Measuring Wildfire Firebrands Using UAV-Mounted Stereovision Sensors

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1. Problem

- Wildfires, exacerbated by climate change, pose threats to health, property, and lives of civilians and firefighters.
- Firebrands (small, high temperature particles formed during the combustion process) can be carried aloft by winds and ignite spot fires beyond the perimeter of the main fire, accelerating fire spread and igniting manmade structures [1]
- Technologies to track and predict firebrand kinematics and transport are crucial to mitigating the effects of wildfires.
- NIST has created an 'emberometer' towards this objective, but it is not portable [2]. This limits its deployment and restricts measurement locations to near-ground regions

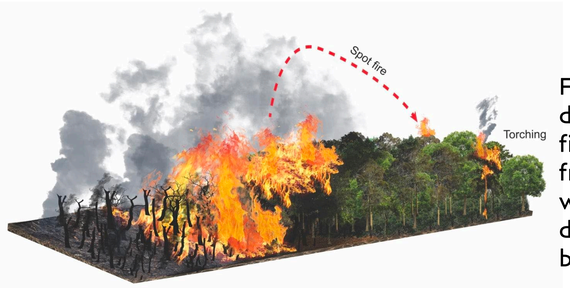


Figure 1. The dynamics of spot fire spread. Graphic from www.ukfrs.com/guidance/search/fire-behaviour-wildfire

2. Objective

- Adapt and improve NIST's design [2] to develop an optical firebrand characterization instrument (OFCI) compatible with an unmanned aerial vehicle (UAV) such that measurements can be taken over a wide range of locations.
- Optimize OFCI performance through careful, detailed lab experiments.
- Collect data on firebrand size, flux, and flight path of firebrands generated in a controlled environment.
- Deploy the OFCI on a prescribed burn to obtain measurements under realistic outdoor conditions.

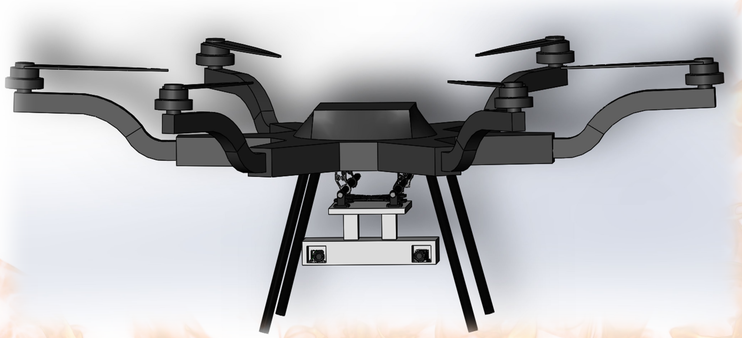


Figure 2. The prototype sensor package design integrated with a UAV.

3. Methodology

We are developing the prototype using a two phased approach.

- Static OFCI development: Designed a static sensor setup using stereovision to capture and analyze firebrand behavior. We are testing the OFCI with a firebrand generating apparatus under laboratory conditions.
- Drone integration and testing: Following validation of the OFCI, we will mount onto a drone for real-time firebrand data capture.

Figure 3. Firebrands lofting from the apparatus against a dark background for testing. The firebrands are produced by burning wooden dowels then loading into the apparatus.

4. OFCI

- The OFCI is being designed to be an open source, inexpensive, portable sensor package compared with efforts by NIST [2].
- Video capture is done by a pair of synchronized cameras via a Jetson Nano microcontroller.
- Footage is converted via Python into a format compatible with Open PTV, an open-source particle velocimetry software that detects particle movement to estimate positions, velocities, and particle fluxes.
- Data is output into text files for data analysis processing or 3D display in Unity

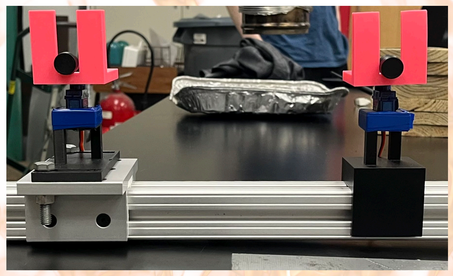
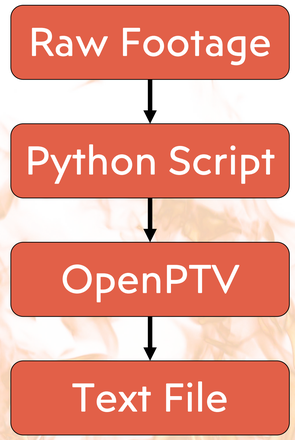


Figure 4. Adjustable OFCI apparatus camera mounts



5. Preprocessing

- A firebrand generating apparatus has been built and a firebrand generation protocol has been established for repeatability.
- A Computer Vision (CV) algorithm has been developed to enhance the contrast between the firebrand particles and the background in the frames obtained from the camera footage.
- The images are passed through a single channel (red) in RGB and then grayscale.
- This image data is fit to be used in Particle Tracking Velocimetry software to produce more accurate results than if CV had not been applied.

Figure 5. Preprocessed frames of footage from a firebrand simulation test, taken simultaneously with the two cameras.

6. Outlook

Moving forward our goals are:

- Determine minimum distance and angles of camera system
- Finalize the video to data conversion process with an accompanying standardized data analysis procedure
- Design of the final payload
- Field testing of drone-OFCI integration on a controlled burn

References

[1] S. Zen, J. C. Thomas, E. V. Mueller, *et al.*, "Development of a field deployable firebrand flux and condition measurement system," *Fire Technology*, vol. 57, pp. 1401–1424, 2021, https://doi.org/10.1007/s10694-020-01074-x.

[2] N. Bouvet, E. D. Link, and S. A. Fink, "A new approach to characterize firebrand showers using advanced 3D imaging techniques," *Experiments in Fluids*, vol. 62, no. 9, pp. 1–14, Aug. 2021, https://doi.org/10.1007/s00348-021-03277-6.

[3] J. C. Nathanael, C. Hung, and K. Huat Low, "Preliminary Investigation of Wake Vortex Generated by Spinning Quadrotor Propellers Using Overset Mesh," *AIAA Scitech 2021 Forum*, Jan. 2021, doi: https://doi.org/10.2514/6.2021-1309.

Acknowledgements

The team would like to thank the Gemstone program for their support, as well as Prof. Arnaud Trouvé (FPE) for his initial mentorship. We are also grateful to Dr. Nicolas Bouvet (NIST) for his advice and insight into the working principles of the NIST emberometer, and Adetola Koiki (FPE) for her assistance and collaborative efforts with the project.