Drone-Enabled Sensing and Monitoring of Tree Canopies

Team 14

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***Abstract*— This multiphase project was proposed as a senior design project for the College of Engineering and Engineering Technology at Northern Illinois University by the Morton Arboretum, which is located in Lisle, IL. The ultimate objective of the project was to develop a universal sensor mount capable of accommodating small scientific instruments that can clamp onto tree canopy branches and is capable of being deployed and retrieved with a DJI Matrice 600 Pro UAV. The main motivation behind this project is that the tree canopy environment is difficult to study, as it cannot be easily accessed by humans. Research of tree canopies and the canopy environment is important, as it can help monitor tree health, monitor pest and disease outbreaks, provide a greater understanding of tree failure in storms, and support many other areas of biological research. Monitoring devices currently have to be deployed manually. The Morton Arboretum proposed that unmanned aerial vehicles (UAVs) could be used to more efficiently deploy monitoring devices onto tree canopy branches. The team conceptualized and designed a novel system capable of achieving the ultimate project objective. Prototypes of the universal sensor mount and deployment system were fabricated and tested. The universal sensor mount can be successfully secured to tree branches. However, further optimizations of the deployment system are necessary before the device is ready for integration with the UAV.**

I. Introduction

There is a need for a more efficient method of studying the canopies of trees and the unique environment within the canopies. Current practices of manually deploying data collection devices in the tops of trees have multiple shortcomings. Deploying devices in tree canopies by hand is time-consuming, labor-intensive, and can result in damage to the tree. Additionally, there is always an element of personal safety risk to the person placing the sensors in the trees. Most of these shortcomings arise from the fact that tree canopies are difficult to access [1]. Thus, a method of deploying data collection devices onto tree canopy branches from unmanned aerial vehicles (UAVs), is desirable for The Morton Arboretum. Devices with similar motives have been developed, such as the system in [2].

To more efficiently deploy sensors and data collection devices in tree canopies, an electromechanical system was proposed, conceptualized, and designed that will enable a DJI Matrice 600 Pro UAV to deliver scientific research payloads to canopy branches ranging from 3 to 10 centimeters in diameter. The initial target weight for the system set by The Morton Arboretum was 3.0 pounds. The other major design requirement was that the universal sensor mount (USM) needed to be capable of accommodating sensor packages weighing up to 250 grams.

To meet the above design requirements, a system consisting of three main subsystems was designed and prototyped. The three subsystems include a USM, deployment/retrieval system (DRS), and controller system (CS). Sensors and other data collection devices can be attached to the USM. The USM is the subsystem that gets deployed onto tree branches and left behind for a data collection period. The USM is resistant to adverse weather, as it may remain deployed on branches during rain and thunderstorms. The USM incorporates two torsional spring clamps to passively attach to tree branches. The gripping mechanism is actuated by a servo motor on the DRS, which is suspended from a pole beneath the UAV. The USM is secured in the housing of the DRS until deployment by a secondary servo motor. Both servo motors in the DRS are capable of being powered from an outlet underneath the UAV. To retrieve the USM, the deployment DRS end effector can be swapped out for a simple, retrieval hook to capture a cable loop attached to the USM. The DRS servos will ultimately be controlled by the stock DJI Matrice 600 Pro UAV controller with a channel expansion kit.

II. Materials and Methods

Due to the significant weight constraint for the design, weight was the most important factor in material selection for the USM and DRS. Consequently, the team's design utilizes both machined aluminum components and parts 3D printed from polylactic acid (PLA) filament.

The USM designed by the team is depicted in Fig. 1 and the deployment system (DS) design by the team is depicted in Fig. 2. The USM consists of an extruded PLA body, two aluminum 6061 rotating clamps, two music-wire steel torsional springs, and two aluminum 6061 adjustable rigid clamp arms. The torsional springs and rotating clamps are held in position on the USM body by press-fit extruded PLA plugs. To ensure that the USM and a 250-gram payload could remain safely secured to the target range of tree diameters, torsional springs with constants of 2.93 in.-lb./rad were selected. The top of the USM body has arrays of holes to allow the arboretum to attach a wide range of payloads. Based on the diameter of target tree branches, the fixed clamps can be

Fig. 1. USM design.

Fig. 2. DS design.

fastened to one of four positions to ensure that the USM has sufficient torque to remain secured to the branches.

The DS design in Fig. 2 consists of an extruded PLA housing, bearing block, USM mounting brackets, and incremental angle hinge. Furthermore, the system incorporates an aluminum 6061 drive shaft, two aluminum 6061 roller arms, and two nylon rollers. One servo motor rated at 35 kg-cm rotates the shaft and another, identical servo motor is used to lock and unlock the USM in the housing by rotating a fixture that indexes with the USM body.

III. Results and Discussion

The original USM and DS designs utilized aluminum and extruded PLA components. However, in response to the restrictions introduced by the COVID-19 pandemic, the team redesigned the USM and DS to produce the initial prototypes in Fig. 3a, which consist nearly entirely of 3D printed PLA components.

The USM prototype was tested across the range of target tree branches with a 280-gram payload and the device remained firmly secured to tree branches as desired, even when disturbances were introduced to the tree branches. The USM prototype also properly indexes within the DS prototype.

To test the DS prototype, the servo motors were connected to a power supply and controlled with potentiometers and an Arduino Uno microcontroller as shown in Fig. 3b. The secondary servo motor used to lock the USM in place functioned as desired as long as the servo remained energized. However, before the

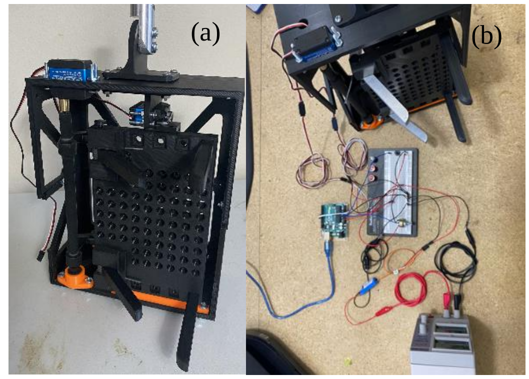

Fig. 3. USM and DS prototypes (a) and bench testing configuration (b).

drive shaft servo could supply sufficient torque to open the USM clamps, the setscrew joint between the servo coupler and drive shaft sheared the drive shaft PLA. For future revisions of the DS prototype, the authors recommend machining the drive shaft from aluminum 6061 as was originally intended and increasing the mechanical advantage of the roller arms.

IV. Conclusions

Overall, to progress towards The Morton Arboretum's ultimate goal of deploying and retrieving small scientific instruments on tree canopy branches with a DJI Matrice 600 Pro UAV, the authors have conceptualized, designed, and prototyped components of a novel system. An optimal design was selected that consists of three main subunits: the USM, DRS, and CS. The team successfully completed the first phase of the design project by producing a functional prototype of the USM. The team also made significant progress in the second phase of the project by designing, fabricating, and testing an initial prototype of the DS. Further optimization of the DS is recommended before integration with the UAV.

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