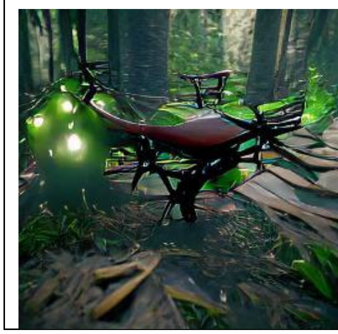
CS486C – Senior Capstone Design in Computer Science

Project Description

Project Title: Project Glasswing: automated UAV navigation in forest understories

Sponsor Information:



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Project Overview:

Applications for UAVs are numerous and growing, with the readily available and improving technology, and affordable and declining price points. At the same time, sensor technology such as LiDAR and environmental sensing is advancing at a rapid clip. Environmental researchers are now regularly combining these tools to conduct monitoring above forests and other ecosystem types, and this research has proven to be fruitful. For example, we are now able to monitor forest health, measure carbon stocks, predict fire risk, and estimate aspects of biodiversity from UAV-mounted sensors. Yet, all these metrics miss most of what is actually happening inside of forests, underneath the canopy. This is a major gap in our ability to measure and monitor forests at scale.

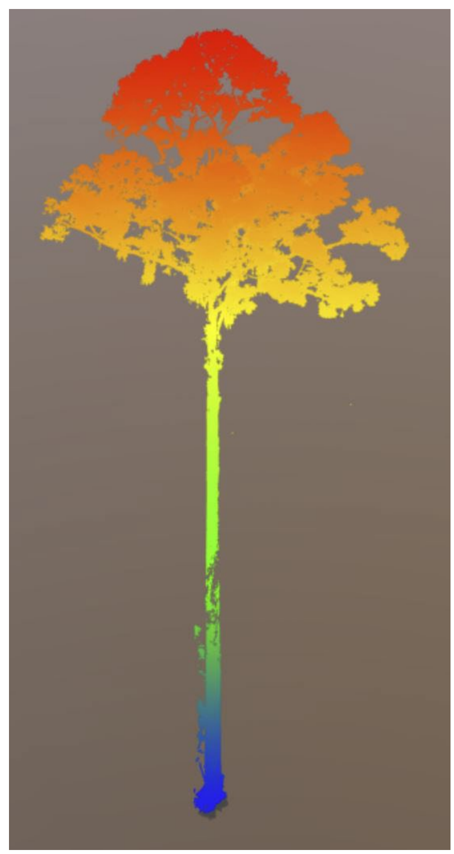

Figure 1. A 3D scan (combined TLS and SfM) of the world's tallest tropical tree.

I study the relationship between forest structure and forest function, mostly in the tropics but also in temperate forests such as those here in Flagstaff. Questions we ask include, for example, how the structure of a forest relates to how much carbon it takes up from the atmosphere, how structure can help forests be resilient to climate change, and how the architecture of individual trees relates to their life history strategies. I use UAV's to study forests from above with hyperspectral optical sensors, and from below with terrestrial LiDAR scanning (TLS), Structure from Motion (SfM), and microenvironmental sensing techniques (see my brief talk about TLS here, and some 3D tree models here). This work is yielding new insights into how forests function around the globe.

Conducting research in forest understories is laborious and time consuming. For example, scanning one hectare of forest with a TLS instrument takes around one week with 2-3 people dedicated to the task. Deploying microenvironmental sensors throughout a forest requires tree climbers and specialized instrument development. Even when carried out well, their access to the canopy is limited and, consequently, as such, very few comprehensive understory measurement campaigns that successfully combine structure and function have been carried out.

To enable quicker and more comprehensive measurement of understory structure and microenvironments, we envision developing a UAV platform capable of navigating forest understories. Sensors such as LiDAR, cameras for SfM, and microenvironmental sensors such as light and humidity sensors, would be mounted to the UAV. It would navigate the understory while the sensors take measurements in 3D space. The UAV would be able to detect obstacles (trees, lianas, vegetation) and steer around them.

The first phase of development of this platform would omit the UAV and guide a platform held by the user around a forested area – or a lab with obstacles. Key features for a **minimum viable product** would include:

- Automatic detection of objects down to a centimeter or smaller in diameter in a horizontal plane and a cone ~20 degrees up and down from the horizontal.
- Basic goal-oriented movement towards a preferred direction.
- A basic indication to the user of which direction to move in, and how far.

A **useful system** would include:

- Identification of paths safe to travel given the size of the "UAV"
- Ability to look spherically (not just in the horizontal cone) so more vertical movement up and down could be achieved

Stretch goals could include:

- A display screen showing the user the planned path to take through the forest/obstacle
- An autonomous, goal-oriented navigation module that, given coverage goals, would attempt to visit as much of the designated 3D space of the understory/obstacle course as possible (while avoiding the obstacles, of course). This is akin to a Roomba trying to visit all the bits of your floor. But in this case, your floor is 3D. The visitation algorithm could be based on stochastic rules (such as the less intelligent Roombas), or could know something about the space and try to visit it all more efficiently.

A successful project would have lasting impacts on the forest ecology and climate modeling community. With a substantial step forward in understory navigation, further steps would be taken to implement this system on a live drone. Once complete, the data available to understand the functioning of forests would greatly increase, and would push models to new limits in their ability to understand how and why forests respond to climate change, and what we can do about it.

There are, of course, a number of other possible applications. These include both military and commercial applications. As such, there is a chance that this platform could be spun into a business if successful. There would be significant demand for an autonomous obstacle-avoiding drone.

Knowledge, skills, and expertise required for this project:

- Interest in interfacing with plug and play hardware sensors such as ultrasound and lidar sensors.
- Use of navigational operations and physical situational awareness using multiple sensors
- Linux programming

Equipment Requirements:

Costs for equipment will be provided by the sponsor and/or the Dean's office as needed

- A development platform (e.g., laptop or computer) and software/tools freely available online
- Processor (raspberry pi or equivalent), perhaps header board to interface with sensors
- Lidar, ultrasound, and other small, inexpensive sensors
- Battery(s) as needed
- Basic materials for a platform (wood would probably be fine)
- Small LED display for stretch goal

Software and other Deliverables:

- 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 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.