Modeling Forest Fires with Cellular Automata

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*Abstract*—Forest Fires pose a danger not only to the wildlife that inhabit the forest, but also the communities that surround them.

Keywords—Cellular Automata, Thermal Radiation, Forest, Cell

# Introduction

The goal of this project is to produce a two-dimensional cellular automata such that it can reproduce the spread of a forest fire in a grid-like forest. The question this study poses to answer is the following: “Can a Cellular Automata, using factors such as the temperature, the height, the spread, and thermal properties of a Pin Oak tree adequately recreate a forest fire made up of Pin Oak trees? If not, to what degree can those factors model a forest fire with that criteria? Would we be able to model

# Motivation

This topic is useful as it would allow people to potentially preempt a forest fire’s front before it causes serious harm to the surrounding wildlife or towards any nearby civilization. A cellular automata can be useful as it would allow cells to act as trees in a forest and have similar thermal interactions, given the right state parameters. I believe that showing how forest fires can grow using cellular automata can give not only emergency workers a good idea of how a fire can spread in a model, but also how much damage they can potentially do under given circumstances.

# Related Works

## Forest fires spread modeling using cellular automata approach

This model uses four distinct states in order to represent fire growth: a burning state, an igniteable state, a burnt state, and a growing state. Its rules for evolution go in a cycle, essentially, with a burnt cell turning into a growing cell in the following step, and then an ignitable cell in the step after that. For their forest landscape, they use a real landmap generated using imagery from the several projects in order to predict fire growth in a simulation of a real environment. The map they used corine codes which represent the likelihood of those cells to burn. They ran several experiments wherein they would place the initial ignition point in a certain area of the map, such as a less dense area or an area with a higher amount of trees with wind conditions. Their conclusions were that the model could be useful in preventative measures as well as showing potential damage of an area.

## A model for predicting forest fire spreading using cellular automata

They define the state of the cell to be the ratio of its burned area to the cell’s total area. The local rule of the cells sums up the neighbors’ states, with diagonal neighbors’ states having the square root of 2 multiplied onto it beforehand in order to integrate the factor of distance into the rule, as each cell is 1 unit away from its adjacent neighbors. They use matrices of the rate of spread for a fire in order to determine how fast the fire front spreads. By setting this matrix, they are able to construct a digital “landscape” the cellular automata represents through the value they input. For example, to simulate something like a building that has a low rate-of-spread, they put a 0. This has the effect of controlling the speed of the fire front.They also incorporate wind into their model, which changes how the fire spreads on its own. Lastly, they also consider the height of the land in the cell. They conclude that this type of model is the first of its kind, being able to represent multiple type of forests and landscapes.

* 1. *How my model will be different*I intend to create a model that will simulate the heat transfer between trees in a moore neighborhood around a cellular automata. The idea is to have the trees exchange heat and, using real-world equationf of radiant heat transfer, simulate how the heat would be traded between trees that are already on fire with those that have yet to burn. With this setup, I hope to model how the temperature grows for various trees close an already ignited tree.

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# Method and Approach

As stated before, this model will be using real-world equations to model the heat transfers between cells in order to more accurately model a forest fire’s growth. In addition, the model will use an elementary approximation of wind in the way that trees downwind of a burning tree will receive more heat being produced by that burning tree.

## Cellular Automata

The Cellular automata I will be using will allow for four states:

### The “Normal” State: This state contains a non-burnt tree that is at no risk of burning

* + 1. The “At-risk” State: This state contains a tree that is close to another tree inside of its Moore neighborhood. This sees the tree’s temperature rise as time goes on.
    2. The “Burning” State: This state contains a tree that is actively burning with its temperature above 250 degrees Celsius.

### The “Burnt” State: This state contains a tree that has already burnt, but still interacts with the surrounding environment with its leftover heat from burning.

## Cells

Each tree has properties such as it own trunk diameter, its own height, spread, density, and its own temperature, the latter of which changes as time goes on based on the heat radiated from another tree.

## Tree chosen

The tree that I have chosen is the Pin Oak tree. We have chosen this tree due to its ability to grow in many places and the fact that it grows just north of Tennessee, so it is close by to home.

* 1. *The Setup*  
     The setup involves a “forest” represented by the cellular automata. When creating the cells, there is a 65 percent chance of a cell containing a tree. This is meant to simulate the variable distances between trees.

##### Acknowledgment *(Heading 5)*

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