Predictive Wildfire Simulator

Jacob Ochs – Westmont College '18

Computer Science Senior Capstone Project

Motivation

Wildfires are notoriously difficult to predict – there are almost innumerable environmental factors which affect their course. However, if there was a way to predict the course of a wildfire utilizing a graphical model and real-time data, we would be better prepared for the devastation of wildfire and better informed in how to combat its spread. Coming on the heels of the largest wildfire in California state history, the Thomas Fire in Santa Barbara and Ventura Counties, this project concept is especially pertinent to the daily lives of all Californians. This application is meant to be available to the general public via an Internet map interface, accessible to anyone, from anywhere, with the fire simulation initialized from any location in the continental United States. To ensure accuracy, geoanalytics software, a mathematical scoring model, and a graphical map simulation will enable the user to easily and accurately view the predicted path of a fire with an easy to visualize graphical simulation.

Fire Behavior Factors

Exhaustive combinations of all environmental factors affecting fire growth and behavior are nearly impossible to calculate, especially within the scope of a semester-long project. However, observations of more complex fire behavior data models serves to inform how we will model our own data flow of environmental factors. While some existing systems (mostly from divisions of the U.S. Government) take into account up to 189 distinct variables, there are three universal environmental distinctions which affect fire behavior: **weather**, **fuel** and **topography**. A relatively simple data information flow graph is presented below, courtesy of the US Forest Service's Wildland Fire Assessment System (USFS – WFAS).

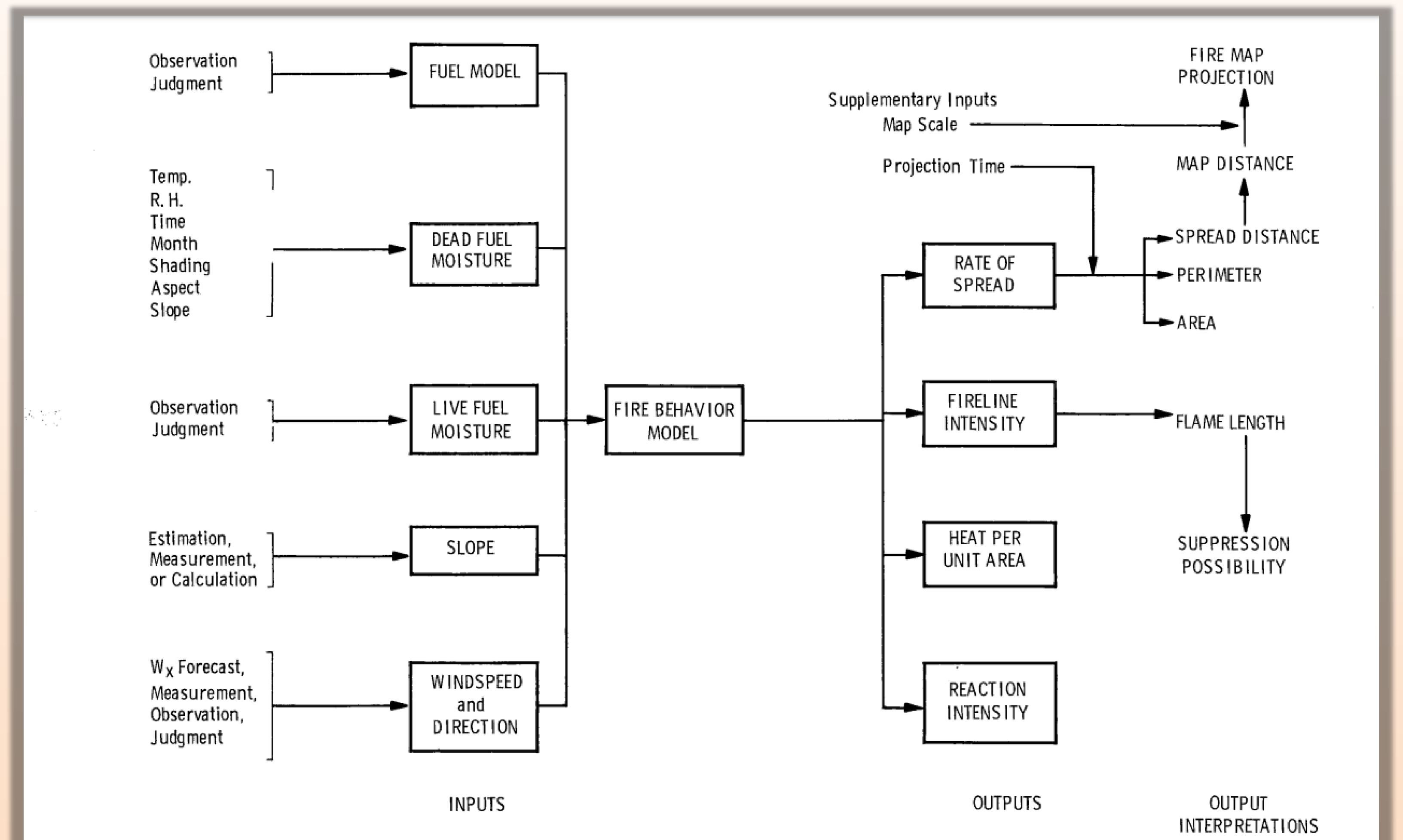


Figure I-1.—Fire behavior prediction system information flow.

Source: https://www.fs.fed.us/rm/pubs_int/int_gtr143.pdf

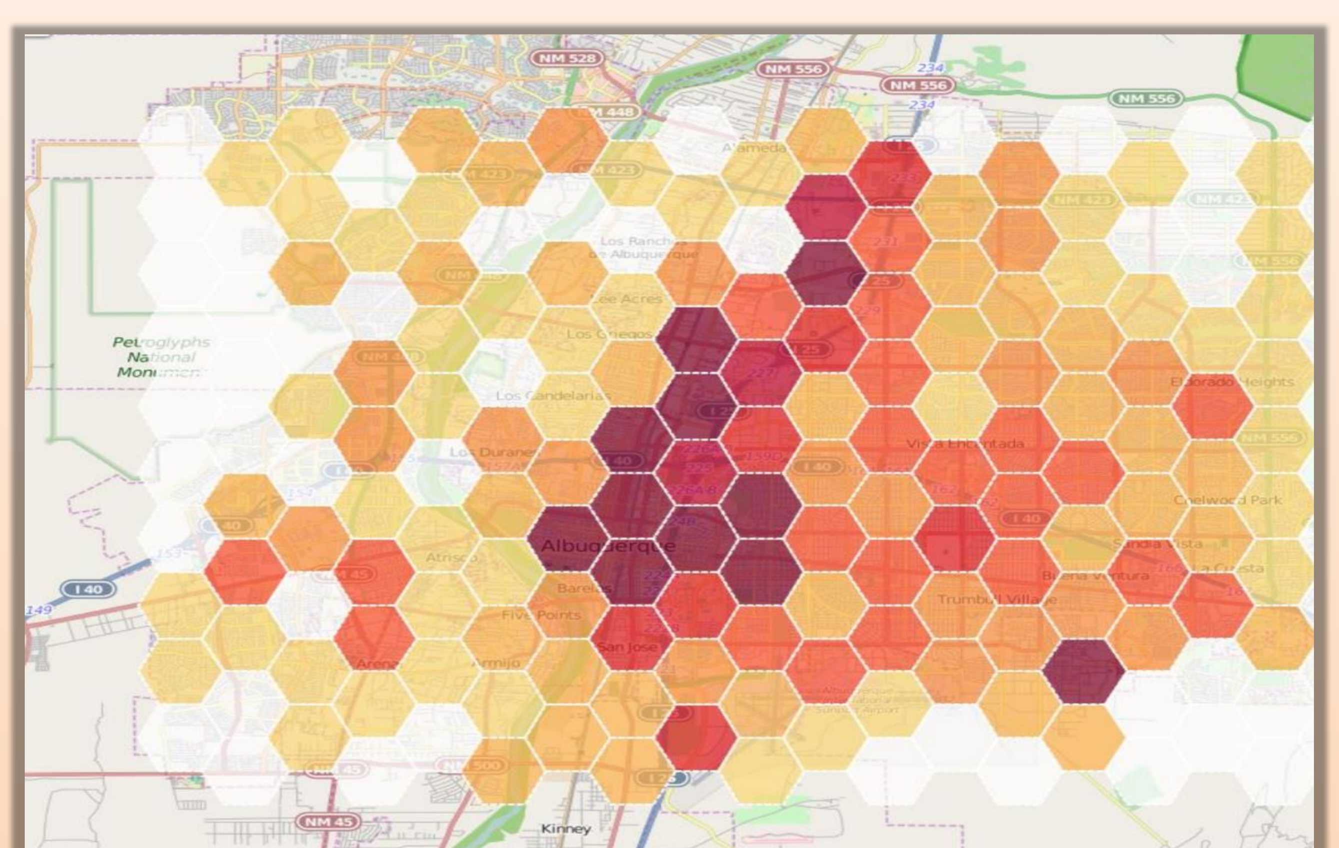
AFTI Scoring Method

Given weather, fuel and topography data for an arbitrary coordinate location, we are tasked with the problem of how to translate this raw data into numeric values which accurately represent the relative fire danger of the coordinate location. To achieve this, the **Aggregate Fire Threat Index** (AFTI) scoring method is created, which takes as input six independent variables of fire behavior. Calculating the score for each variable yields a number from 1-4, which we then multiply by the variable's assigned weight to return the final score for this variable. Addition of all variables' score yields our final coordAFTI score for the specified inate location, with values ranging from approximately 0-35. In this model, larger scores represent greater fire danger. The AFTI Scoring Table is shown below, although certain special combinations of data will return an AFTI score of 0, for which this graph does not account.

	1	2	3	4	Weight
Wind	0-5	6-12	13-19	20+	2.0
Humidity	76-100	51-75	26-50	0-25	1.0
Precipitation	Heavy	Light	Scattered	None	1.8
Temperature	<0-40	41-64	65-84	85+	1.2
Fuel	0-12	13-25	26-38	39-50	1.5
Slope	0-5	6-15	16-30	31+	1.2

Graphical Simulation Method

Upon calculation of an arbitrary coordinate location's AFTI Score, graphical simulation of the wildfire's geographic course is simulated through the overlay of a variable-size hexagonal grid on the map interface. Through aggregation of the coordinate-specific AFTI scores within each hexagon, we can utilize a simple process known as **hexagon binning** to display a color-coded time-lapse of the fire's projected growth over a span of up to five days. Finally, a simulation of this hexagrid will progress as each hexagon is theoretically consumed, which is based on the hexagon's combined AFTI score. An example of data-driven hexagon binning is shown below.



Technologies

For ubiquitous access, this project is a web application with all calculations being done on the client-side. As such, I have chosen AngularJS and NodeJS as the primary frameworks from which to build the application. All basemaps and layers are provided through the Leaflet, OpenStreetMap, OpenWeatherMap, and Google Maps libraries. Geoanalytics and hexagon binning graphics and processing are provided through the TurfJS library in coordination with Leaflet.

Data Sources

To ensure an accurate fire simulation, accurate real-time data is imperative. All weather and wind forecast data is provided through the OpenWeatherMap API. Topographic fuel and vegetation data is provided through the US Forest Service's daily NDFD Fire Danger Forecast service, available each day from their website. Finally, topographic slope is calculated by data received from the GoogleMaps Elevation API.

Conclusion

Due to the vast complexity inherent in wildfire prediction, resulting simulations are by no means guaranteed to be accurate. However, given the relative simplicity of the AFTI scoring model combined with the ubiquitous access of a in-browser web application, the goals of this project are not meant to compete with current systems of fire prediction, many of which exist as entire departments in government. There is certainly much more progress to be done on this as well as other fire behavior projection models. By essentially trying to predict the unpredictable, no fire simulation or forecast should be taken as fact, as was evident in the wildly unprecedented, unpredictable nature case of the Thomas Fire and many others.

Additional improvements to this project include but are not limited to: fine-tuning of the model to simulate the course of past wildfires in history, addition of more environmental behavior factors to aid in overall AFTI score accuracy, possibly asynchronous processing of scores for each hexagon, streamlined aggregation of AFTI scores within each hexagon, and fine-tuning the distance variables of the hexgrid map overlay for greater accuracy.

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Contact Information

Email: jochs@westmont.edu