Accelerated Sign Inventory and Management

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Acknowledgement

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• Georgia Department of Transportation
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Outline

• Research need
• Introduction to sensing system
• An enhanced sign inventory procedure
• Case study on I-285
• A prototype of GIS-based sign management system
• Preliminary study of sign retroreflectivity condition assessment using mobile LiDAR
Research Need
Research Need (1)

• FHWA requires all agencies having jurisdiction over a road to establish and implement a sign assessment or management method to maintain minimum levels of sign retroreflectivity.

• A comprehensive sign inventory and management system is indispensable to support the implementation of a selected plan.
Research Need (2)

• For state DOTs, the number of signs on interstates, state routes, and secondary state routes is large. The manual survey effort is overwhelming.
  – In GDOT, an estimate of more than 3 million traffic signs are to be inventoried.
  – A study by LaDOTD indicates a rate of 43 min/sign (2,601 hours spent for 3,646 signs during the entire pilot project).

Reference: Wolshon, B. Louisiana Traffic Sign Inventory and Management System, Louisiana Department of Transportation and Development
Research Need (3)

• Excessive time of exposure to open traffic increases the safety concern of the data collectors
  – High vehicle speed, limited lateral traffic sign offsets, etc. increase the risk of data collection in field
  – Overhead signs with less accessibility for the data collectors brings in additional problem
    • Temporary traffic control might be needed
    • Data collection rate might be greatly reduced
Research Need (4)

- Video logging provides a safe and effective means to retrieve roadway data including traffic signs. However, it can be labor-intensive, time-consuming and costly conducted by manual data review image-by-image, especially for agencies maintaining large roadway networks.
  - There are 18,000 centerline-mile state-maintained highways in Georgia; there would be 14.26 million images if three images (left, right and center view) are captured every 20 ft.
Research Objective

• Develop and validate methodology to improve efficiency of sign inventory
  – Use mobile LiDAR to automatically detect signs
  – Use video log images to automatically detect and recognize signs
  – Perform QA/QC and visual condition assessment

• Use GIS platform to manage signs
GDOT’s Inventory on New Signs

• GPS-enabled PDA
• Barcode Scanner
• Digital camera
GDOT’s Current Practice on Sign Maintenance

• Annual process
  – Daytime drive-through visual inspection
  – Nighttime drive-through visual inspection
  – Inspection results are recorded in Maintenance Management System
  – Plan the outstanding work (washing, repair and replacement)
Ongoing Research Project

• To collect signs on all interstate highways (2,500 centerline miles)
  – GPS location
  – Linear reference system (RCLINK and milepoint)
  – Sign type
  – MUTCD code
  – Sign condition (post failure, dirty, obstruction, and surface failure)

• To validate the enhanced sign inventory procedure using digital images and mobile LiDAR
Introduction to Sensing System
Georgia Tech Sensing Vehicle
3D Line Laser Imaging

Transverse direction: 1 mm

Elevation: 0.5 mm

Data points collected per second and width covered:

\[
2 \text{(lasers)} \times 2048 \text{(points/profile/laser)} \times 5600 \text{ HZ} = 22,937,600 \text{ points}
\]

\[
2 \text{(lasers)} \times 2048 \text{(points/profile/laser)} \times 1 \text{(mm)} = 4.096 \text{ m}
\]
Mobile LiDAR and Digital Camera

High-resolution Light Detection And Ranging (LiDAR)
Enhanced Sign Inventory Procedure using Video Log Images and Mobile LiDAR
Sign Inventory Procedures

1. Visually review all images and manually enter all sign data
   - Sensing Technology
     - All Detected? [No, Yes]
     - Reduced Video Log Images
       - Image Processing for Sign Recognition
         - All Recognized? [No, Yes]
         - Manual Detect and Recognition with Reduced Data Input
           - Condition Assessment Using Mobile LiDAR
             - All Accessed? [No, Yes]
             - Manual Condition Assessment with Reduced Data Input

2. Sign Locations, Attributes, and Conditions

3. Mobile LiDAR and Image Processing for Sign Detection

Sign Detection

Sign Recognition

Condition Assessment
Sign Detection and Recognition

Color Segmentation

Shape Detection

Pattern Matching
Use LiDAR Data for Sign Detection
Preliminary Assessment of Enhanced Sign Inventory Procedure (1)

- To quantify the benefit of the proposed enhanced procedure compared to the traditional manual method
- The benefit was measured by the average processing time for each traffic sign in the test section
Preliminary Assessment of Enhanced Sign Inventory Procedure (2)

- The test section was selected on I-95 south bound between MP 100 and MP 105 containing 47 traffic signs with different shapes, colors, and conditions
- An additional survey using the manual process (PDA) was conducted by GDOT to collect about 100 traffic signs on different roadways (interstate and state route)
## Preliminary Assessment of Enhanced Sign Inventory Procedure (3)

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<td>74</td>
<td>244</td>
<td>288</td>
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Experimental Study

Interstate highway (I-95)
17.5 miles
127+2 signs

State route 67
6.9 miles
41+9 signs

State route 275
5.2 miles
43+6 signs

Interstate highway (I-95)
17.5 miles
127+2 signs
## Experimental Study (cont’d)

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<td>R2-6</td>
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<tr>
<td>E1-1</td>
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<td>9.2%</td>
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<tr>
<td>W8-13</td>
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<td>7.7%</td>
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<td>R2-1</td>
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<td>W20-1</td>
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<tr>
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<td>W4-1</td>
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<td>D3-2</td>
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<td>R8-3a</td>
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<tr>
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<td>6.3%</td>
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<td>M1-5</td>
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<td>4.2%</td>
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<tr>
<td>M3-1</td>
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<td>4.2%</td>
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<tr>
<td>W16-8a</td>
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<td>4.2%</td>
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<td>W2-2(l)</td>
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<td>W16-8</td>
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<td>M1-5</td>
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<td>W1-4(l)</td>
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<td>W1-4(R)</td>
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## Testing Results

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<tr>
<th></th>
<th>I-95</th>
<th>SR-275</th>
<th>SR-67</th>
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<tr>
<td>Distance</td>
<td>17.5 miles</td>
<td>5.2 miles</td>
<td>6.9 miles</td>
</tr>
<tr>
<td># of Signs</td>
<td>129</td>
<td>49</td>
<td>50</td>
</tr>
<tr>
<td>FN</td>
<td>14</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>FP</td>
<td>6</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Detection Rate</td>
<td>90.6%</td>
<td>81.6%</td>
<td>80%</td>
</tr>
</tbody>
</table>
Case Study on Interstate 285
Large-scale Test on I-285

128 survey miles (two-way); more than 40,000 images captured
Sign Condition Categories

Post Failure  Dirty  Obstructed

Surface Failure

Note: Based on GDOT’s Foreman’s Manual 2008
Distribution of Sign Categories

Total Signs: 2,969
Distribution of Overhead Signs

Signs with high potential risk to road users

Total Overhead Signs: 643
Example Overhead Sign
Distribution of Signs in Poor Conditions

Total Damaged Signs: 252
Example Damaged Signs (1) - Truck Gust
Example Damaged Signs (2) - Dual-Post
Example Damaged Signs (3) - Post Failure
A Prototype GIS-based Sign Management
GIS-based Sign Data Query
Individual Sign Information
Summary of Sign Information

![Sign Management Tool](image)

**Overall Statistics**

- Total Number of Signs: 2939
- Total Number of Dirty Signs: 12
- Total Number of Post Failure: 71
- Total Number of Obstructed: 21
- Total Number of Cantilever Signs: 82
- Total Number of Sign-Bridge Signs: 325
- Total Number of Other Overhead Signs: 236

**Distribution of Overhead Signs**

- Cantilever (12.75 %)
- Sign-Bridge (50.54 %)
- Other Overhead (36.70 %)
Preliminary Study of Sign Retroreflectivity Condition Assessment using Mobile LiDAR
Research Need

• Current ASTM standard using a retroreflectometer is a manual method that is time-consuming, labor-intensive and costly.

• No mobile traffic sign retroreflectivity condition assessment method has been successfully implemented by state DOTs.

• There is a strong need to develop a cost-effective and objective traffic sign retroreflectivity condition assessment method.

• 3-D point cloud along with retro-intensity collected by mobile LiDAR make it possible to assess sign retroreflectivity conditions.
Research Objective

• To explore the feasibility of developing an automatic traffic sign retroreflectivity condition assessment method using mobile LiDAR technology.
Proposed Methodology to Assess Sign Retroreflectivity Condition Using Mobile LiDAR

Data Acquisition
- Mobile LiDAR
- GPS
- Roadway Images
- IMU
- DMI

Data Processing
- Spatial Clustering
- Retro Normalization

Data Analysis
- Sign Condition Classification (Good/Poor)

GOOD
POOR
Thirty-five stop signs with engineer grade sheeting were collected in Pooler, Georgia.
Experimental Test – Signs Collected in Pooler

\[ y = 0.9867x + 0.62708 \]
Implementation Consideration

- Further tests on other types of engineer grade traffic signs, e.g. speed limit signs, warning signs, etc., to study the sensitivity of the proposed method on different colors.
- Further tests on other types of sheeting to study the sensitivity of the proposed method on different materials, e.g. prismatic.
Q/A
Retroreflectivity vs. Retro-intensity (LiDAR)

\[ RA = f(I_N) = A \cdot I_N + B \]
\[ I_N = I_N(I_O, \alpha, d) \]

\( RA \) – Retroreflectivity
\( I_N \) – Normalized retro-intensity from LiDAR
\( I_O \) – Original retro-intensity from LiDAR

\( \alpha \) : LiDAR incidence angle
\( d \) : LiDAR beam distance
Retro-Intensity vs. Beam Distance

- Beam Distance Test
  - Angle $\alpha = 0^\circ$
  - Distance $d = 20 - 165$ ft.
Retro-Intensity Normalization

- Beam Distance Normalization

The retro-intensity value is normalized to the beam distance of 41 ft. by adding the value of $\Delta f(d)$ to the original value.
Retro-Intensity vs. Incidence Angle

• Incidence Angle Test
  – Angle $\alpha = 0 - 90^\circ$
  – Distance $d = 41$ ft.
Retro-Intensity Normalization

• Incidence Angle Normalization

The retro-intensity value is normalized to the incidence angle of $20^\circ$ by adding the value of $\Delta f (\alpha)$ to the original value.
Traffic Sign Point Cloud Extraction

- Initial sign region extraction

- Boundary effect removal