Wildfire Drone

Jimmy T. Banh, Ziming Li, Suzan B. Nasona

Northern Arizona University
College of Engineering, Informatics, and Applied Sciences

Abstract

The recent increase in wildfires globally has highlighted its effects in producing environmental pollution, damage or loss of property, crops, resources, animals, and people. To address this issue, our design team was able to contribute to our client's ongoing effort to monitor wildfires using Unmanned Aerial Vehicles (UAVs). We were to design a wireless communication system that uses Software Defined Radio (SDR) to transmit aerial data such as images, GPS location, and information about the environment surrounding the fire from a drone to a base station. The data from the SDR receiver would be processed at the ground station through an interface with a personal computer to display images of the fire in real-time. This project is a collaboration with the Computer Science team, who were to produce the classification, object detection, and segmentation algorithms for assessing and locating the fire. To satisfy the requirements, we created a system architecture modeling the behavior of the three subsystems of our wildfire monitoring system and identified its main functions. We then constructed the final product through prototyping, building each subsystem, and integrating the system. Lastly, we tested the system to ensure that it meets requirements before delivering the final product to our client. Based on our results, the system functions autonomously, transmitting images and text files with sensor information such as temperature, humidity, and altitude based on the fire's location to the ground station upon user request. Unfortunately, the system does not provide the GPS location of the fire.

System Requirements

The major requirement of the project:

- The system should **function autonomously** enabling data transmission between the drone and base station
- The system should utilize a **user friendly interface** enabling the user to switch between the High Definition (HD) and thermal camera, provide real time images of the fire, the GPS location, and environmental conditions of the surrounding during the fire.
- The system must integrate the fire classification, object detection and image segmentation algorithms created by the Computer Science (CS) team

The wildfire monitoring system is comprised of three subsystems: Drone, Communication and Base Station. The Drone Subsystem consists of the drone which has an onboard microcomputer, cameras, sensors for monitoring the environmental conditions, and an SDR. The communication subsystem consists of one SDR located on the drone and a second SDR at the base station for data transmission. At the base station a personal computer is utilized to interface with a user through a graphical user interface (GUI). The GUI provides the user with relevant information about the state of the fire.

Design of the System

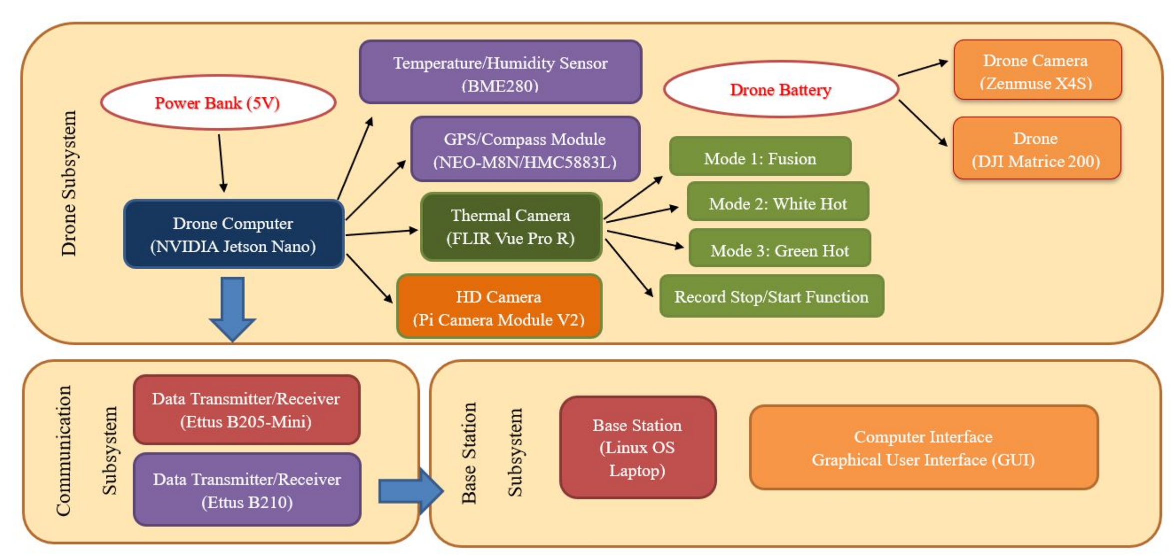

Figure 1. System Architecture

- **Drone Subsystem:** On the Drone, hardware interfaces occur through USB, camera serial interface (CSI), and general-purpose input/output (GPIO) pins of the microcomputer, Jetson Nano
- **Communication Subsystem:** Consists of two SDR, one placed on the drone and the other at the base station
- **Base Station Subsystem:** Represented by a personal computer enabling user interaction with the drone through the GUI

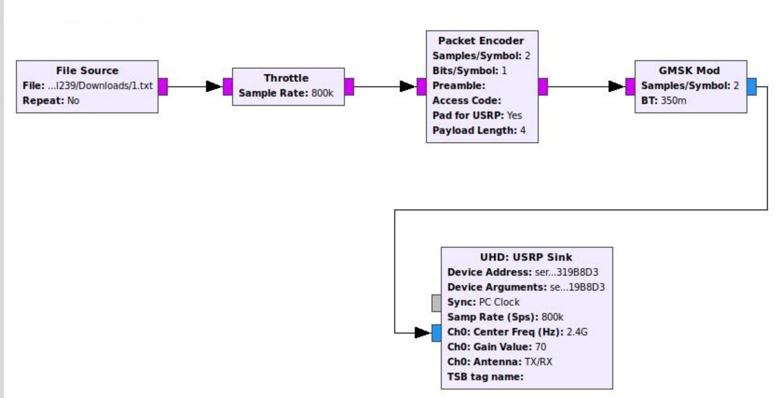

Figure 2. GNU Software Design for transmitting text through the SDR

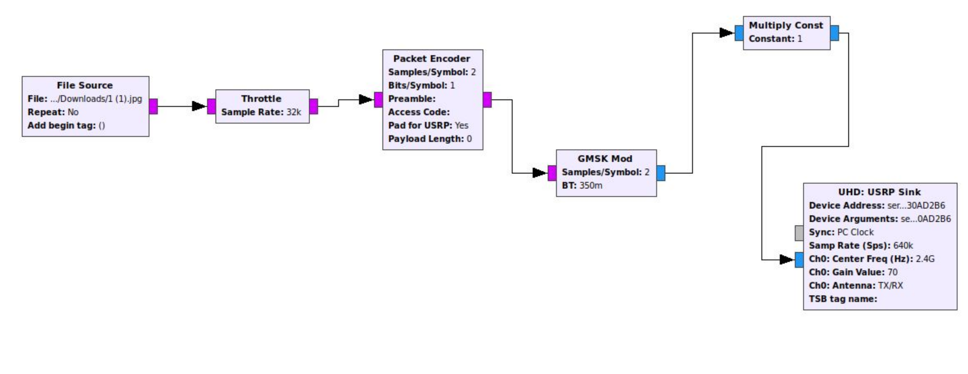

Figure 4. GNU Software Design for image transmission through the SDR

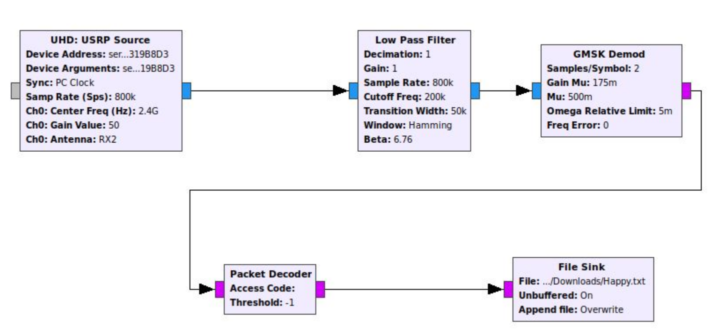

Figure 3. GNU Software Design for receiving text through the SDR

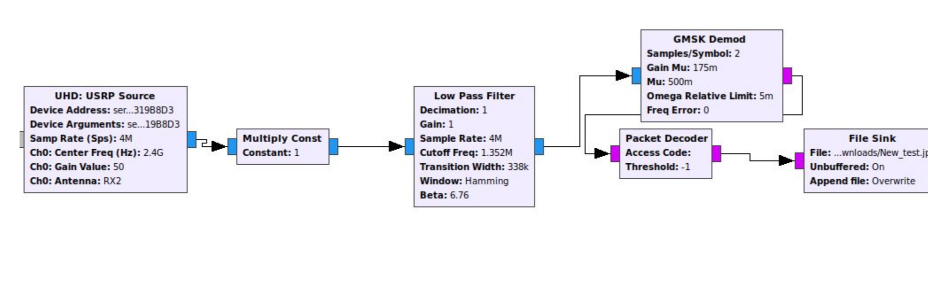

Figure 5. GNU Software Design for receiving images through the SDR

Results

Drone Subsystem Results

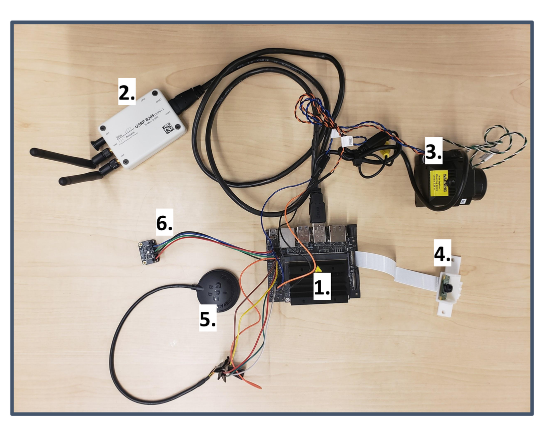

Figure 6. Drone Subsystem hardware setup

1. Nvidia Jetson Nano
2. SDR Transmitter & Receiver
3. Thermal Camera
4. HD Camera
5. GPS & Compass Module
6. Temperature, Humidity & Altitude Sensor

Figure 7. DJI Matrice 200

White Hot Green Hot Fusion

Figure 8. Thermal camera viewing modes

Figure 9. Sensor output file

Base Station Graphical User Interface Results

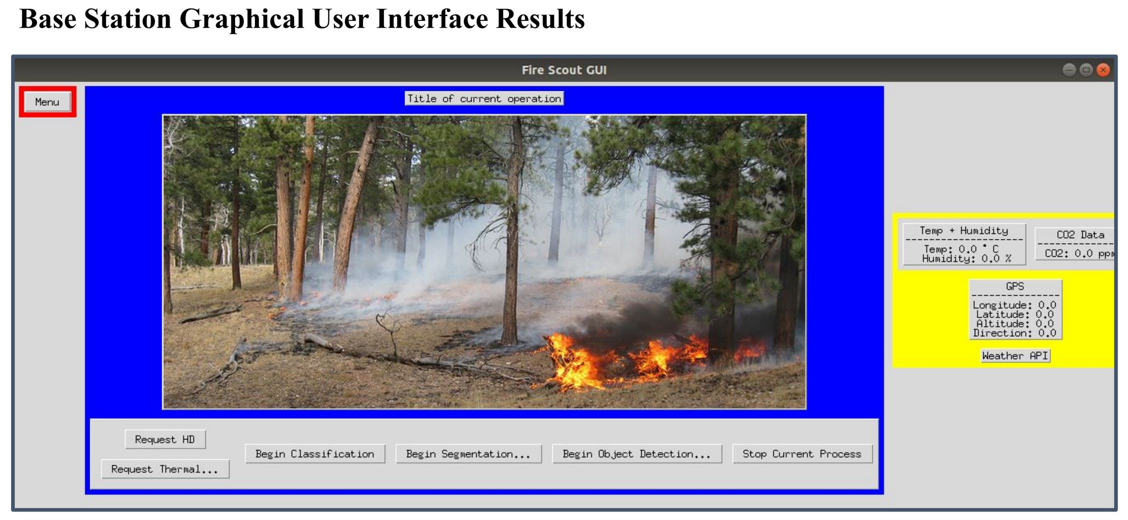

Figure 13. GUI Display

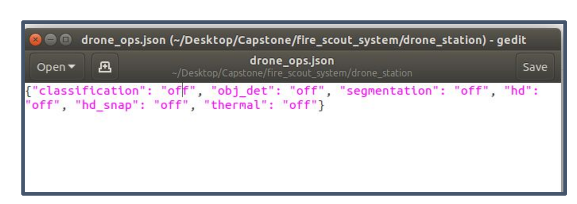

Figure 14. File generated by the GUI

CS Algorithm Results

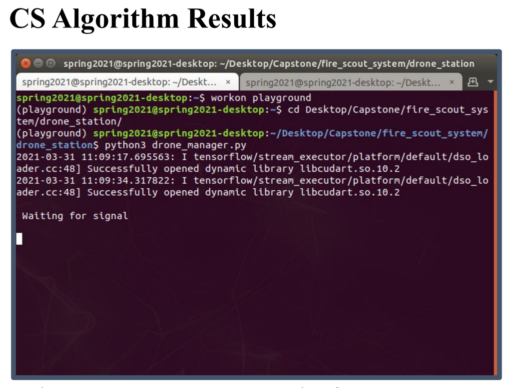

Figure 10. Jetson Nano waits for GUI Output

Figure 11. Object Detection Model

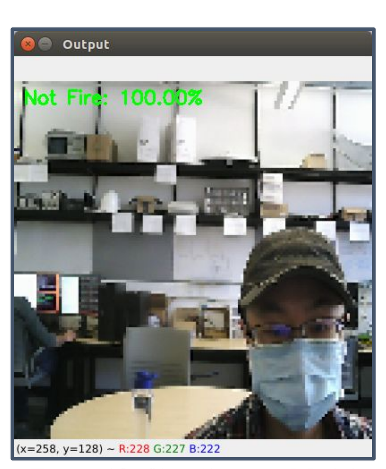

Figure 12. Classification Model

Communications Results

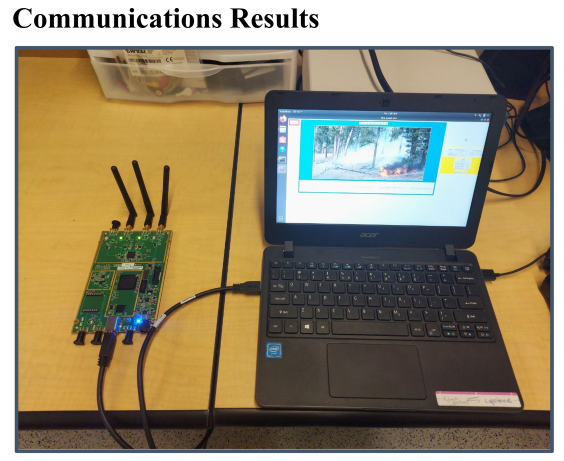

Figure 15. SDR B210 Interfaced with the Base Station Computer

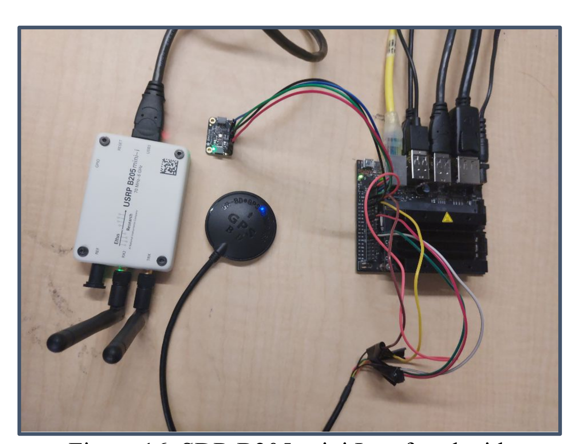

Figure 16. SDR B205-mini Interfaced with Nvidia Jetson Nano

Analysis of Results

Based on the results, the major requirements of our project was met with the exception of the implementation of the GPS sensor:

- The system functions autonomously
- The system autonomously provides the user with relevant data about the state of the fire
  - Data of the environmental conditions of the surrounding of the fire such as temperature and humidity
  - Images of the fire
  - The GPS sensor could not be implemented thus the system is unable to pinpoint the location of the fire
- The system autonomously captures images of the fire using the both the HD and thermal cameras
- The system is able to switch between the three viewing modes of the thermal camera: fusion, green hot and white hot
- SDR communication system automatically transmits data
  - At the base station: Text files are received every three seconds and images every eleven seconds
  - Design limitation: system is able to successfully receive images that are less than 200KB whereas transmission of images larger than 200KB result in data loss or shifting

Conclusion

We were able to complete the major requirements of autonomous data transmission, interfacing The GUI with the SDR, cameras and sensors, and integrating the computer science algorithms. Unexpected difficulties occurred during the project requiring additional time to resolve which limited the amount of time we could invest in optimizing all functions of the system. This limitation hindered us from being able to mount our hardware on the drone in *Figure 7* and test our system while in flight.

Lessons Learned:

- Gained experience in wireless communication using Software Defined Radio
- Gained familiarity with the Nvidia Jetson Nano, its GPIO and CSI ports for autonomous systems
- Deepened our familiarity with the Linux Ubuntu System
- Improved our python programming skills
- Gained experience working with the Raspberry Pi camera
- Gained experience working with a thermal camera and utilizing its duty cycle to switch between the three camera modes
- Gained experience working with sensors
- Collaborating within our design team and an interdisciplinary team on a common task
- Improved our project management skills
- Improved our problem solving and critical thinking skills

Difficulties Encountered Throughout the Design Process:

- Limitation in the design of the SDR communication system which only enables data transmission of files less than 200KB
- Difficulties interfacing with the serial communication of the Nvidia Jetson Nano to implement the GPS sensor
- Hardware complications occurred where the microcomputer had insufficient power supply resulting in frequent termination of the system
  - Resolved the issue by utilizing the AC adapter, which provides 4 Amps to the Jetson Nano

Improvements for Future Development:

- Improve image transmission capability of GNU radio SDR communication design to transmit images greater than 200KB

References

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