Visualize Wildfire Spread Progress in Valley

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Dataset

A dataset derived from the 2022 SciVis Contest is chosen for this project. The dataset is obtained from running simulations of fire and atmosphere models by scientists. The researchers simulated various parameters, including radius of curvature, wind direction, and different topologies, mountains, and valleys. The mountains are idealized topographies, while the valley models the shape of a northern New Mexico canyon. The valley simulation is based on a real incident. On June 26, 2011, a fire started in Santa Fe National Forest. It quickly spread and burned over 150,000 acres of forestland in northern New Mexico due to strong wind and low humidity, and was recorded as the largest wildfire in Mexico state at that time, named "Las Conchas Fire". In this project, we aim at the valley dataset (valley_losAlamos) because it is the simulation result from a real event. By visualizing the valley dataset, we may have more insight into how a wildfire progresses and its effect on vegetation in the real world. The mentioned dataset can be found at https://wifire-data.sdsc.edu/data/SciVis2022/.

The valley dataset provided has about 75 vts files, each file is the result samples at a specific time in ten-second increments. The first fifty seconds are used to ignite the fire and balance the wind. In this project, the visualization will focus on the fire after the ignition so the files before the fifth output will be ignored. Each vts file includes several scalar fields, as shown in the following table, which allows researchers to do a holistic analysis of various factors, such as wind, humidity, and vegetation. In this project, only a subset of scalar fields are utilized, namely temperature, oxygen concentration, and the density of dry fuel, highlighted in gray. The first two scalar fields are visualized to find the location of the burning fire and smoke. The last scalar, density of dry fuel, is adopted to compare the vegetation distribution before and after the fire across and validate the location of the fire.

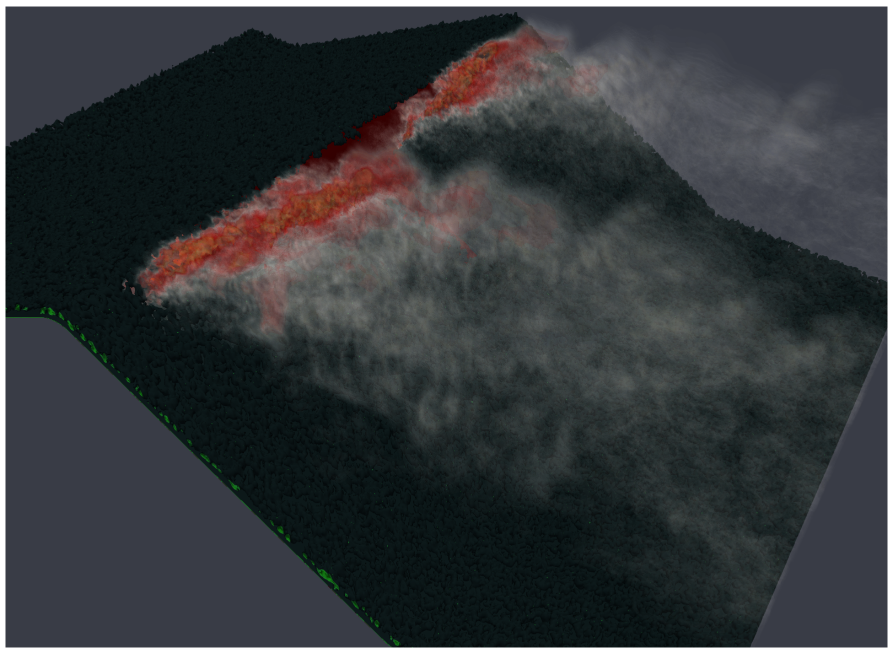
Scalar Fields	Meanings
`O2`	oxygen concentration
`convht_1`	convective heat transfer (W/m^3)
`frhosiesrad_1`	fire-induced radiative heat transfer to the fuels (W/m^3)
`rhof_1`	bulk density of dry fuel (kg/m^3)
`rhowwatervapor`	bulk density of the moisture released to the atmosphere as a result of fire (kg/m^3)
`theta`	potential temperature (K)
`u, v, w`	Three component vectors of wind

The StructuredGrid files (vts file) can be loaded by VTK vtkXMLStructuredGridReader API without any preprocessing or conversion. However, the size of each vts file is pretty large, about 1 GB per file, and it takes a long time to load a single vts file by the Python VTK module. Since some scalar fields included in the vts file are not used in this project, the Paraview tool will be used to remove the unneeded scalars and compress them to expedite the following visualizations.

Problem Statement

To better understand the spread progress of the Las Conchas Fire wildfire, this project plans to achieve two main goals after adopting several visualization techniques and analysis. 1) Discover the location of the fire and smoke, 2) Visualize and observe the spread progress of the Las Conchas Fire and its effect on vegetation. The following paragraphs will detail the objective of each item, respectively.

The first step of analyzing an object is to pinpoint its location. Once the location of the object is known, the following visualization and observation will focus on that specific place and time. Regarding the study of a wildfire, two main components of fire need to be found. Flame is the first object which this project plans to discover and visualize, while the smoke is the second one. The following figure shows the expected visualization result of smoke and flame without vegetation at a specific time. However, this project also plans to visualize vegetation to validate the finding result from the first goal and gain a more realistic visualization result.



[1]

Second, the wildfire moves according to various factors as time goes by and the ultimate target of this project is to obtain some sort of animation that clearly shows the movement of the Las Conchas Fire. After the site of the wildfire is located, the movement of the fire is visualized and examined. To achieve this goal, this project plans to visualize the flame and smoke over a range of a period. Once implementing the visualization of the wildfire at a fixed time, a suitable time range of simulation is required to decide. The same visualization techniques in the first item are applied to every time step after fifty seconds (skip the ignition) for selecting the time frame. The best time period is chosen based on the static visualization result at each time step which has the best result of showing the spread progress of the wildfire and its effect on the density of vegetation. Finally, this project will create an animation to show the movement of wildfire and the variation of vegetation density in the valley. The result can help us have a better understanding of the spread of the Las Conchas Fire and its effect on the vegetation in the New Mexico Canyon.

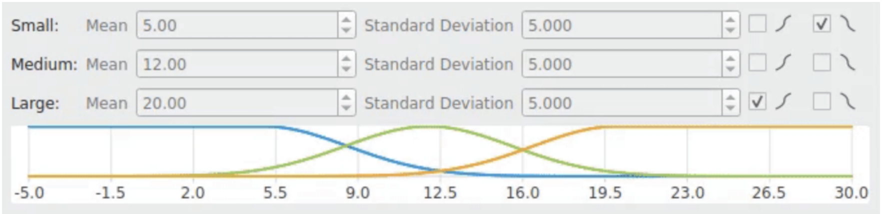
[1] Visualization sample from IEEE 2022 SciVis Contest: https://www.lanl.gov/projects/sciviscontest2022/report.pdf

Methodology

To visualize the wildfire spread, we need to first locate the wildfire at different moments. We will make use of the temperature data (`theta`) to define the transfer function for volume rendering. To make it more accurate, we can leverage the oxygen concentration (`O2`) and the density of dry fuel (`rhof_1`) information to see the location where they change the most rapidly. It would precisely indicate the trail of the wildfire.

Also, we will visualize the vegetation density to further represent the trail of the wildfire progress. Simply applying the color mapping to the valley geometry according to `rhof_1` would meet our goal.

We will create a set of UI controllers to manually set the most desirable range of values representing both flame and smoke. Then, we can design a transfer function to render them. The opacity of the smoke would be much lower than the one of the flame to mimic reality. We would build a simple UI component allowing the user to tweak the transfer function directly in the application. The following image is an example UI to define a transfer function.



Finally, we can combine all images rendered. This would create an animated visualization to see the wildfire dynamically, which provides a more intuitive way to visualize the dataset. If the machine could render the visualization fast enough, a slider to control the timestamp for the wildfire could also be implemented.

Milestones

In the first week, we will create a set of UI toolkits to visualize the flame and smoke in the valley dataset. We will manually pick some time steps to verify if our encoding correctly depicts the wildfire.

Once the wildfire is located, we can generate the visualization images in different timestamps with the wind vector field. This could take multiple trials to create a set of neat images for higher animation quality.

Last week, we will implement a UI tool to visualize the wildfire in different time steps and combine the images mentioned above to create an animation. We will also work on the slides for the representation.

References

- IEEE 2022 SciVis Contest: Vorticity-driven Lateral Spread Ensemble Data Set. https://www.lanl.gov/projects/sciviscontest2022/
- SciVis Contest 2022: Vorticity-driven Lateral Spread Ensemble Data Set. https://virtual.ieeevis.org/year/2021/poster_a-sciviscontest-posters-2022.html
- How Wildfires Spread and Why: Visual Multi-field Analysis of Vorticity-driven Lateral Spread Ensembles https://virtual.ieeevis.org/year/2022/poster_a-sciviscontest-posters-1009.html
- Wildfire Storytelling: How does Vorticity-driven Lateral Spread happen? https://observablehq.com/@ruiq/wildfire_storytelling