Simulating Wildfire Spread Using Physically Accurate Models

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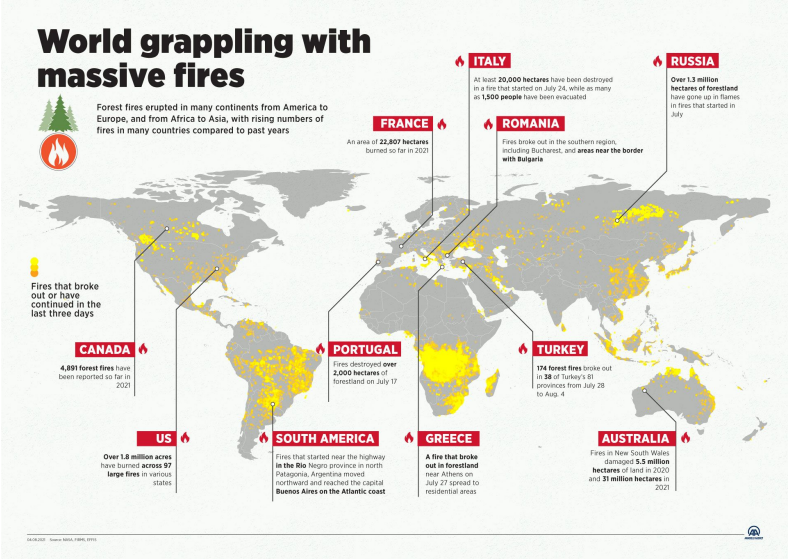
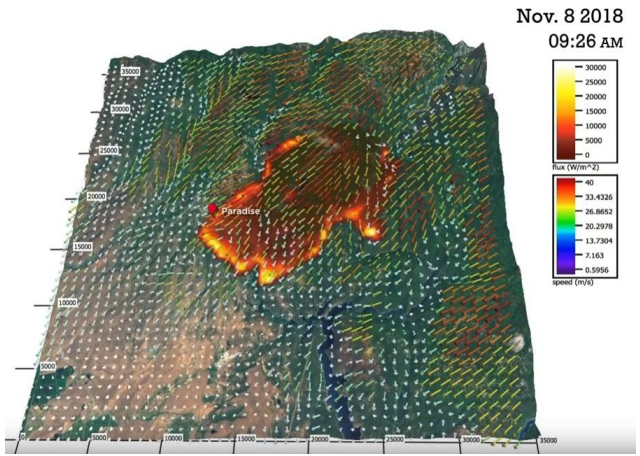
Need and Overview

- As **climate change** continues to exacerbate the frequency and intensity of **wildfires** around world, it is becoming increasingly important to find new ways to **accurately predict** and combat their spread
- The behavior of wildfires is incredibly difficult to predict since accurate models require **many variables** that have traditionally been **computationally expensive**
- We want to develop a **GPU-based** tree burning **simulation** that leverages **parallelism** and **modular** tree designs to both efficiently and accurately simulate the spread of wildfires





Goals and Outcomes

- Create geometrically accurate **tree models** and **fluid dynamics** simulations for fire spread
- Generalize this approach to a **forest**, and introduce new effects that arise from the **aggregate burning** such as wind and flammagenitus clouds
- Tune **environmental parameters** such as forest density, tree species, and terrain topography to further enhance the fidelity of our wildfire simulation

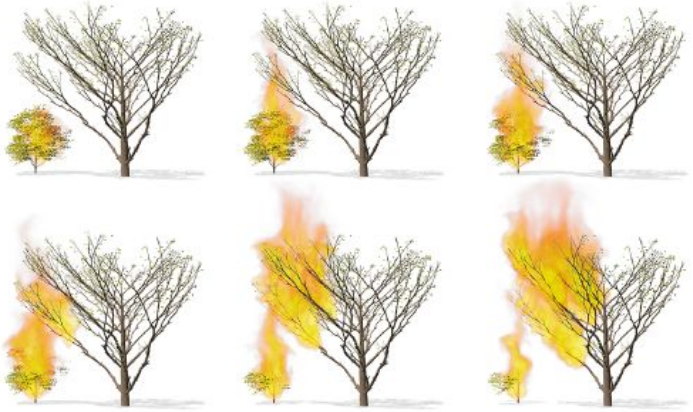


Fig. 6. Vertical fire spread onto a big tree from a small tree underneath.

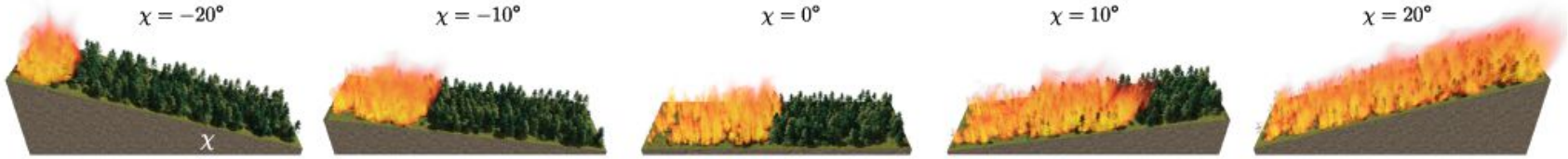


Fig. 8. Snapshots showing simulations of fire spread on inclined planes with different slope angles $\chi \in \{-20°, -10°, 0°, 10°, 20°\}$ (from left to right).

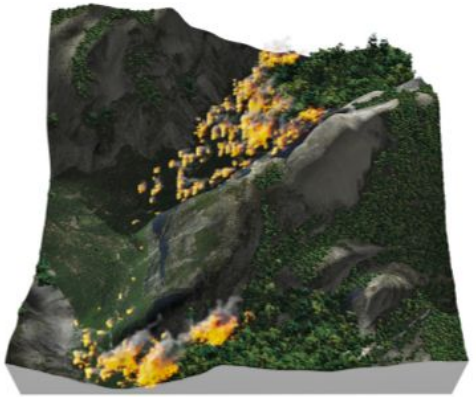
Our Schedule

- Milestone 1: Setting up the **code framework** required for the simulation and render
  - What are the kernels and data structures needed to both define our system state and how that state will be updated
  - Initial, basic computation and visualization of key steps as proof of concept
  - A good starting point for the rest of the project
- Milestone 2: Working **implementation** and **integration** of simulation + render
  - “Hello world” sandbox visualizing 1-2 trees catching on fire
- Milestone 3:
  - Creation of the **forest** and **wildfire effects** (“fire” clouds, rain, wind, etc.)
- Final: **Performance evaluation** + **parameter fine-tuning** + **Key findings**
  - Wow factors, stress testing, making it unique

Planned APIs, Platforms, and Architecture

- Compute + Render
  - Option 1: C++/Cuda (simulation) and OpenGL (rendering)
  - Option 2: Vulkan (or even OpenGL?) with Compute Shaders
- Potential fluid dynamics solver:
  - https://g3dflow.com/Releases/index.html

C++ and (**CUDA** or **Compute Shaders)**



Shaders (GLSL)

Potential Differentiators from Research Paper

Adding some unique elements to simulation that increases its realism and/or performance.

- Procedurally generated terrain to model a wider variety of real world ecosystems
- Introduce undergrowth to the simulation since this is a major contributing factor to wildfires (may cause massive drops in performance though)
- Introduce some spark generation function that can generate sparks somewhere in the grid and be carried by the wind vector field around the simulation and start new fires
- Introduce tree dynamics like in the first paper with Cosserat Rods (might also greatly hinder performance)

References

Images

- https://wildfiretoday.com/2018/12/31/modeling-the-spread-of-the-camp-fire/
- https://www.aa.com.tr/en/world/wildfires-ravaging-forestlands-in-many-parts-of-globe/2322512

Papers

- Hädrich, T., Banuti, D. T., Pałubicki, W., Pirk, S., & Michels, D. L. (2021). Fire in Paradise. *ACM Transactions on Graphics*, *40*(4), 1–15. https://doi.org/10.1145/3450626.3459954
- Pirk, S., Jarząbek, M., Hädrich, T., Michels, D. L., & Palubicki, W. (2017). Interactive Wood combustion for botanical tree models. *ACM Transactions on Graphics*, *36*(6), 1–12. https://doi.org/10.1145/3130800.3130814

Code

- https://github.com/art049/InteractiveWoodCombustion