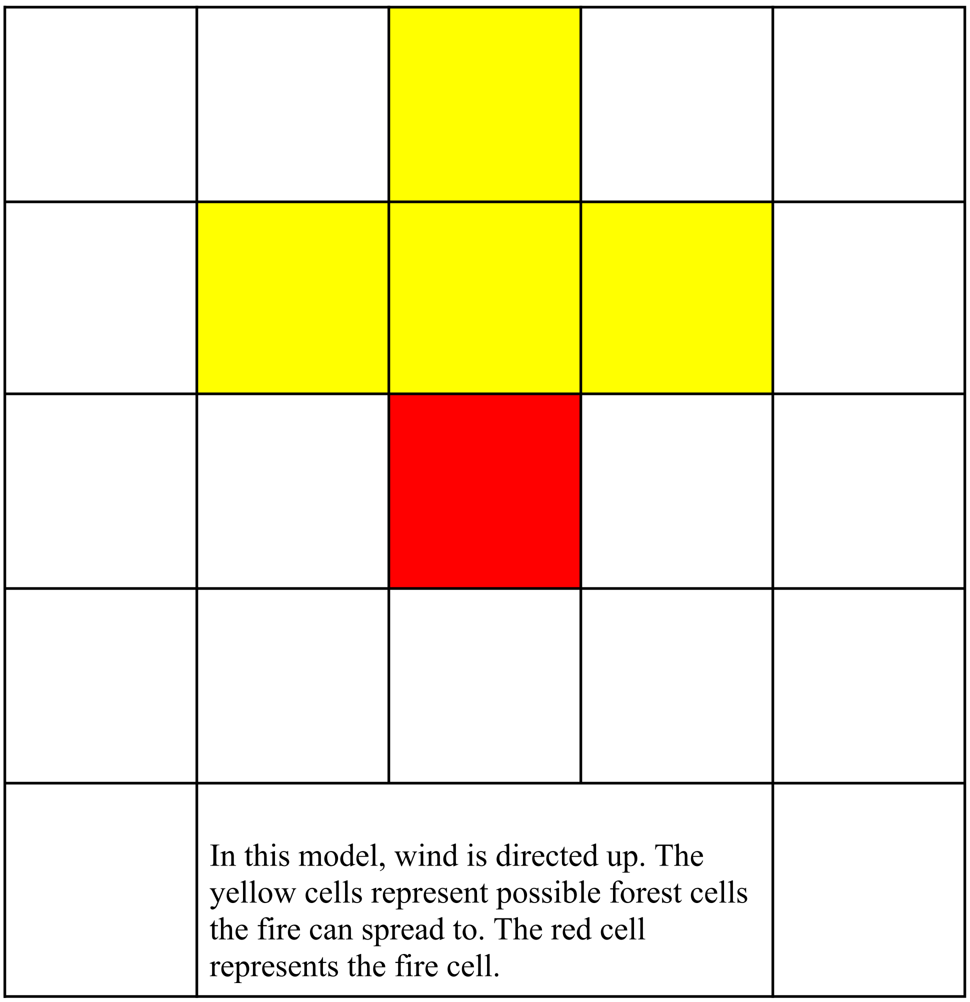
To maintain a reasonable run time and level of complexity for this model, certain assumptions and restrictions were made. For example, the domain of this model will always be a rectangle with a predetermined width and height. All agents within this rectangle are only influenced by other agents within the rectangle. This causes some agents like those near the middle to be influenced by more agents than agents on the edge of the domain. For this simulation we assume that fire can spread to forest agents and that fire can not spread to water agents. We are also assuming that fire has the same probability to spread to applicable forest agents and that agents stay on fire for five time steps. In addition to being realistic, these assumptions allow for results to be generated quickly and the effects of different factors to become clear.

Agent Behavior

There are four types of agents that are used in this model. Forest agents appear green, water agents appear blue, fire agents appear red, and burnt agents appear black. As outlined above, fire can only be spread to forest agents. In the default version of this simulation, fire can only spread to the agent directly above, below, to the right, and to the left of a fire agent. When a simulation with wind is selected by the user, the way in which fire spreads becomes more complex. The direction of the wind has an equal chance to be up, down, left, or right in the model. When wind is involved, fire spreads to the agents above, below, to the left, or to the right of the agent it would spread to if wind was not involved. The models below show the possible spread for a fire agent in a simulation without wind and in a simulation with wind directed up.



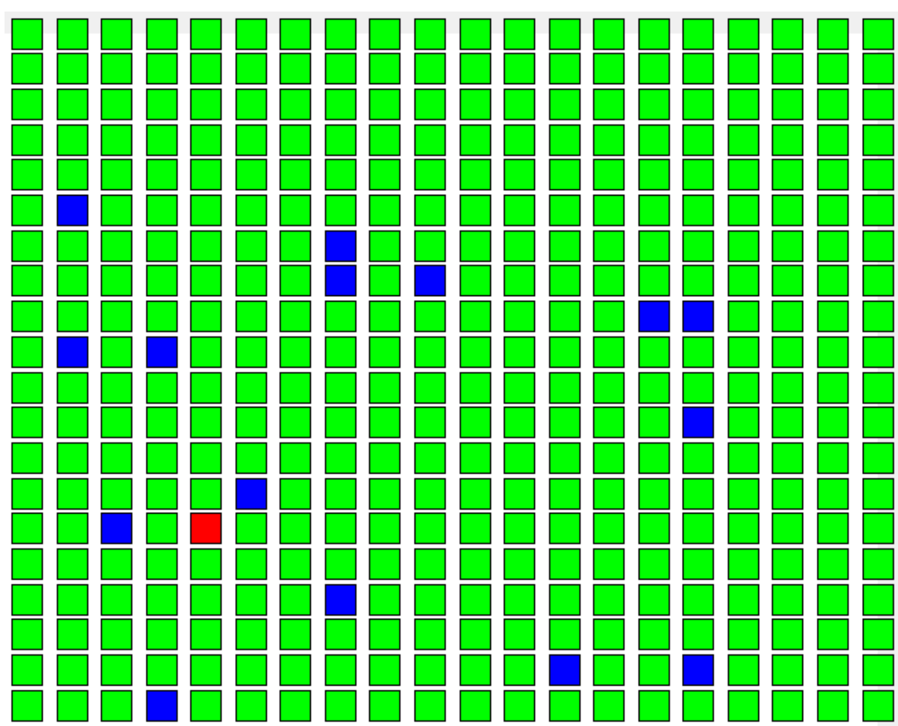




Regardless if wind is included or not, once an agent has been on fire for five time steps, the fire agent will turn black, becoming a burnt agent. Burnt agents can no longer spread fire and similar to water agents, they can never become a different type of agent. The probability of fire spreading from any fire agent to a forest agent is 25%. This means that the more fire agents near a forest agent, the higher the chance for that forest agent to catch fire. The probability for this forest agent to catch fire can be modeled by the equation $P = (1 - (.75^\wedge n))$ where n is the amount of fire agents that can spread fire to the forest agent.

Agent Generation

Before any agents are generated, the program will ask the user if a river is wanted. If a river is not selected, the program will generate a grid of agents with the width and height being equal to the variables "width" and "height" which each have a value of 20 by default. Each agent in this grid has a 95% chance of being a forest agent and 5% chance of being a water agent. A random forest agent is then chosen to become a fire agent which is what all fire agents will stem from. If a river is chosen before generation, a vertical river composed of water agents will randomly replace all agents with a certain x value. This takes place after generating the forest agents, but before generating the fire agent to avoid overwriting the fire agent.



Implementation

This simulation is very similar to cellular automata with one major difference. Normal cellular automata models will have an agent change based on their surroundings. In this simulation, agents change other agents. For example, instead of forest agents changing based on surrounding fire agents, fire agents change nearby forest agents. The plotting method used in this program is also somewhat unorthodox. The state of each agent is contained in a two dimensional array as a string. Each string is made up of a character for the color of the agent followed by an “s”. For example, a forest agent is represented by “gs” in the array, which when plotted produces a green square. This simplicity allows for the plotting algorithm to be efficient and easy to understand. The plotting algorithm plots the agent in a position according to their x and y values in the array and takes their color from the string array “fire” which holds the agent colors and shapes as written above.

Results and Discussion:

When the chance of fire spreading to applicable agents is 25%, the fire will usually spread to every forest agent in the grid unless they are protected by water agents. This protection can either be in the form of a river or randomly generated water agents that happened to have formed around the forest agent. Since without wind the fire can only spread to forest agents touching fire agents, the fire will never cross a river. However, when wind is included and in the direction that the fire needs to cross the river, the fire will be able to cross the river due to the increased range it gains from the wind. Wind also greatly speeds up the spread of fire in the direction it is blowing but makes it impossible for the fire to spread in the opposite direction. The fire will still spread to directions perpendicular to the direction of the wind, but only while also spreading in the direction of the wind. Below are four sample simulations, some contain wind and some contain a river.

Simulation without a river and without wind(https://drive.google.com/file/d/1D7fr2ZLuQ-F_aMK7nKzc9r6BaZFB6p0k/view?usp=sharing)

Simulation without a river with wind(https://drive.google.com/file/d/1w5Hi-5vrorlbtoD2VnXyLBB-1pAgTkwJ/view?usp=sharing)

Simulation with a river without wind(https://drive.google.com/file/d/1K8oe0h8_5NXwR1cFeDvmZ1v9QQd7h6rq/view?usp=sharing)

Simulation with a river with wind(https://drive.google.com/file/d/1HBtKJ9wFJuumnl7NVTNIAf94HbtzNhgY/view?usp=sharing)

Conclusion:

I feel that I have succeeded in creating a realistic model of how fire could spread in a forest. Creating this simulation was an excellent way to better my understanding of cellular automata and how to implement it, even if my methods were somewhat unconventional. The way I coded this simulation caused many different errors and other problems along the way which allowed me to hone my problem solving skills. Many of the problems I ran into would have been mitigated had I started with a different structure. In the future, I would like to spend more time planning on how different parts of my program interact before making large amounts of progress.

I am satisfied with the results I have generated so far and plan to continue working on this project on the side to further explore its potential. While this project was a large amount of work, there are several factors I originally planned to include that I had to cut out due to time constraints. Within the next year, I plan to add factors like temperature, humidity, and precipitation and also change how the random agent generation works. Additionally, I am interested in trying to implement cellular automata in a conventional way that involves agents changing based on their surroundings instead of agents directly changing other agents. I believe the visuals of the simulation could also be improved to better represent the agents and their different states.

Sources Cited

Martin Thomas (2022). Fire Spread Model (https://www.mathworks.com/matlabcentral/fileexchange/74499-fire-spread-model), MATLAB Central File Exchange. Retrieved May 2, 2022.