LOWERING THE BAR FOR LIDAR POINT CLOUD EXPLORATION AND USE IN MAPPING

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Introduction

Lidar point cloud (LPC) data collected from airborne platforms contains a wealth of information about the landscape. From the Earth's surface to the tops of trees, the reflected laser pulses deliver information about their intensity, density, number of returns, and travel time. Results provide detailed 3-D maps that contain contextual information that can be used for analysis and visualization. Knowledge of remote sensing and geographic information systems (GIS) is generally required to make use of LPC data. Developed to simplify corridor visualization (CorVis) and analysis of LPC data, CorVis is an easy to use free and open-source tool for 3D visualization of LPC data along a vector line network and for computation of related lidar metrics. CorVis makes the valuable attribute data of LPCs easily accessible for research applications such as characterizing riparian zone or migration corridor vegetation structure, as well as the study of related built environment, and generating related statistics that can be employed in cartographic representation.

The CorVis tool extracts LPC information in a way that makes mapping and analysis easier and reproduceable. The open-source tool provides new ways to analyze and measure corridors vital to ecosystem health and environmental resilience and to identify relevant patterns, vulnerabilities, and change. Spatial analysis and 3-D mapping along linear paths are required in many circumstances, such as stream or riparian zone studies, transportation network planning, and powerline maintenance and monitoring. Understanding of these environments requires information about above ground built and natural structures (Vogt et al., 2007). LPC distribution and attributes, such as density and intensity, hold detailed and pertinent information related to vegetation structure, land surface type, and the built environment (figure 1).

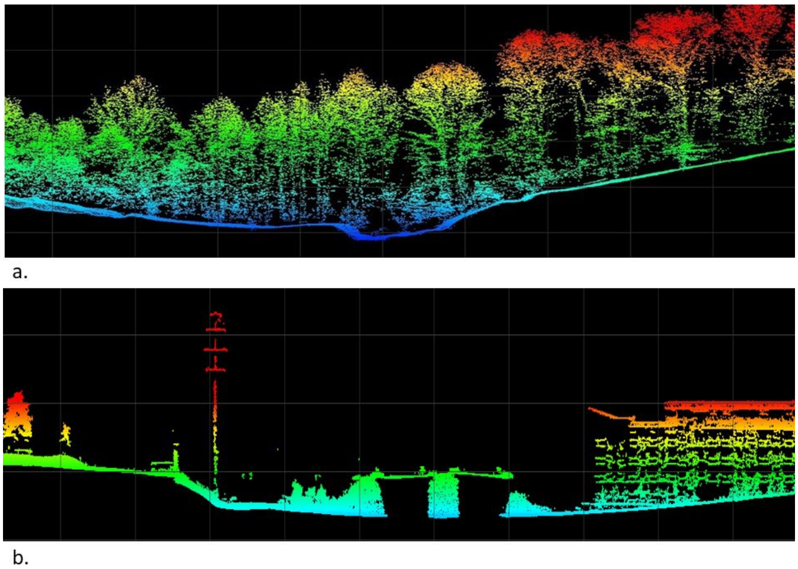

Figure 1: LPC cross-sections with elevation attribute color-coding of a) a stream corridor and b) adjacent road and powerline corridors. Existing tools allow for simple cross-sectional views of LPC, but no tools are available for 3D traversal or the generation of concurrent attribute statistics.

The CorVis tool allows a user to tailor 3-D traversal of any vector line network through an LPC. CorVis also generates corridor statistics to facilitate quantitative analysis and characterization. The statistics include point density, intensity, and return-count distribution within a given 3-D range determined by xyz parameters as well as LPC aggregation spacing for building a voxel grid. Potential research applications include identifying clusters and vertical ranges unique to riparian species and detecting changes along a stream corridor over time. Such outputs are suitable to traditional regression and other machine learning computations, but also deep learning algorithms where linear, or series data analysis is a growing field of study, with algorithms originally designed for language and text processing inspiring new research and processes (Kratzert et al., 2018). LPC attribute statistics are recognized as important metrics for forest canopy structure as well as delineating the built environment (Hartling et al., 2021). Examples of corridors that can be explored and mapped using CorVis include: migration routes, streams, shorelines, roads, railroads, powerlines, administrative boundaries, firebreaks, faults, and geologic contacts.

To the best of the authors' knowledge, there is no other tool that automatically generates LPC statistics and visualizes properties along linear segments and corridors. Existing strategies for LPC analysis require multiple tools and time-intensive data formatting. The tool presented here was developed as open-source software with the potential of linked access to USGS web-hosted LPC data. The USGS 3-D Elevation Program (3DEP) is collecting high-resolution LPC data for the conterminous United States and making the data publicly available (Arundel et al., 2018; Stoker and Miller, 2022). The 3DEP lidar-derived DEMs are arguably the most widely used derivative of 3DEP lidar data because of existing workflows and GIS tools. Yet, LPCs are a rich source of information that is not generally easy to see or use. CorVis makes exploration and incorporation of 3DEP LPC data accessible to individuals inside and outside of the remote sensing discipline, with no special experience needed.

Method

The CorVis tool uses a given set of vector lines, in common data formats such as ESRI shape file and GeoJSON, to generate a 3D corridor grid in the LPC with options to choose corridor width and height. The 3D grid spacing is user defined to allow for a range of applications and densities of output statistics. Grid spacing can be tuned and lidar points filtered to optimize attribute visualization in the user interface. Linear reference points are then generated for the feature giving geographic coordinates and distance along the line of unit length segments, such as centring measurements every 10 m along the vector line. With the reference line segment coordinates, CorVis aligns a perpendicular voxel grid and aggregates the LPC attributes for visualization and reporting in text format and plots. Open-source tools employed in the development of CorVis include Open3D, three.js, Geospatial Data Abstraction Library (GDAL), and Point Data Abstraction Library (PDAL).

CorVis reads LPC las files and indexes the data in k-dimensional (k-d) tree or octree format for efficient access and visualization of the data. Limitations related to random access memory (RAM) and requirements for caching have not yet been determined and are subjects of ongoing research. Substantial development effort has been devoted to researching existing tools and algorithms for efficient handling and visualization of the large LPC datasets. One option for handling LPC data is Entwine Point Tile (EPT) format, which is a flexible octree-based format (https://entwine.io/entwine-point-tile.html).

Discussion

The CorVIS tool is developed as an open-source tool with the source code to be released from the USGS-approved git repository. Future research and development needs include developing built in connections to USGS 3DEP data and web services using Jupyter notebooks. CorVis could also be adapted into a Jupyter Notebook application, supporting easy access and documentation as well as future development of increased functionality and links to other applications. Other potential work includes adding functions to enable cluster analysis and 3-D mesh surfaces of LPC to enhance visualization.

Disclaimer:

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