

Utilizing LiDAR and Multispectral Imagery for a Comprehensive Tree Risk Assessment in Transmission Corridors

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Introduction

- Overhead power lines are a common sight in our communities yet have the tendency to be overlooked in our urban landscape. Recognized or not, tree line contact (TLC) with power lines caused the Northeast Blackout of 2003 (NERC 2004) and some of the worst wildfires in Southern California history. With power lines spanning more than 5 million miles in the U.S. and traversing difficult terrain, it's imperative to accurately inspect an electrical right-of-way (ROW) for the minimum vegetation clearance distance (MVCD). In recent years, utility providers have been experimenting with unmanned aerial vehicles (UAVs) to collect LiDAR (Light detection and ranging) and NDVI (normalized difference vegetation index) data for ROW inspections. However, software can be expensive and may require outsourcing data to a third party unfamiliar with utility standards.
- To ensure the effective utilization of aerial data and inspection of the ROW, an open-source and comprehensive workflow was developed that accounts for tree health, distance to power lines and tree crew operations in the field. The analytical pipeline sets up the user interface to process the data and allows for editing the source code and provides a report for tree crews to efficiently resolve tree risks along the ROW.

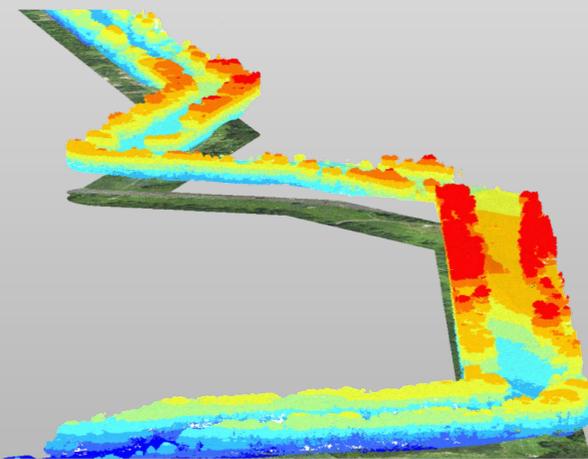


Figure 1. LiDAR point cloud of a transmission ROW and multispectral imagery below

Data and Data Sources

- Data for this project was released by approval of the utility provider and my technical applications department on the condition of keeping certain information confidential and for exploration of this thesis. Aerial data consisted of LiDAR and multispectral imagery acquired by UAV flights along a transmission ROW. LiDAR processing was completed using the LAsTools suite, while final analysis to generate the tree risk report was done in QGIS. All software is open-source and free to download.

Dataset	Details	Source
LiDAR	LAS format	Electric utility provider
Multispectral Imagery	ECW format, 4-inch resolution	Electric utility provider

Methodology

- LiDAR processing began by establishing ground points which set base heights for trees, power lines and subsequent features in the point cloud. The LAsheight tool was used to filter for power line and tree classifications. LAS2shp tool exported power line points as a shapefile, while LASboundary exported tree canopies as polygons for QGIS compatibility.
- The Python script interprets tree health by applying the NDVI formula $(NIR - R) / (NIR + R)$ to all multispectral images in QGIS, and styles the results using the coded symbology. Because imagery was in .ecw format, it was important to design the script to locate and reference the red and near-infrared bands for the NDVI formula.
- The Fixed Distance Buffer in QGIS was used to create the 30-foot MVCD around the power lines. Also in QGIS, the Intersect tool clips sections of the tree canopy that encroach the 30-foot buffer, that when combined with the NDVI metric, permitted final analysis of identifying risk trees along the ROW. Lastly, the Add Raster Values to Feature tool inputs NDVI metrics in the attribute table of the canopy intersection which can then be exported and shared.

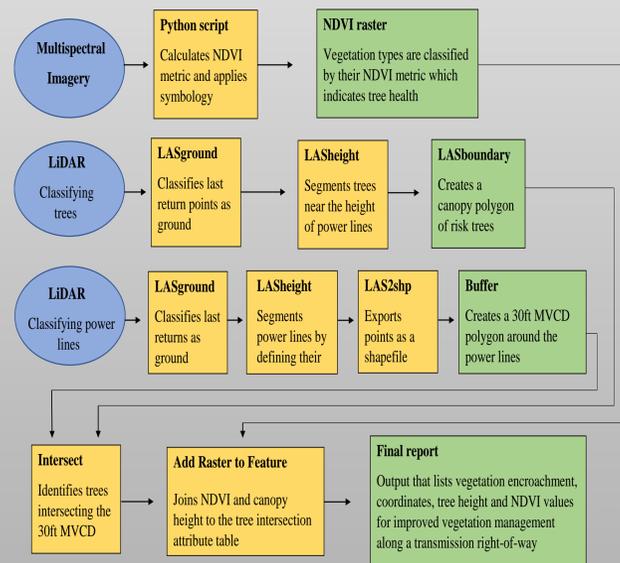


Figure 2. Graphical workflow

Timeline

Task	April				May				June				July			
	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4
Power line segmentation	█	█	█	█												
Tree canopy segmentation			█	█												
Python script					█	█	█	█								
QGIS analysis									█	█	█	█				
Tree risk report															█	█

Results

- The results from the Python script took four weeks to develop, but expedited an otherwise time-consuming task, and clearly represents overall tree health. Reviewing the NDVI raster in QGIS (Figure 3A), the discrimination of trees from grasses and shrubs were produced by the symbology section in the Python script. Because the NDVI raster successfully identifies trees with varying health and categorizes lower vegetation (i.e. shrubs and grasses) as separate classifications, ground crews will be able to accurately locate trees with compromised health and prescribe appropriate work orders. Referencing the true-color multispectral imagery, one tree showing a concerning NDVI metric was confirmed and identified by the Python scrip (Figure 3).

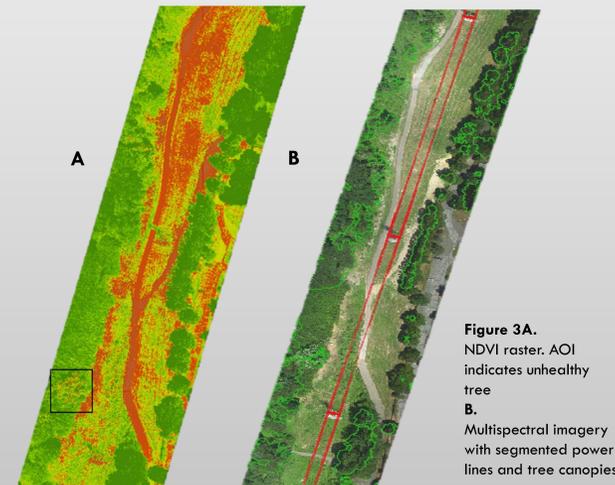


Figure 3A. NDVI raster. AOI indicates unhealthy tree
B. Multispectral imagery with segmented power lines and tree canopies

- Tree and power line segmentation from the LiDAR point cloud was overall successful and fulfilled its purpose as inputs in the Intersection tool for identifying tree encroachments. Despite remnants of tree canopies in the power line segmented file, and vice versa, these anomalies were easily removed in QGIS. After applying the Intersect tool in QGIS, the Add Raster to Feature tool successfully generated a comprehensive report consisting of tree health, location and height.

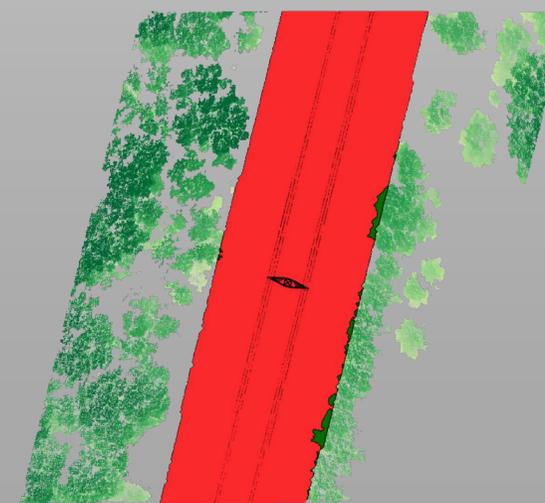


Figure 4. Tree height DEM with 30ft buffer (red) and tree intersections (green)

1	min_x	min_y	NDVI_1	Canopymax
2	883716.69	628687.31	0.72	54.73
3	883716.69	628687.31	0.71	63.17
4	883716.69	628687.31	0.63	44.68
5	883716.69	628687.31	0.66	51.25
6	883716.69	628687.31	0.69	49.41
7	883716.69	628687.31	0.56	57.95
8	883716.69	628687.31	0.72	44.99
9	883716.69	628687.31	0.66	53.26

Figure 5. Excerpt of the tree final report in Excel

Discussion

The results have real-world implications as they can increase the reliability of overhead electrical equipment and help to prevent tree related outages and wildfires. The open source nature of the workflow partners well with the utility industry as regulations tend to change frequently to accommodate updates in high-fire areas and sensitive habitat expansion. By significantly decreasing the time it takes to complete the inspection, the workflow eliminates subjective decisions and reduces human error caused by exhaustion throughout a day's work in the field while completing an assessment of a transmission ROW in less time and with better success than humanly possible. A limitation of using open-source software as the preferred method was the current limitation of 3D processing in QGIS. The most recent version of QGIS (3.2.1) introduces some basic 3D viewing capabilities, but to date does not offer 3D analysis. Also, QGIS 3.2.1 did not allow integration of LAsTools and had the tendency to crash when viewing large LAS datasets.

Conclusion

Because similar proprietary software can be costly and with lessening FAA restrictions on UAVs for utility inspections, this project may motivate utility providers to have LiDAR equipped UAVs on standby at each substation and utility contractors to have as an asset to leverage in the field (Reid and Searels 2016). The next phase, and purpose of the project, is to incorporate the workflow into one inspection cycle of the circuit to test the functionality and results of the project. After calibrating the source code to reflect last year's tree inventory, the workflow will be field tested on next year's inspection cycle to study how effectively it improves the inspection process. Precise tree risk mitigation will save the utility provider maintenance costs and ensure the safety of the ROW and field crews, as concluded in the work of Manyame and Jackson (2017), combining LiDAR and NDVI metrics with GIS analysis significantly decreased field incidents and greatly improved the reliability of the transmission ROW.

Submitted in partial fulfillment of the requirements of the Masters of Science in Geographic Information Science (MSGISci), August 11, 2018.

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