Locating Smoke Plumes & Fires Accurately

New Mexico

Supercomputing Challenge

Final Report

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Team 17

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Executive Summary

While forest fires are a natural occurrence, their impact leaves a devastating mark on Earth. They contribute to global warming due to their carbon dioxide emissions. They also cause a lot of destruction of land and are a danger to humans and animals. In the last couple of years the negative effects of forest fires have been seen globally. With the rise of forest fires there is an urgent need to create more efficient solutions. In our effort to help, we created code that can find the angles in a triangle. With this code it is easier to use triangulation to calculate the distance between the smoke and the cameras. This code can help firefighters locate and track the smoke from the fires, helping them address the issue faster.

Introduction

a. Forest Fires

Forest fires have been steadily increasing in the United States. According to research from NCEI.Monitoring.Info@noaa.gov, In 2021 the US experienced 58,733 wildfires, with 7,227,371 acres of land burned. And in 2022, the number of fires has risen to 66,255, ruining 7,534,403 acres of land. Once land has been lit on fire the area's habitat and vegetation becomes unusable; the quality has fallen. People are forced to leave their homes due to damages. Air quality is affected by the fumes, shutting down tourism and indirectly affecting the economy. Even when the fire is stopped there are still many problems; clean up, rebuilding of homes, and agricultural and soil support. After an area has burned it is more likely to experience flash floods. Wind is an important factor in wildfires; if the fire is in an area with strong wind the fire will spread at a fast rate.

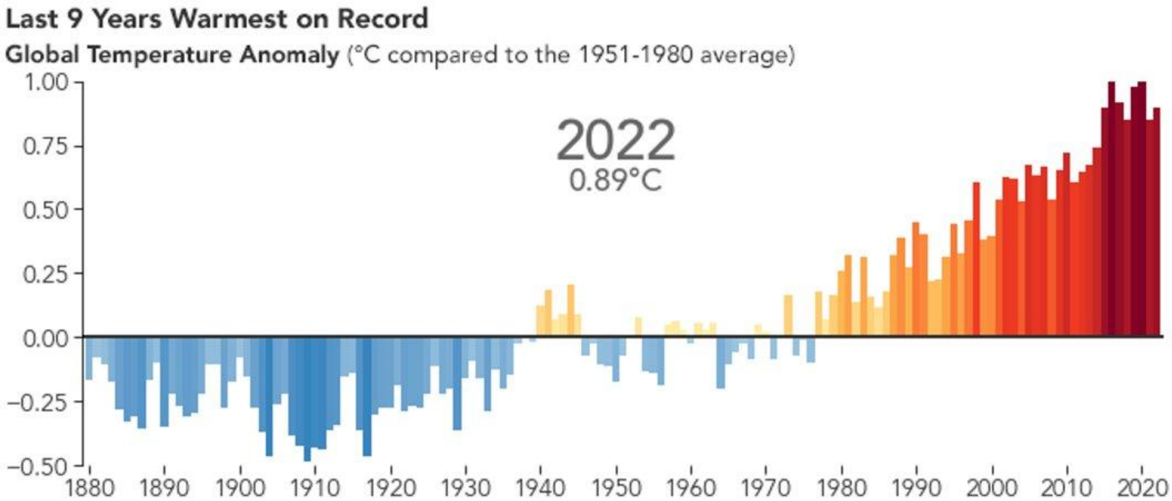

Figure 1: Nasa graph of Global Temperature Throughout the Years (NASA Earth Observatory)

We can see that with the rise of global warming there has also been a corresponding rise in wildfires. (Meaning that an increase to wildfires is tied to global warming.)

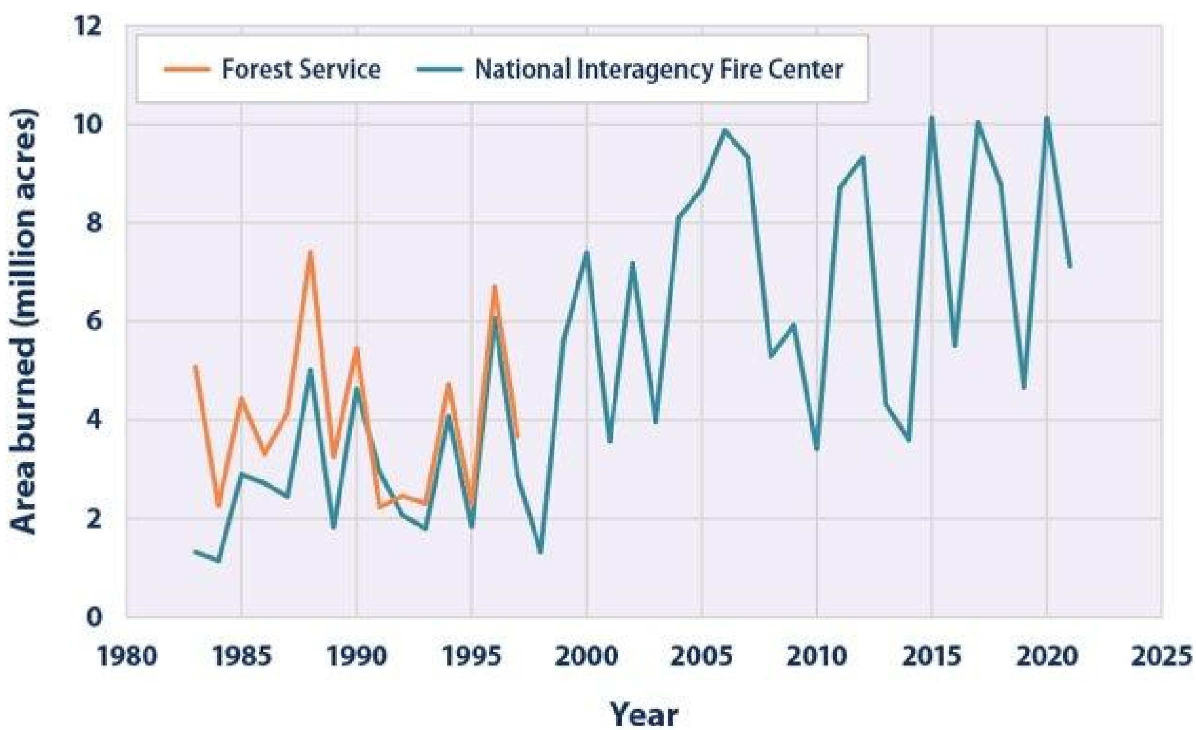

Figure 2:
This indicator tracks the frequency, extent, and severity of wildfires in the United States.

Wildfire Extent in the United States, 1983–2021 (National Interagency Fire Center)

Figure 2 shows annual wildfire-burned area (in millions of acres) from 1983 to 2021. The two lines represent two different reporting systems though the Forest Service stopped collecting statistics (orange line) in 1997 and is not planning to update them. Those statistics are shown here for comparison.

b. Past Approaches

We based our project on past Supercomputing Challenges done by other NMSA students. The NMSA supercomputing team of 2019-2020's "It 'bout to Get Lit Up In Here" modeled forest fire risks in northern New Mexico. Their model mapped how wildfires spread. In 2021-2022, NMSA students worked to model smoke plume dynamics from imagery. They focused on making a model for the creation of a smoke plume. Their model showed how smoke is created from a wildfire.

Additionally, there are scientists out there who are working towards creating an accurate model of wildfires, one that can respond in real time. Alert Wildfire has set cameras all across the south west in order to help alert first responders of a wildfire – especially those that are in more rural areas. Using data from the cameras they are able to better address a fire and determine its location.

c. Project Goal

To help avoid the damage caused by wildfires, we plan to help first responders locate and predict the location of fires. We plan to accomplish this by mapping and predicting a fire's location from remote camera imagery. Using images from previous fire data, we can triangulate the location of a smoke plume. With the help of crowdsourcing, it would be possible for people to take photos of current fires and send them directly to firefighters to help them locate and map fires.

We want to make it so someone can use their phone and take a photo or a video to provide real time information. We hope that one day we will be able to provide first responders with real time information and predictions of where the fire is and where it is heading.

Model Framework

a. Method

In order to locate a smoke plume we need to know how far the smoke plume is from the camera. This is impossible to do using only one camera, because there are too many unknowns. The use of a second camera allows us to determine how far the object is from each of the cameras. The use of a third camera allows us to determine the exact location of our smoke plume.

b. Triangulation

Triangulation is the networking or measurement and tracing of triangles in order to find the relative position and distance of points that are spread over a region or territory. We can determine where the smoke plume is using the location on our phone and the information about the camera that took the photo. We have to know which way the camera is pointing.

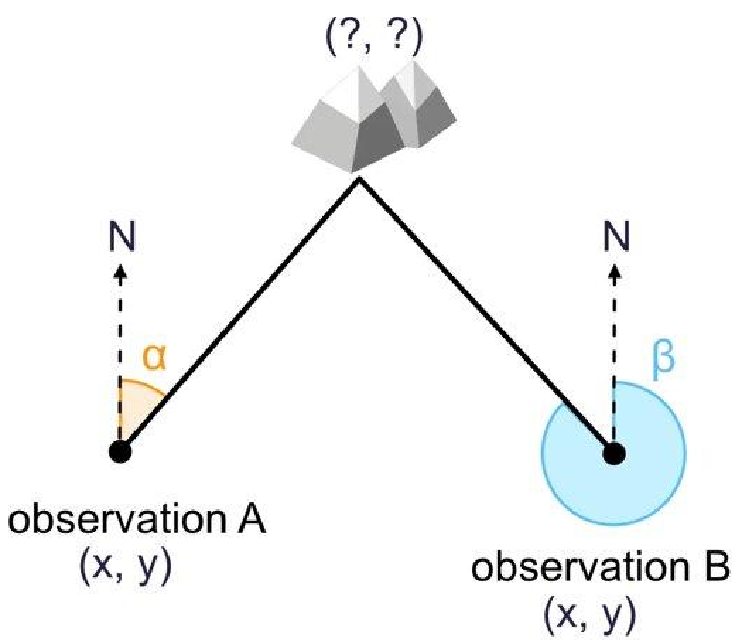

Figure 3: Online calculator (Triangulation Calculator)

c. **Math**

This is the Law of Cosine. We can use this when trying to figure out the angle when we only know the side lengths of an object. We can use this later to help determine the distance of an object using the focal length of a phone and size of object in pixels and distance between the two phones. Overall helping us determine the distance between an object and the camera. Which leads us to being able to solve the SSS triangle and the ASA triangle formulas.

The SSS triangle meaning is (Side-Side-Side) and by using this formula it helps us indicate that all sides of a triangle are equivalent to the corresponding sides of the other triangle. The ASA (Angle-Side-Angle) triangle formula states that when two angles and the included side of one triangle are congruent in two angles by including the side of another triangle, that is when the two triangles are congruent.

By using these formulas and knowledge we combine them with the cameras and with that we put it in our code to help us through our coding on NetLogo.

$$cos(C) = a^2 + b^2 - c^2 2ab$$

$$cos(A) = b^2 + c^2 - a^2 2ab$$

$$cos(B) = c^2 + a^2 - b^2 2ab$$

d. Code

We started our model using a pink ribbon and a tree. We tied the pink ribbon to the tree and took images of the ribbon using our phones. We recorded where the photos were taken and where the pink ribbon was. We used these photos in order to start building our model.

We have written code that is able to find the angles in a triangle when we input the distance between the cameras and the object. This will help us when we have to use triangulation to figure out the distance and angle between the phones and the smoke plume. We also have imported images into NetLogo in order to start calculating the distance to an object. Our code is also able to find a specific point on an image in NetLogo and report which pixel it is on.

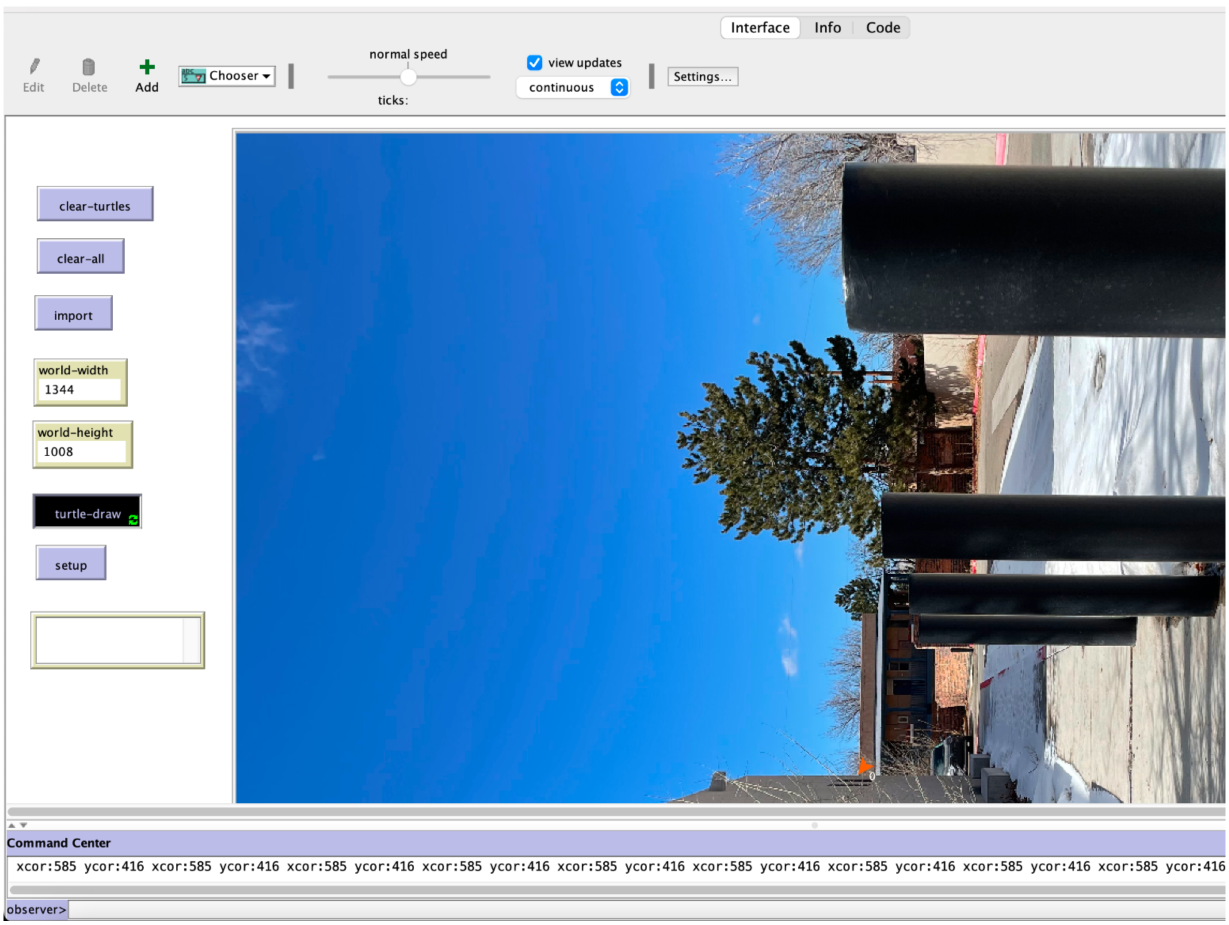

Figure 4: Pixel being located with our NetLogo code

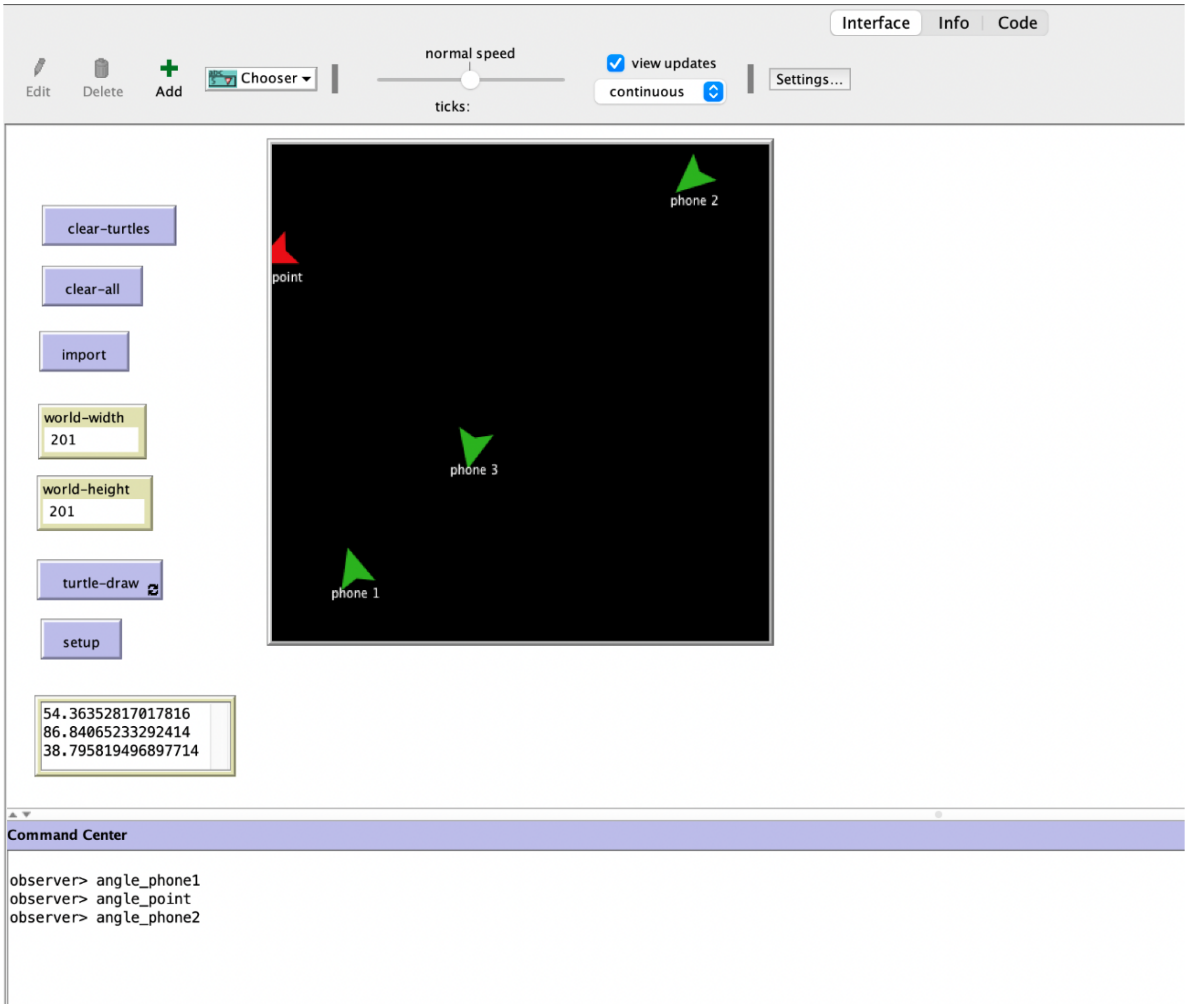

Figure 5: NetLogo code of camera and point location

Results

In our model, using the import button allows the user to import their image. In order to not distort the image the world-width and world-height need to be adjusted in settings in order to match the image's original height and width. Using the mouse down button allows the user to place a turtle which reports which pixel it is on. When we only know the side lengths of an object we can use the pixel coordinates and the focal length of the camera to determine which directions the object is in. Based on the focal length on a camera we are able to determine the field of view for that image. When we take the direction that the camera is pointing and combine this with which pixel or pixels the object shows up in we are able to determine the direction which the object is. If we knew the real life size of the object in real life and in pixels we could determine the location of the object using only one phone. However, because we don't know what the size of the object is, we have to rely on a second photo to help us determine the size and location of the object. If the direction of where the camera is pointing is unknown the use of a third image is required in order to figure out the size of an object.

A portion of the math was put into NetLogo and it can calculate the angles between the turtles labeled point, phone1, and phone 2. These locations for the turtles are currently set at random. However, this shows how we can solve a SSS triangle using NetLogo. The output for the angle between the turtles is reported in the output box.

Conclusion

Our goal is to help build a safer future. We want to make it so someone can use their phone and take a photo or a video to provide real time information. We hope that one day we will be able to provide first responders with real time information and predictions of where the fire is and where it is heading. We have done a substantial amount of research about fires and triangulation. With the help of our mentor Stephen Guerin we were able to acquire images and data from previous fires. Currently we are working on writing code that will help us to triangulate smoke clouds from images. We are also looking at existing code to help find correlating points in different images of the same plume.

a. Takeaway

Moving forward we plan to use a different language to code in. NetLogo was great for us to use to gain a better understanding of coding. However, it was not the best language to code our model in. NetLogo is simple and has many restrictions. In order to not crash NetLogo we had to reduce the images in our model to one third of the original quality. In a different language we want to develop something that could possibly be turned into an app or website that is accessible to the public.

b. Future Goals

In the future we hope to improve our models convenience and create a more practical application. Currently, someone who wants to triangulate an object using our code has to input a lot of information and do some of the calculations manually. Once we have sufficient code, we also need to be able for the model to identify the smoke plume on its own. Our code would need to be able to find characteristics within that smoke plume and find the same characteristics in other images. Our goal is for anyone to be able to upload a photo and their location and not have to do any of the math. Hopefully, with technology being at large crowdsourcing will provide useful information that will provide computers with ample data.

In the end we want to make a model that can represent a fire in real time and predict its next move, using live data to locate an on going fire and create an accurate representation. In order to predict where the fire is heading we want to develop a model with an accurate representation of the environment that can also show us where the fire is heading.

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We would like to thank our teacher sponsor, Mrs. Rowe, for providing resources and support which helped us complete our project. Our mentor Stephen Guerin for guiding us through the project and also providing knowledge on coding and research. Past NMSA students for their contributions towards the related interest in our field of coding and environmental science. We would also like to thank the Supercomputing Challenge judge panel for providing assistance and their expertise.

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