Accelerated Sign Inventory and Management

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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

Record the data

Mount the bar code

Measure the sign

Take a picture

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)

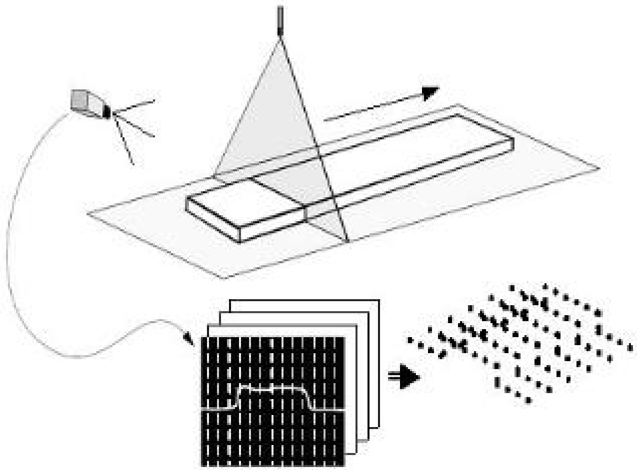
Ongoing Research Project

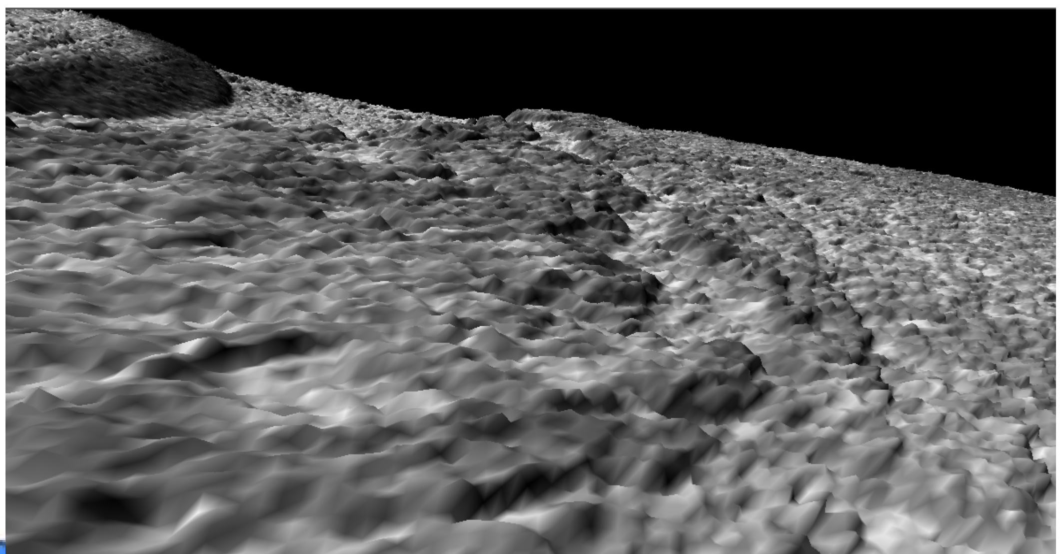
- To collect signs on all interstate highways (2,500 centerline miles)
  - GPS location
  - Linear reference system (RCLINK and milepoint)
  - Sign type
  - MUTCD code
  - Sign condition (post failure, dirty, obstruction, and surface failure)
- To validate the enhanced sign inventory procedure using 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

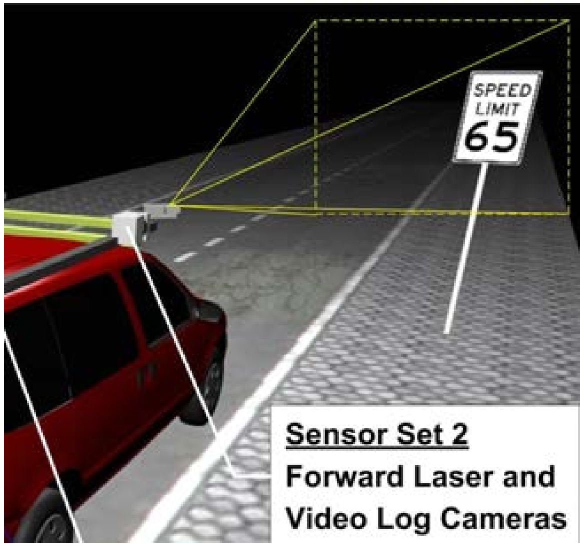
Data points collected per second and width covered:

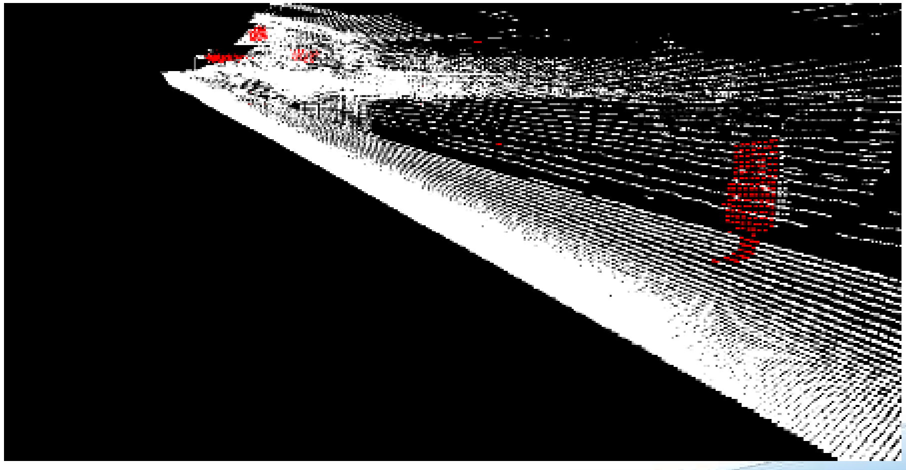
2 (lasers) * 2048 (points/profile/laser) * 5600 HZ = 22,937,600 points

2 (lasers) * 2048 (points/profile/laser) * 1 (mm) = 4.096 m

Mobile LiDAR and Digital Camera

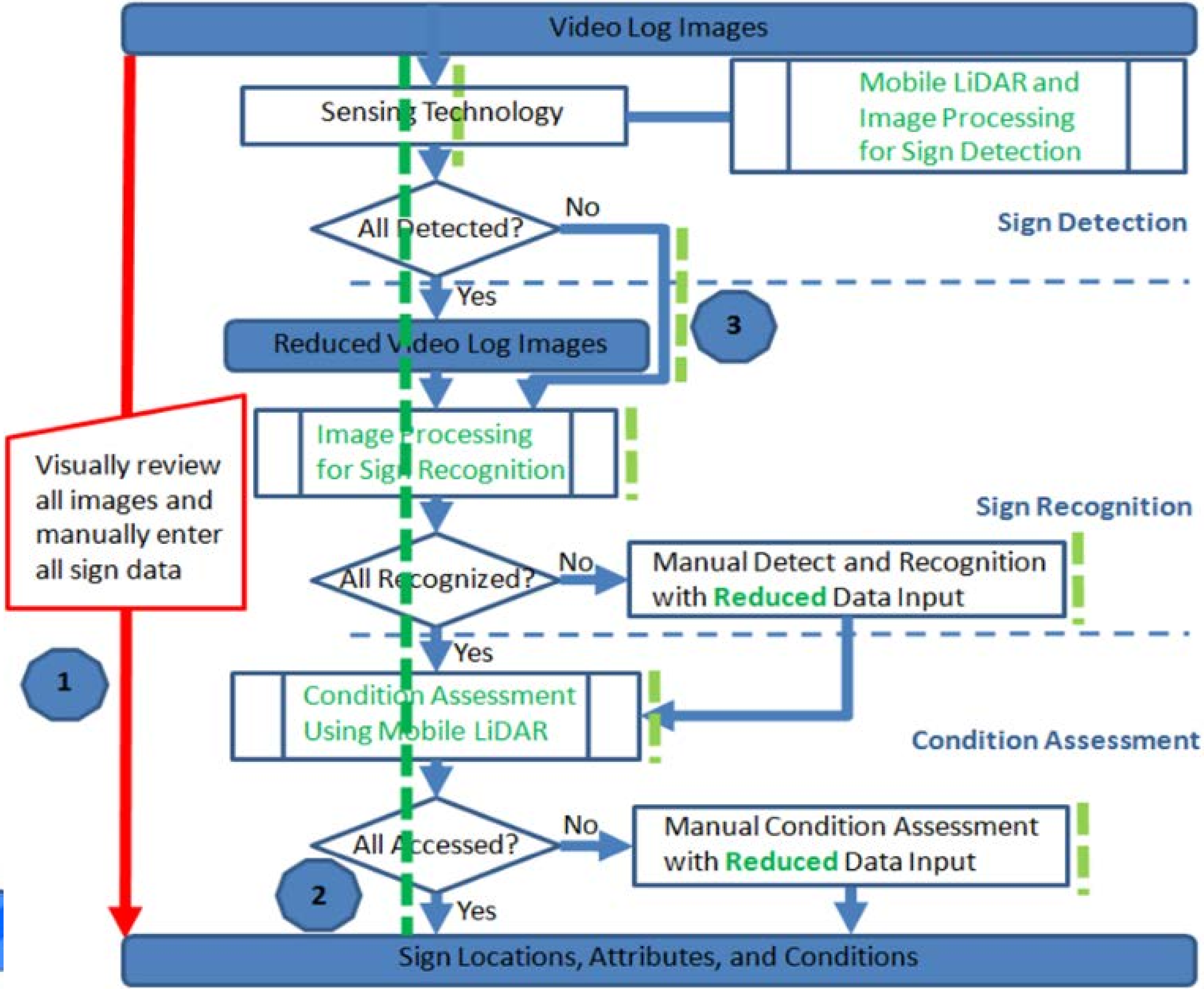
High-resolution Light Detection And Ranging (LiDAR)



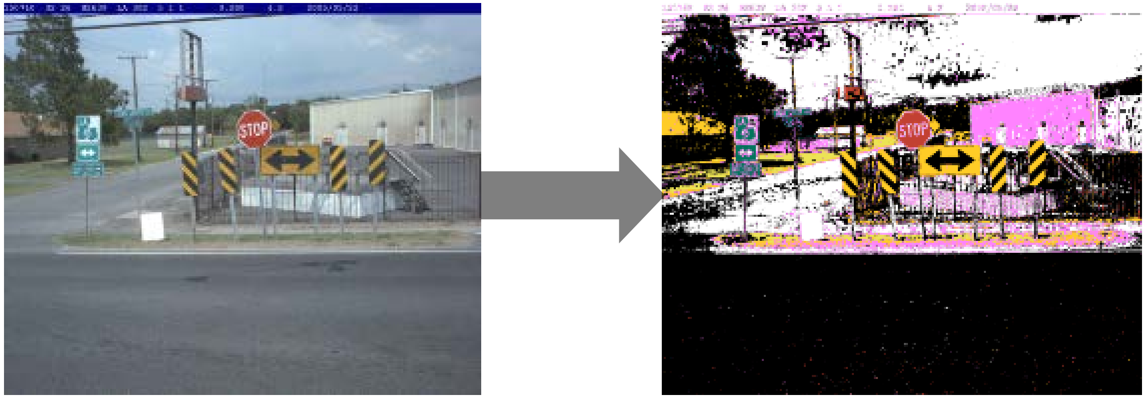


Enhanced Sign Inventory Procedure using Video Log Images and Mobile LiDAR

Sign Inventory Procedures



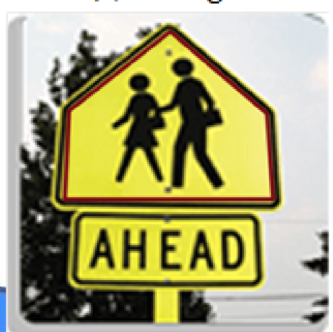
Sign Detection and Recognition



Color Segmentation

(a) Triangle

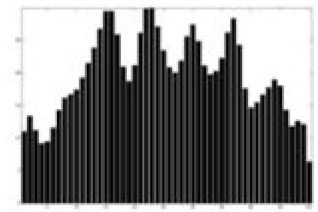
(b) Rectangle



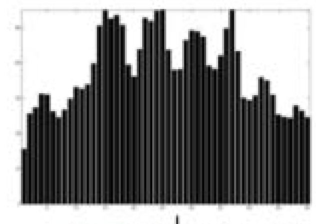
(c) Pentagon

(d) Octagon

Shape Detection



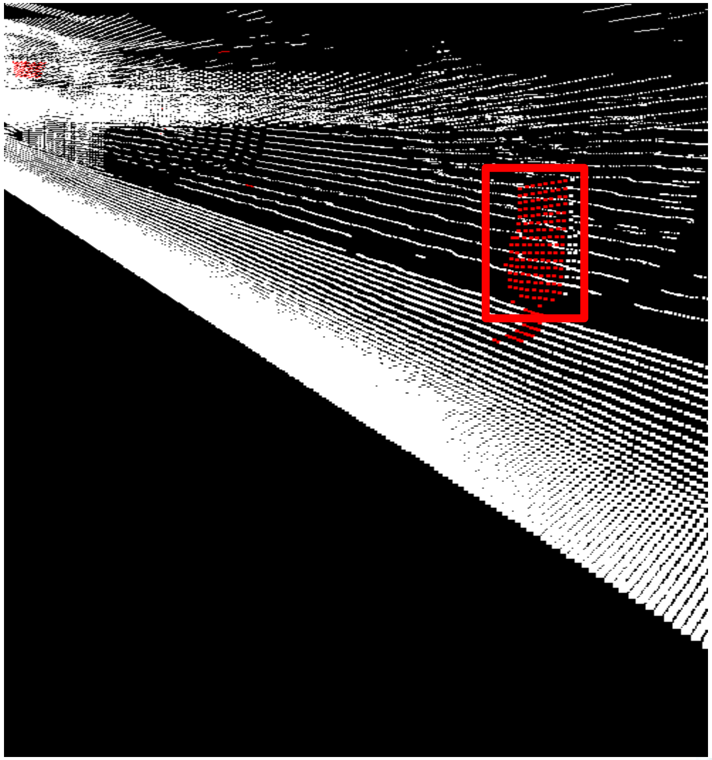
(c) validation column vector, generated by re-sampling (a) to the size of 50 elements



(e) reference stop sign column vector

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

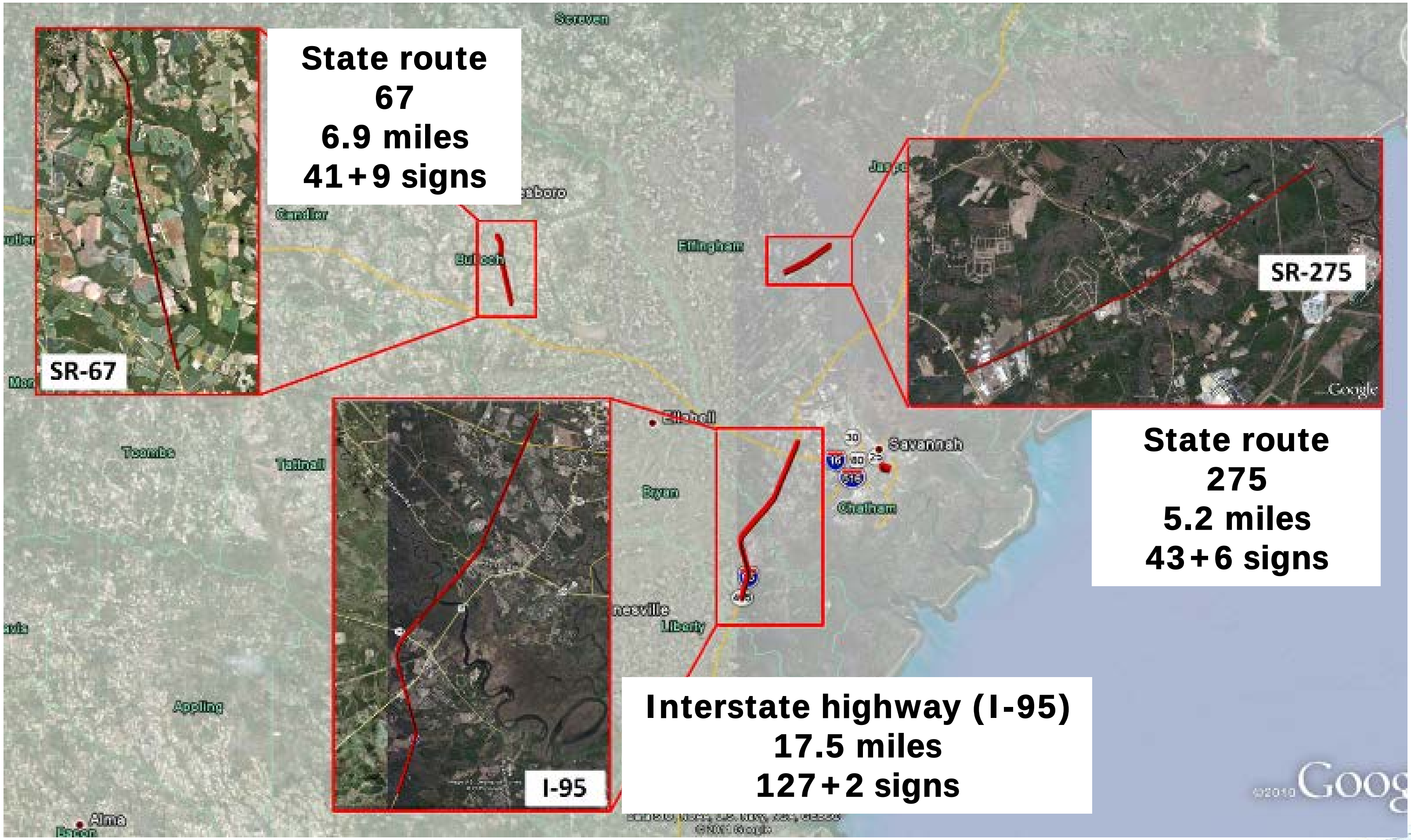
Preliminary Assessment of Enhanced Sign Inventory Procedure (2)

- 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)

	Image-Enhanced Procedure	LiDAR-Enhanced Procedure	Manual Process (In-office)	Manual Process (In-field)
Processing Time (sec/sign)	148	74	244	288

Experimental Study



Experimental Study (cont'd)

I-95		
Sign Type	**Count**	**Percentage**
D10-2	19	14.6%
R2-6	17	13.1%
E1-1	13	10.0%
SSS	12	9.2%
W8-13	10	7.7%
R2-1	6	4.6%
W20-1	6	4.6%
E5-1a	5	3.8%
W4-1	5	3.8%
D3-2	4	3.1%
R8-3a	4	3.1%
D2-3	3	2.3%
RM	3	2.3%
GA-Buckle	2	1.5%
I-2	2	1.5%
I-31	2	1.5%
M1-1	2	1.5%
M3-1	2	1.5%
D10-3	1	0.8%
D2-2	1	0.8%
D5-7a	1	0.8%
FHWA-Space	1	0.8%
G20-1	1	0.8%
I-3	1	0.8%
M1-10	1	0.8%
R2-5a	1	0.8%
TTS-Ripples	1	0.8%
W13-3	1	0.8%
W1-8	1	0.8%
W5-4	1	0.8%
Unknown	1	0.8%

SR-275		
Sign Type	**Frequency**	**Percentage**
R8-3a	13	27.1%
R3-17	6	12.5%
R2-1	5	10.4%
D10-1	3	6.3%
R1-2	3	6.3%
M1-5	2	4.2%
M3-1	2	4.2%
W16-8a	2	4.2%
W2-2	2	4.2%
R15-1	1	2.1%
R5-1	1	2.1%
S5-1	1	2.1%
S5-2	1	2.1%
W10-1	1	2.1%
W11-4	1	2.1%
W1-2	1	2.1%
W14-1	1	2.1%
W16-3a	1	2.1%
W2-1	1	2.1%
unknown	1	2.1%

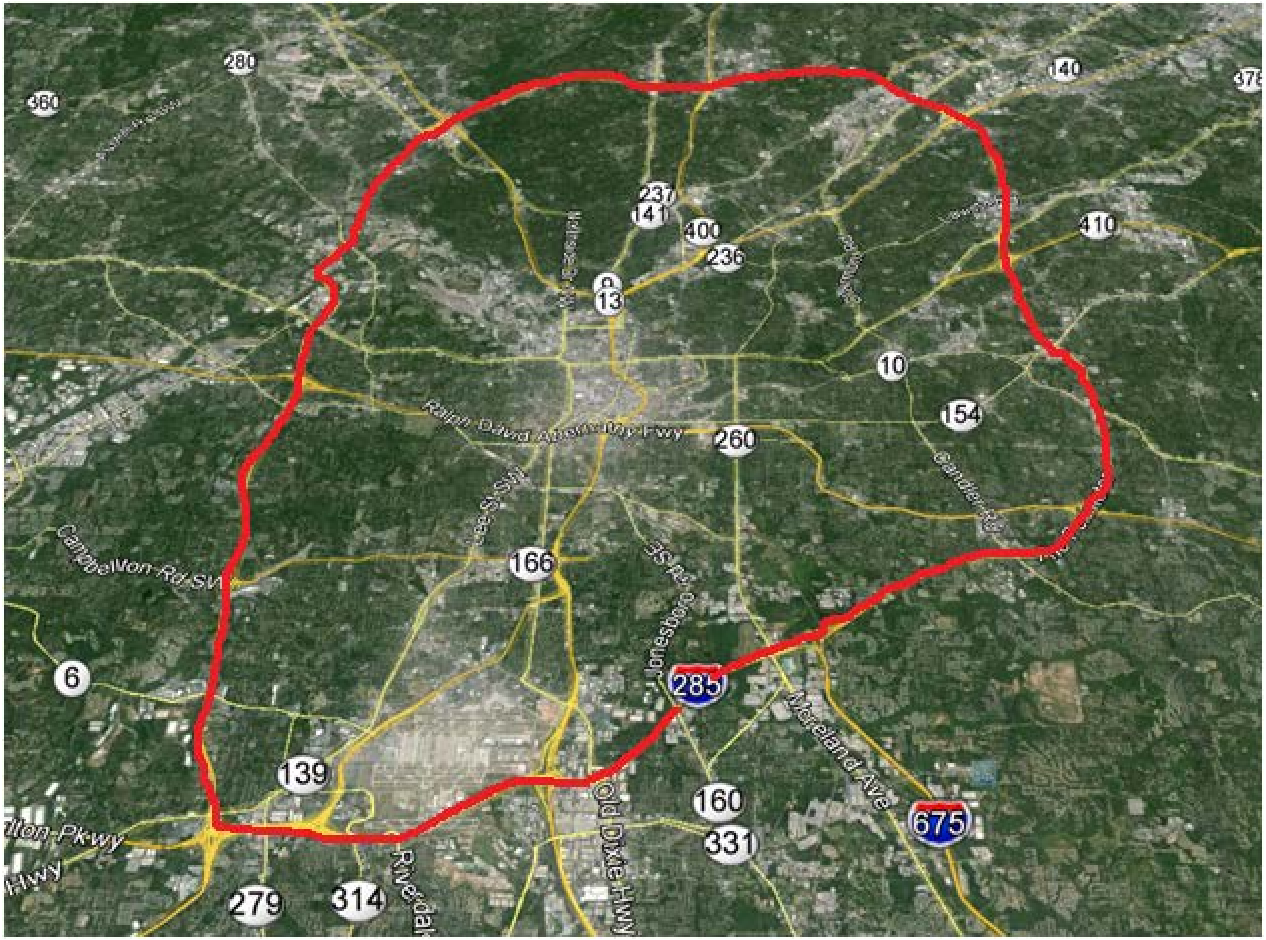
SR-67		
Sign Type	**Count**	**Percentage**
OM-3R	12	23.5%
W1-8(l)	6	11.8%
W16-8a	5	9.8%
W2-2(l)	5	9.8%
W16-8	3	5.9%
M1-5	2	3.9%
M3-3	2	3.9%
W1-4(l)	2	3.9%
W1-4(R)	2	3.9%
W2-1	2	3.9%
W2-2(r)	2	3.9%
W8-13	2	3.9%
I-3	1	2.0%
S3-1	1	2.0%
W1-2(l)	1	2.0%
W1-2(R)	1	2.0%
W2-3	1	2.0%
Unknown	1	2.0%

Testing Results

I-95		SR-275		SR-67	
Distance	17.5 miles	Distance	5.2 miles	Distance	6.9 miles
# of Signs	129	# of Signs	49	# of Signs	50
FN	14	FN	9	FN	10
FP	6	FP	1	FP	1
Detection Rate	90.6%	Detection Rate	81.6%	Detection Rate	80%

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

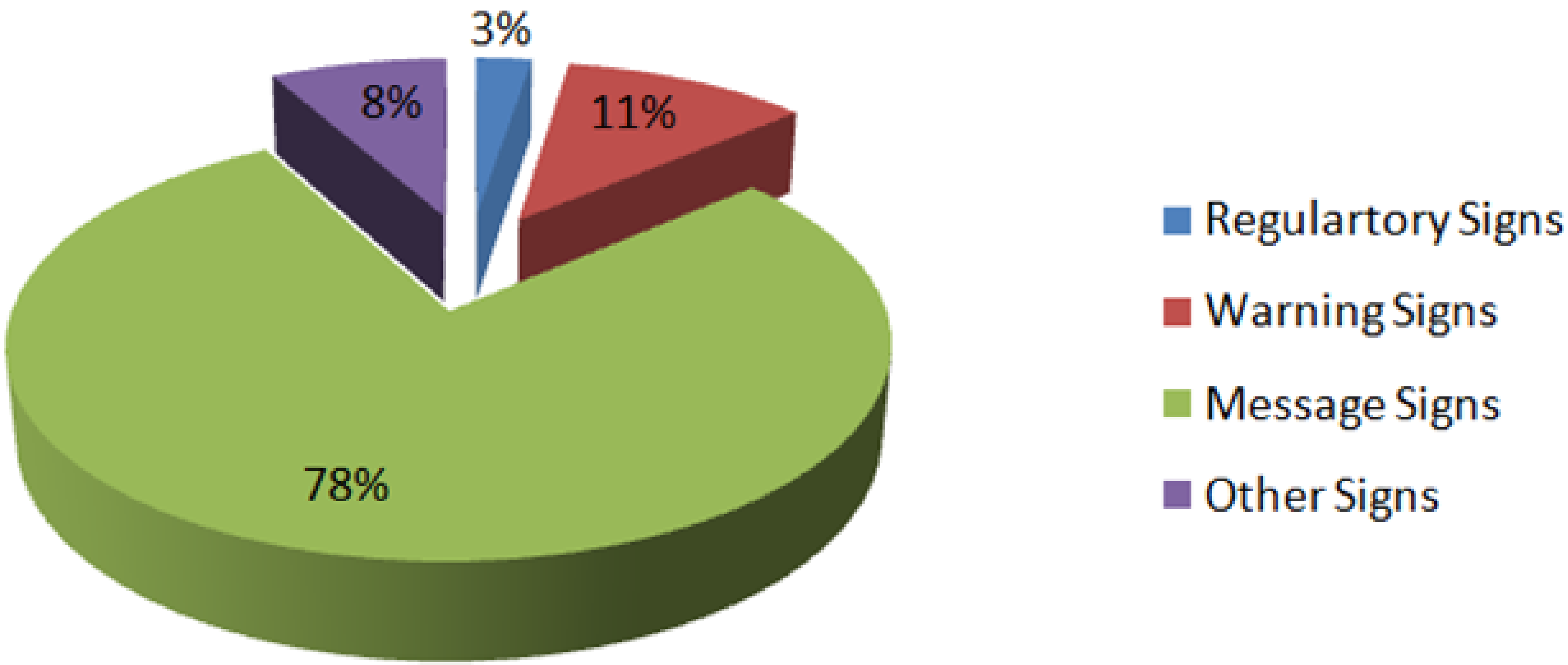
Dirty

Obstructed

Surface Failure

Note: Based on GDOT's Foreman's Manual 2008

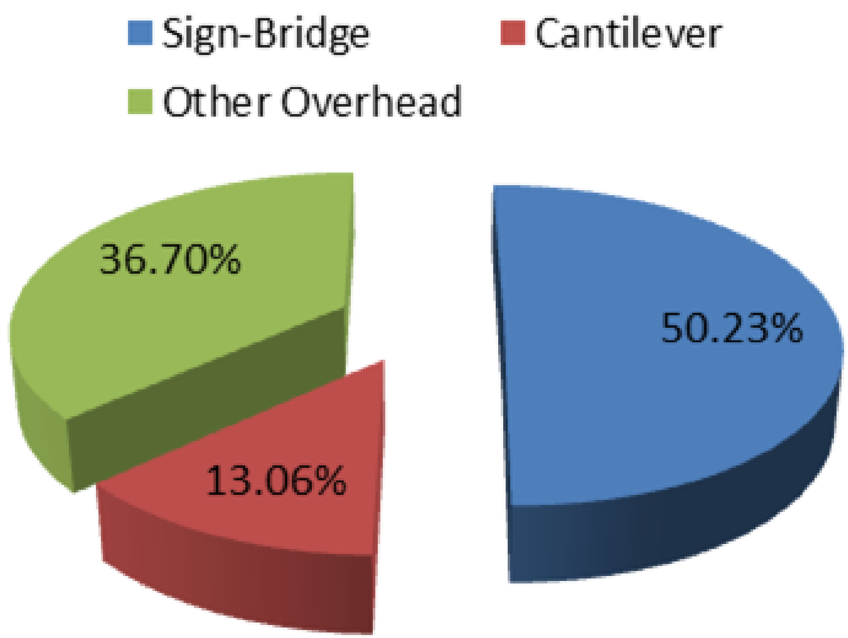
Distribution of Sign Categories



Total Signs: 2,969

Distribution of Overhead Signs

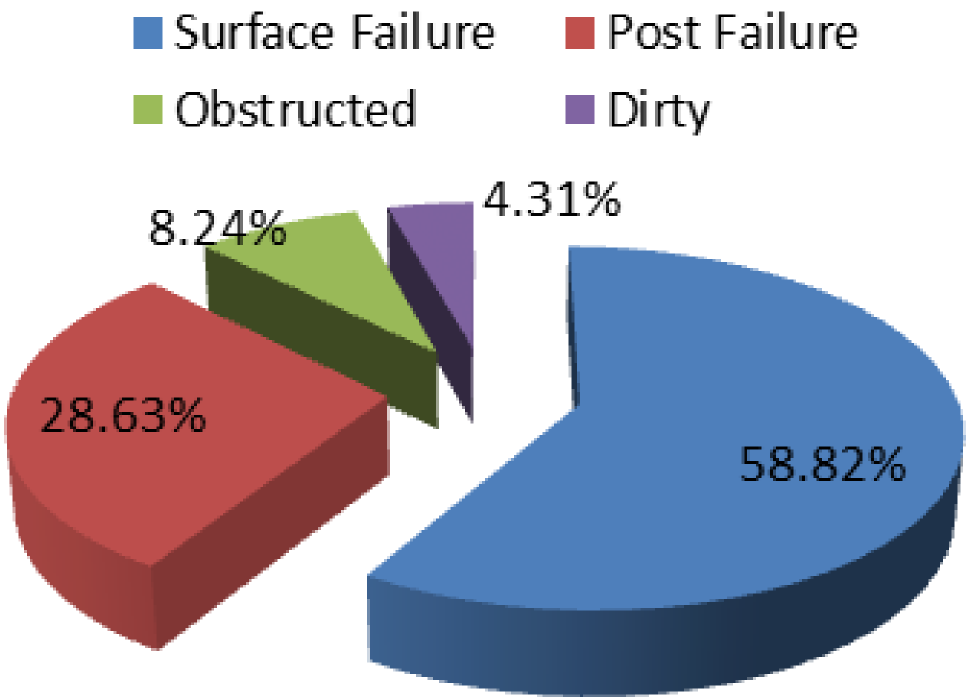
Signs with **high potential risk** to road users

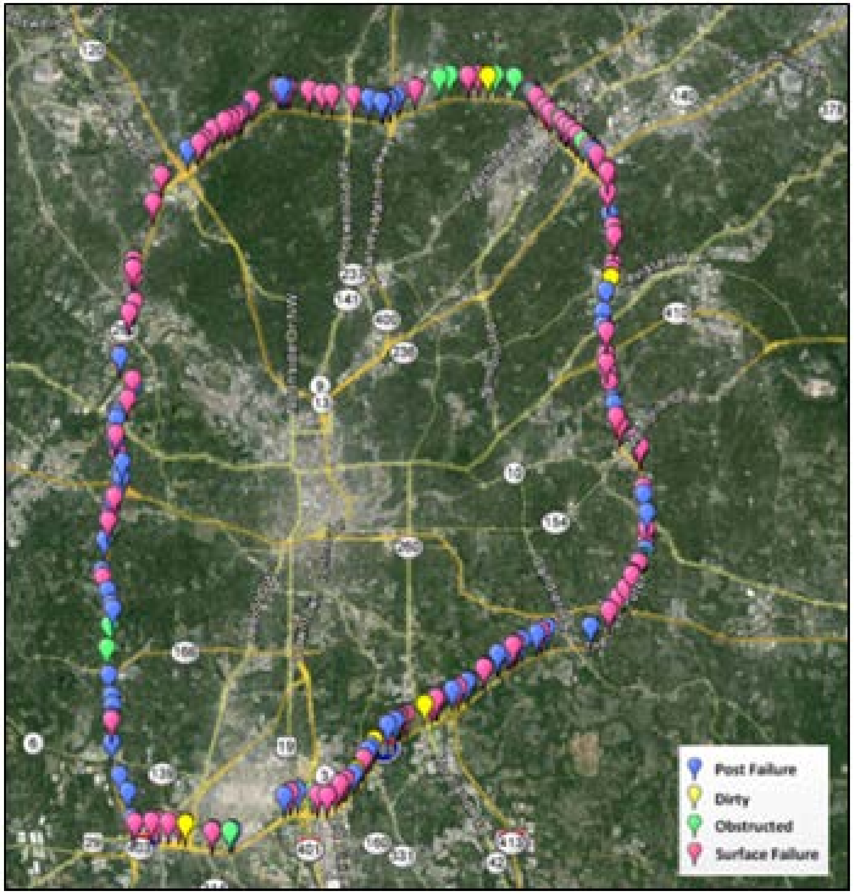


Total Overhead Signs: 643

Example Overhead Sign

Distribution of Signs in Poor Conditions





Total Damaged Signs: 252

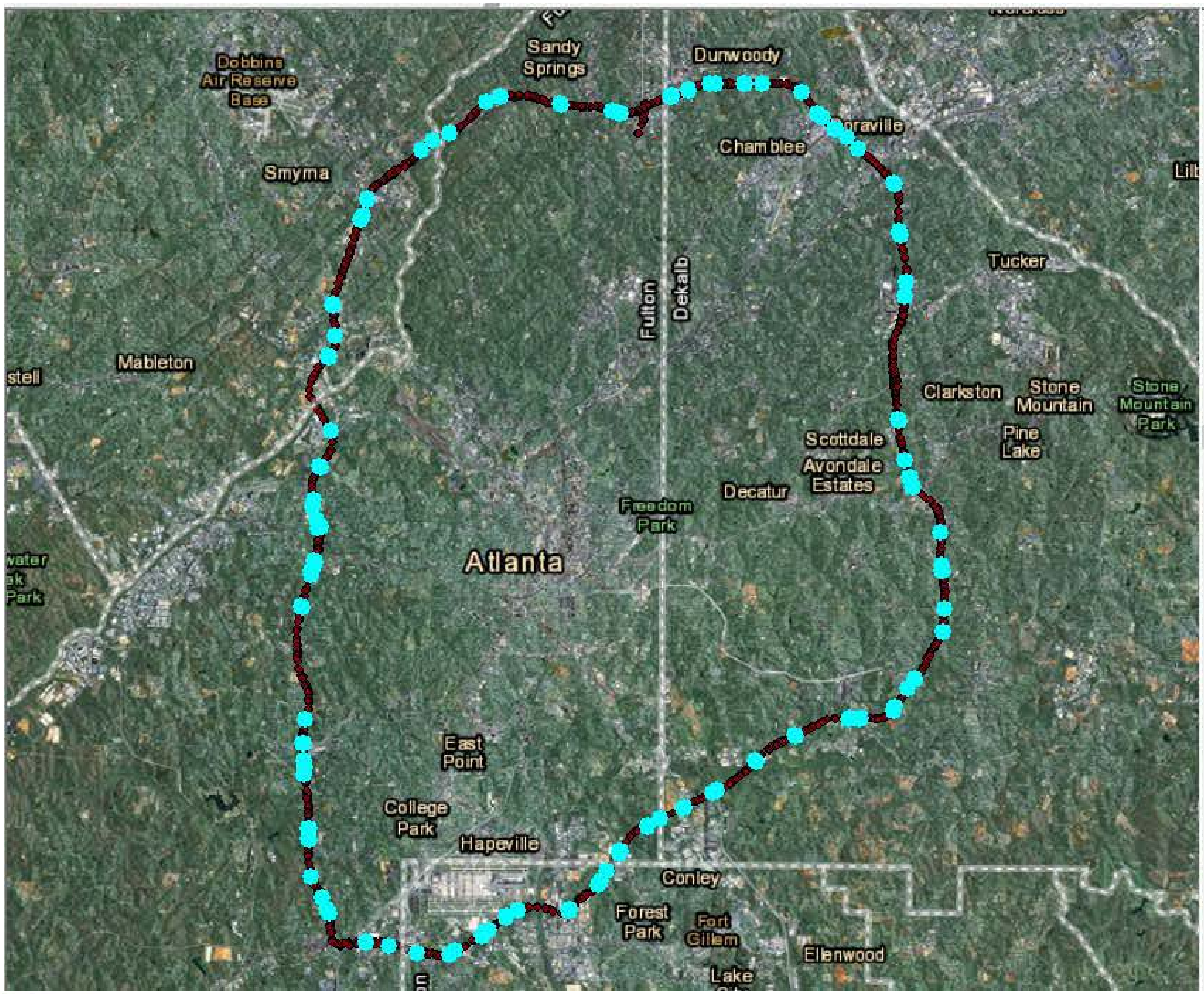
Example Damaged Signs (1) - *Truck Gust*

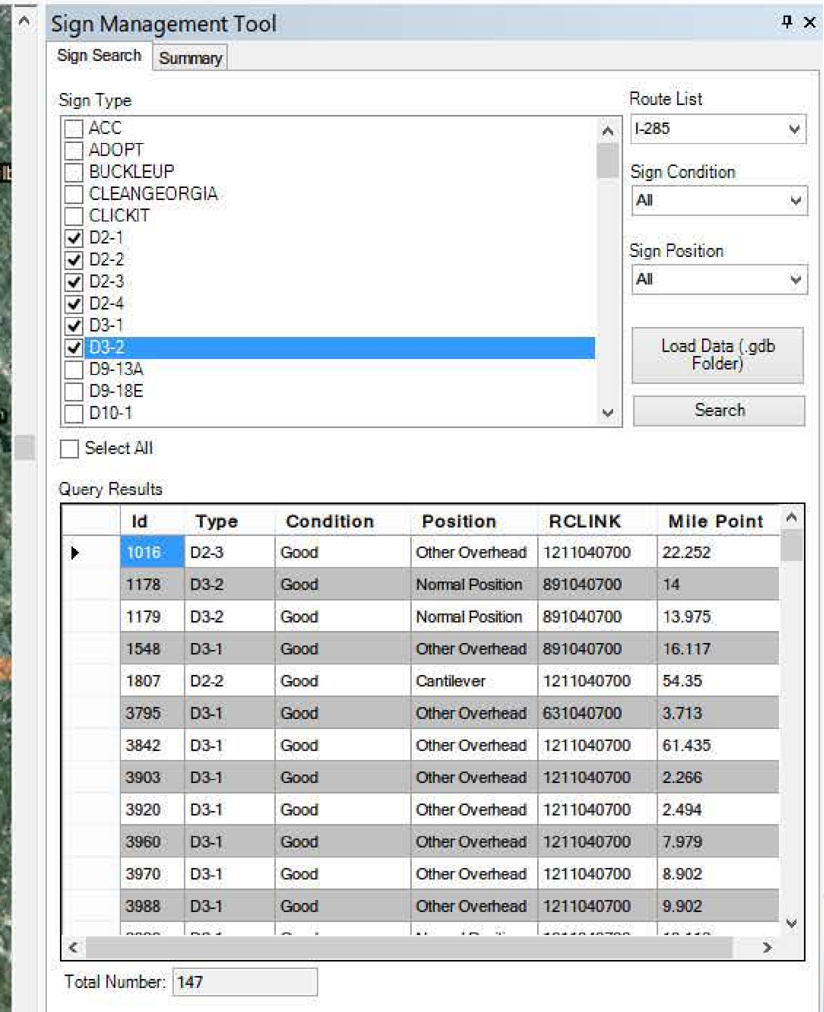
Example Damaged Signs (2) - Dual-Post

Example Damaged Signs (3) - *Post Failure*

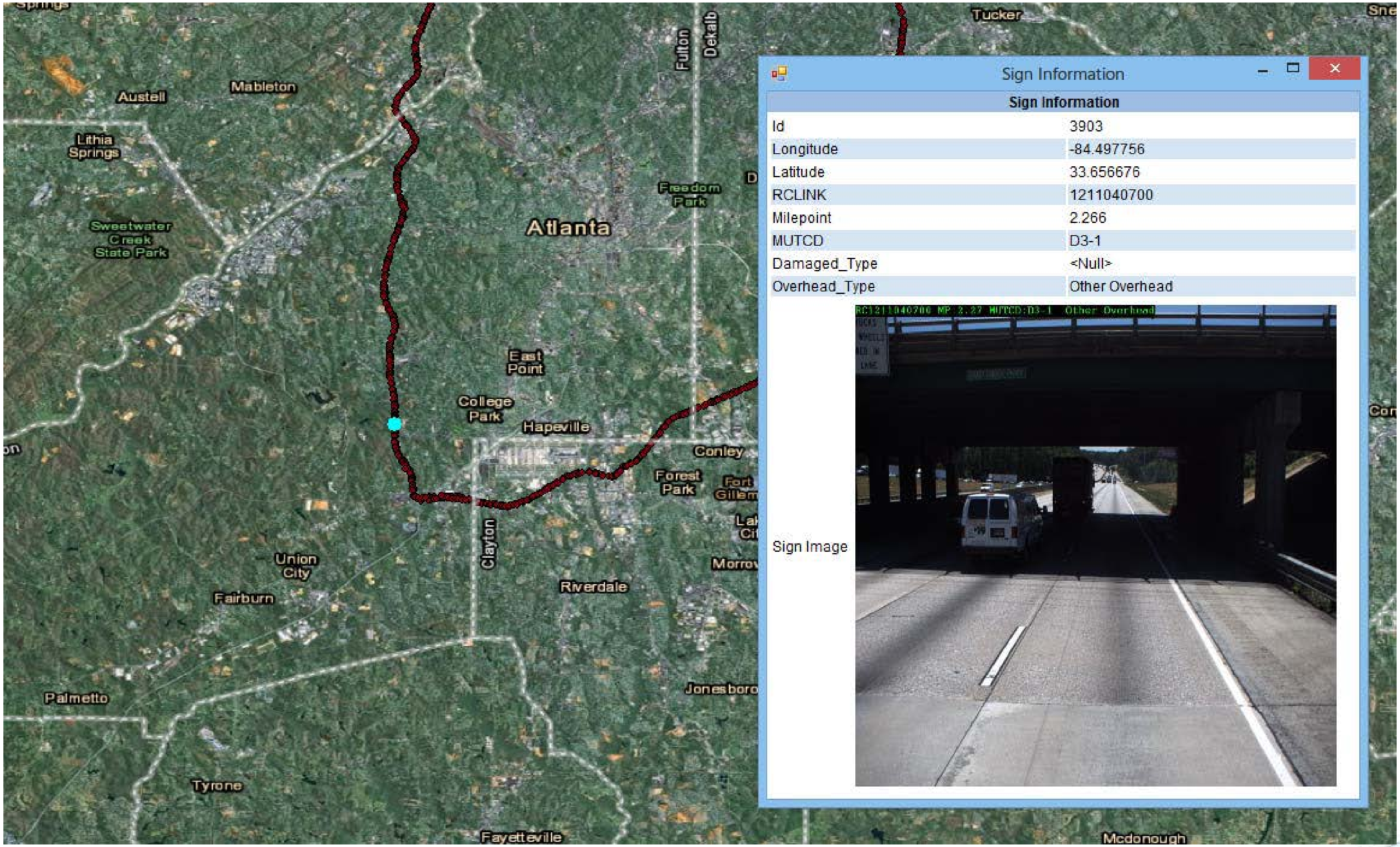
A Prototype GIS-based Sign Management

GIS-based Sign Data Query

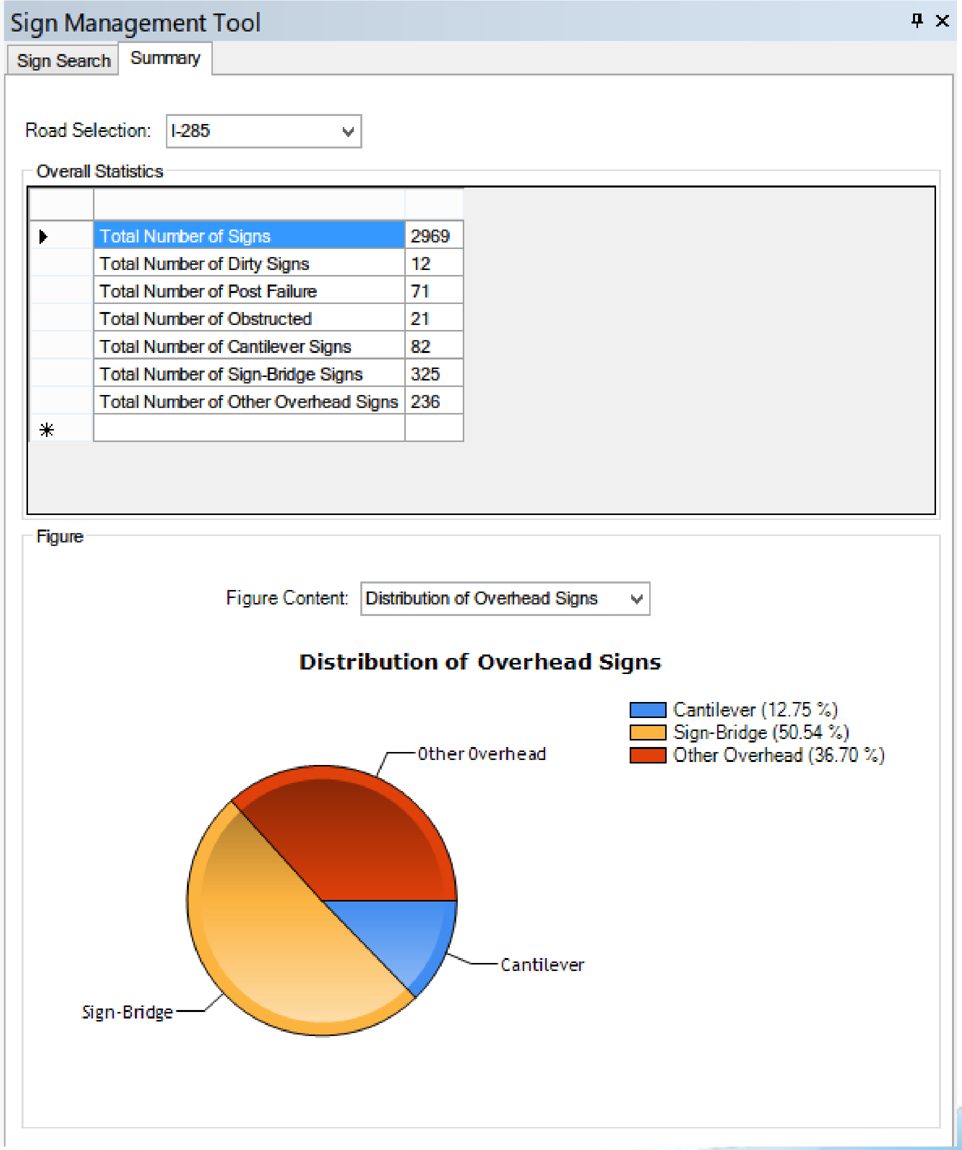




Individual Sign Information



Summary of Sign Information



Preliminary Study of Sign Retroreflectivity Condition Assessment using Mobile LiDAR

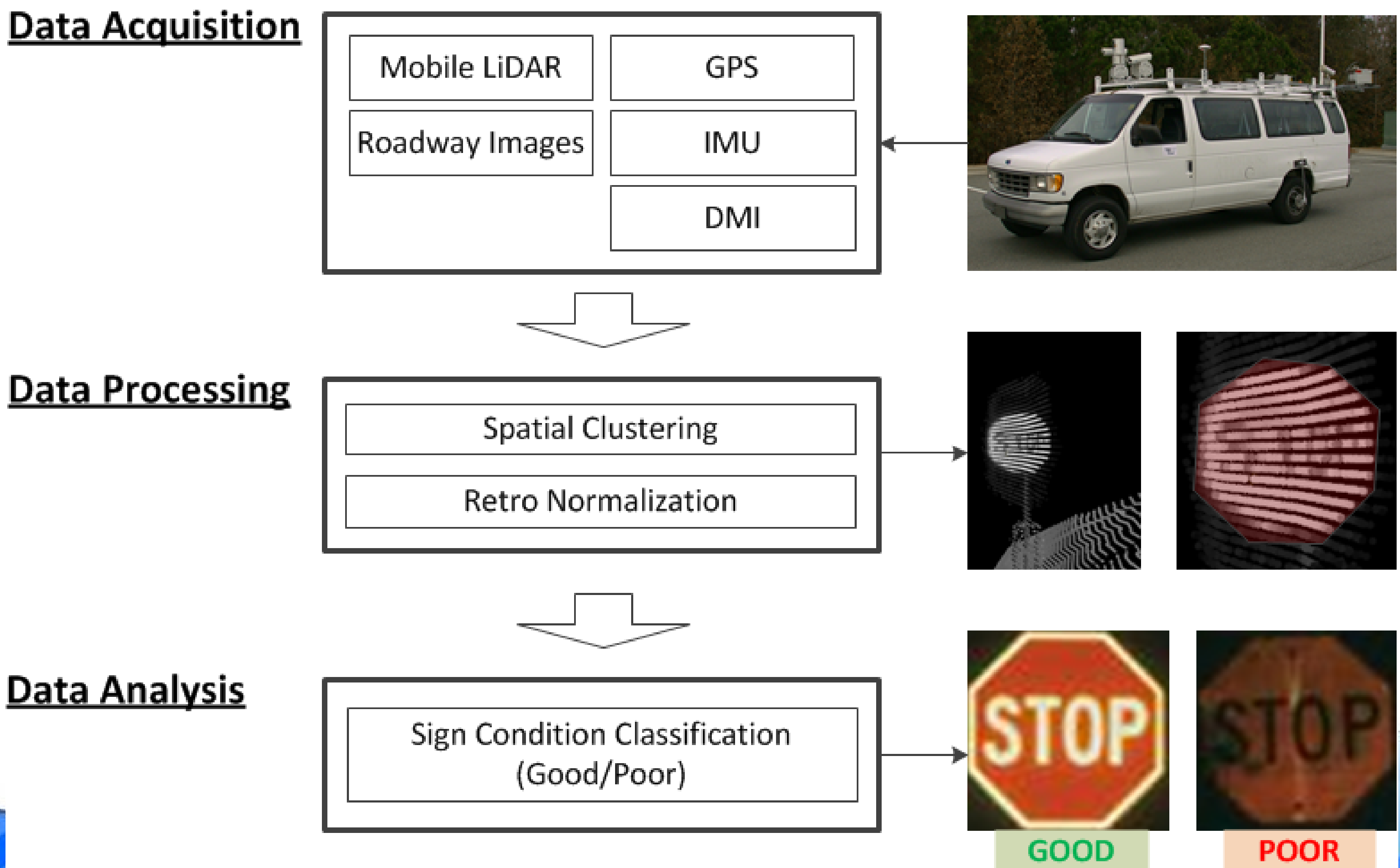
Research Need

- 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.

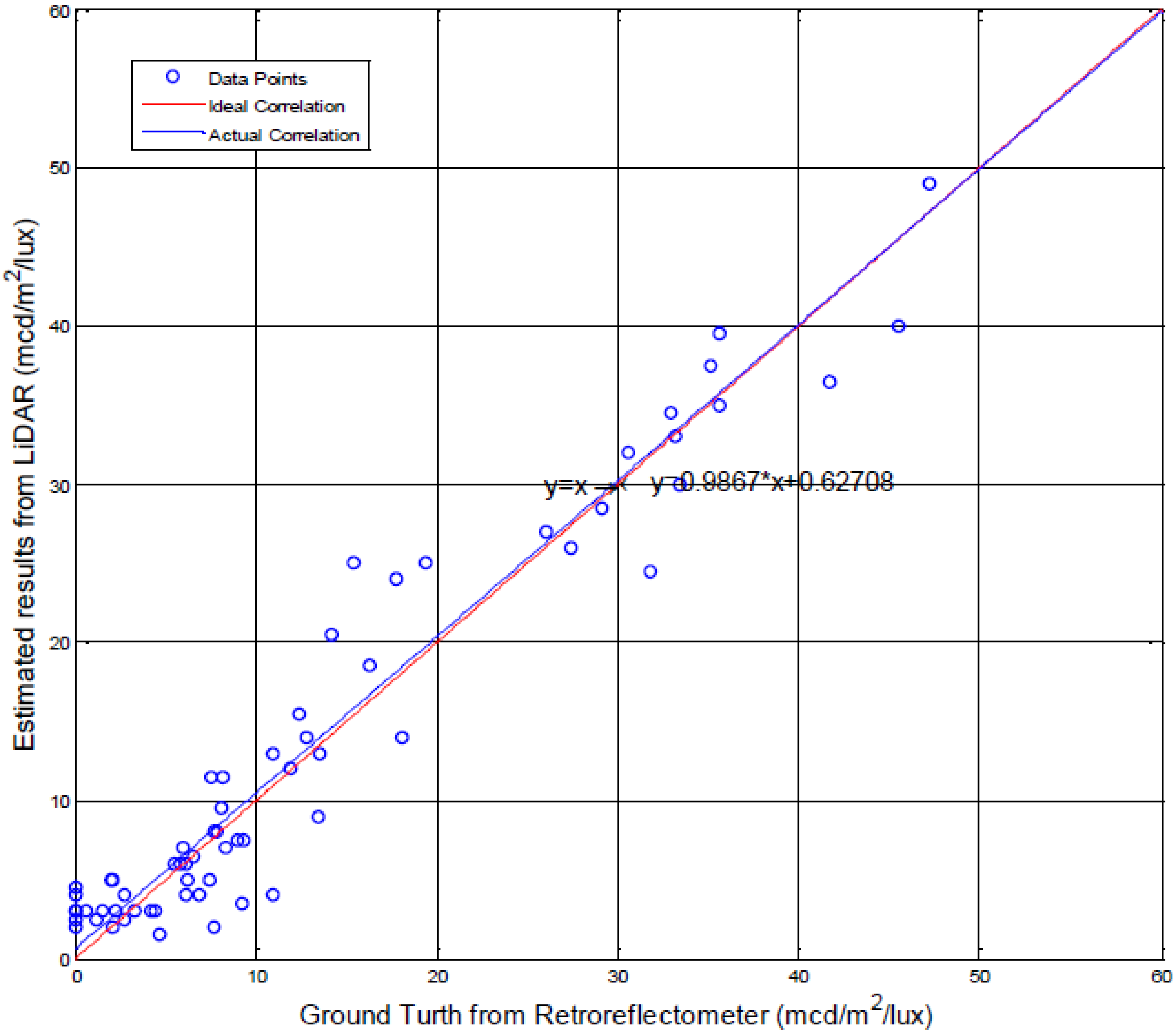
Proposed Methodology to Assess Sign Retroreflectivity Condition Using Mobile LiDAR



Experimental Test

Thirty-five stop signs with engineer grade sheeting were collected in Pooler, Georgia

Experimental Test – Signs Collected in Pooler



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

Backup Slides

Retroreflectivity vs. Retro-Intensity (LiDAR)

$RA = f(I_N) = A \cdot I_N + B$

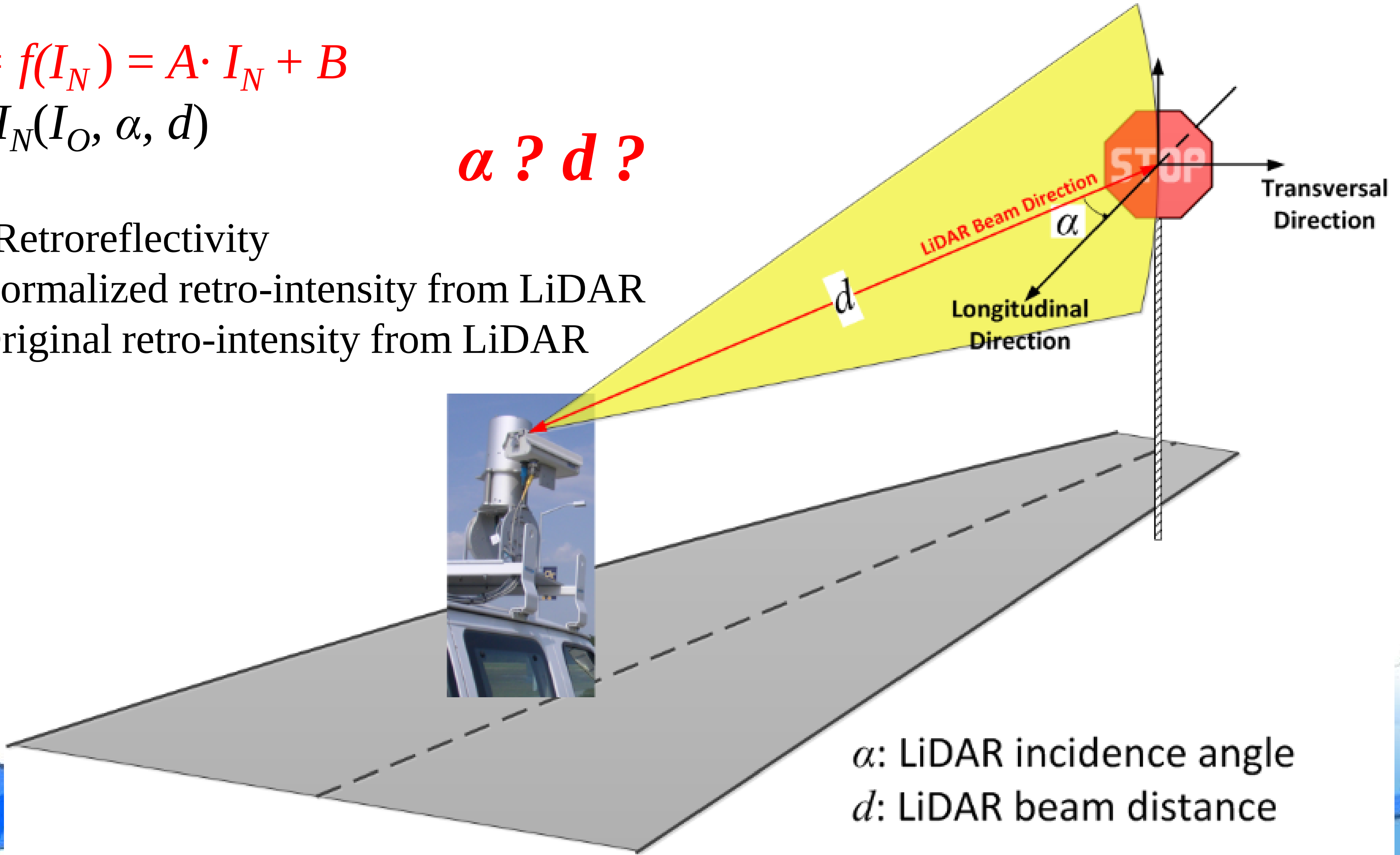
$I_N = I_N(I_O, \alpha, d)$

α ? d ?

RA – Retroreflectivity

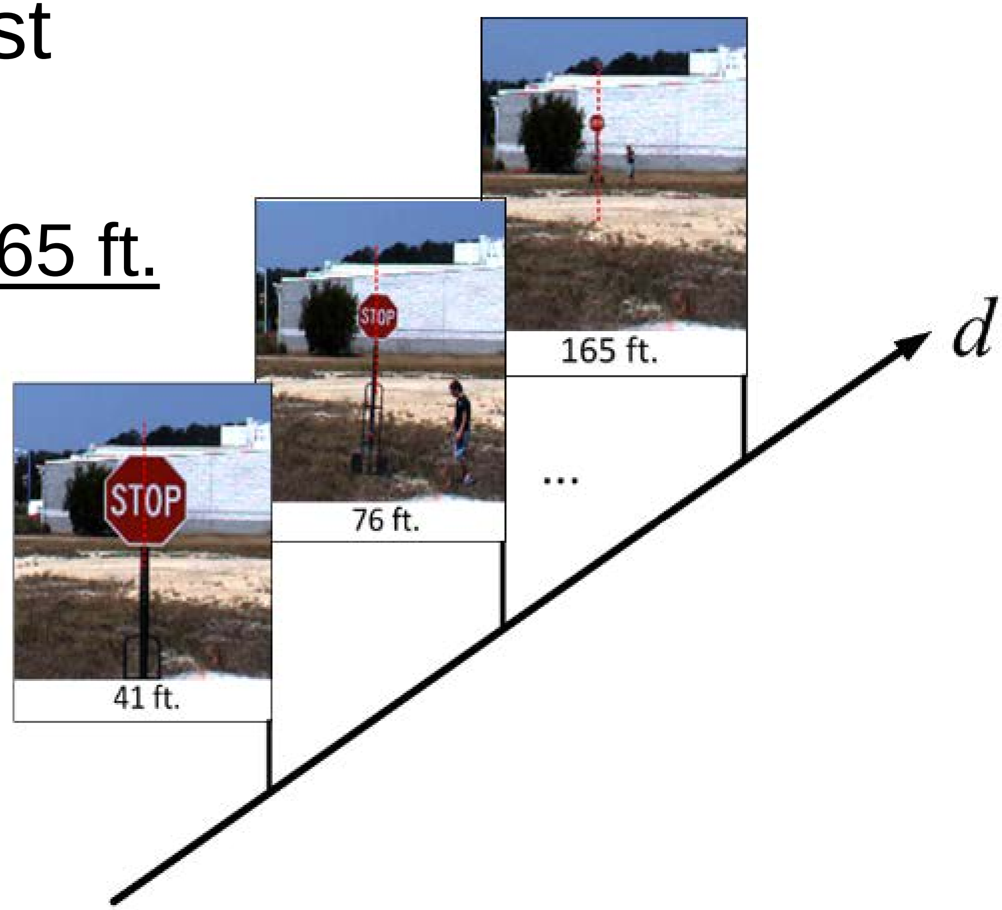
I_N – Normalized retro-intensity from LiDAR

I_O – Original retro-intensity from LiDAR



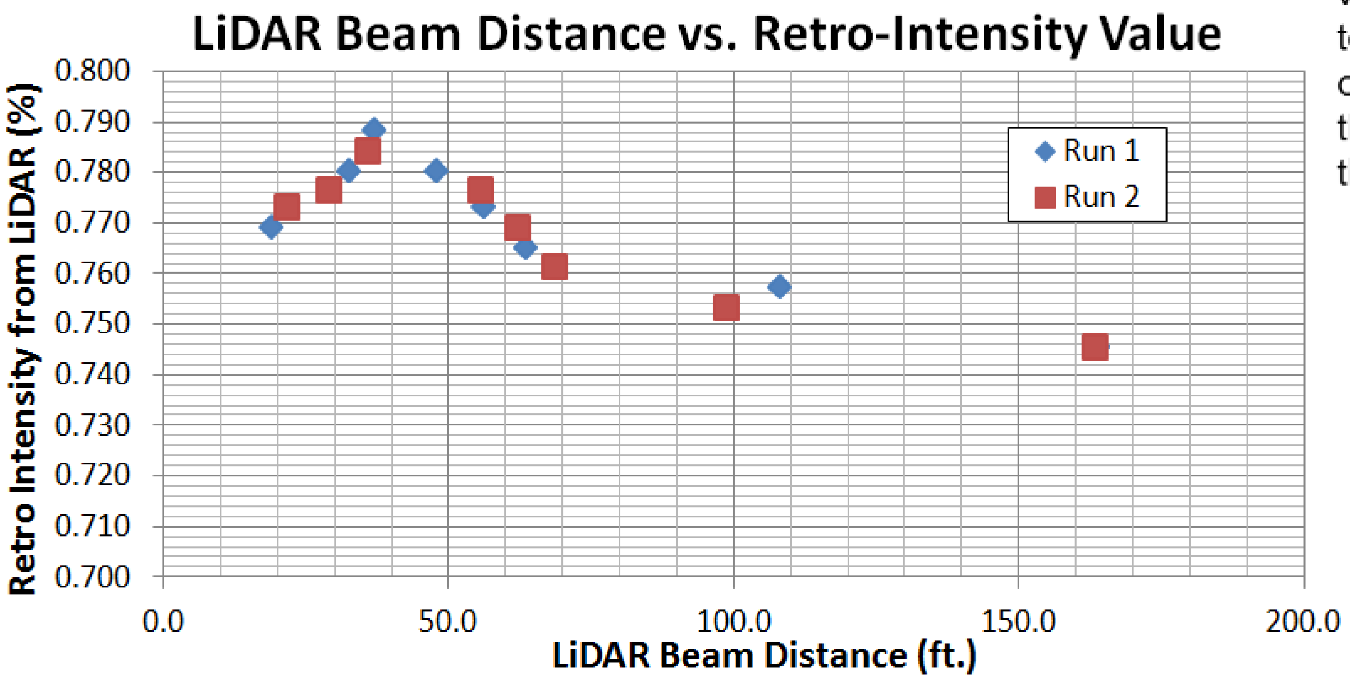
Retro-Intensity vs. Beam Distance

- Beam Distance Test
  - Angle α = 0°
  - *Distance* d = 20 - 165 ft.



Retro-Intensity Normalization

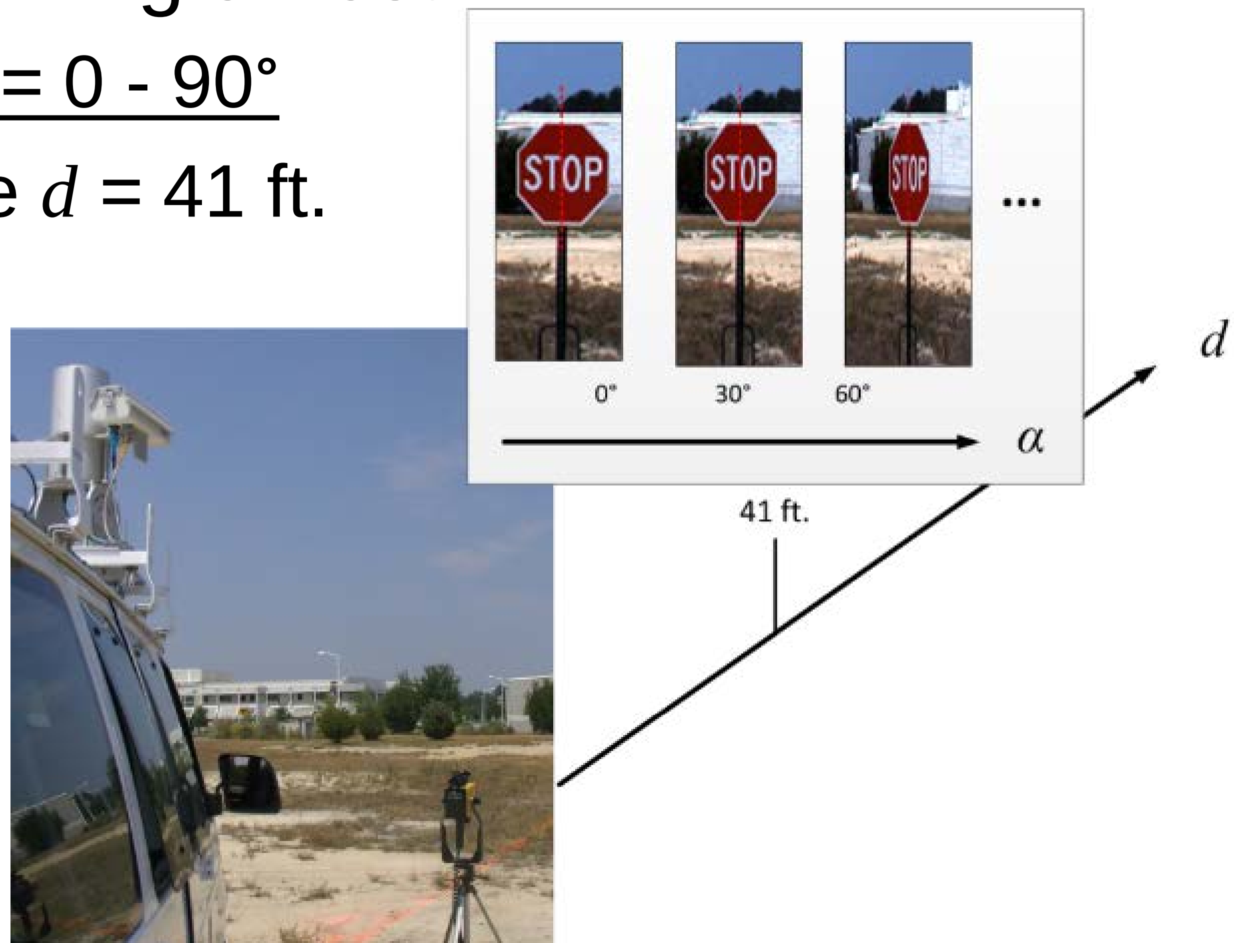
- Beam Distance Normalization



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.

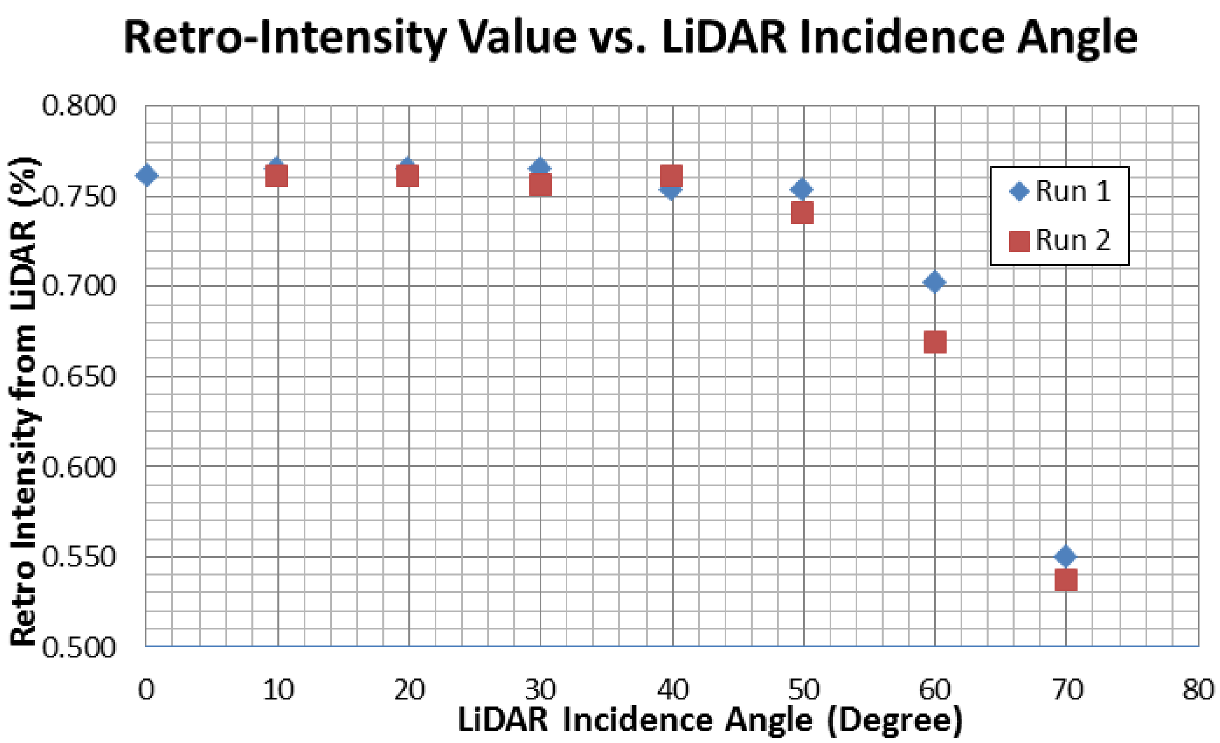
Retro-Intensity vs. Incidence Angle

- Incidence Angle Test
  - Angle α = 0 - 90°
  - Distance d = 41 ft.



Retro-Intensity Normalization

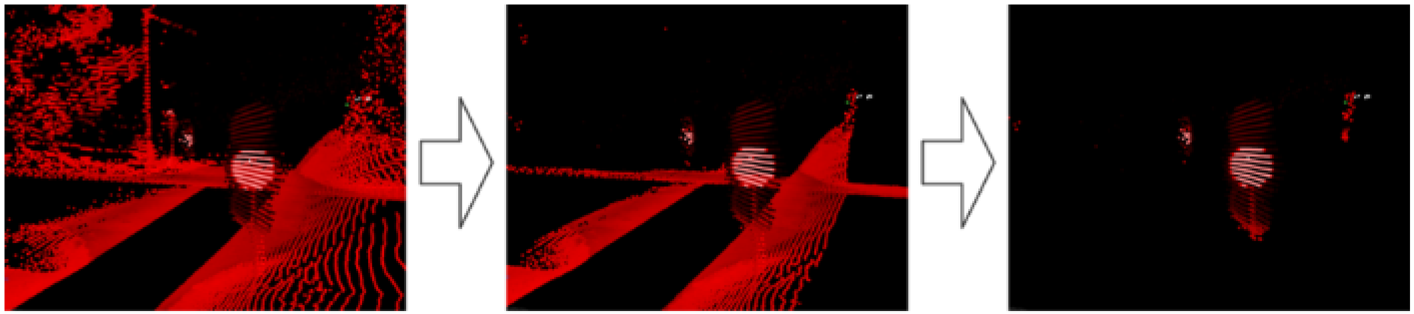
- Incidence Angle Normalization



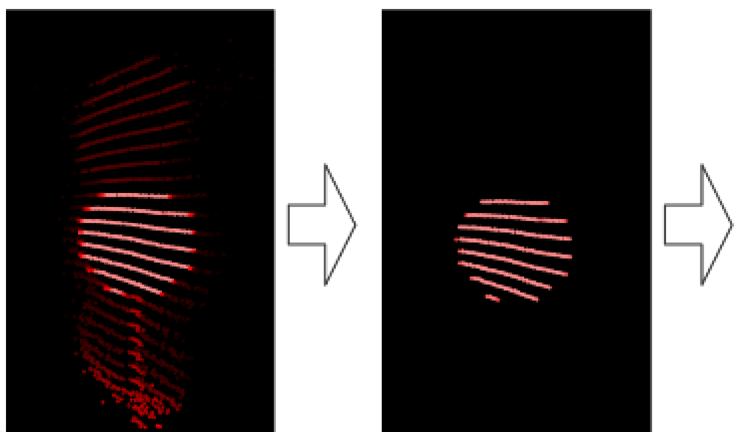
The retro-intensity value is normalized to the incidence angle of 20° by adding the value of $\Delta f(\alpha)$ to the original value.

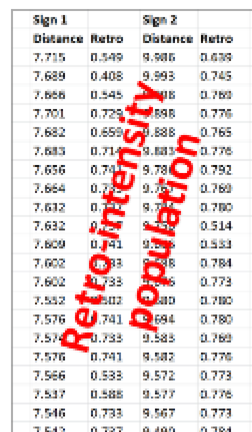
Traffic Sign Point Cloud Extraction

- Initial sign region extraction



- Boundary effect removal





Sign 1		Sign 2	
Distance	Retro	Distance	Retro
7.715	0.549	9.986	0.639
7.689	0.408	9.993	0.745
7.666	0.545	[illegible]	0.760
7.701	0.729	[illegible]	0.776
7.682	0.659	[illegible]	0.765
7.683	0.714	9.883	0.776
7.656	[illegible]	[illegible]	0.792
7.664	[illegible]	[illegible]	0.760
7.632	[illegible]	[illegible]	0.780
7.632	[illegible]	[illegible]	0.514
7.609	0.741	[illegible]	0.533
7.602	[illegible]	[illegible]	0.784
7.602	0.733	[illegible]	0.773
7.552	[illegible]	[illegible]	0.780
7.576	0.741	[illegible]	0.780
7.574	0.733	9.583	0.760
7.576	0.741	9.582	0.776
7.566	0.533	9.572	0.773
7.537	0.588	9.577	0.776
7.546	0.733	9.567	0.773
7.542	0.737	9.490	0.784