A Comparative Analysis of the Effects of Work Zone Lane Marking Materials and Marker-Painting Methods on LiDAR Point Cloud Measurements

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Poster No. 12428

Abstract

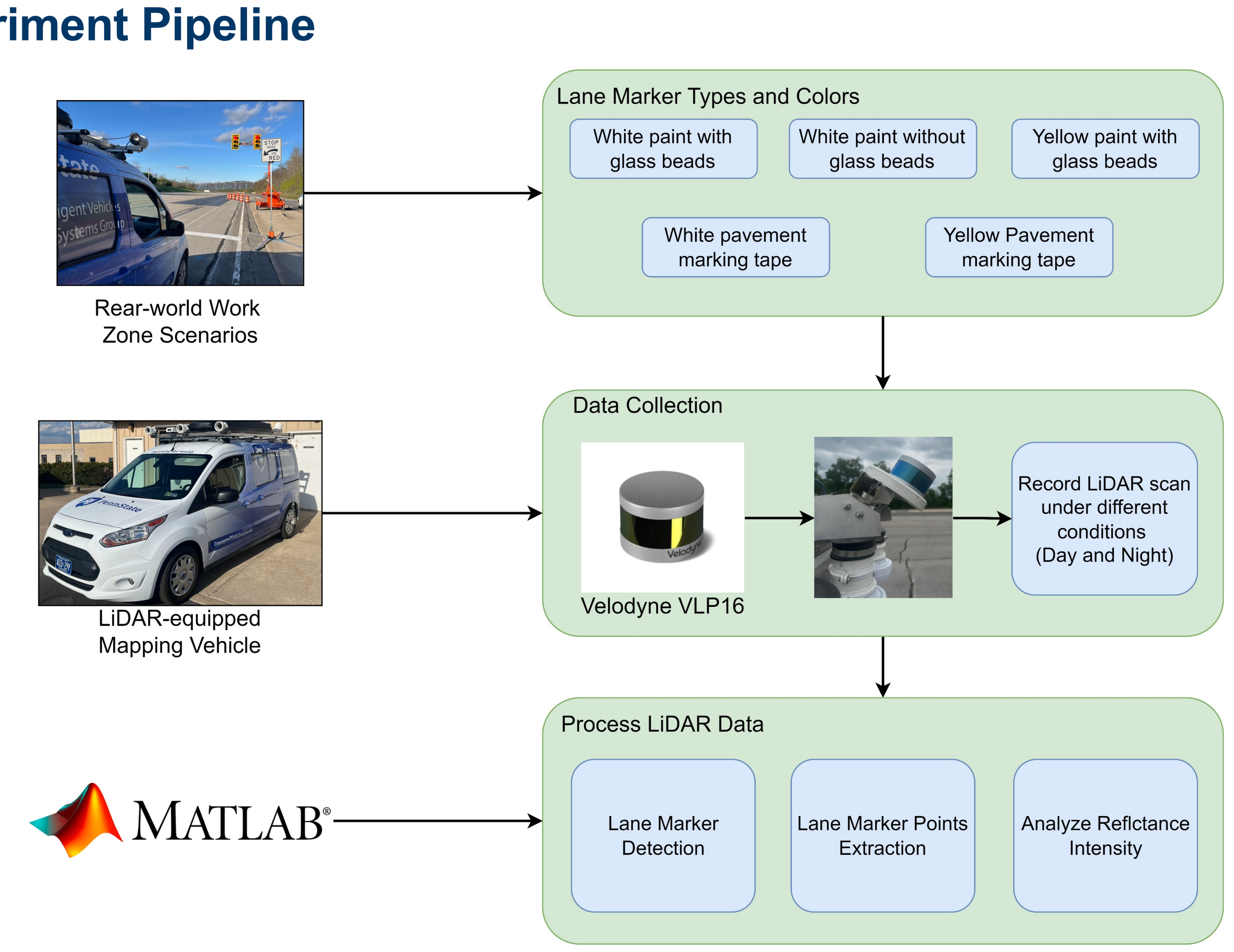
Autonomous vehicles (AVs) heavily rely on accurate perception of their surroundings for safe navigation as well as accurate maps of their environments. As a key AV and mapping sensor, LiDAR (Light Detection and Ranging) offers precise detection and ranging capabilities crucial for detecting lane boundaries and other road markings. Unlike many other sensors, LiDAR exhibits robust performance across a wide range of illumination situations (day and night, low visibility, etc.) ensuring consistent and reliable behavior. Lane markings, essential for navigation, vary considerably in their material composition, sensitivity to weather, and surface characteristics, thereby influencing LiDAR performance. This work is motivated by an ongoing project to assess AVs and high-definition mapping of work zones. Work zone marking variations can be particularly extreme due to the common mixture of paint types (with and without glass beads incorporated into the paint), lane tapes and tape types (tape colors), and marking cover-up methods; these variations are often all used simultaneously. As part of this project, the team conducted a comparative analysis of LiDAR performance with respect to these variations.

Introduction

- Accurate perception of lane markings is crucial for the safe navigation of autonomous vehicles (AVs). As AVs rely heavily on LiDAR for mapping and environment detection, understanding how different lane marking materials impact LiDAR performance is vital.
- LiDAR provides precise detection and ranging capabilities, crucial for detecting lane boundaries and other road markings for AVs. It performs reliably across various illumination conditions (day/night, low visibility).
- Work zone markings often include a mix of lane marking types, their material composition, color, and surface characteristics can significantly influence LiDAR detection performance.
- This research compares the performance of paint with glass beads, paint without glass beads, and pavement marking tape in both white and yellow colors under day and night conditions.

Methodology

Experiment Pipeline



Methodology

Lane Marker Types and Test Cases

To comprehensively evaluate the effects of different lane markers on LiDAR point cloud measurements, data collection was systematically conducted under controlled conditions, including on both day and night scenarios.

Test Case	Lane Marker Type	Color	Day	Night
1	Paint with Glass Beads	White	✔	✔
2	Paint with Glass Beads	Yellow	✔	✔
3	Paint without Glass Beads	White	✔	✔
5	Pavement Marking Tape	White	✔	✔
6	Pavement Marking Tape	Yellow	✔	✔

Evaluation Metrics

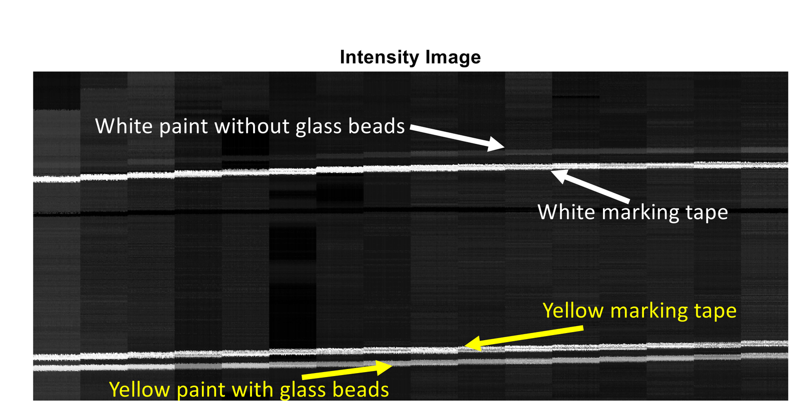
- **Reflectance Intensity:** Measures the amount of light reflected by the lane marking material back to the LiDAR sensor.
- **Point Cloud Density:** Number of LiDAR points per unit area on lane marker.
- **Consistency Under Different Lighting Conditions:** The stability of reflectance intensity and point cloud density across different lighting conditions (day and night).

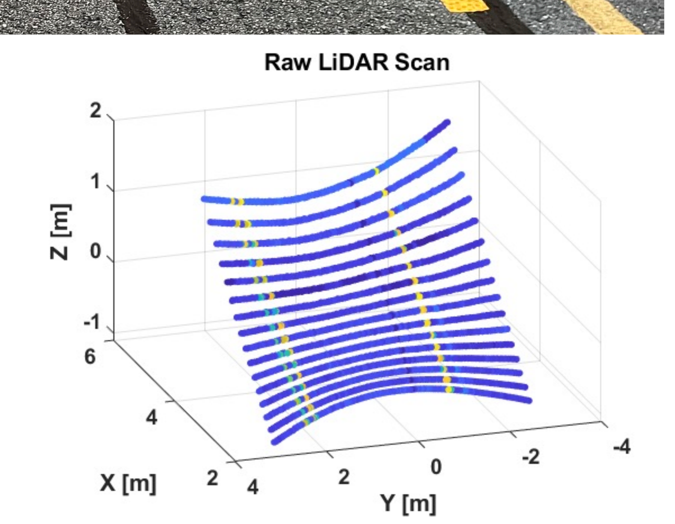
Experiments and Results

Scenario Setup and Data Collection

- The paint lane markers were painted by the PennDOT paint truck in August 2023.
- Pavement marking tapes were taped side by side with the existing lane markers to provide a comprehensive comparison.
- For each test case, the vehicle was parked at a fixed position along the roadway.
- Data collection was conducted under controlled weather conditions to minimize external environmental factors such as rain or fog that could affect LiDAR performance.
- The LiDAR sensors continuously recorded point cloud data, capturing detailed measurements of the lane markings and their surroundings.
- Data recording was conducted for a specified duration to ensure sufficient data was collected for analysis.
- The collected LiDAR data was securely stored and cataloged for each test scenario, with separate datasets for day and night conditions.

Work zone lane marker layout example

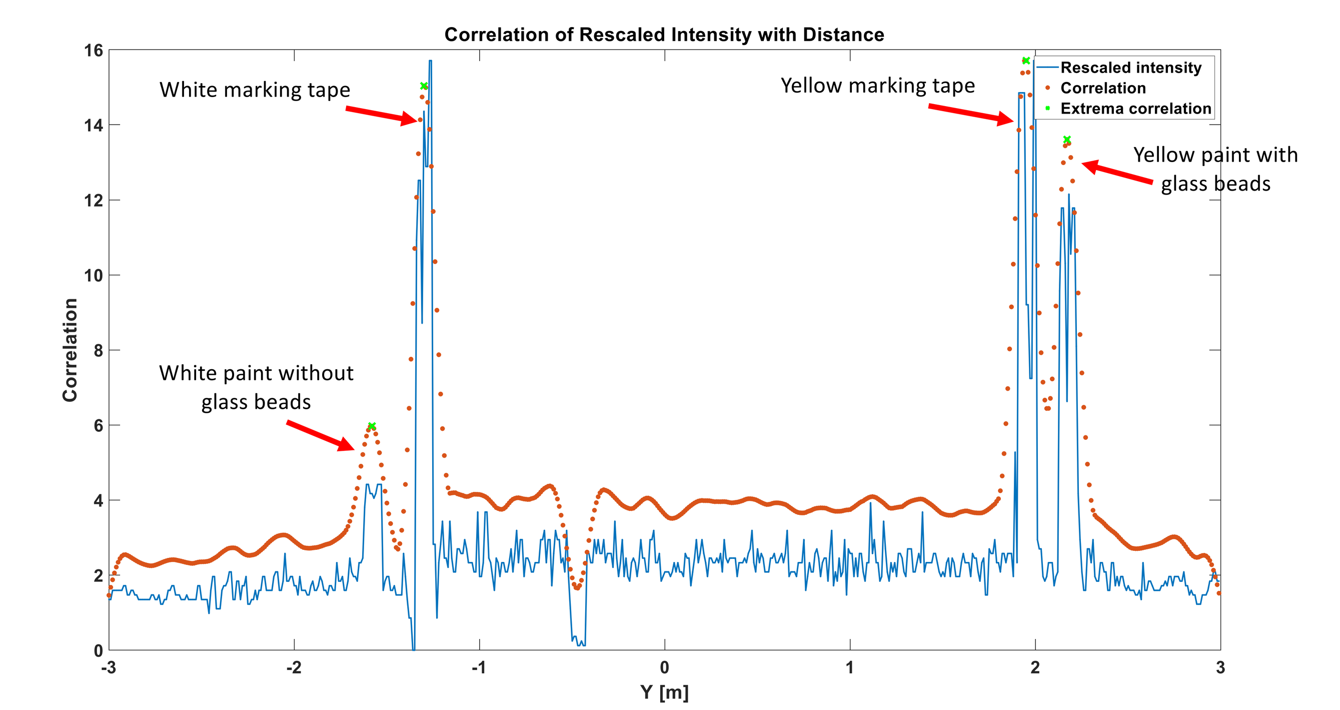




Experiments and Results

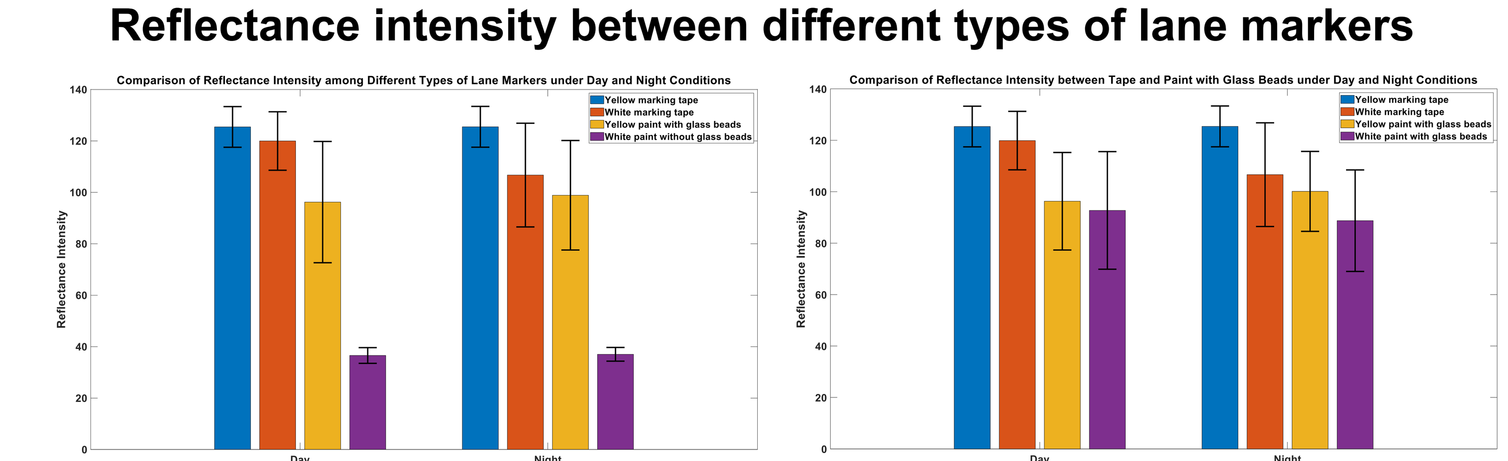
Data Process

- Trim the data to only include points within a specified XYZ-coordinate range in the LiDAR coordinate system to reduce data volume.
- Interpolate data points using a specified Y array as query points to create a smooth representation of the lane markings.
- Calculate the intensity correlation and find the extrema for all scans with corresponding correlation values.

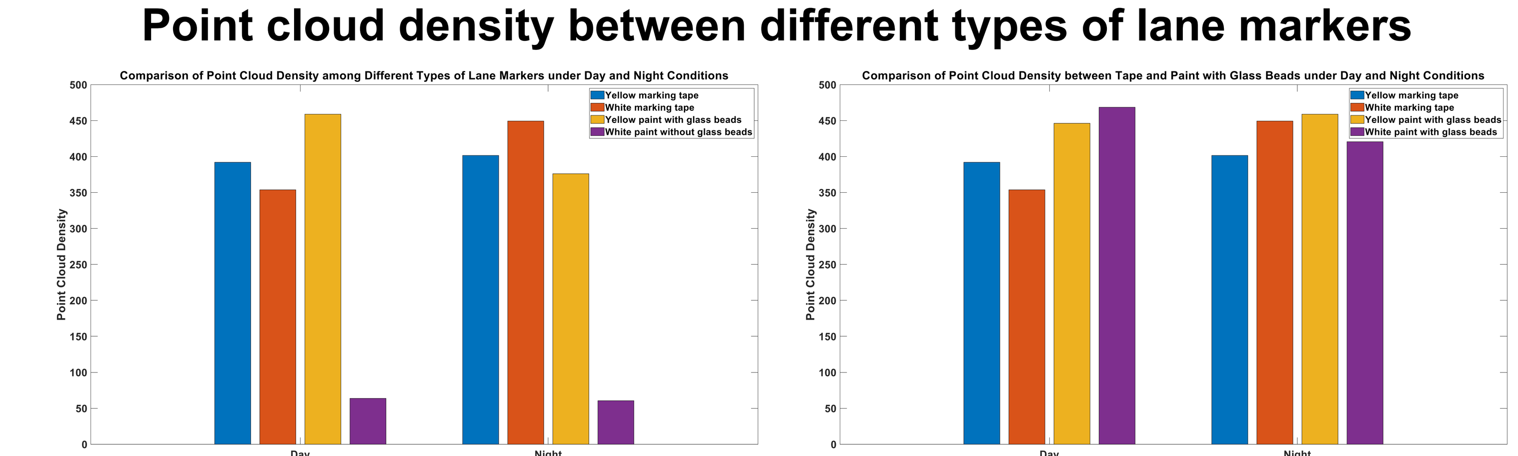


Experiment Results

Reflectance intensity between different types of lane markers



Point cloud density between different types of lane markers



Conclusions

- This poster provides valuable insights into the performance of different types of lane markers under various conditions, clear differences were observed in LiDAR performance based on lane marker types used in the work zones.
- There was not significant decrease in reflectance intensity at night, which indicates LiDAR's reliably across various illumination conditions.
- The findings highlight the importance of choosing appropriate types of lane markers to enhance LiDAR detection and ensure safe and reliable AV navigation in work zones.