Drone Enabled Sensing and Monitoring of Tree Canopies

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***Abstract*—This project was proposed to Northern Illinois University, College of Engineering and Engineering Technology by The Morton Arboretum. The objective was to design and create a device to mount and retrieve a sensor arrays in tree canopies. These sensor arrays will be used to give the arboretum a better understanding of the environment of the canopies. The device that was created is to be attached to and manipulated by the DJI Matrice 600 Pro drone. The device utilizes multiple systems that are interchangeable onto the drone to deploy and retrieve the sensor arrays from tree canopies.**

I. INTRODUCTION

The conditions of the tree canopy can provide information on tree health, outbreaks of pests and disease, and a better understanding of tree failure. The objective of this project was to find a more efficient way to study tree canopies due to their large size.

The team worked on two specific subcomponents, which is part of a larger scale project with various other systems. Morton Arboretum would like to have a sensor array, or other devices, that can be placed in and removed from a tree canopy. The current prototype allows for the devices to be fixed to a universal sensor mount (USM) shown in figure 1(B). The USM will be deployed into the tree canopy by a deployment system (DS), shown in figure 1(A), that is fixed to a pole attached to a drone.

When the device is to be removed from the canopy, the DS will be replaced with the female end (funnel) of the retrieval system (RS), figure 1(C). This configuration will enable the drone to make a connection with the USM and remove it from the canopy. After the USM has been retrieved, the arboretum can access the data collected by the sensor array or other devices.

The information that is attained by the devices deployed into the canopies is detrimental for a greater understanding of the environment of the canopies. The purpose of this project was to make it safer and more efficient for devices to be deployed and retrieved from areas that are difficult to reach by a person.

II. METHODOLOGY

Universal Sensor Platform:

Since the universal sensor platform is being lifted by the drone and left in a tree for extended periods, the weight must be kept low. Polylactic acid (PLA) plastic was chosen because it is used in 3D printing as well as its cost effectiveness and relatively low density. Aluminum was used for parts that experience loads. A requirement of the USM is that it must be able to host an array of sensors and devices, so many attachment points were necessary. The USM remains attached to the tree using aluminum claws. There are two rigid claws that can be moved to allow different sizes of branches. The other two claws provide the clamping force using torsion springs. Part of the retrieval system is also attached to the USM. There is now a bracket which allows for the retrieval spike to be mounted away from the tree branch to ensure clearance for the retrieval funnel. The spike is attached to the end of the bracket and provides a connection point for the funnel during the retrieval process.

Delivery System:

The delivery system houses the USM during transport and engages the claw mechanism on the USM. It connects to the drone through a 12-foot telescopic pole. The DS has a servo motor powering a clamp that holds the USM in place. This clamp also pushes the USM out of the DS when a positive connection between the USM and tree branch is made. Another, more powerful, servo motor was added that turns a cam that overcomes the springs on the USM and opens the claws, allowing the claws to reach around the branch. The clamp then releases and the USM is left on the branch. Since weight is a significant design factor, components that were not load bearing were made from PLA. The system was also skeletonized to remove any unnecessary weight. Any load bearing components were machined from 6061 aluminum. The DS was also redesigned to accommodate the new USM design.

Electrical System:

The electrical system for the DS was completely redesigned from the original concept. With the replacement of the main drive servo for a larger model came a larger demand for current. This forced the team to use a battery pack external to the drone power supply. The team decided to use two lithium-nickel-manganese-cobalt oxide ($LiNiMnCoO_2$) batteries that were able to supply the required current and voltage. Additionally, an Arduino Uno microcontroller is utilized to generate the pulse-width modulation signals that are utilized to create the position data for the drive and clamp servo motors. Furthermore, the microcontroller takes the data input from the drone and measures the input signal pulse width to determine the switch positions on the drone remote controller. Using the switches on the drone remote allows the drone operator to control the position of the servo motors while the deployment system is in flight and during sensor platform deployment operations.

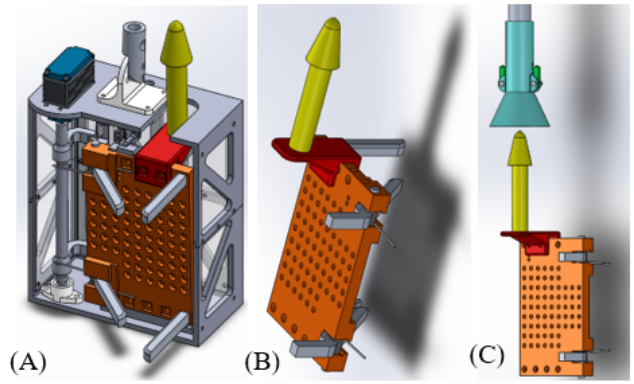

Figure 1: DS and USM (A), USM (B), RS and USM (C)

Retrieval System:

The retrieval system retrieves the USM after the data collection is over. It also connects to the drone using the same 12-foot telescopic pole. The RS is made from PLA, like the other systems for weight reasons. The RS connects to the spike on the USM, and the drone removes the USM from the tree. It was designed to give the drone operator a large margin of error when retrieving.

III. RESULTS

A. *Retrieval System*

The testing of the retrieval system was conducted on free standing branches of various sizes. The extension pole was attached to the drone with the retrieval funnel attached at the end. The drone pilot maneuvered the drone above the USM, and carefully lowered onto the spike of the USM. The latch of the cone engages the spike, and then the drone removed the platform from the branch.

B. *Deployment System*

Currently, the DS has been tested on a bench but has not been flight tested. Simulations of various pieces of the DS have been successful, including software testing. Drone data output has been verified.

C. *Universal Sensor Mount*

The testing the USM underwent showed that it was successfully able to clamp onto branches of various thicknesses. It was discovered that when the branches are very thin, the USM has difficulties attaching.

IV. DISCUSSION

A. *Future Direction*

One future consideration for our team was to remanufacture the sensor platform components from a more durable material than PLA plastic. Aluminum, or other lightweight metals, would hold withstand elemental forces and heat far better than that of plastic. Deformation of the PLA will be a consideration of long-term use of the sensor platform.

B. *Issues*

The main issue we encountered with our design was the proper sizing and operation of the drive servo motor. The first servo motor that we were using was incorrectly rated for the required amount of torque that was required. When the team performed a torque analysis of the original servo, it was discovered that the manufacturer of the servo misrepresented the amount of torque that was supplied by the servo.

C. *Successes*

The modification of the deployment system to accommodate the larger servo motor went especially smooth. Despite nearly the entire case for the deployment system needing to be re-printed to make the accommodation, the redesign did not create any timeline setbacks. Additionally, the entire retrieval system was redesigned. This allowed easier removal of the USM from the tree canopy as well as simplifying the attachment of the drone to the sensor platform during the removal process.

D. *Some Common Mistakes*

One of the minor mistakes that the team encountered during the build of the design was the choice of wire connectors during the build of the electrical components. During original assembly, wire splices were used in place of a complete build of a wire harness. This caused several issues with open connections and system functionality.

V. CONCLUSION

The prototype that was developed for Morton Arboretum to help study tree canopies. The environment of tree canopies can help the arboretum understand disease, insect life, wildlife, and overall tree health. The previous are important to know because it will allow for a deeper understanding of the problems in tree canopies. This information will give Morton Arboretum, as well as other groups, a better understanding of how to handle canopy issues. This information can also help understand tree failure. Tree failure can be very dangerous to the health of people as well as preventing property damage.

The team refined and redesigned an existing prototype to address functionality issues and new restraints. The primary alterations where completely redesigning the RS and near completely redesigning the electrical system.

Throughout this project the team was faced with numerous problems and limitations. Relying on the knowledge gained from their studies and past experiences, the team was able to effectively and efficiently use their engineering skills to overcome these obstacles.

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