UAV Swarm for Early Wildfire Detection via Onboard Sensing and Smoke Plume Tracking

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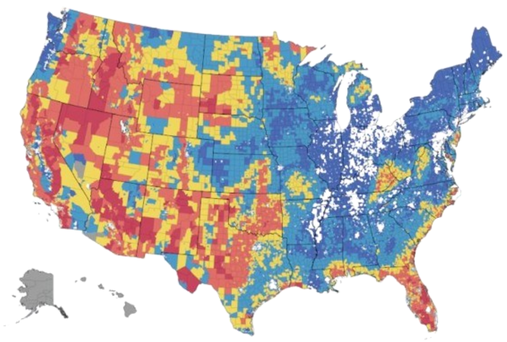
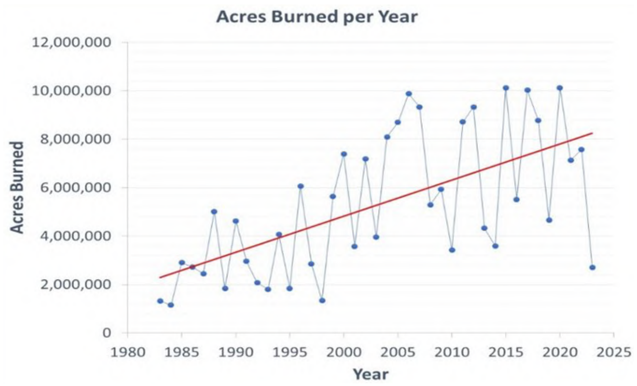
Background

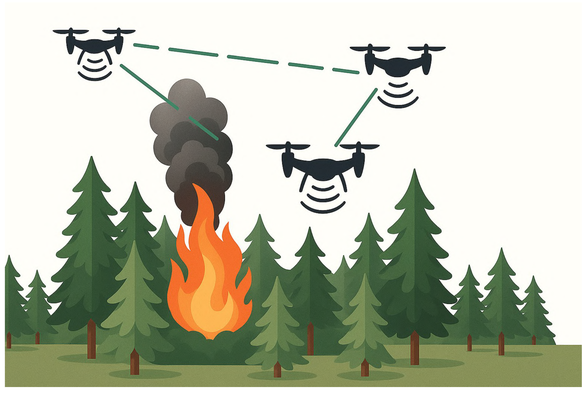
- Wildfires are one of the most destructive natural hazards threatening the US and have the potential to cause severe damage to vegetation, property and most importantly, human life.
- In order to minimize these negative impacts, it is crucial that wildfires are detected at the earliest possible stages, while they are still small enough to be easily extinguished or contained.
- The figures below show high wildfire risk areas in the US as well as the growing trend of wildfire destruction [1][2].





Solution

- A cost effective and scalable solution for early wildfire detection is to utilize **a swarm of unmanned aerial vehicles** (UAVs) equipped with chemical sensors and a model-based tracking algorithm for **efficient wildfire smoke plume tracking**.
- The model-based tracking algorithm will utilize a spatiotemporal model of wildfire smoke plume dynamics in order to **accurately track the chemical concentration** gradient of the smoke and therefore **lead the UAVs to the source of the smoke**, i.e. the wildfire.



References

[1] K. C. Short et al., "Spatial dataset of probabilistic wildfire risk components for the conterminous united states," 2016. https://www.fs.usda.gov/rds/archive/

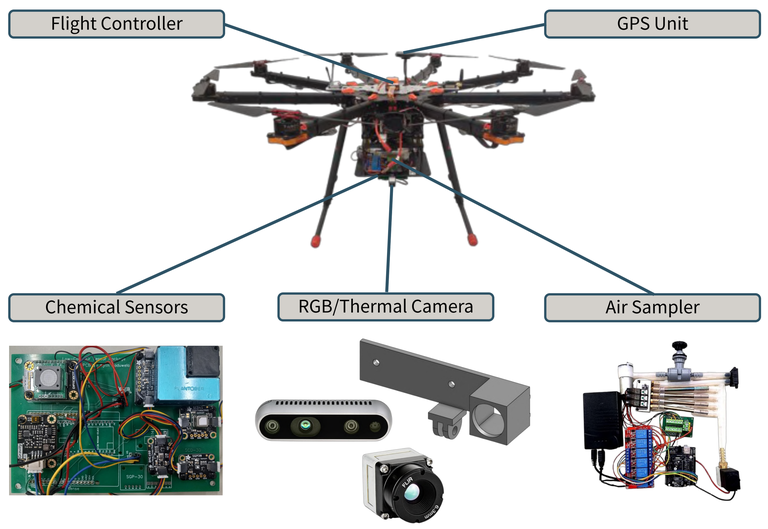
[2] K. Hoover et al., "Wildfire statistics," Congressional Research Service, Tech. Rep., 2021. https://www.nifc.gov/fire-information/statistics/wildfires

Methodology

Phase I	UAV-Based Chemical Detection
Phase II	Data Driven Smoke Plume Dynamics Modeling
Phase III	Model-Based Control For Smoke Plume Tracking
Phase IV	Implementation and Validation

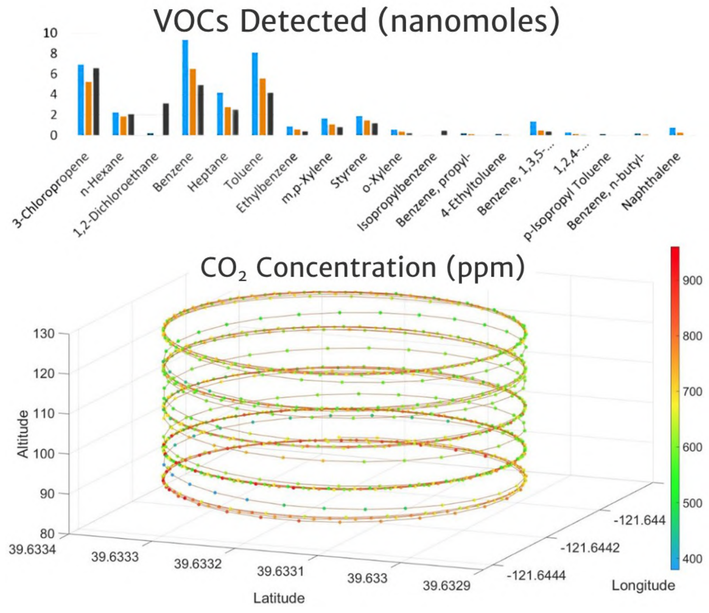
Phase I

- An octocopter UAV platform equipped with chemical sensors has been developed and tested.



- The UAV was used to collect chemical data (including CO_2, CO, PM2.5 and VOCs) from smoke at controlled fire experiments.

Results

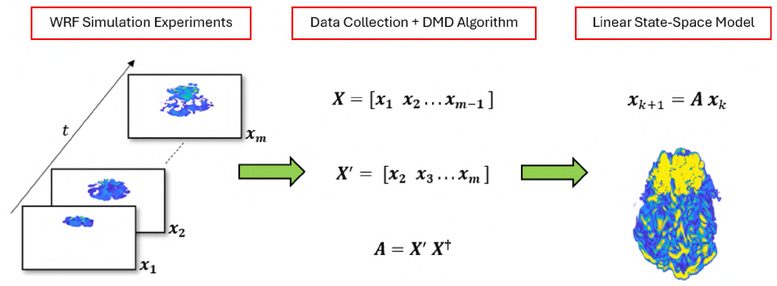


- This chemical data is being used together with synthetic data from physics-based smoke simulations to develop a data-driven model of smoke plume dynamics in Phase 2.

Present Work

Phase II

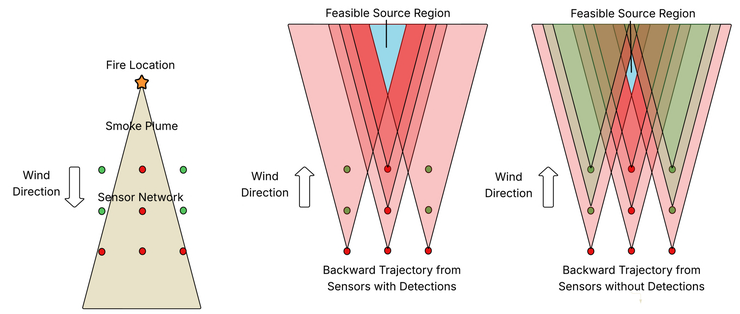
- A data-driven smoke plume dynamics model is being developed using the extended Dynamic Mode Decomposition (eDMD). The model is learned from synthetic data generated by the Weather Research and Forecasting (WRF) model coupled with a fire spread model (SFIRE).

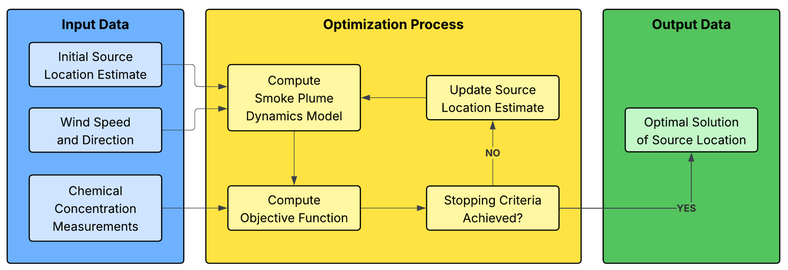


Future Work

Phase III

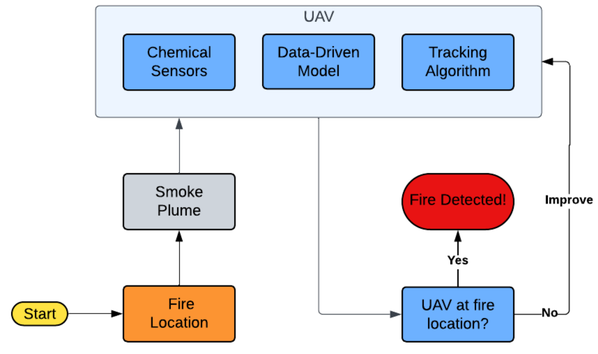
- The model from Phase 2 will be used in a model-based tracking algorithm together with real-time chemical measurements to guide the UAV in determining the source of a smoke plume. A similar method will be adopted in the case of a network of static chemical sensors.





Phase IV

- The algorithm will be implemented onboard the UAVs and validated during controlled fire experiments.



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