Name(s)

Samyak Surti

Project Number

S0830

Project Title

Cellular Automata-Based Mathematical Model for the Spread of Forest Fires

Abstract

Objectives

Taking into consideration the most important physical factors of fire spread, the objective is to develop a cellular automata-based mathematical model that can accurately predict the spread of forest fires in order to aid firefighters in fire containment and evacuation.

Methods

A cellular automata is developed modifying a simple Python-based cellular automata framework developed by Luis Antunes that uses matplotlib. His single layered cellular automata was modified to accommodate additional layers representing the physical factors considered, such as fuel load, wind patterns, and topological features. Functions to initialize the maps were added. To evolve the configuration of the cellular automata, a transition rule that defines the propagation of the fire is defined in the program, taking into account, separately, the effect of each of the physical factors.

Results

Under hypothetical ideal conditions, where the fuel is spread uniformly across the lattice and there are no wind patterns or topological features accounted for, the fire simulated propagated in a perfect circle. As physical factors were added in the program one by one, the shape of the fire's spread shared striking similarities to the empirical Rothermel model. Indigenously developed, the mathematics behind the propagation of the fire, in the context of the cellular automata, matched up with previously developed empirical models. However, new observations made by firefighters in the Carr and Camp fires in California were incorporated, that made the model potentially more accurate than existing models.

Conclusions

The performance of the cellular automata-based mathematical model demonstrates the effectiveness of modeling complex dynamic systems such as fires using a simple set of rules derived primarily from vector calculus. This approach provides, not only a more succinct way to define the spread of forest fires in comparison to previously defined empirical models, it also provides an avenue to model other similar complex dynamic systems. Computationally, cellular-automata based approaches can be made even more efficient using GPU-based parallel processing.

Summary Statement

A cellular automata-based mathematical model is developed from scratch to accurately simulate the spread of forest fires.

Help Received

Luis Antunes' GitHub page aided me in working with a simpler cellular automata framework without having to create one of my own, allowing me to focus on the mathematical aspects of the model. My father helped me understand how to use LaTeX.