Development and Validation of Methodology and Tool to Estimate Retroreflectivity of Pavement Markings Using LiDAR

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Research Needs

Pavement marking retroreflectivity plays a significant role in communicating drivers their location with respect to roadway lanes, particularly during low light and low visibility conditions. As such, retroreflectivity plays an important role in traffic operations and safety.

Moreover, a recent ruling from FHWA introduced a mandate for transportation agencies to maintain minimum levels of retroreflectivity on public roads, resulting in the need for agencies to measure and monitor pavement markings in order to maintain compliance with such requirements. Under this new ruling, agencies maintaining certain public roads, such as freeways, must establish a program to monitor and report retroreflectivity levels by September of 2026 (4 years after the ruling issuance date).

Typically, retroreflectivity of pavement markings is measured using retroreflectometers operated manually or mounted on mobile devices. However, even though mobile setups allow for the collection of measurements at driving speeds, they require special equipment and represent significant costs. Therefore, improvements leading to retroreflectivity estimates without

extensive data collection needs could represent a significant reduction in related costs and data processing.

The proposed project targets an opportunity to achieve such benefits, by repurposing LiDAR datasets the agency already collects periodically, and postprocessing them to extract retroreflectivity estimates intended to supplement and eventually replace field measurements using reflectometers.

Research Objectives

The main objective is to develop and validate a methodology and a tool to estimate retroreflectivity of longitudinal pavement markings using LiDAR datasets, as follows:

1) Develop a process (i.e., a method implemented by a tool) suitable to monitor pavement retroreflectivity using LiDAR data periodically collected by the agency. Such a process is expected to improve efficiencies by reducing the need to collect specific data with pavement marking retroreflectivity, and to provide a significant advancement in the agency plans to set a program to monitor retroreflectivity, as recently mandated by new FHWA standards due for implementation by 2026.

2) Develop a computer tool implementing the proposed methodology from the previous objective, such that data ingestion, processing, and outputs are largely automated.

3) Given a set of inputs, the tool will produce estimates of retroreflectivity levels and an assessment of their compliance with the minimum values required per the FHWA ruling.

Research Methods

This project intends to repurpose LiDAR datasets that UDOT collects periodically, and postprocess them to extract retroreflectivity estimates intended to supplement and eventually replace field measurements using reflectometers. Thus, existing datasets LiDAR surveys and retroreflectivity measurements will be used to:

- Develop models based on traditional statistics to establish an initial set of relationships that can serve as a basis to more advanced methods.

- Identify and develop advanced models using machine learning techniques to enhance the ability for the models to capture expected retroreflectivity levels and their variation more accurately.

- Use of computer tools to develop an executable application to ingest and process LiDAR data to produce estimates of pavement marking retroreflectivity.

Relevance to Strategic Goals

The objectives proposed in this project are directed and strongly linked towards improvements in **safety**, as the primary USDOT strategic goal. Likewise, the project directly impacts practices leading to effective utilization of resources, enhancing an agency's ability to preserve the existing transportation system.

Educational Benefits

Under the supervision of the PI, one graduate student is directly involved with every single aspect within the proposed research. This includes the data preparation, design of the methodology, data analysis, and development of a computer tool to implement the methodology and obtain reportable outcomes on retroreflectivity of pavement markings using LiDAR datasets.

Outputs through Technology Transfer

Outcomes form this project are expected to have multiple avenues for technology transfer activities, including a seminar and presentations to researchers and practitioners, as well as serving as a significant step towards further development into policies related to estimating retroreflectivity of pavement markings. Such policies, in turn, are expected to lead to a sustainable program for maintenance of such pavement treatments, and ultimately to improve safety.

In terms of the proposed seminar and presentations, among a number of alternatives, the PI is expected to accomplish the following:

- Seminar as part of UDOT's Continuing Education program using a hybrid format with participants joining in person and online. Such seminars are widely attended by practitioners from the agency as well as consultants in the area, both within the state and regionally.

- Conference presentation to disseminate the outcomes of the project, with a main target being TRB's Annual Meeting. Likewise, technical committee presentations are an open avenue for such presentations with multiple committees as potential target in the project's topic.

In addition, enhancements to the tool as part of the proposed project will allow the team to disseminate the computer tool through avenues discussed in coordination with UDOT. Thus, the outcomes of the project will have further potential to reach practitioners and researchers through a source code and/or the executable application tool directly available through a website maintained by the PI or through a site provide by UDOT. A document accompanying the computer tool will be developed to illustrate the uses of the tool and sample reports of retroreflectivity assessments that could be used to support federal reporting.

Lastly, the findings from this research are expected to serve as the basis for further development of a comprehensive plan to maintain and report retroreflectivity pavement markings at the state level. Such maintenance plan is needed not only to meet new federal requirements, but also to improve efficiencies and ultimately safety.

Expected Outcomes and Impacts

This research is expected to provide with the following research outcomes:

- A new methodology to assess levels of pavement marking retroreflectivity using LiDAR datasets.

- A determination of the retroreflectivity levels assessed through the methodology, regarding their compliance with the minimum values specified by the new FHWA ruling and a confidence level on this determination.

- A computer tool to be used by the Utah Department of Transportation (and possibly others) to input LiDAR data, process the data through the proposed methodology, and to determine the estimated retroreflectivity compliance with FHWA ruling.

Altogether, this research is expected to produce a significant stepping stone conducive to establishing a long-term plan to assess and report levels of retroreflectivity pavement markings in light of the new FHWA ruling on minimum levels to be maintained on certain public roads.

Work Plan

The following are the proposed set of major tasks to accomplish the project objectives. It is noted that the listed tasks are often concurrent, so there may be overlap between them.

Part 1: Feasibility Assessment

1) Postprocessing of existing LiDAR surveys and field retroreflectivity datasets. Processing raw LiDAR and retroreflectivity data to be prepared for analysis. *(Estimated completion date: 3 months after start date)*

2) Model exploration, including machine learning approaches. Processing raw LiDAR and reflectivity data to be prepared for analysis. We need to investigate different modeling techniques, such as various machine learning algorithms, to analyze datasets most efficiently. *(Estimated completion date: 5 months after start date)*

3) Initial methodology incorporating data processing and modeling. The collection of processed data and the creation of an efficient model will allow an initial assessment of retroreflectivity to be made. *(Estimated completion date: 6 months after start date)*

4) Mid-project report, including initial assessments and presentation to technical advisory committee. Preparing the interim report to represent initial results and methodology to advisors and stakeholders of the project for receiving feedback. *(Estimated completion date: 7 months after start date)*

Part 2: Development and Validation of Methodology

1) Automation of scalable data processing. Making the data processing automated and scalable for larger datasets. *(Estimated completion date: 10 months after start date)*

2) Refinements to a methodology for large-scale data. Enhancing the methodology for dealing with large datasets. *(Estimated completion date: 11 months after start date)*

3) Model validation for different lane types and conditions. The model's performance is tested under different types and conditions of lanes. *(Estimated completion date: 11 months after start date)*

4) Development of a tool implementing the proposed methodology. Designing a tool that can be used to implement the methodology. *(Estimated completion date: 12 months after start date)*

5) Final report and presentation to technical advisory committee. Preparing the final report based on the method, tool, and the generated results. *(Estimated completion date: 12 months after start date)*

Part 3: Enhancements to Computer Tool, Dissemination Materials, and Tech Transfer

1) Development of practical examples and documentation to use the computer tool developed as part of the project, and generate reports to support maintenance decisions and federal reporting. *(Estimated completion date: 10 months after start date)*

2) Calibration and validation of additional datasets for an enhanced set of conditions where retroreflectivity can be obtained. Examples of these conditions include lower-volume segments and different in-service time elapsed since the last treatments. *(Estimated completion date: 10 months after start date)*

3) Preparation and delivery of seminars and presentations with researchers and practitioners as primary audience, as described in the tech transfer plan.

Project Cost

Total Project Costs: $105,000
CTIPS Funds Requested: $ 50,000
Matching Funds: $ 55,000
Source of Matching Funds: Utah Department of Transportation