Wildfire Behavior Model

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Team 48
Los Alamos High School

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Executive Summary

After the Cerro Grande fire, Los Alamos County decided to thin the unburned areas to reduce the threat of crown fires. This method of thinning had never been done before. No one knows whether this is effective in reducing the threat of fire or not. Although no one knows how effective thinning is in reducing the threat of fire, this model may help determine whether thinning was effective in reducing the threat of another fire like Cerro Grande.

Before 1910 low intensity surface fires would come through every four to seven years. These fires would consume pine needles and dead matter. The Forest Service passed legislation to suppress these fires beginning in 1910. This caused a large build up of pine needles and an increase in the number of trees per acre. Along with high winds, this caused the Cerro Grande fire to become a crown fire. The purpose of thinning is to reduce the threat of having a crown fire.

To see a fire spread in a realistic manner we needed a graphical program. We chose StarLogo for it's good modeling concepts and efficient coding capabilities. We chose to model a fire in Acid Canyon, a canyon that did not burn in the Cerro Grande fire, but easily could have. Acid Canyon is located directly below Los Alamos High School, and there is good data on the area. By modeling a specific area, rather than a randomly generated map, we got more realistic results.

The program aims for elegance, ease of use, and flexibility. StarLogo helped with all of these aspects with its simple interface with buttons and sliders to customize the program, and vast array of built-in functions. When the user runs this program, it imports aerial photos for elevation, slope, and fuel density, and sets the variables up based on these images and the sliders. When the user starts the go function, the program starts the fire, which moves based on the wind and slope, and burns trees based on their fuel and species components. As the program is running, the user can view real time results on the screen.

Introduction

After the Cerro Grande Fire, Los Alamos County thinned to reduce the risk of crown fires in areas that did not burn. Acid Canyon was one of the locations that was thinned. Acid Canyon drains into Pueblo Canyon, which is the main canyon running through Los Alamos. The Fuel Reduction Forest Restoration project (FMFR) was meant to reduce the potential for crown fires in Los Alamos. The idea of thinning is something entirely new in the world of forest ecology. There are few models or simulations publicly available to determine when a crown fire happens. With the threat of large wildfires in the western United States increasing, models to determine how a wildfire spreads are needed. Our model simulates a wildfire starting in Acid Canyon and traveling through Pueblo. This would be used with pre-thinning and post-thinning data to determine if the thinning was effective in reducing the threat of crown fires. This model will not only help the County of Los Alamos, but may be used in other parts of the country that have urban-forest interfaces. Our fundamental question is “Was the thinning of Acid Canyon effective in reducing the threat of a crown fire?”

Description

Our three main goals in developing the program were elegance, ease of use, and flexibility. Our program’s elegance is achieved with well-written code, and no unnecessary or overly complicated functions. Our code is shorter than code from other projects, because it is optimized, and takes advantage of many of StarLogo’s built-in functions. Our program is easy to use because it has an intuitive interface with buttons and sliders that are easy to understand. Our program is flexible because any set of data images may be incorporated, regardless of what area they apply to.

Our model is a simplification of reality in many aspects, but it maintains the key components to give realistic results. The major limitations of the program include simplified equations, two-dimensional wind, and limited humidity compensation. By simplified equations, we mean that some equations used to calculate fundamental aspects of the program may be approximated or optimized to increase the program’s speed. Because there is no three-dimensional vector quantity for the wind, the temperature flux equation had to be simplified, and we were unable to compensate for wind change based on canyon walls. We were forced to do this because wind variation can be extremely complex, and it is not the primary focus of our model. Because a critical temperature for ignition is determined before the program is run, the humidity is not calculated during runtime. We believe this to be a safe assumption because of the limited moisture in Los Alamos. We believe that we managed to maintain accuracy despite these limitations, and may compensate for some of these limitations in future models.

Results

Unfortunately, we are not yet able to obtain complete results in the time available. Because the burn function of the program is not yet finished, we have not been able to do a complete model in StarLogo, but a complete program with results will be made available at the expo. This problem was caused by the fact that we needed to significantly redefine our objectives well into the project. If we were to repeat this process, we would be much more careful about choosing our goals in the abstract, and would make sure that our original goals are reachable with the time given.

Conclusions

We have composed a model that depicts how a wildfire will progress in a Ponderosa Pine forest fairly accurately. We have made this possible by using actual data taken from Acid Canyon (Los Alamos, NM) during a thinning season in late 2005. Topographical pictures of Acid Canyon, including those of elevation, fuel load, and slope have been added to make a realistic model.

Our most significant original achievement was the ability to layer multiple images in StarLogo to make our data set. To our best knowledge, this has not been done before, and is a great accomplishment in addition to using StarLogo's modeling concepts.

If we continue this project later, we will keep similar objectives for our model, but rewrite the program for C^{++}, so that we can take advantage of the language's extensive libraries and wide range of functionality. Also, we can adapt our program to harness the full power of our school's supercomputer.

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The technical support of this project has been excellent, and we would like to thank the New Mexico Supercomputing Challenge, for allowing us to add two new great additions to our team and referring us to Nick Bennett, who was able to help with our modeling concepts when we needed it most. Finally, we would like to thank the great people at MIT who took part in making StarLogo, a programming language with truly phenomenal potential.

Appendixes

Appendix A: Code

Turtle

```
to go
 burn
 move
 ignite
 diffuse-temperature
end

to burn

end

to move
 vectorsum
 fd fire-speed
end

to vectorsum
 let [:xsum ((patch-slopeangle * (sin patch-slopeheading) * 1) +
(patch-windspeed * (sin patch-windheading)))]
 let [:ysum ((patch-slopeangle * (cos patch-slopeheading) * 1) +
(patch-windspeed * (cos patch-windheading)))]
 seth atan :xsum :ysum
 set fire-speed sqrt((:xsum ^ 2) + (:ysum ^ 2))
end

to ignite
```

```
end

to diffuse-temperature

end
```

Observer

```
patches-own [patch-temperature patch-elevation patch-
slopeheading patch-slopeangle patch-windheading patch-windspeed
fuel-density fuel-temperature-critical]
turtles-own [fire-speed]

to setup
 ca
 ask-patches [set patch-temperature global-temperature set
patch-windheading global-windheading set patch-windspeed global-
windspeed]
 import-picture; import fuel2000.png or fuel2005.png
 ask-patches [set fuel-density pc]; sets the fuel type (range:
low, medium, high)
 import-picture; import slope.png
 ask-patches [set patch-slopeangle (atan pc 1)]; sets the verti-
cal angle component of the patch-slope vector
 import-picture; import elevation.png
 ask-patches [set patch-elevation 2203.704 - (pc * 9.4827)];
sets the elevation (range: 2118.36 - 2203.704 meters)
 find-slopeheading
 ask-patches-with [xcor = screen-half-width or xcor = -1 *
screen-half-width] [setpc 9]; draws left and right border
```

```
 ask-patches-with [ycor = screen-half-height or ycor = -1 *
screen-half-height] [setpc 9]; draws top and bottom border
end

to find-slopeheading
 repeat 50 [diffuse4 pc .5]; blurs the screen to give better
sense of general direction
 ask-patches [
  let [:xsum (pc-at (xcor + 1) ycor) - (pc-at (xcor - 1) ycor)]
  let [:ysum (pc-at xcor (ycor + 1)) - (pc-at xcor (ycor - 1))]
  set patch-slopeheading atan :xsum :ysum]; sets the horizontal
angle component of the patch-slope vector
end
```

Appendix B: Data / Input Images

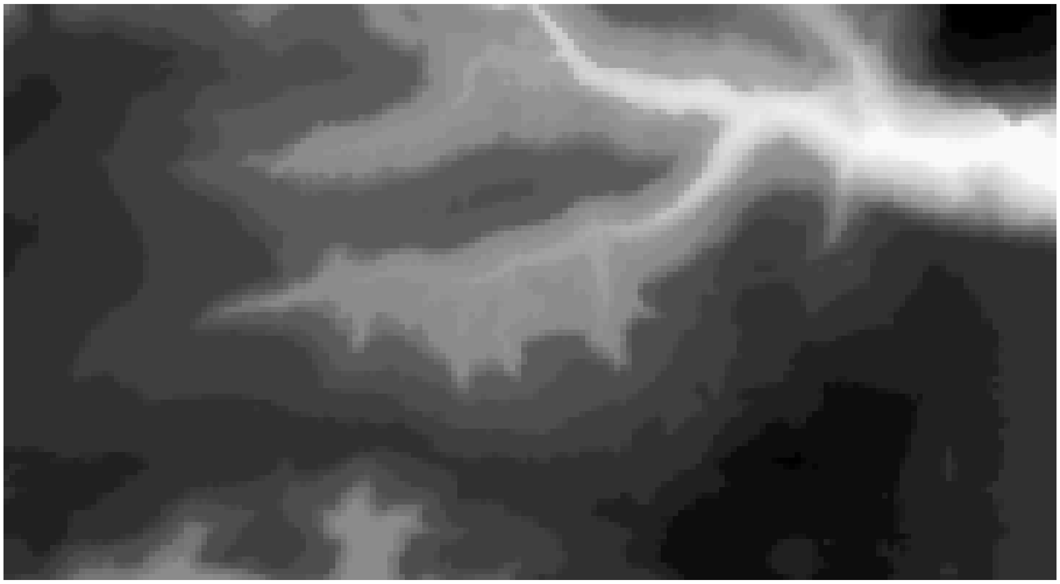

Fig B.1 - Elevation map of Acid Canyon - This image, provided by Mr. Hogan, was the fundamental factor in calculating the topography of the canyon. StarLogo supports 64 values in the grey spectrum, so Mr. Bennett advised us to map the image to these values to prevent dithering. White is at 2204 meters, while black represents an elevation of 2118 meters.

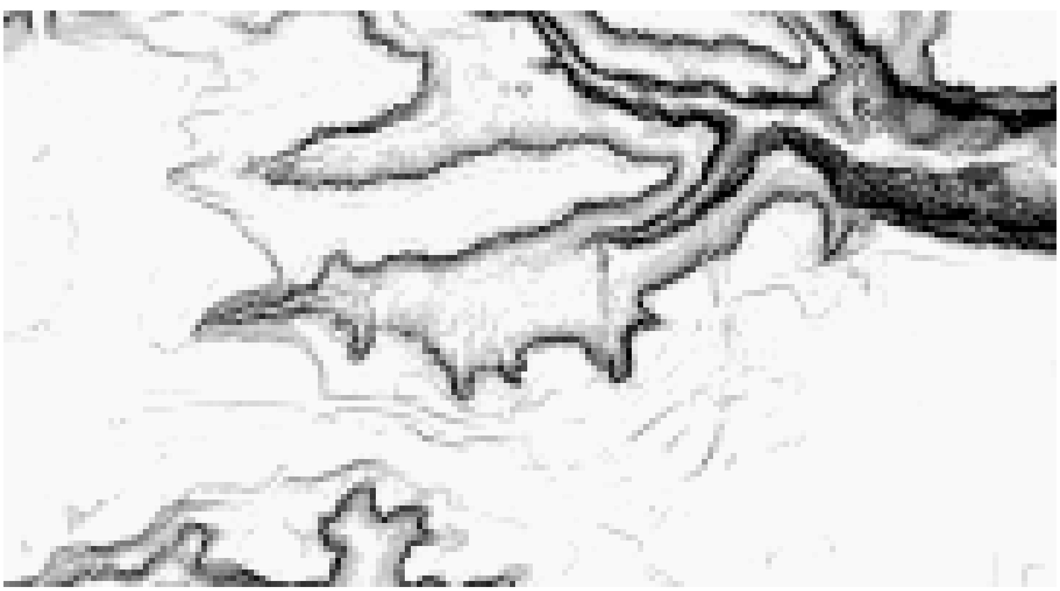

Fig B.2 - Slope map of Acid Canyon - Although slope can be calculated based on change in elevation, this map was needed to check or formula for such calculations. Also, some of it was used as data for more accurate slope measurements.

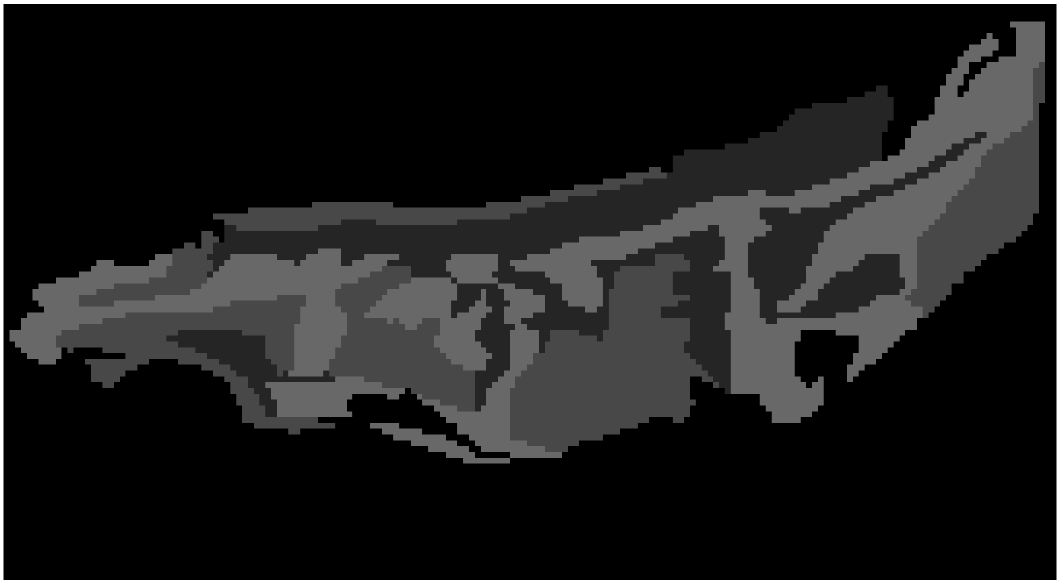

Fig B.3 - Fuel map of Acid Canyon (2000) - The fuel categorized in to high, medium, and low, based on aerial photographs, and mapped by Mr. Hogan. Lighter values represent greater density.

Fig B.4 - Fuel map of Acid Canyon (2005) - Post-thinning equivalent of Figure B.3

Appendix C: Additional Materials

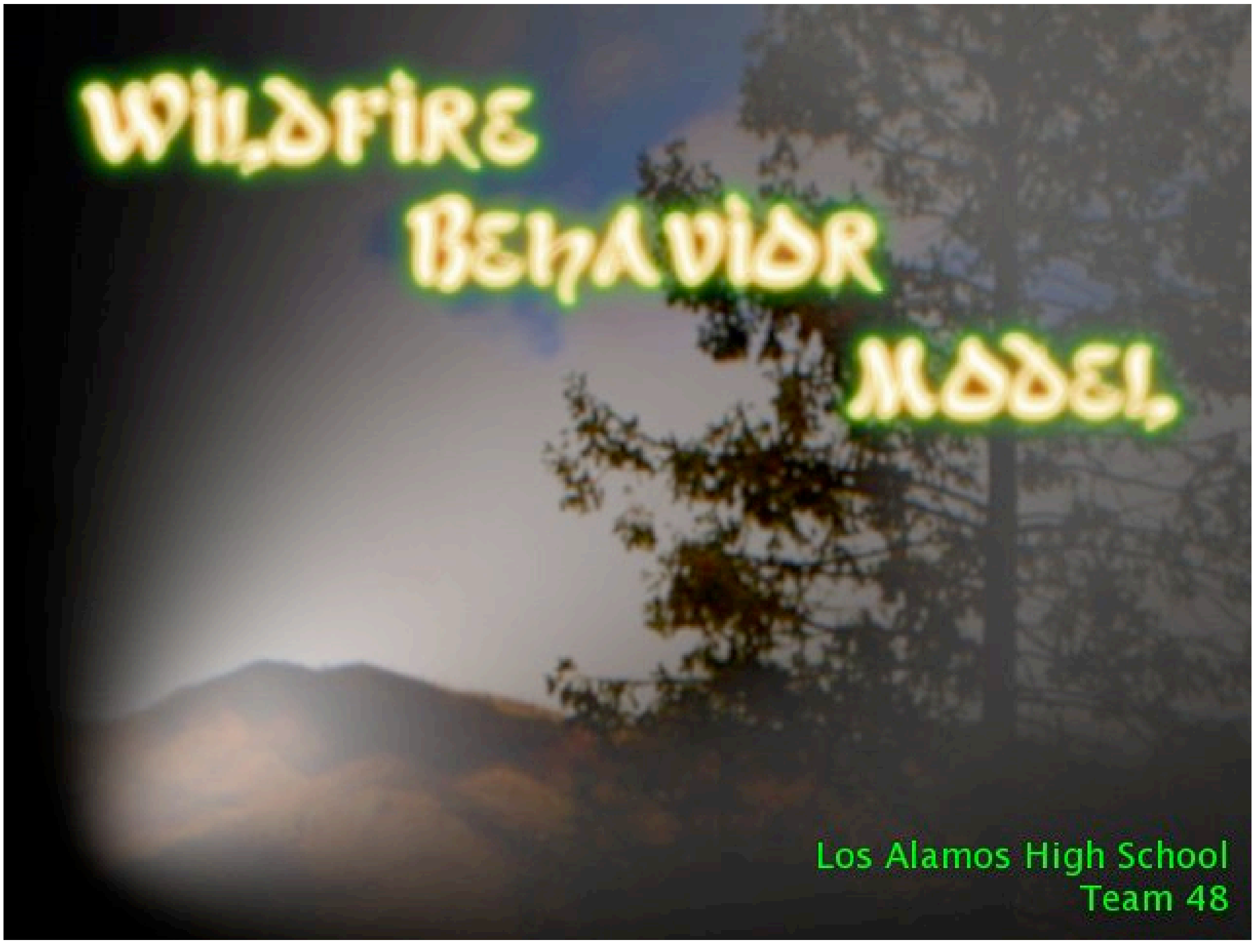

Fig. C.1 - Project Logo - This is the logo we created to help identify our project. We may modify our logo format to fit the medium we are working with. The text at the top is from http://www.cooltext.com/*, but all other work is original.*

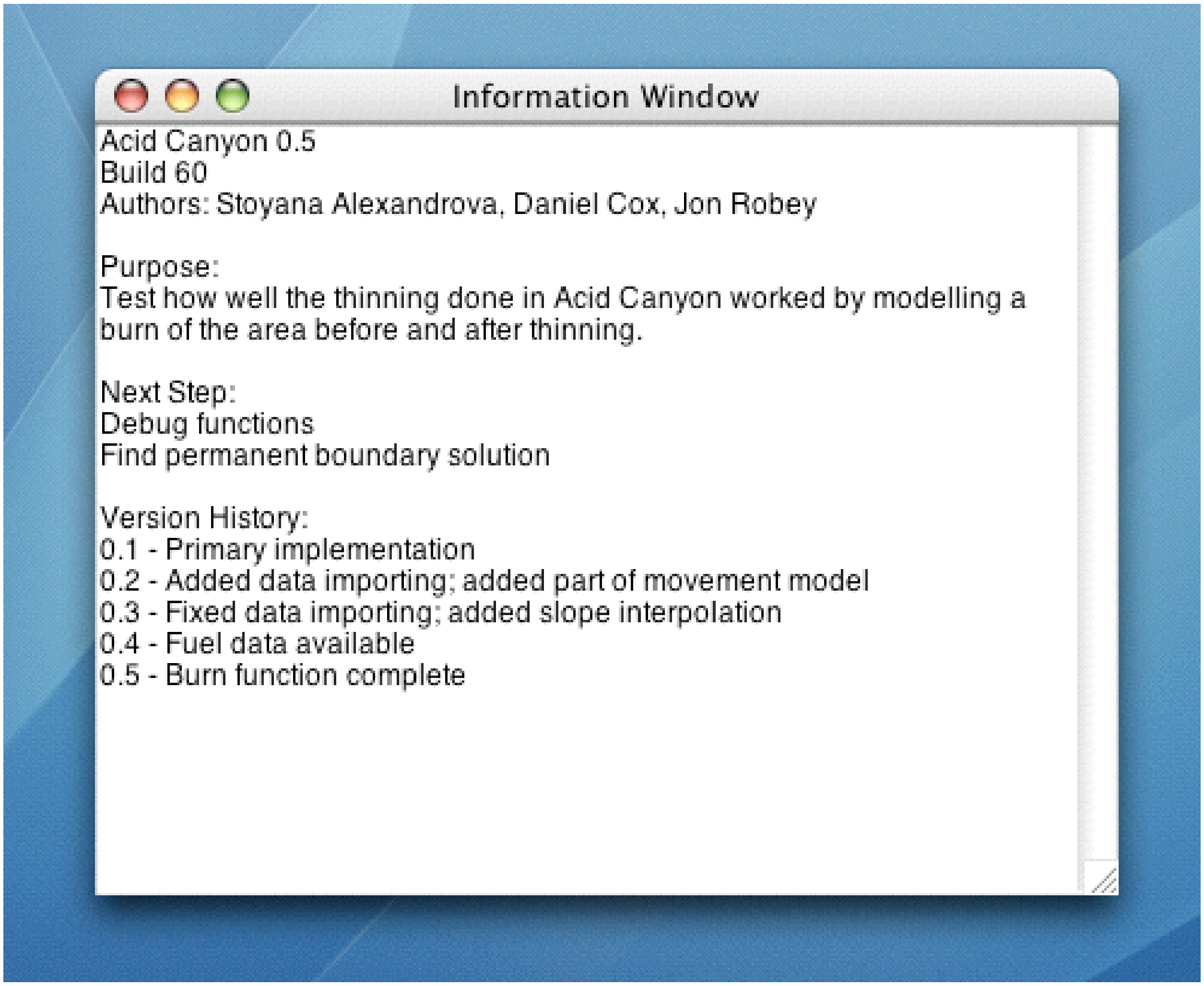

Fig C.2 - Info Window - This window of the program provides some information about the project history and current progress