CS486C – Senior Capstone Design in Computer Science

Project Description

Project Title: Wildfire Drone: Aerial Imaging, Fire Detection, Classification, and Clustering

Sponsor Information:

NAU NORTHERN ARIZONA UNIVERSITY School of Informatics, Computing, and Cyber Systems

Dr. Fatemeh Afghah, Associate Professor
School of Informatics, Computing, and Cyber Systems (SICCS)
fatemeh.afghah@nau.edu

Alireza (Ali) Shamsoshoara, PhD student, Afghah Lab

Northern Arizona University

Project Overview

Wildfires destroy lots of private and public infrastructures every year around the world. We remember the Flagstaff museum fire during the last summer. It brought lots of costs and damages to Flagstaff's people, firefighters. Moreover, many forest and pine about 1,900 acres of trees between the Elden peak and San Francisco Peaks were eliminated and burned. California wildfires damaged 18,000 houses, infrastructures and caused $3.5 billion damages to the private and public owners in 2018. During the early stage of the fire, having an accurate data and information about the state of a wildfire can be very important to remove the fuel from the area and to stop expanding the fire growth. In this capstone project, our aim is to use both electrical and computer skills to come up with a practical solution to collect aerial information and detect the fire based on the gathered information.

The Problem

Many techniques based on imagery from satellites or manned aircraft exist to collect information from the fire location, but these techniques are not real-time and collection of such imagery is expensive and, in the case of aircraft, can endanger human life. What is needed is a fast, cheap, and effective method to monitor a fire's expanse and movement dynamics. Semi-autonomous aerial drones, also known as Unmanned Aerial Vehicles (UAVs) could address this need and play an important role for disaster situations such as wildfires and floods to help first responder teams: they can be deployed almost instantly, are relatively lost cost, and can move in three dimensions to easily gather imagery of a fire from various perspectives. A remaining challenge in deploying UAVs in fire management is simply processing the amount of data they produce. Currently, UAVs are used most as an "eye-in-the-sky", piloted by a human operator to get a look at a particular situation. Ideally, however, a drone would be a semi-automated tool for continuous data collection and automated updating of situational maps used by fire managers: it would be programmed to fly in a scanning pattern over the fire area, collecting thermal and visual imagery. In near-real-time, this imagery would be processed to automatically identify areas of fire/no fire, clustering them in a "smart" fashion to extract fire regions; the results would be used to update a comprehensive graphical fire map in the command center. Performing such classification is not simple, as it is not always clear which areas are actually on fire vs. just smoky. We are therefore interested in exploring the capability of AI technologies (machine learning) to help with this classification challenge. To provide data for this effort, we have recently collected a dataset of aerial images using regular and infrared cameras during prescribed fires in flagstaff and plan to perform more field tests during this academic year (Figs 1-3).


Figure 2: Normal aerial image

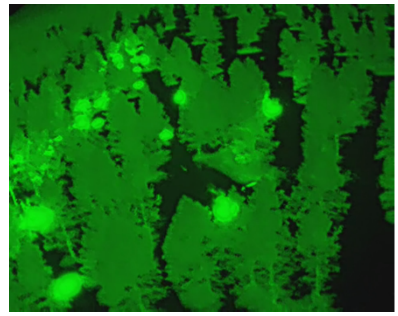
Figure 1: Green heat map

The Project

We envision exploring this challenge using a joint EE-CS team, address both the hardware and software development sides of the problem. Some key aims of the project overall will be:

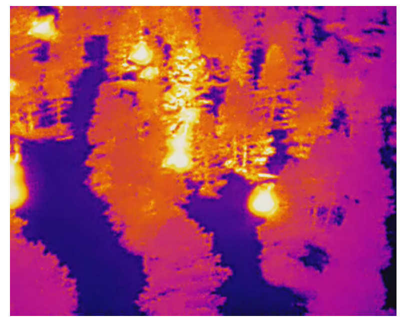
Figure 3: Fusion heat map

- The drone should be able to find the source of the fire in a forest area and autonomously find its path trajectory toward the fire.
- The drone will send telemetry and video to a base station. The data transmission is either directly or through other drones with multi-hop communication.
- The drone or the base station are able to identify the objects in the images (early fire, fully burned area, human, animal, fire trucks).
- The drones will be able to coordinate their collected images and provide a full-view of forest fire area.
- The fire detection algorithm (implemented on the drone or the base station) should be able to cluster the fire region, prioritize the regions, and model the fire spread.
- This drone is will be able to switch between the manual (human flown) and autonomous flight modes.

The EE subteam will have primary responsibility for developing the drone itself, including accessing the cameras, collecting the imagery, and dealing with navigation/flight. The CS subteam will focus primarily on the "fire detection algorithm", which could involve a combination of traditional image processing (e.g. for course navigation) and AI-based classification of fire images. Both teams will ensure decoupling of their project elements in early phases of the project to allow unfettered independent progress; for instance the CS team will create a simple test harness to simulate the drone in basic fashion, i.e., provides a stream of images on demand. Of course, both teams will work together to ensure that the two halves of the project develop in complementary fashion and are seamed together to create the final complete UAV unit for final delivery.

Detailed Achievement Goals

This project, if successful, will provide a drone and base station system able to identify the location of a fire, scout that fire, provide the map of fire spread, and relay information about the fire from the drone to the base station through multi-hop communication in remote regions when a direct link between the drone and base station is not available. Some specific aims to be used for evaluating project success include:

Satisfaction Standards for EE sub-team

- Exemplary - The processing and computation unit (Software-defined Radio (SDR), edge TPU- low-power AI Processing unit) testbed is ready for on-board image processing and communication testing. This would include integration of fire detection, path planning and optimal communication together. This system is fully functional.

- Good - The processing and computation unit (Software-defined Radio (SDR), edge TPU- low-power AI Processing unit) testbed is ready for on-board image processing and communication testing. The system is able to utilize the camera drone and is able to do real time video streaming between the drones and the base station. Here the drone decision making is done on the drone, in real or almost real time.
- Fair - The processing and computation unit (Software-defined Radio (SDR), edge TPU- low-power AI Processing unit) testbed is functional, but all decision making must operate in centralized manner.
- Poor - No SDR communication is functional. There is no video streaming.

Satisfaction Standards for CS sub-team

- Exemplary- The fire detection, object detection, clustering and spread model is implemented, tested and evaluated on the developed onboard processing unit. This would include integration of the path planning and optimal communication among the drones together.
- Good- The fire detection, object detection, clustering and spread model is implemented, tested and evaluated on a desktop computer. This would include integration of the path planning and optimal communication together.
- Fair- The fire detection, clustering and spread model is implemented, tested and evaluated on a desktop computer.
- Poor- No path planning and fire detection.

Knowledge, skills, and expertise required for this project:

- **Computer Science**: Familiar with machine learning concepts such as Classification, Clustering, supervised and unsupervised learning. Familiar with techniques such as SVM, K-Means, Deep Neural Network (DNN). Having some background knowledge or being interested in image processing techniques.
- **Electrical Engineering**: Familiar with embedded systems and mini computers especially, NVidia Jetson Nano and Raspberry Pi. Having basic knowledge of serial communication protocols such as UART/USART/I2C/SPI to control the camera via drone's on board computer.

Equipment Requirements:

- A drone with regular and infrared cameras; to be provided by client.
- Software-defined radios; provided by client.
- No further specialized equipment beyond resources typically available to the team (development stations, IDEs, open-source software frameworks) should be needed.
- Any equipment not free or immediately available will be purchased and/or facilitated by the sponsor

Software and other Deliverables:

- The software applications and completed UAV drone as described above, deployed and tested successfully in a real-world environment (though not necessarily in a wildfire!). Must include a complete and clear User Manual for configuring and operating the software, as well as continuing its development.
- A strong as-built report detailing the design and implementation of the product in a complete, clear and professional manner. This document should provide a strong basis for future development and/or extension of the product.
- Complete professionally-documented codebase, delivered both as a repository in GitHub, BitBucket,or some other version control repository; and as a physical archive on a USB drive