Hazard Harbinger: Precise Prescription Burning Area Localization via a LiDAR-mounted Drone and System of Embedded Nodes

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***Executive Summary*— The functionality of the LiDAR multiscan100 allows for a wide variety of use cases for creating large scale models of environments. In order to utilize and demonstrate its 360º fullframe capabilities, we propose a design to map out a forest region in order to identify areas for prescribed burning, a common practice to prevent wildfires that requires thorough planning. We have designed and tested a novel system that integrates an airborne LiDAR system and deployable sensor nodes, which provide a full model with environmental data to aid burn plans and can be further generalized for other use cases.**

***Keywords*— Wildfire, prevention, LiDAR, drone, sensor, UAV, SNN, ALS, TLS**

1 Introduction

To address the increased frequency and intensity of wildfires across the world, fire managers have been practicing controlled burning to remove excess dead, flammable, and overgrown vegetation. In order to execute controlled burning safely and successfully, they require a comprehensive burn plan that accounts for the land's topography, vegetation, and environmental conditions, such as humidity, air quality, etc. Our project aims to provide fire managers with a 3D fuel map, which depicts the spatial arrangement and characteristics of the land and vegetation, and environmental data so that they can plan for controlled burning operations more effectively.

The existing systems for creating such fuel maps have two main issues. The first issue is that there are no cohesive systems presented by one company to do a complete controlled burning environment analysis. Rather, they rely on the cooperation of multiple projects and companies. The second issue is the lack of fine granularity in scanning forest areas, as the current systems generally utilize sparse weather stations for collecting atmospheric data and large aerial LiDAR systems (ALS) for scanning just the canopy of forests. There are other scans being used, but generally this relies on using high altitude vertical ALS scans and attempting to reconcile them with horizontal scans made by people on the ground.

Our product is a land inspection system to collect and process both topographical and environmental data. Our system has two components. The first uses an airborne LiDAR system (ALS), which can scan a forest region to provide a 3D point cloud of the land and vegetation. Then, the 3D point cloud can be processed to produce the final 3D fuel map. The second component is the embedded sensor nodes. These nodes are cheap and energy-efficient pieces of hardware that can be simply placed across the forest floor and will passively collect environmental data. Combining both the fuel map and this data results in a complete and efficient system for providing fire managers with the information they need for identifying controlled burning locations without onsite human investigation outside of simple drone operation.

2 System Description

The first component in our system is the ALS, which includes the multiscan100 mounted on a drone. Our system can scan above and below the canopy to provide data on the vegetation and topography of a forest region. Using this data, we can produce a 3D point cloud and derive a digital terrain model (DTM) that analyzes the land's topography and a canopy height model (CHM), which determines vegetation height. From the CHM, we can perform tree segmentation to identify the distribution of tree clusters. We also derived the percentage of canopy cover and vegetation density at different height stratas in each region. To better visualize these models and identify at-risk areas, we've created 2D heat maps of the models.

The second component is the Sensor Node Network (SNN), composed of many individual low-power sensor nodes (referred to as motes) with a long service time (> 2-month minimum lifetime).

Each mote collects data on temperature, humidity, pressure, Volatile Organic Compounds (VOC), PM2.5, and Ozone. To enable low-power operation, an intermittent computing framework is used to collect and aggregate data. The mote's default state is a low-power sleep state, supplying power only to required volatile services. When a predetermined period elapses, a timer watchdog interrupt wakes the mote, which will then collect samples from each sensor before returning to a sleep state.

The drone serves as the aggregation point using Wake Up Radio (IEEE 802.11ba) to wake up the mote and signal wireless data transfer to the drone. We utilize the LoRaWAN protocol to create a network of motes over a large area.

The motes essentially are able to gather all the other environmental information that the ALS does not capture to fill in the necessary data in order to provide users with the full picture of the scanned region and its environment.

3 Commercial Potential

Although systems for mapping forest regions do exist, the projects of accomplishing this to the full extent are only in development and generally require vast scopes of data which have to be gathered from different sources. Our design provides all of the data into a single package with a higher data granularity. The main limitation to our design is only the size of the drone as the multiscan100 is easily able to map out regions without pivoting due to its view in every direction, requiring only a brief flight time in order to accurately record a section of a forest.

This allows for those companies that are working on mapping out forest areas or developing large scale heatmaps for wildfire prevention to be able to act self-sufficiently, generating any data that they need. Because our system is more localized as it requires flight lower to the forest, companies can use our project as a method to fill in patches in data both for 3D modeling as well as environmental data since data from weather stations can be incredibly sparse in certain regions.

And there is no need to concatenate different sources of data since we provide both pointcloud and environmental data with our product. If more or less data is needed from the motes, they are easily modifiable for any other data that a company might need. Additionally, due to the low power nature of the motes and the components we used, they are very low cost to produce and can last up to a year on the charge of just regular batteries. The only cost of the project itself is limited by the drone and the LiDAR itself, with other expenses being minimal.

4 Future Development

Although we propose and have tailored our system for usage in wildfire prevention, its use extends past the current implementation. In general we have created a surveillance system which is able to map out any area, creating a 3D point cloud, and cheap motes which can be modified to collect any type of environmental information.

Therefore, this system can easily be used for mapping out other things, such as architecture, terrain, or city infrastructure. Instead of using the forest mapping models, it is possible to simply substitute software and machine learning models to identify roads, buildings, cars, etc. We can use it for surveying for damage in hard to reach areas such as radio towers and bridges, or gather more general environmental information to aid weather stations. The uses for a general purpose system which is able to provide all the data by itself without external support are limitless. All that needs to be done to modify it is just swapping out what models are used and to match what is being surveyed and for what purpose.

As a result, we expect that our system can be useful not only in wildfire prevention as we have intended it to be, but also in any other case that would require making a 3D model of an outdoor area with environmental data.

In the future, by combining this with more advanced machine learning models and computational power, it might be possible to make it even more generalized by making the software capable of identifying any type of common outdoor shape or object. However, such a design would require more development. In our project, we focused on a specific topic and succeeded in being able to map out trees and vegetation as proof of the concept of how our system can be utilized.