Hochschule
für Technik
Stuttgart

EXTRACTION OF TRAFFIC SIGNS FROM POINT CLOUDS

Master Thesis

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Introduction

- A point cloud is a set of data points in some coordinate system.
- Mobile and Terrestrial laser scanners are widely used for scanning of urban areas.
- Problems of point cloud processing: discrimination and classification of objects from point clouds; machine learning.
- Challenge: extraction and classification of traffic signs by their types.

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Area of investigation

- Recorded in 2009 and 2015 around HFT Stuttgart.
- Dozens of traffic signs.
- Lamp posts; poles; traffic lights; trees; wires etc.

Figure 3. Area of investigation (from: Google Maps).

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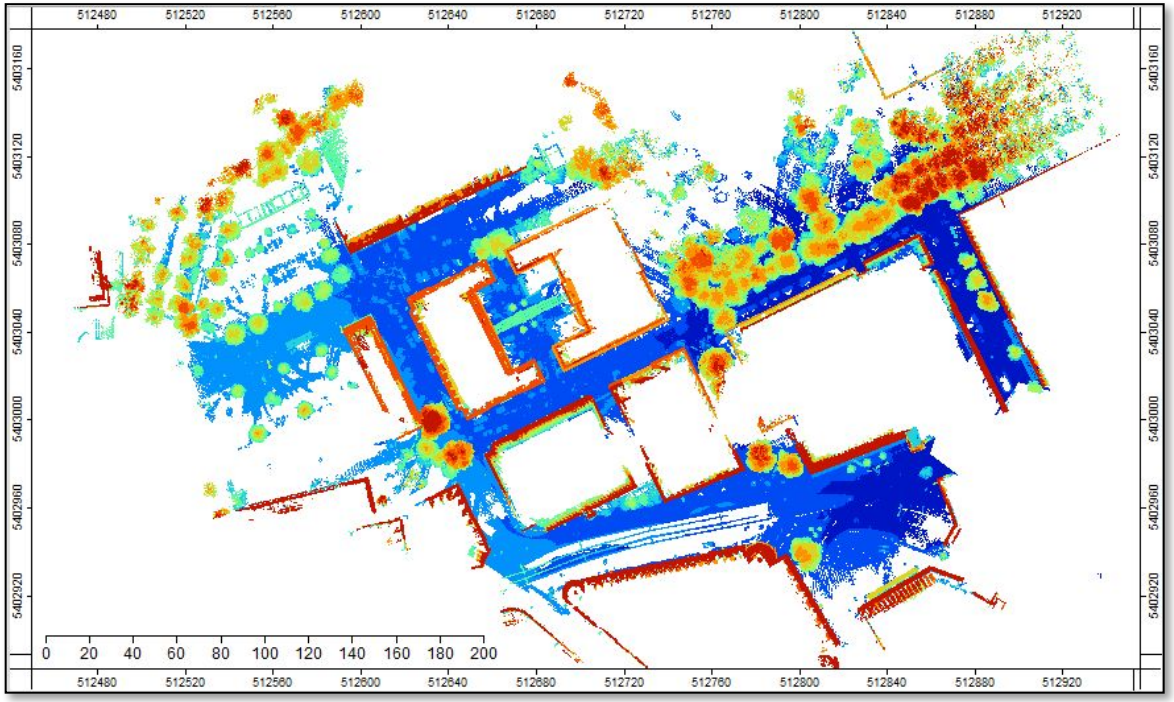


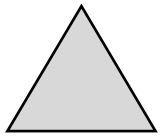
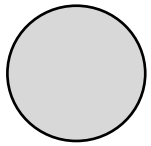
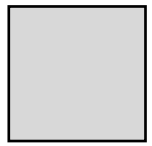
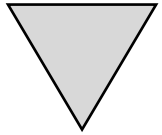
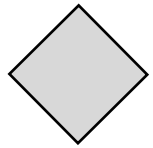
Figure 3. Area of investigation.

Objectives

1. **Eliminate redundant data**
2. **Extract pole-like objects**
3. **Extract traffic signs**
4. **Extract traffic sign's plates**
5. **Develop shape descriptors**

Objectives

The main goal: Signs classification

1. **Warning signs**  
1. **Regulatory signs**  
1. **Information signs**  
1. **Vorfahrt gewähren**  
1. **Vorfahrtstraße**  

Related literature

Gross, H., Thoennessen, U., 2006.

- Investigated eigenvalues λ_1, λ_2, λ_3.
- Defined eigenvalues combinations for some typical situations.
- Successfully extracted lines, edges and planes.

Eigenvalues and Eigenvectors

Moments:

$$\tilde{m}_{ijk} = \frac{\sum_{l=1}^{N} \left(x_l - \bar{x}\right)^i \left(y_l - \bar{y}\right)^j \left(z_l - \bar{z}\right)^k}{R^{i+j+k} N}$$

Covariance matrix:

$$M = \begin{pmatrix} \tilde{m}_{200} & \tilde{m}_{110} & \tilde{m}_{101} \\ \tilde{m}_{110} & \tilde{m}_{020} & \tilde{m}_{011} \\ \tilde{m}_{101} & \tilde{m}_{011} & \tilde{m}_{002} \end{pmatrix}$$

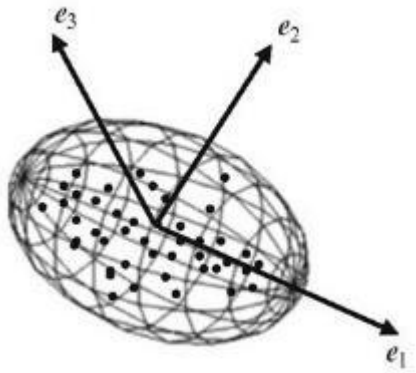


Figure 4. Eigenvectors and eigenvalues (source: www.what-when-how.com/advanced-methods-in-computer-graphics/collision-detection-advanced-methods-in-computer-graphics-part-2).

Related literature

Kazhdan M., Funkhouser T., Rusinkiewicz S., 2003.

- 3D shape matching.
- Rotation invariant descriptors.
- Spherical Extent Function.

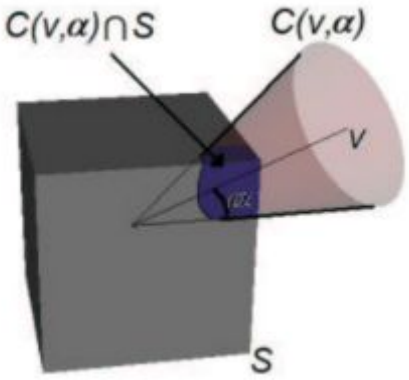


Figure 5. Visualization of the Radial Variance for a cube. (Source: Kazhdan M., Funkhouser T., Rusinkiewicz S., 2003. Rotation invariant spherical harmonic representation of 3D shape descriptors.).

Related literature

Convex Hull

Alpha Shape

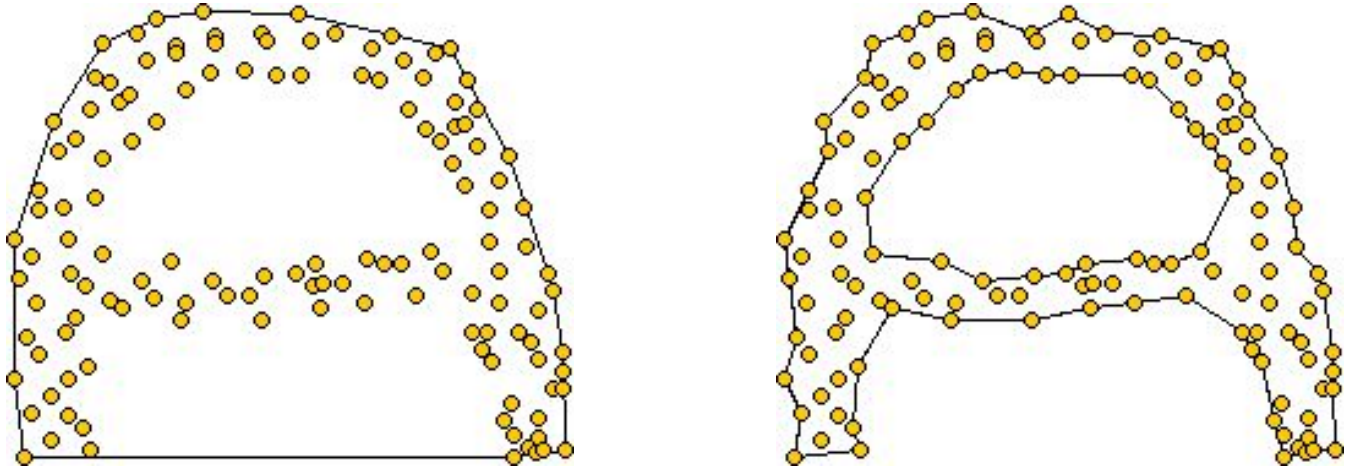
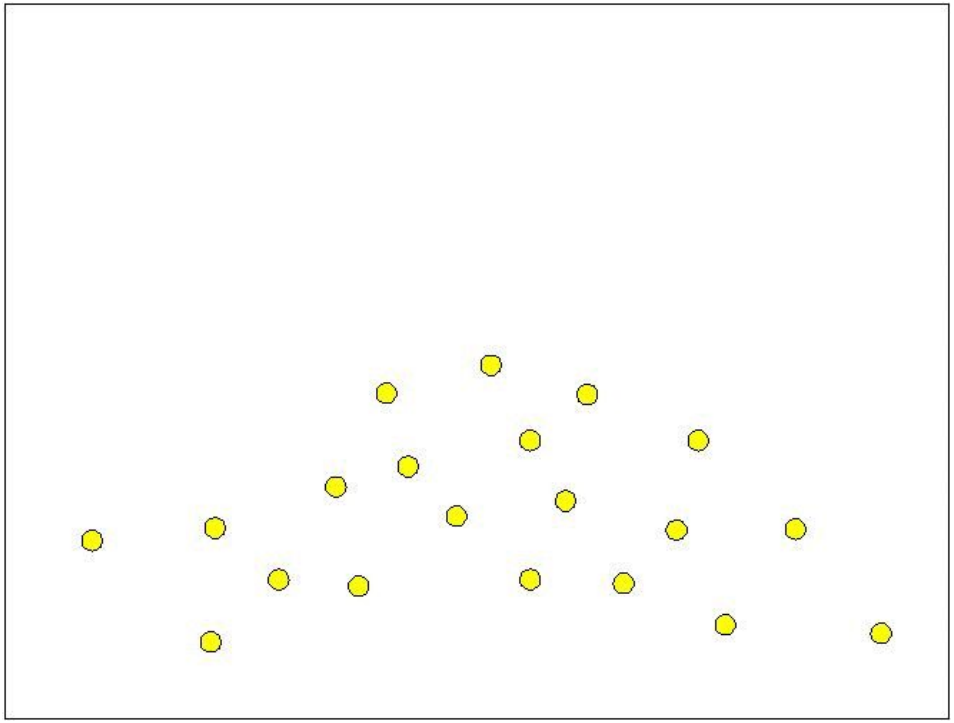
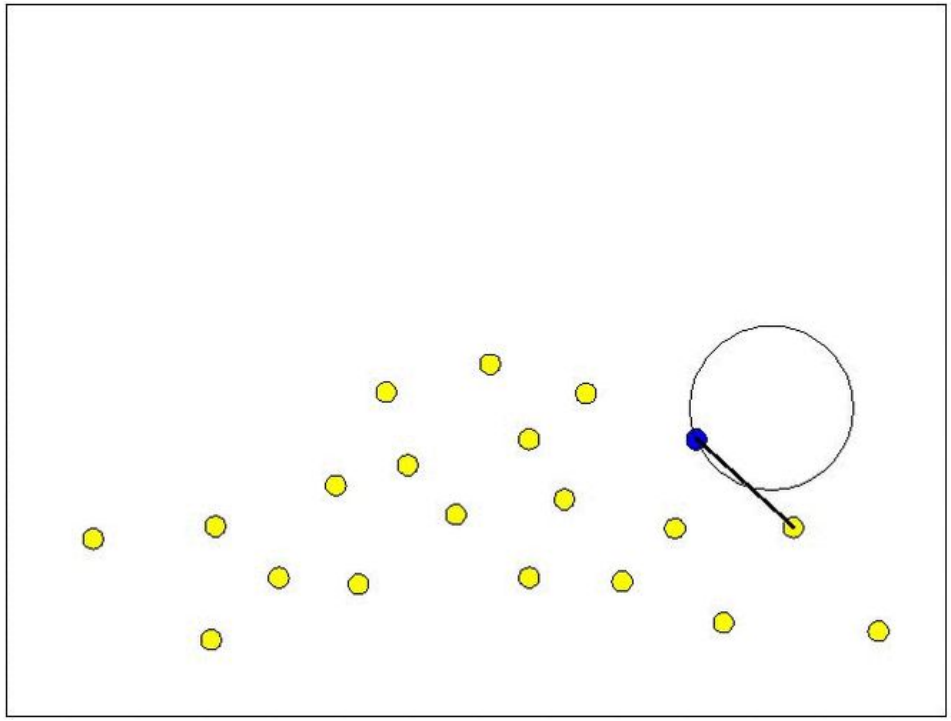


Figure 6. Convex Hull and Alpha Shape
(source: http://cgm.cs.mcgill.ca/~godfried/teaching/projects97/belair/alpha.html).

Alpha Shapes algorithm



Alpha Shapes algorithm



Alpha Shapes algorithm

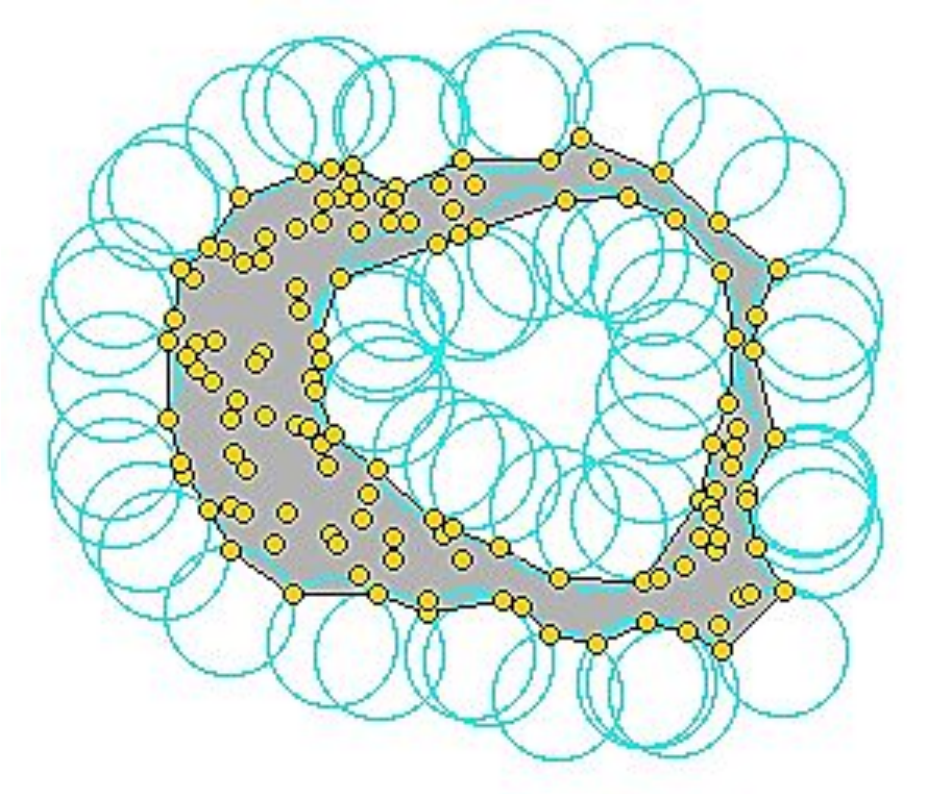


Figure 7. *Alpha shapes extracting principle.*
(Source: Shen Wei, 2008. Building Boundary Extraction Based on LiDAR Point Clouds Data.)

Methodology

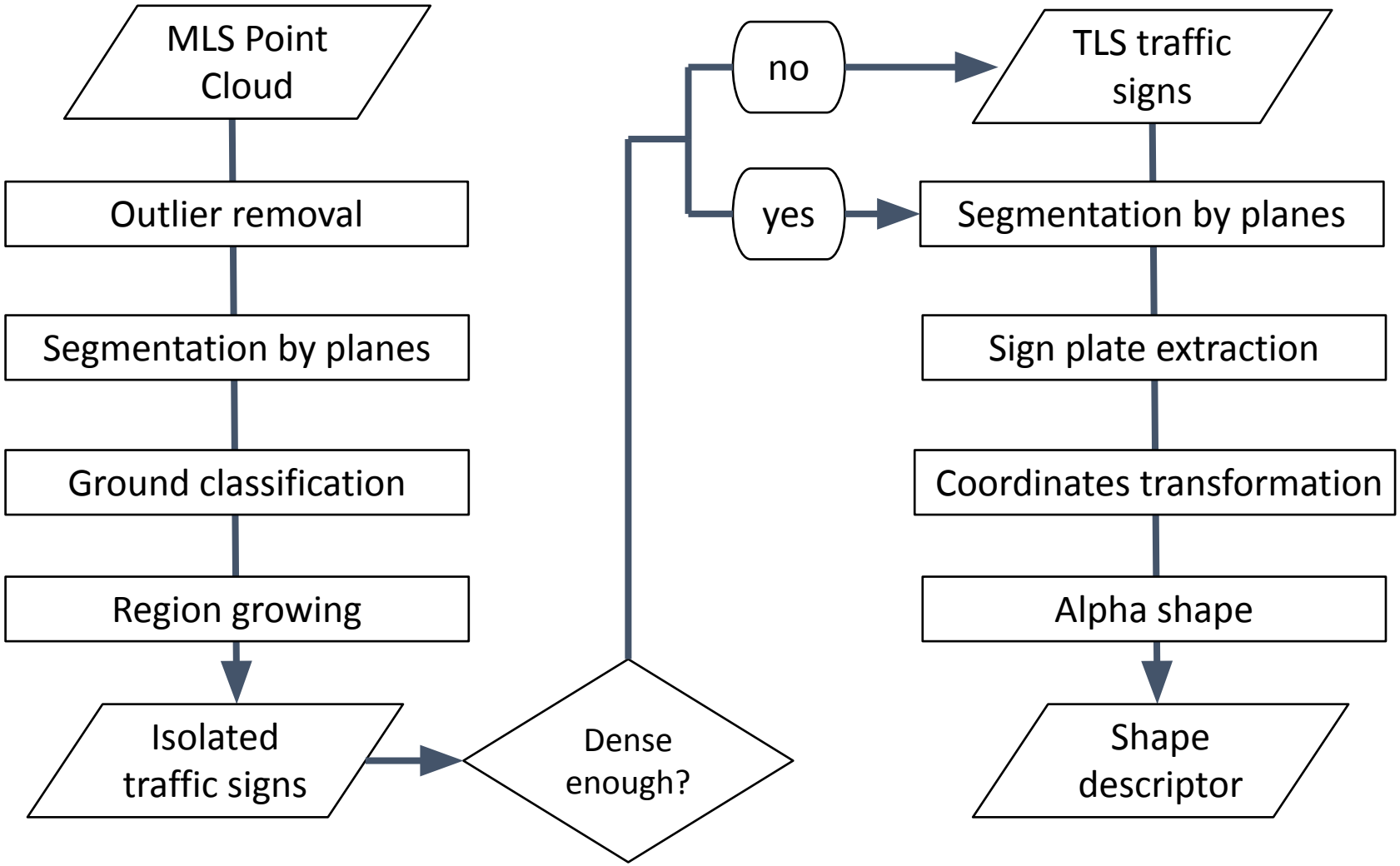
- **Remove ground points**
- **Extract pole-like objects**

MLS

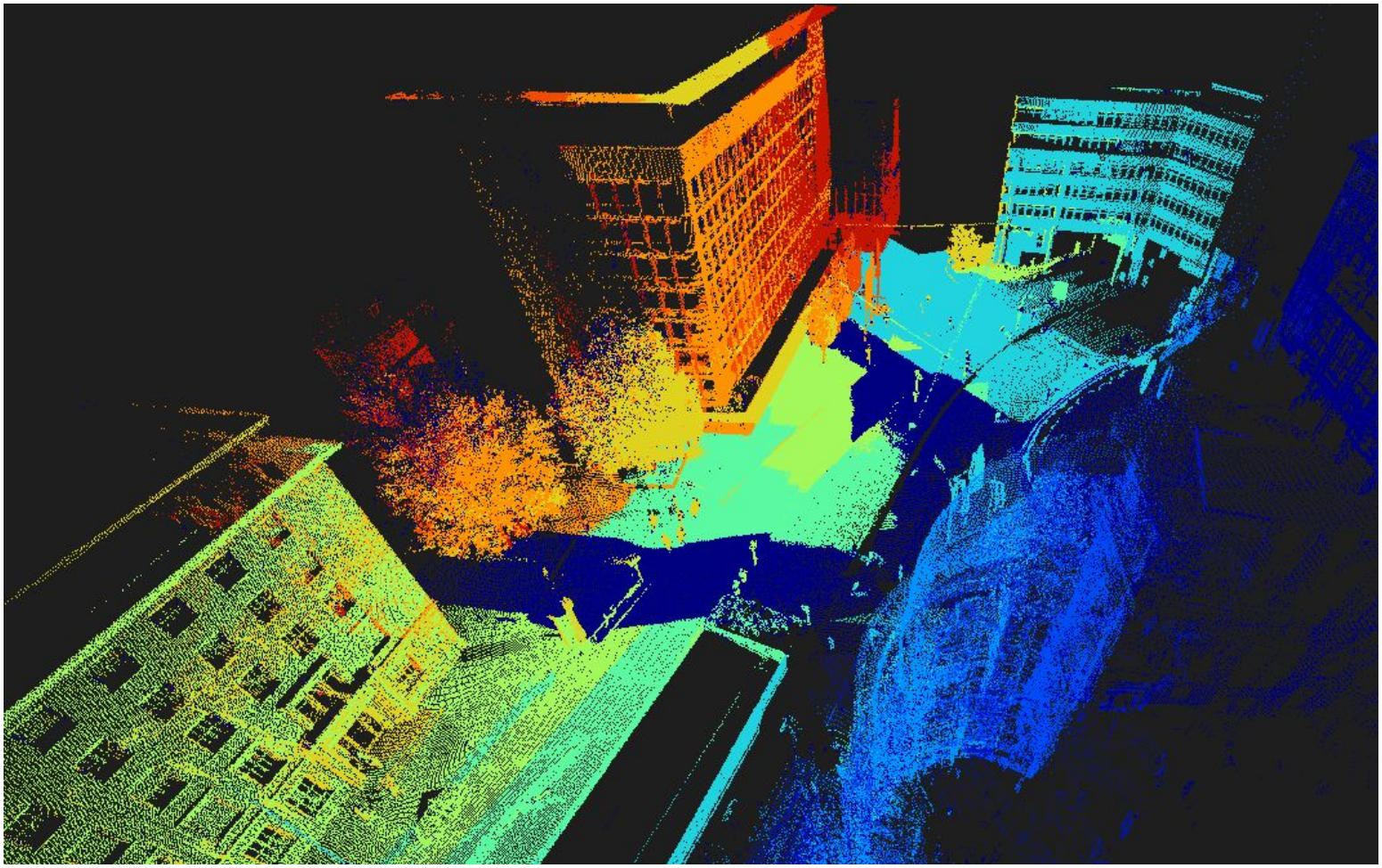
- **Separate plates from poles**
- **Purge redundant points**
- **Develop Shape Descriptor**

TLS

Methodology

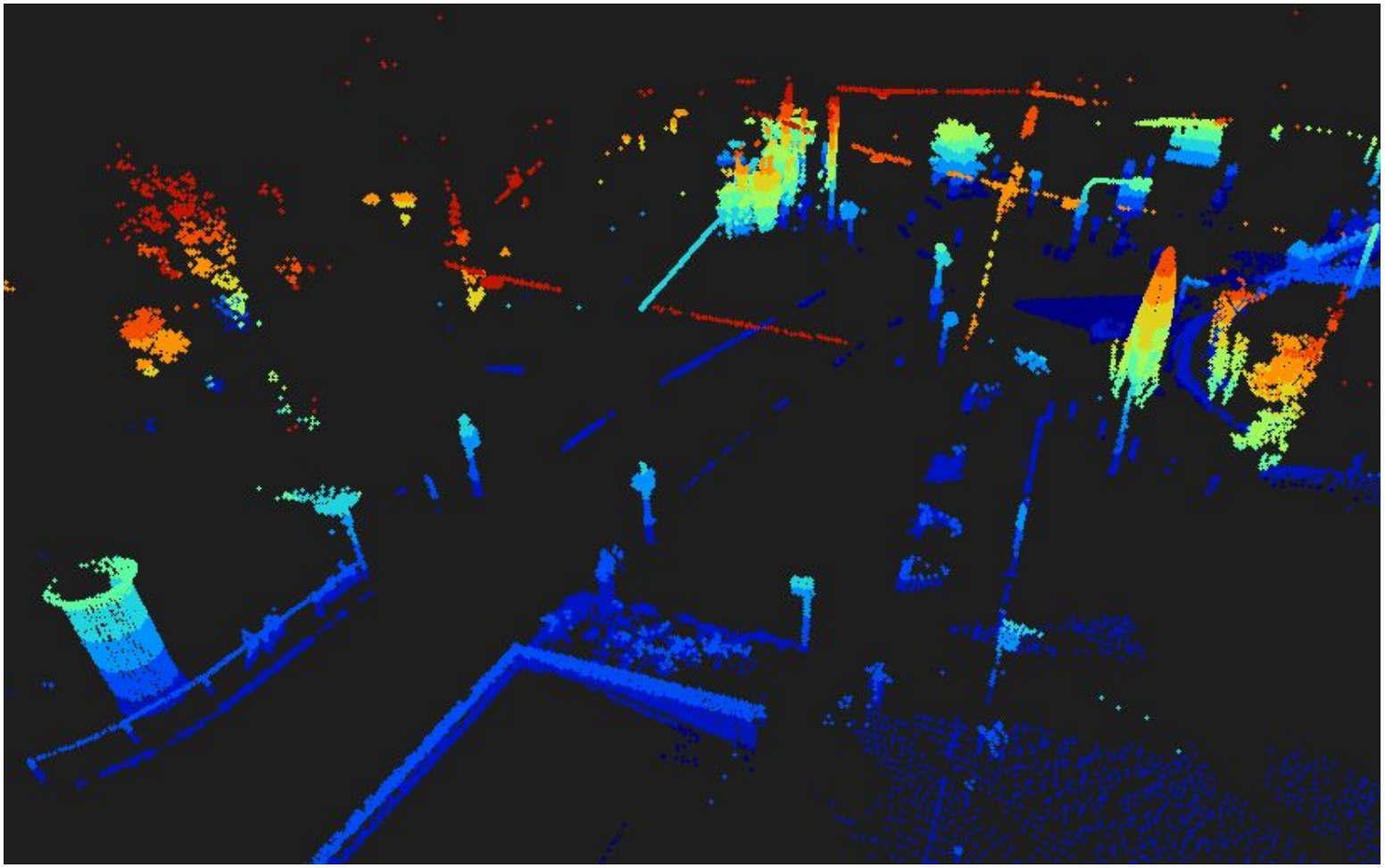


Implementation and results



Segmentation by planes

Implementation and results



Z Variance < 4m

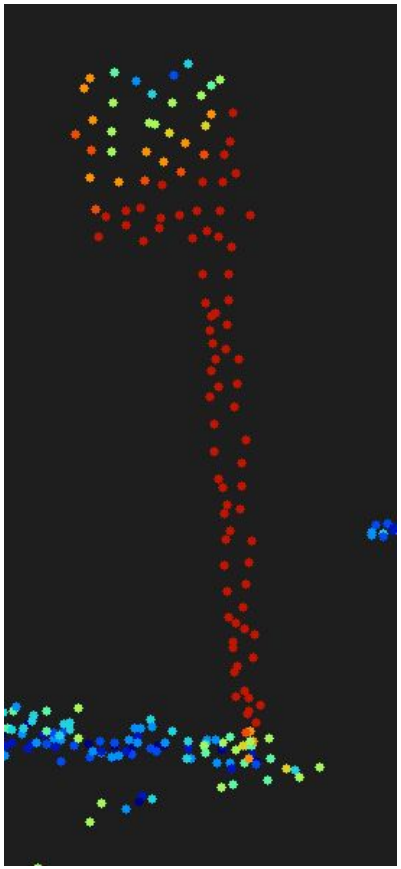
Implementation and results

Region Growing

- Seed Point features:
  High Linearity + Vertical Angle

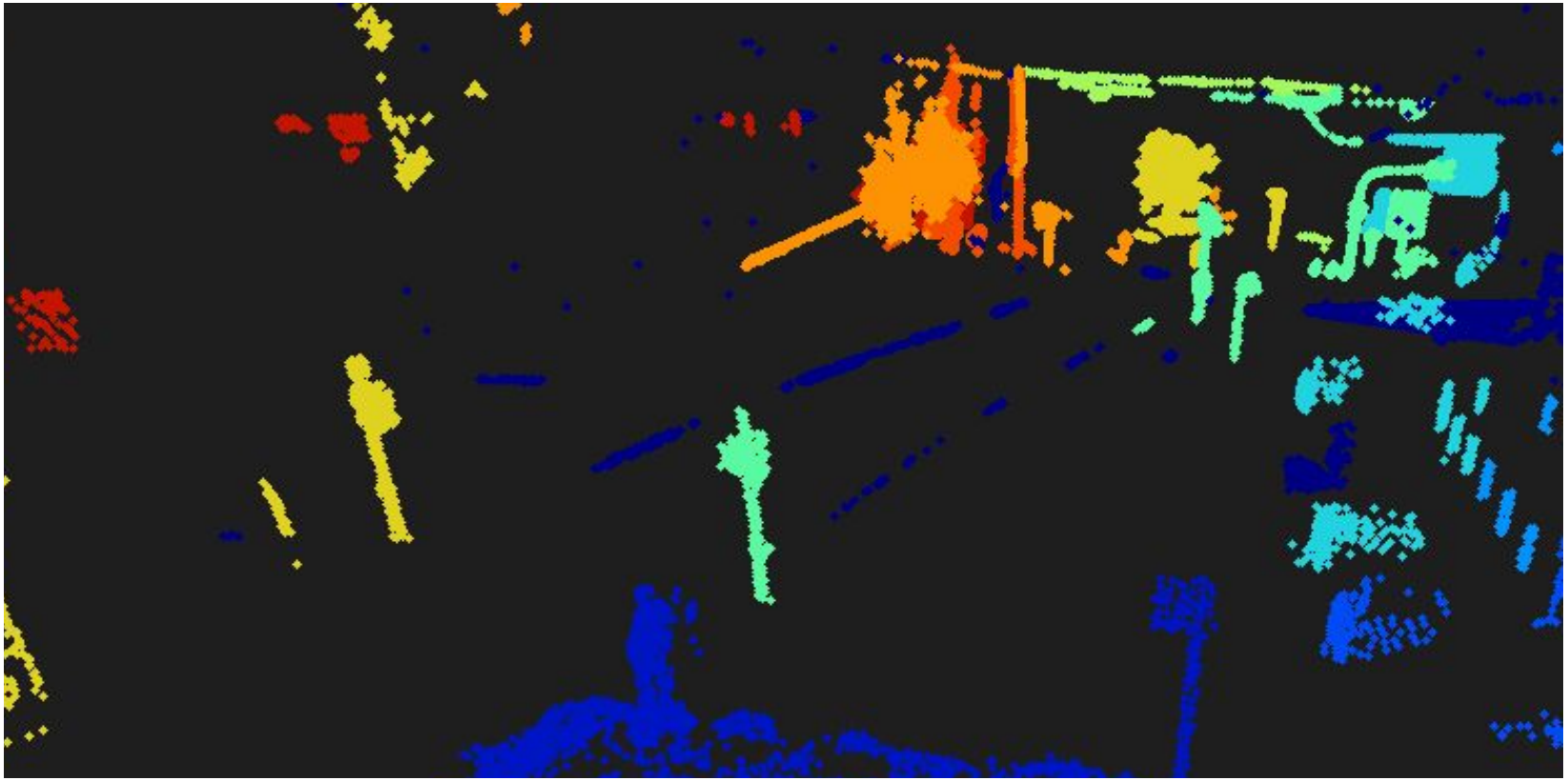
  Linearity: 80 … 100 %
  Vertical Angle: 80° … 90°
  Seed Point = Lin + VA > 160

- Search Radius:
  1.8 … 2.0 m



Seed Points: vertical elongated objects

Implementation and results

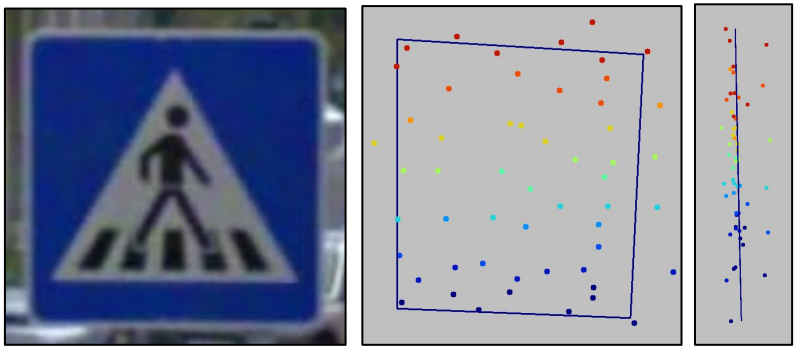


Detection of pole-like objects

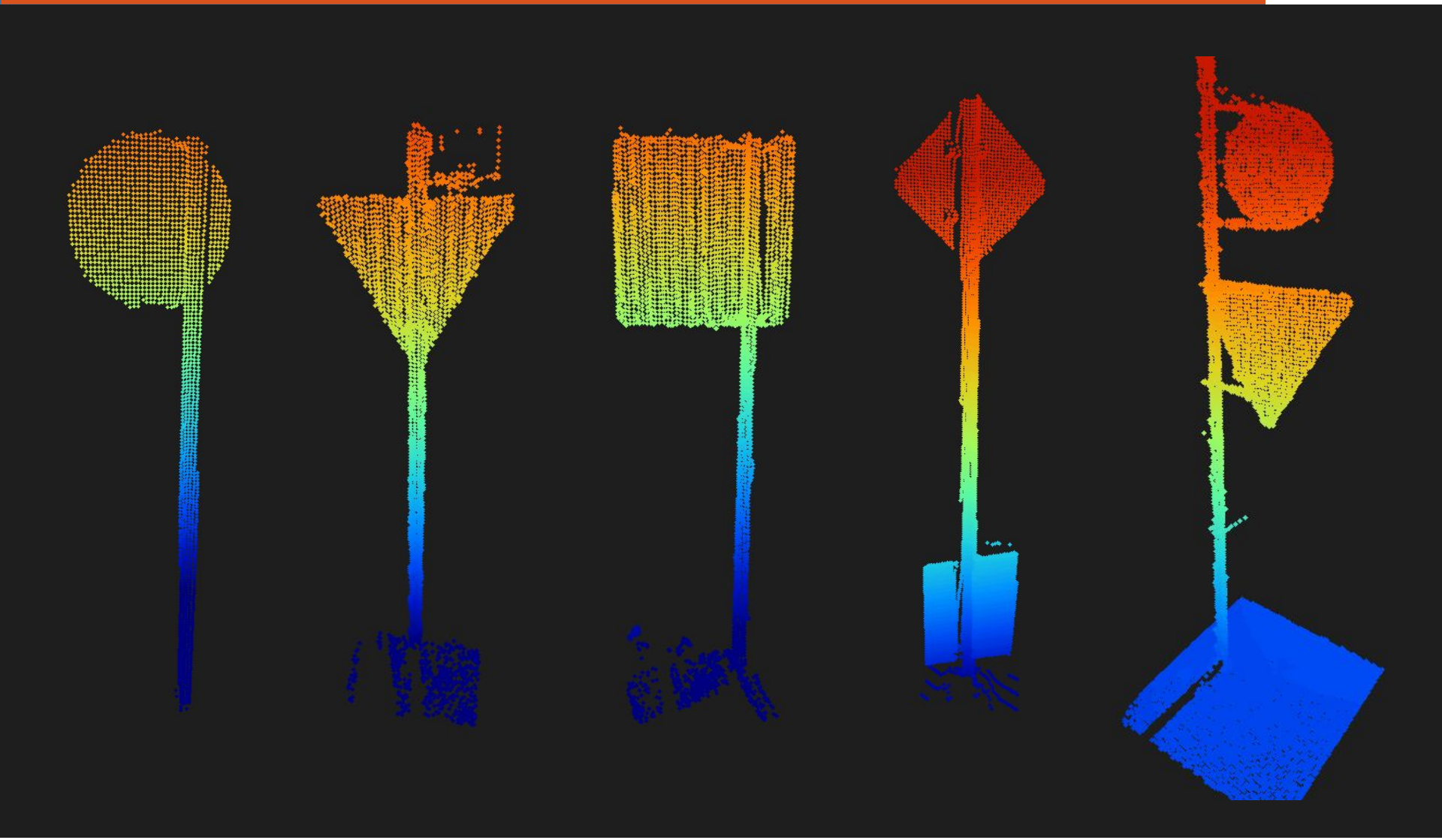
Implementation and results

Traffic signs' shapes from MLS Point Cloud

- Not sufficient point density !



Implementation and results



Signs taken with Terrestrial Laser Scanner (TLS)

Implementation and results

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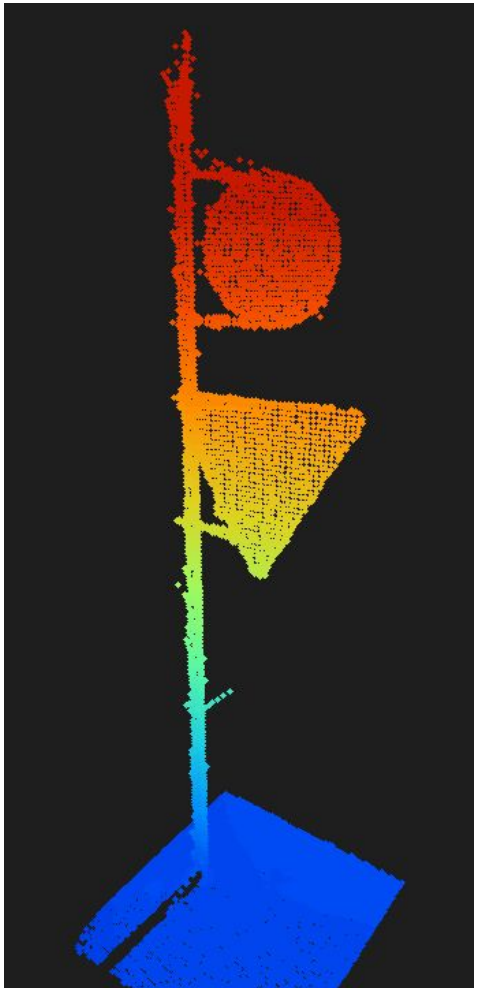
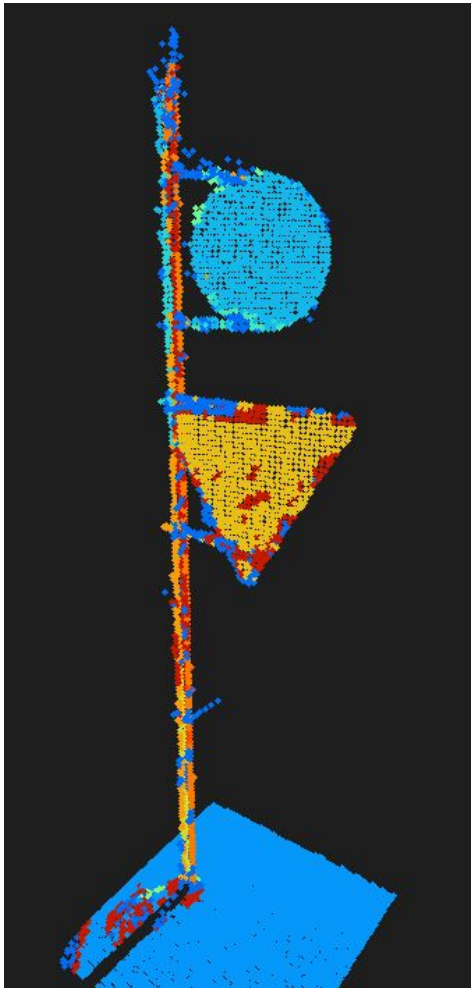
Segmentation by planes



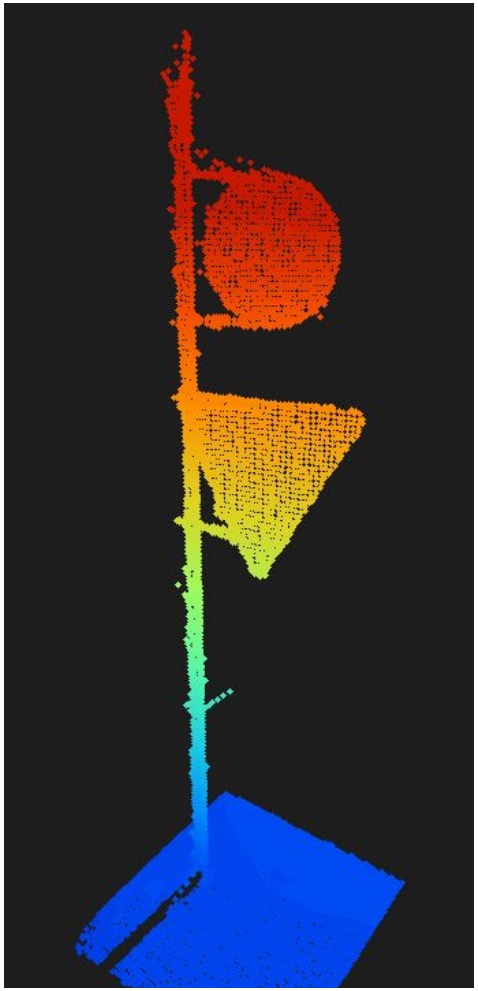
Z - coded

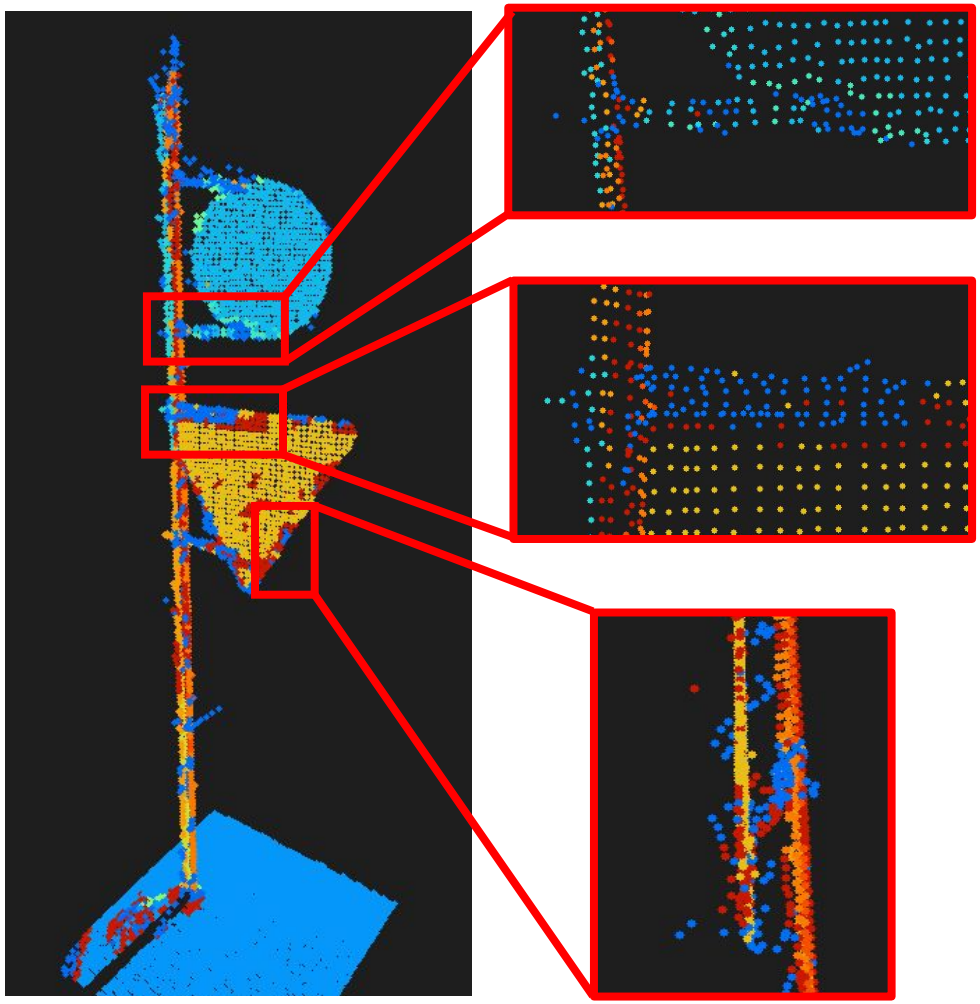


Segment ID

Implementation and results

Segmentation by planes





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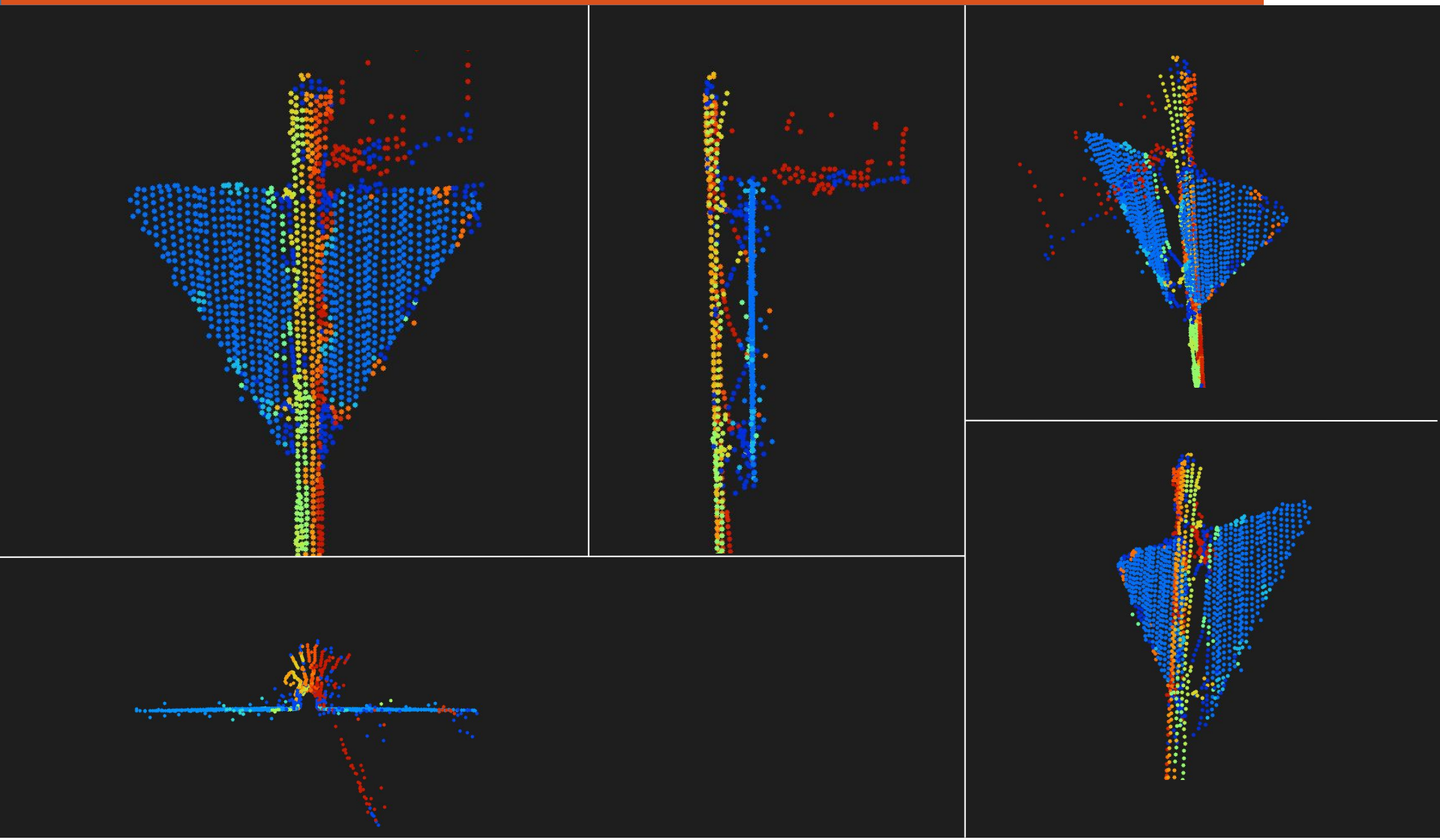
Segment ID

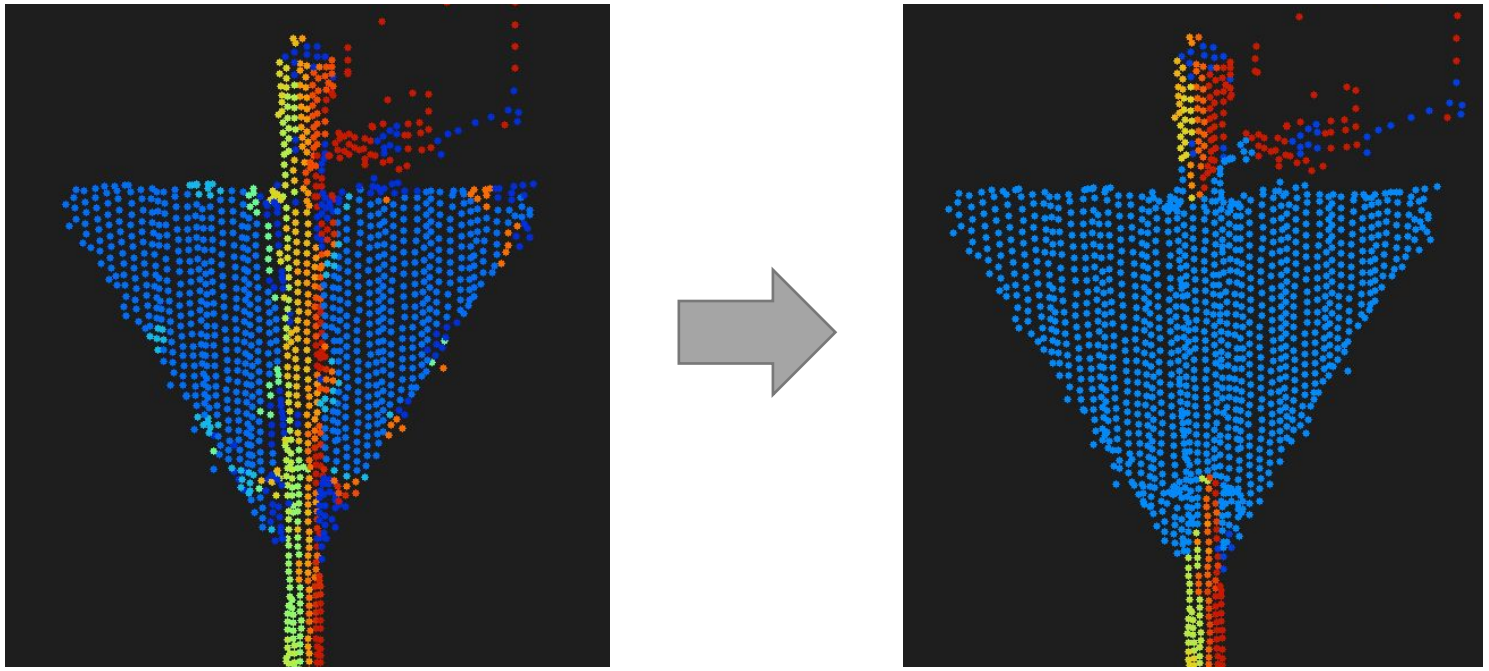
Implementation and results



Segment ID

Implementation and results

Assigning adjacent points to the segment

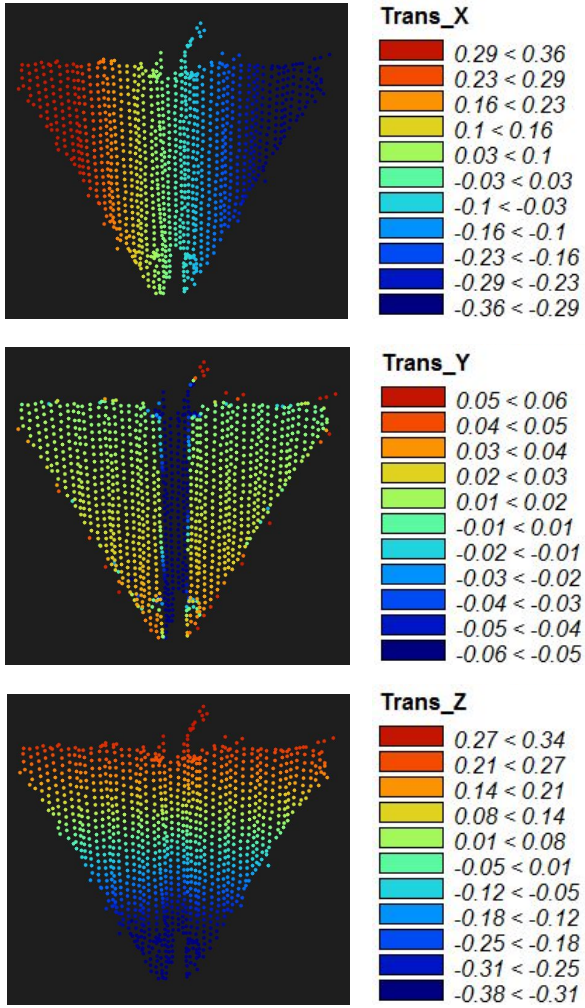


- **Search in neighborhood around segment points**
- **Within radius *R* take the points into the segment**
- **Assign segment features to the captured points**

Implementation and results

Local coordinates transformation

- **Extract the class**
- **Considering [X Y Z] and [Nx Ny Nz] transform to [Trans_X Trans_Y Trans_Z] with a local coordinate system**
- **Read [Trans_X Trans_Z]**



Implementation and results

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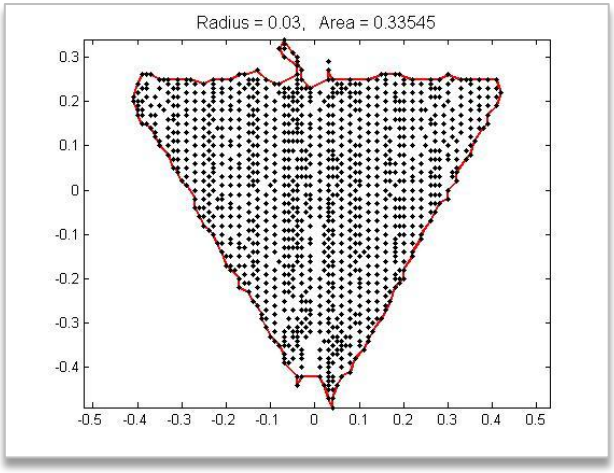
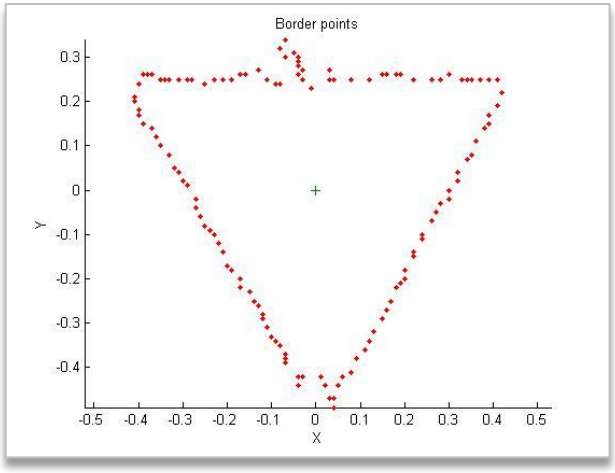
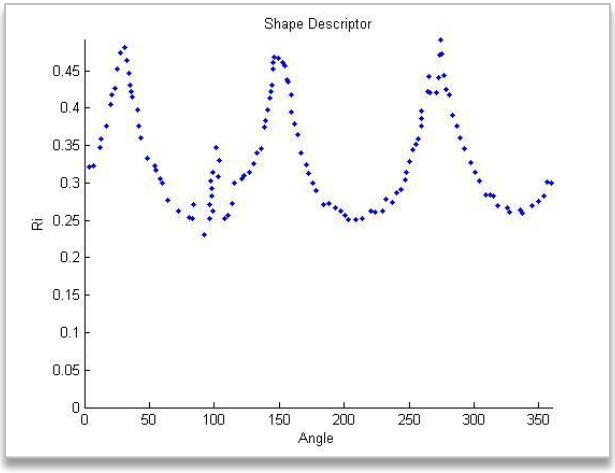
Alpha Shape and Shape Descriptor







- **Alpha shape**
- **Extract border points**
- **Find center of mass (x_0, y_0)**
- **Find spherical coordinates of *Pi***
- **Shape descriptor (r_i, α_i)**

Implementation and results

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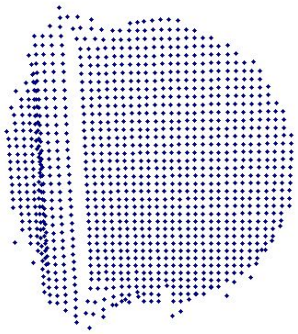
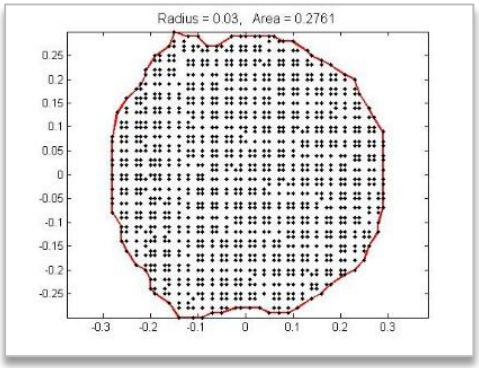
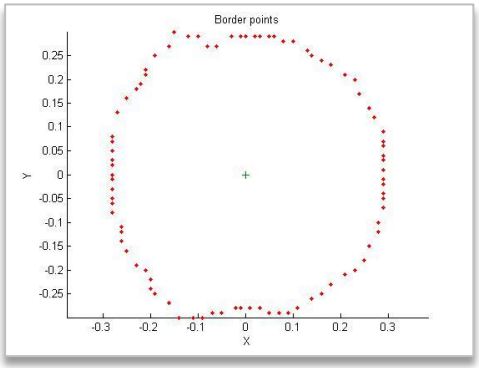
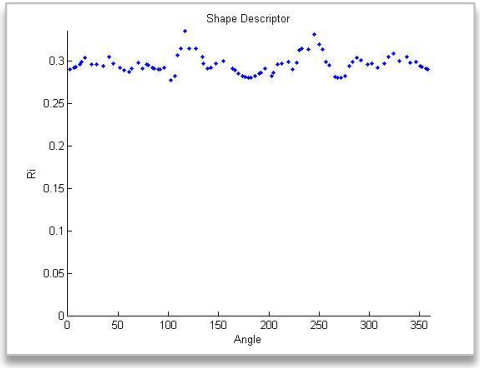
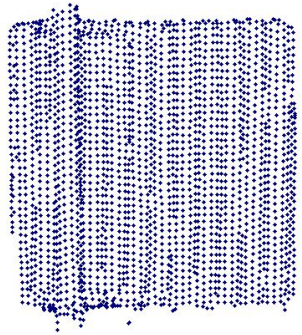
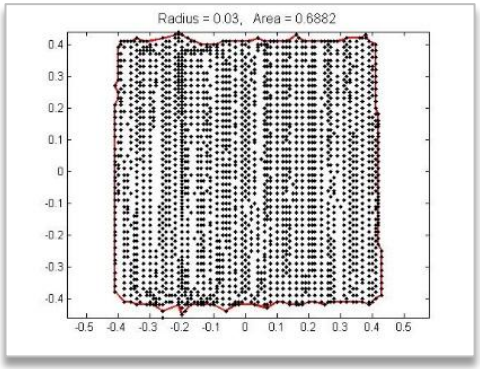


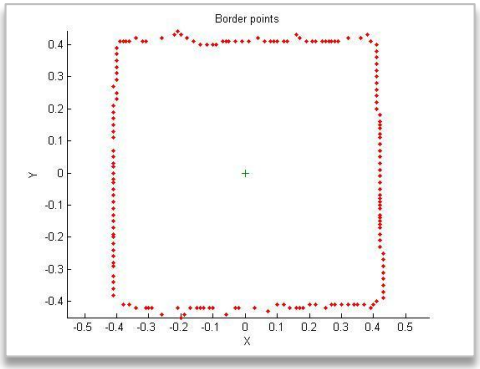


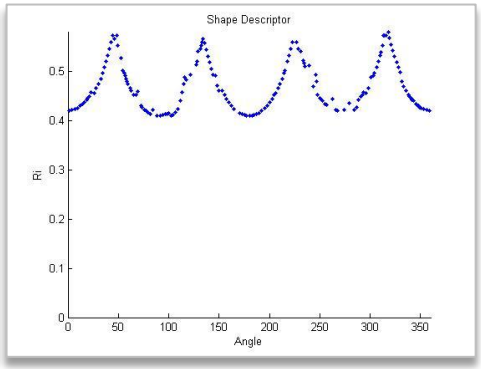


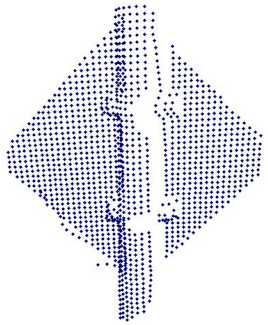


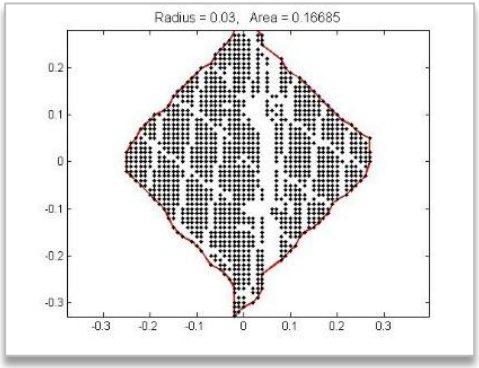


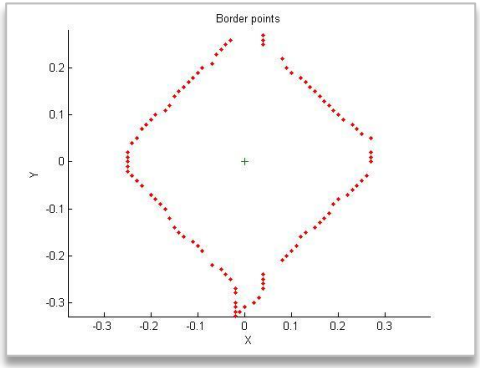


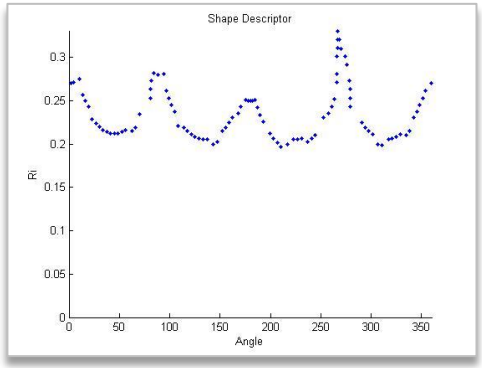




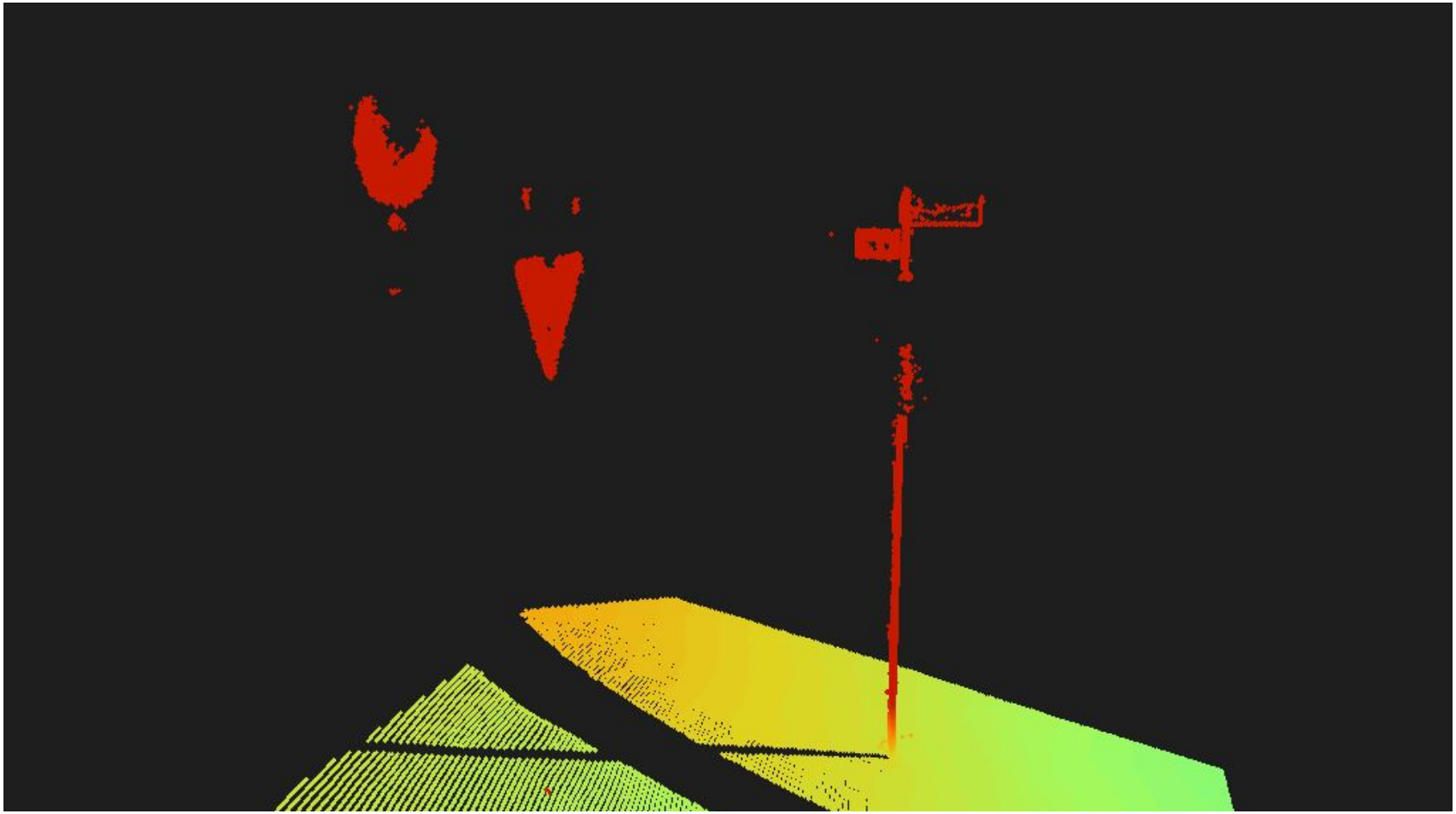








Discussion



Range errors in capturing of a traffic sign

Capturing of retro-reflective materials

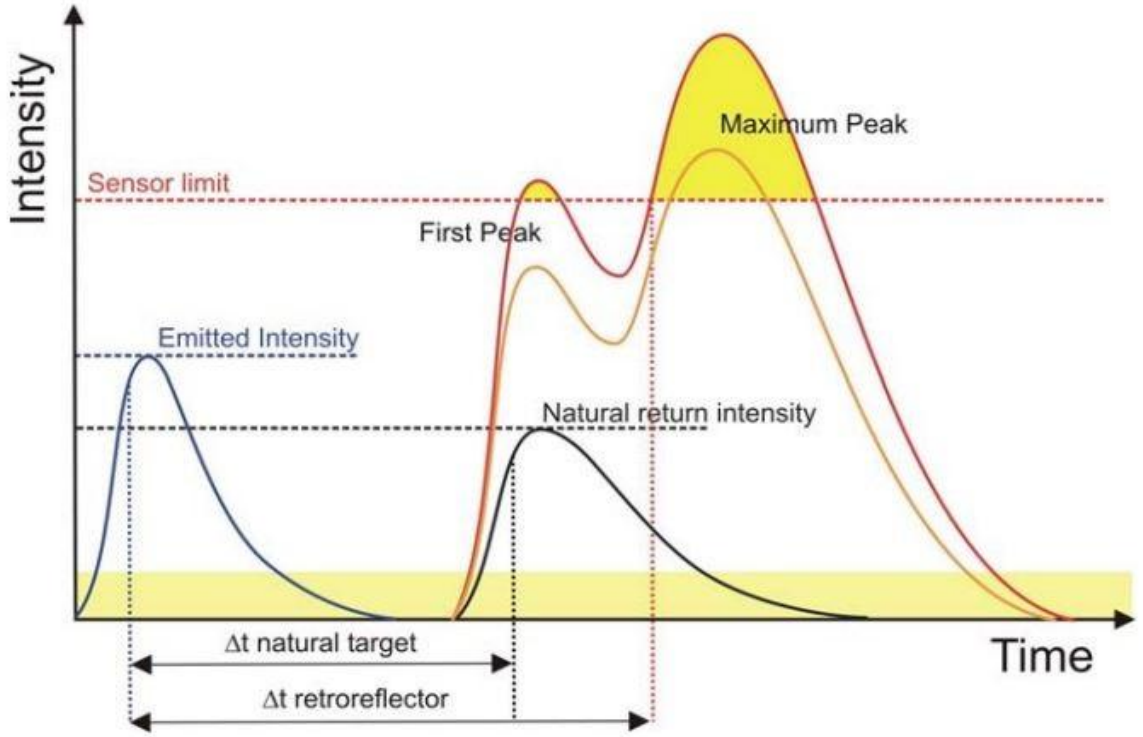


Figure 4. Hypothesis for a modified pulse waveform reflected from retro-reflective materials. (Source: Pesci, A.; Teza, G., 2008. Terrestrial laser scanner and retro-reflective targets: An experiment for anomalous effects investigation.)

Discussion

Shape Descriptor for complex signs