Aerial Lidar Processing

Marco Flowers
Dept. of Computer Science
University of California - San Diego

Pramukh Govindaraju
Dept. of Computer Science
University of California - San Diego

Bryan Zhu
Dept. of Bioengineering
University of California - San Diego

Special Thanks to:
Eric Lo
Prof. Ryan Kastner

Abstract

Archaeologists are surveying the Mayan jungles in order to discover hidden ruins. To do this, they need to map the jungle. However, modern aerial lidar mapping systems are prohibitively expensive. In this paper, we describe the creation of a mobile aerial lidar processing system for use on a drone. We implemented an end-to-end pipeline for acquiring raw data and processing into a finished product that allows for ease of use in the field. With traditional plane charter lidar systems costing into the hundreds of thousands of dollars, we believe that by mounting our system on an octocopter, we can satisfy archaeologists constraints at a significantly lower price, with enough accuracy to provide actionable data.

Introduction

In the Guatemalan rain forests, there are many hidden Mayan ruins that are of great interest for archaeologists. Archaeologists and historians study these ruins in order to gain a better perspective on how our ancestors lived. However, these areas are hard to navigate through and the ruins are hard to locate. For this project, we hope to be able to take an aerial approach to surveying the rainforest and locating these ruins.

Figure 1. Illustration of Traditional LIDAR capture. Source: LIDAR-America.com.

Traditional aerial lidar mapping systems do exist, requiring expensive commercial equipment and a plane charter. If even available in remote Central or South American regions, they are prohibitively expensive for usage by archaeologists.

Figure 2. Quanergy M8 Lidar Sensor, our sensor of choice.

With the advent of self driving cars, many companies have developed significantly cheaper and more portable Lidar sensors. To obtain aerial imagery of the rainforests, we plan to mount a Lidar sensor (namely, the Quanergy M8) onto a drone and flying the drone above the treetops. Lidar systems work by rotating and constantly sending out pulses of light. By measuring the differences in return times and in wavelength, a lidar system can generate a 3d model of its target. While the lidar can generate instantaneous point clouds, we need rotational and positional data from an Inertial Navigation System, in order to piece these point clouds together to generate a map. In this paper, we compare two different INS systems, the Vectornav VN-300 and the significantly cheaper Microstrain 3DM-GX35.

Another important factor for an aerial lidar system is the ease of use in the field. Since we hope to provide a broad solution that includes the hardware and software necessary to perform these scans in the field. To achieve this we wanted to create an easy to use export process that would allow archaeologists to collect the data in the field and export it into a format easily analyzable.

Technical Material

INU Comparison

To project point clouds from the lidar into 3D space an Inertial Navigation Unit(INS) is needed to record the position and orientation of the lidar when taking a scan. We had a couple of different devices to compare that occupy different price and performance points. The first device we looked at was Vectornav VN-300 which combines inertial sensors, Global Positioning System(GPS) antennas, and advanced kalman filtering to provide filtered estimates of position and orientation. The VN-300 has a cost of $5000. We were not able to get accurate position estimates from the Vectornav as the internal algorithms would not converge on a healthy status. To test the orientation accuracy we fixed the position and performed indoor scans. Initially the the scans did not match up when they exported them as the orientation data was incorrect. The coordinate frames of the quanergy lidar and the Vectornav were different and therefore the data did not match up. After experimental testing we were able to determine the necessary transform between the LiDar coordinate frame and the Vectornav which was transforming the Vectornav data by the quaternion (-1, 0, 0, 0).

We also tested a Microstrain 3DM-GX35 which also combines inertial sensors with gps antennas. On the GX35 datasheet it quotes ±2.0° pitch, roll, heading for dynamic test conditions and for arbitrary angles. Compared to .1° for the Vectornav we didn't expect it to perform as well in testing for orientation accuracy. On the position side we were not able to get an accurate lock in testing at UCSD which may have been because of the tall buildings and different signals broadcasting on campus.

Figure 3 shows two scans of the Sealab with the left using the Microstrain and the right using the Vectornav device. Qualititatively the one on the right looks better which matches the datasheets and our expectations.

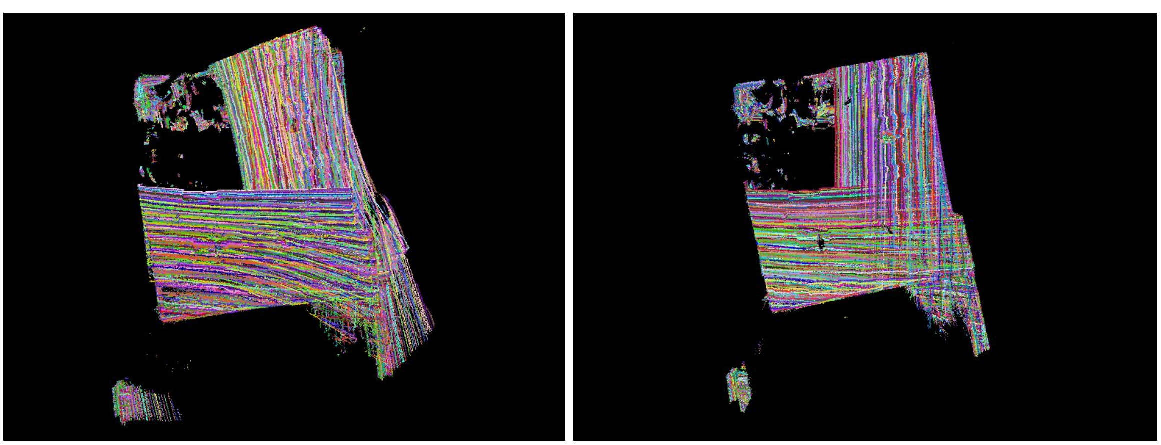

Figure 3. Scans of Sealab using Microstrain(left) and Vectornav(right)

Because we were not able to get reasonable position data from the Vectornav or Microstrain we decided to analyze the BX316 GNSS RTK board from Tersus GNSS. Kinematic positioning from this device from the datasheet should be accurate to 10mm horizontal and 15mm vertical accuracy. We used 2 BX316 one as a base station and one as the “rover” or device whose position we care about. Real Time Kinematic processing requires a radio link between the devices so instead we attempted Post Processing Kinematic readings where both devices record data and the accurate position is calculated after the fact. We performed tests but where not able to get a fixed signal after post processing the data. More testing is needed to figure out why we cannot achieve a fixed signal. Although we were not able to get accurate data from the BX316 we set up a ROS node to read the processed file and input it into the lidar processing system so a set of lidar scans could be played back after inputting the post processed data to match the position and scans correctly.

Export Process

To allow archaeologists to analyze the resulting scans we receive and orient from the LiDAR we needed to add an export process to the ROS system. This would turn the raw data into a format that archaeologists could label and analyze further. To achieve this we first attempted to modify an existing node point_cloud_io which subscribed to the point cloud topic to also receive orientation and position data and tag each point cloud. We had issues with getting the resulting ply files to contain the position and orientation data and so instead used the pcl_ros pointcloud _to_pcd node to export the lidar and position data to pcd files. These files can then be visualized in a viewer such as pcd_viewer. Below is an exported scan of the Sealab being viewed in pcd_viewer.

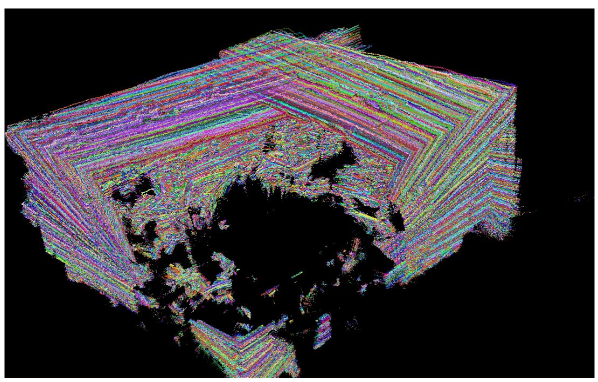

Figure 4. PCD scan output

GUI

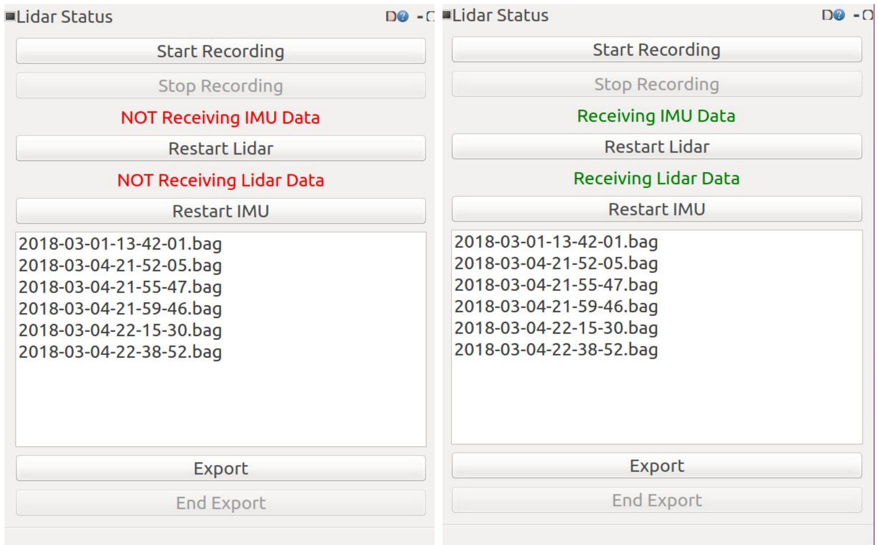

Figure 5. Our GUI monitors sensors to see if they are producing data.

Using rqt, a Qt-based framework for Graphical User Interface (GUI) development for ROS, we developed an easy to use GUI for starting and stopping recording of Lidar and INS data, monitoring the sensors during recording, and running the export process scripts. As shown in Figure 1. The GUI scans the current file system, looking for .bag files, which contain the raw lidar and INS data. The user can select the correct bag file, and with one click, the export scripts are run and pcd files are generated, which can be visualized using appropriate programs.

This simple User Experience is very important in the field, as archaeologists may not have the technical skills to operate a complex system like ROS.

Flight Platform

The flight platform used to transport the LiDAR system utilizes the Foxtech Devourer 130 (D130) Version 2 Coaxial Octocopter frame and a Pixhawk flight controller. The frame is a highly rugged structure weighing in at around 7 kg without any battery or LiDAR mounted. Much of the frame is also constructed of carbon fiber and this allows the flight platform to be able to deal with the harsh environments that can be found in the Guatemalan jungles. The drone also has a max payload of up to 12 kg. The drone is powered by four 6S lithium polymer batteries.

Initially, our first tasks were to disassemble the drone, refurbish all the parts, replace the screws with stainless steel counterparts, and reassemble the drone for flight. In order to ensure the drone would stay together, we applied loctite threadlocker to every screw. This loctite would make it so that during flight, the vibrations of the drone cannot jar loose any screws. Upon reassembling the drone, we took it out to test fly it. At first, the drone flew as it was supposed to. However, while testing the limits of the drone, we encountered some adverse yaw and the drone crashed. Luckily, thanks to the frame of the drone, only the landing gear was damaged and the rest of the drone was salvageable.

After ordering new landing gear, the drone was taken out for another test fly. The previous crash was likely due to a motor not performing as expected due to either current draw issues or the possibility that the motors were not strong enough. During the second test flight, the drone was again able to fly and this time without crashing. However, there were still worrying trends during this second flight reminiscent of the issues that arose from the first test flight. As a result, each individual motor will be placed on a thrust test stand to get a better look at the thrust coming from each motor. For these tests, the motor will be hooked up to a 60V 35A power supply.

Figure 6. On the left is the assembled flight platform with batteries mounted underneath the centerpiece. On the right is an individual motor hooked up to the thrust test stand.

Milestones

Milestone	Deliverable	Status
Achieve Manual Flight	Video of the drone achieving manual flight.	Completed
Productionize the Scan export process	Create easy to use scripts to use in the field that takes raw scan data and generate a visualization.	Completed We created a process for exporting scans and a GUI to make it easy to use in the field for archaeologists.
Generate scan with Accurate IMU data	Scan of Warren mall.	Partially Completed Since we were not able to get accurate position data from the Vectornav, Microstrain or

		RTK gps we took scans of Warren Mall and the Sealab but only using orientation and not position data.
Integrate RTK GPS into the system	Utilize RTK GPS technique to increase GPS accuracy	Not Completed We created a process to integrate the RTK GPS results but were not able to get accurate data from the devices.
Compare Commercial and Quanergy lidar accuracy	Given expected drone flight compare the expected quanergy scan results to what are achieved through commercial acquisition of lidar data.	Not Completed We did not achieve drone flight with the LiDAR device and without position data we weren't able to get real test data to compare with commercial data.
Integrate other sensors to enhance capabilities of our system (Stretch Goal)	Research and experiment with other sensors to supplement the lidar system.	Not Completed We were unable to get to this point as we first wanted to focus on having the flight platform and LiDAR system functioning with the most basic setup possible.
Integrate new Flight Platform (Stretch Goal)	Work with Eric on assembling and tuning the new flight platform as necessary.	Partially Completed The new flight platform was taken out for a test flight and was able to achieve flight. However, there were still concerns about the performance of the drone and we are currently testing the thrust of each motor.

Conclusion

In this project we were tasked with analyzing a cheap aerial LiDAR system for mapping jungles along with a system to process the results for analysis. We analyzed different INS devices and presented our findings. We created an export process and GUI to allow archaeologists to enable easy use in the field. A potential flight platform was refurbished and flown to analyze its feasibility. Currently there is a need for a cheap LiDAR system to enable archaeologists without the funds to purchase an expensive plane based system. Recent findings using plane based systems have discovered Mayan ruins that have changed the the previously thought scale of Mayan activity in an area (BBC). LiDAR scanning in England has found Roman roads (Wired). This technology has shown the ability to increase of historical structures and push the bounds of what we can discover. By analyzing and creating a cheap LiDAR platform, LiDAR scanning could be accessible to more archaeologists around the world. In this project we set out to analyze the feasibility of a cheaper platform and benchmark the differences between commercial LiDAR and our platform. Although we were not able to get to the comparison between commercial lidar and our platform we benchmarked different possible INS devices, integrated them into a system for processing the data, and created an export process that archaeologists can use in the field.

The path for future work is clear through the goal of creating a cheap drone based LiDAR platform that we can compare to plane based systems. To achieve this a stable flight platform will need to be created or bought. The RTK or Vectornav will need to be diagnosed and integrated fully to provide positional estimates. With a full comparable platform ready for testing data can be analyzed from test flights against commercial data. Different LiDAR and INS sensors can be swapped in as necessary to provide different price and performance comparisons. A reference system along with associated source code could be released to the community so that archaeologists could build and operate their own system. Other future areas of interest could be in automatically analyzing and labeling the LiDAR data and adding in different sensors to augment the LiDARs view of the world.

References

Vectornav datasheet
https://www.vectornav.com/docs/default-source/product-brochures/industrial-series-product-brochure-(12-0009).pdf

Microstrain datasheet http://files.microstrain.com/3DM-GX3-35_Datasheet_(8400-0034).pdf

BX-316 datasheet
https://cdn.shopify.com/s/files/1/0928/6900/files/Datasheet_Precis-BX316_EN_0921.pdf?12197405032440294952

BBC Article on Mayan Lidar http://www.bbc.com/news/world-latin-america-42916261

Wired Article on Roman Lidar
https://www.wired.co.uk/article/lidar-mapping-environment-agency-2020-flood-defence-waste-dumping