SPR 866 – PROTOTYPING AUTOMATED FRAMEWORK FOR ASSET EXTRACTION AND CHARACTERIZATION FROM MOBILE LIDAR DATA

DRAFT RESEARCH NOTE

What need led to the research?

ODOT Geometronics operates a survey-grade mobile lidar system to regularly collect point cloud data on roadways statewide. Detailed point-cloud data are captured along with video enabling ODOT to not only see a video of the road similar to Google Street View but also obtain very precise measurements of surrounding features of interest. ODOT's investment in mobile lidar has provided a substantial return on investment. The lidar data supports a wide number of projects and applications, including asset management, sight distance evaluations, pavement and marking evaluations, landslide monitoring, and accident reconstruction. The entire state highway system is typically scanned on a two-year interval, but Geometronics also supports special-purpose projects with the mobile lidar as needed. For asset management and infrastructure monitoring, mobile lidar data provides rich information (e.g., position, orientation, geometry, condition, etc.) of road features, such as road surfaces, road markings, lamp poles, buildings, curbs, sidewalks, driveways, and so forth. While the data collection process is highly efficient and streamlined, manual extraction of features from the data to support ODOT's needs is generally time consuming, subjective, and error prone, especially when analysts lack proper training on the wide range of processing techniques and software.

Although some tools exist for semi-automated extraction of a specific feature (e.g., road markings) from lidar data and have been implemented on a project-by-project basis, they can sometimes require training. Depending on the features and data quality, the performance can rely on user input and fine-tuning. As a result, many tools are not feasible to apply to in statewide asset management programs and do not necessarily provide the desired attributes. Moreover, such tools are usually developed specifically for a certain object (or limited number of objects). Currently, there are no well-defined workflows for data processing and information extraction that can integrate multiple tools together. Simply stacking the tools in the workflow can result in a tremendous amount of duplicated effort and reduces its scalability. To be able to handle the statewide mobile lidar data ODOT collects efficiently, there is a need for a robust workflow with significant automation that can extract many types of features by effectively leveraging various feature extraction tools and algorithms to support applications. In particular, road characterization has been identified as a key application for information extraction from mobile lidar data.

What was done in this research?

This research followed the success from SPR850 which primarily focused on pedestrian crosswalks and bike lanes. The research team completed the following tasks:

1. *Processing Framework and Benchmark Data*

- A workflow was proposed to tackle automated extraction of various transportation assets (e.g., road, markings, curbs, streeside assets) from mobile lidar datasets.
- The benchmark datasets developed in SPR850 was further expanded to streetside assets with an extended classification scheme being established to overcome the limitations from the file formats in storing more complex classification labels.

2. *Ground Feature Extraction*

    - Extensive parameter analysis was conducted to evaluate the effectiveness of the proposed workflow (ground filtering, curb extraction, and road detection). The analysis also provides insights for future fine-tuning.
    - A user-friendly software prototype was designed and developed. It supports batch processing and partial fine-tuning to achieve better results without having to re-run the entire workflow.

3. *Road Characterization*

    - A mobile lidar trajectory-based method was developed to segment, identify, characterize, and visualize horizontal curves, vertical curves, and cross sections.
    - An ArcGIS toolbox including multiple tools was developed to implement the proposed methodology and stored the results in geodatabases.

4. *Streetside Asset Extraction*

    - A workflow was developed to leverage point cloud segmentation algorithms and machine learning models in streetside asset extraction from mobile lidar data.
    - An in-depth analysis of training dataset selection was conducted to evaluate the real-world feasibility of adopting a machine learning model in classifying mobile lidar data.

What were the main findings and recommendations?

This research focused on extracting pedestrian and bicycle infrastructure data from mobile lidar, specifically crosswalks, bike lanes, and medians. Several novel algorithms and tools were developed to automate this extraction process. Key findings and recommendations include:

- *Tool Development:*
    - A prototype software GUI for automatically extracting ground, curbs, road surface, and road markings from mobile lidar data.
    - An ArcGIS toolbox for efficiently identifying, analyzing, and visualizing horizontal curves, vertical curves, and cross sections.

- *Recommendations:*
    - Mobile lidar data can serve as a reliable source for asset management as it captures transportation assets in detail with very high accuracy and efficiency.
    - The mobile lidar data can be preemptively processed through the proposed framework with default settings to reduce duplication of processes and improve the efficiency of data management.
    - During the project, ODOT switched from the Leica mobile lidar system to a Riegl mobile lidar system which can achieve better data quality in terms of accuracy and resolution. The research team tested datasets from both systems and the proposed methodology was demonstrated to be effective. Some parameter fine-tuning may need to be done for different sensors.
    - While the data processing framework is mostly automatic, it still requires some manual work especially for QA/QC purposes.
    - Machine learning and deep learning approaches show some promise in classification and feature extraction. However, it can be significantly impacted by how the training datasets are established in terms of scene types, presence of objects, data structures, and so on.
    - It can be challenging for some deep learning algorithms to be directly adopted depending on their requirements of structuring the data in a certain way and completeness of labeling.
    - Sometimes data annotation can be subjective and ambiguous as the algorithms mostly assume one-to-one match between the data (e.g., data points, segments, objects) and classification labels.
    - Mobile lidar trajectory is demonstrated to be a reliable source for estimating horizontal and vertical road alignment. Road markings captured in the point cloud can help achieve the same goal, but it can struggle for areas where markings are absent or not accurately extracted.
    - For statewide asset management purposes, the use of GIS platforms with the tools developed by the research team is shown to be effective and efficient. The visualization of the results sometimes can be time-consuming and become a hurdle for batch processing. The research team made the visualization module optional and as a standalone tool to mitigate it.

These advancements provide Oregon DOT with more efficient tools for transportation asset management, leading to better decision-making, planning, and maintenance efforts to enhance safety and mobility. It is recommended that ODOT continue to build upon these tools to achieve even higher ROI with their mobile lidar system to support a wide range of applications.

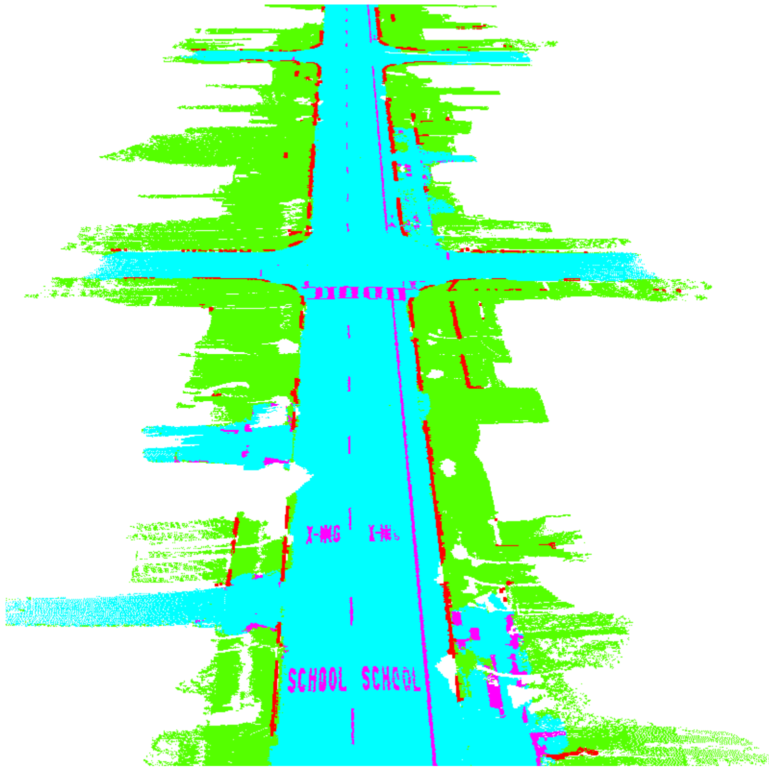

Figure 1. Example of road marking extraction where magenta points represent the road markings, blue represents the road surface, red indicates curbs, and green indicates general ground points

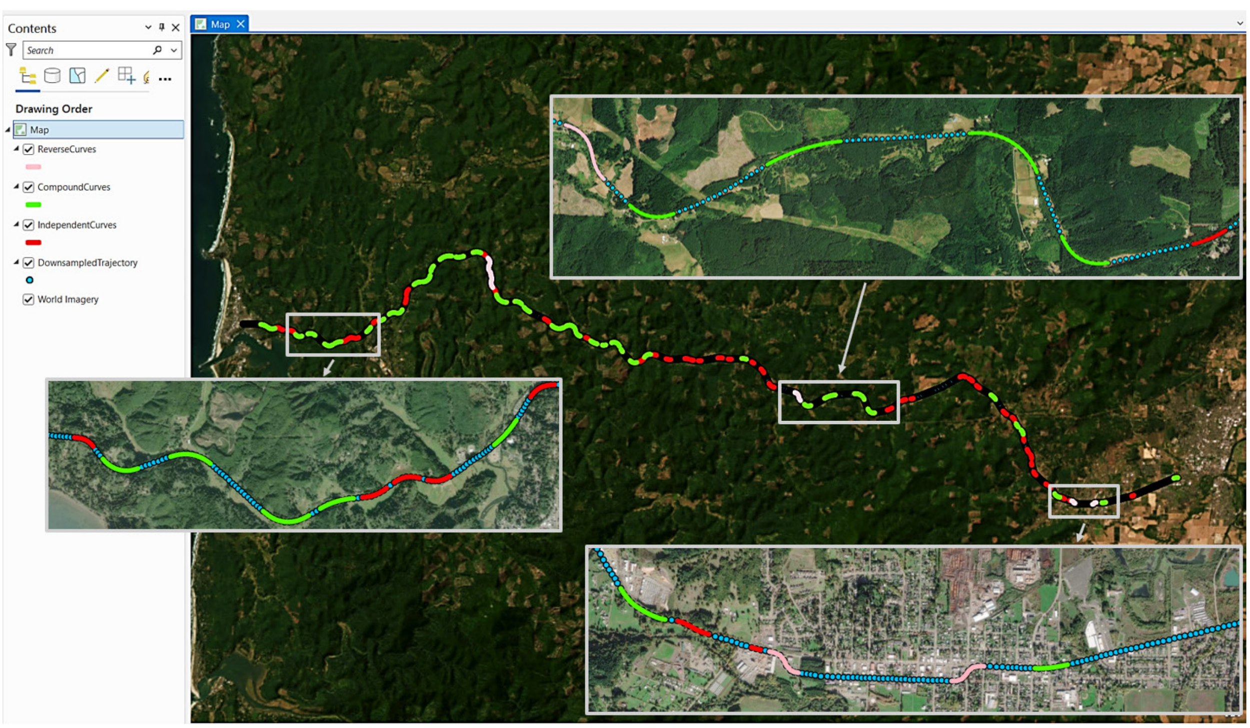

Figure 2: Example horizontal curve identification results.