LiDAR Odometry and Mapping for Terrain Analysis from Unmanned Aerial Vehicles

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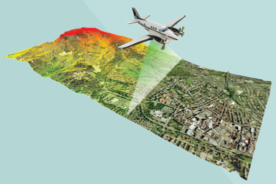
Objective

This project aims to develop a software solution for LiDAR terrain mapping and analysis using the LiDAR Odometry And Mapping (LOAM) technique and the Robot Operating System (ROS) framework.

Understanding LiDAR Mapping

What is LiDAR?

LiDAR is an acronym for Light Detection and Ranging. By firing pulses of laser light in different directions hundreds of times a second, LiDAR measures distances to points on visible surfaces. This information can be converted into a cloud of point data that represents an accurate three dimensional view of the immediate environment.



Typical Data Capture

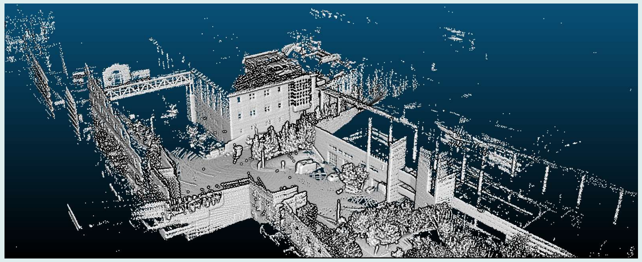
An Unmanned Aerial Vehicle (UAV) can be equipped with a LiDAR sensor to map its surroundings as it flies. Such a map is composed of many thousands of sample points which may be computationally analyzed to gain information about the environment they represent. For example, given a LiDAR-produced map of a landscape, it is possible to automatically distinguish plants from rocks, or to identify river beds and other features.

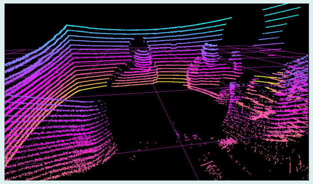
The Point Registration Problem

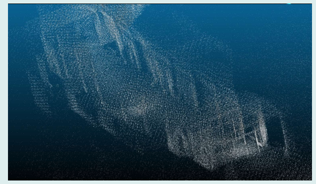
As the UAV moves through the air, the LiDAR points being measured come in at different times and locations. This means that if the points are simply lumped together, many different perspectives will be shown on top of each other, creating a meaningless jumble of information. The points must be aligned in such a way as to “stitch” these different perspectives together, much as a panoramic photo can be stitched together from many constituent images. This process is called point registration, and is one of the major challenges to developing LiDAR mapping software.

Data Capture with LOAM

LiDAR Odometry And Mapping (LOAM) is a variation of the Simultaneous Localization And Mapping (SLAM) algorithm designed to perform point registration specifically for point data gathered via LiDAR. LOAM manages to accomplish this feat in real-time, meaning that the UAV can return from its flight with a fully registered map in its memory, eliminating an extra processing step. LOAM is an essential tool used by this project.







The Sensor Pipeline

The Robot Operating System (ROS) Framework

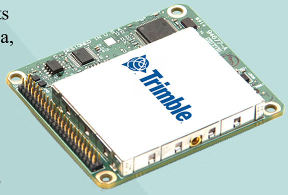
ROS is a middleware that facilitates access to hardware commonly found on robotic systems, as well as providing a message passing system and other useful utilities. Software that uses ROS is usually split into multiple processes, or ROS nodes, that use message passing to communicate with each other. A small computer to run these nodes resides on the UAV along with the sensors.

Interfacing with the LiDAR Sensor

Everything starts with the LiDAR sensor itself. It sends out packets of data containing angles and distances for each point. These packets are received by a ROS node and processed into small unregistered clouds of points in cartesian space. These clouds are then sent along to the next node.

Interfacing with the IMU/GPS

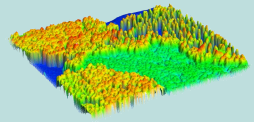
Given only LiDAR points, LOAM produces good point registration results for a short duration or over a small area, but eventually errors propagate. To correct for this drift, an Inertial Measurement Unit (IMU) provides acceleration and orientation data. GPS data is also desirable so that the final map is georeferenced. Sensor readings from an IMU and a GPS are gathered and transmitted by another ROS node.



Putting It All Together

Registration at Last

A third ROS node waits for point clouds and IMU data being sent by the other nodes. Every time a cloud is received, it is stitched onto an ever growing map using LOAM. Every newly registered cloud now has a new location and orientation in cartesian space. These registered clouds are sent along to the last node.



Saving the Map

A final ROS node saves all of the registered point clouds together into a standard file format. This file can be copied from the UAV to another computer for analysis.

Conclusion

Results

This project is an ongoing effort with the potential to yield substantial benefits to programs that maintain and improve the ecosystem services of Idaho communities. New applications of LiDAR mapping technology are being realized all the time, notably in agriculture and forest management.

Future Applications and Improvements

There are many analyses that can be performed on LiDAR terrain maps. These will likely be a focus of future work.

References

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