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COLLEGE OF ENGINEERING | School of Civil and Construction Engineering

# Automated Inventory of Pedestrian Crosswalks, Bike Lanes, and Medians from Mobile Lidar Data

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Oregon Department of Transportation

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NORTHWEST TRANSPORTATION CONFERENCE NWTC

# DISCLAIMER

*Drs. Olsen and Che have financial interests in the company EzDataMD LLC, and commercialization of technology involving point cloud data processing. The conduct, outcomes, or reporting of this research could benefit EzDataMD LLC and could potentially benefit me.*

# Project Overview - Background

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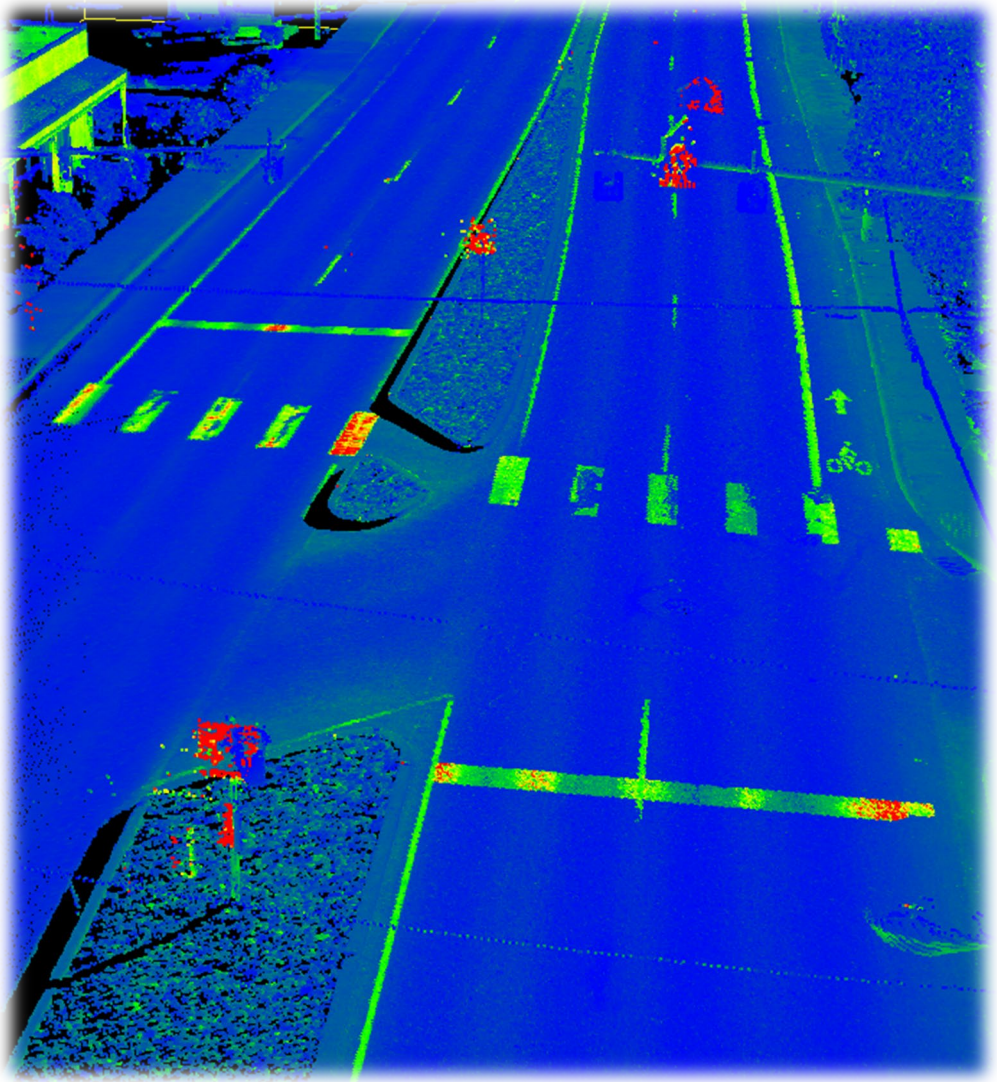
- Pedestrian crosswalks, bike lanes, and medians are important traffic devices for safety
- Currently, there is no comprehensive statewide map of the locations and types (e.g., midblock crossing) of these assets
- Such a map would be very useful for planning, maintenance, systematic safety studies, and many types of network analyses that are important to ODOT and its partner agencies at the local level.
- ODOT Geometronics collects 3D mobile lidar data on a two-year cycle, providing rich geometric and radiometric information of the entire road network



Lidar data color-ramped by intensity

# Project Overview - Objectives

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- Investigate state-of-the-art **machine learning and object segmentation** algorithms for extraction of transportation assets from mobile lidar and photogrammetric data.

- Develop procedures for extracting **pedestrian crosswalks, bike lanes, and medians** from Oregon DOT's mobile lidar data.

- Test results for **several pilot corridors** identifying the locations of bike lanes, crosswalks, and medians to support decision making and integrate data analysis results into Oregon DOT's overall workflows.

- **Document benefits (e.g., time or cost savings, inventory completeness, and improved accuracy)** associated with the developed approaches compared with current processes.

# Previous work

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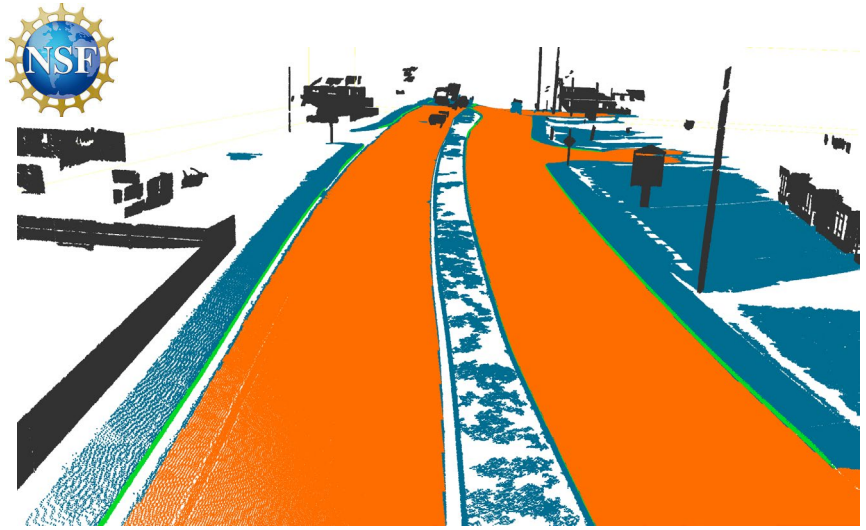
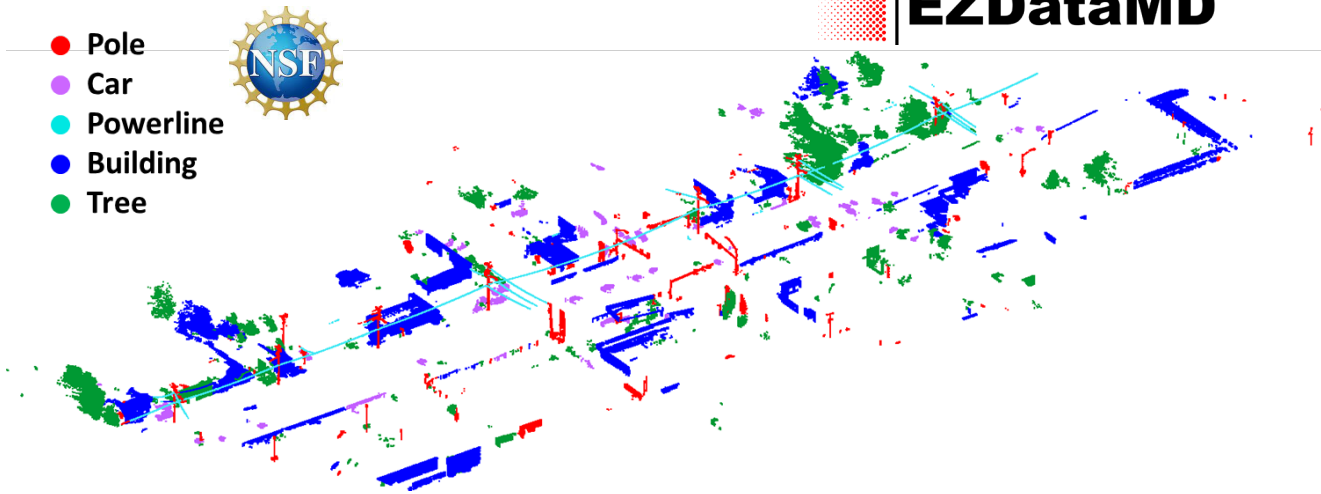
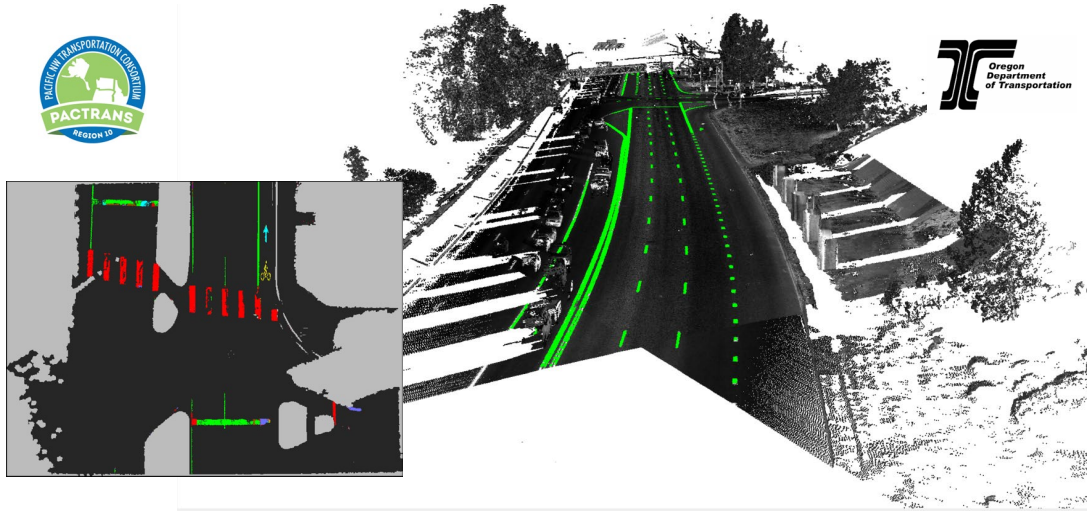
EZDataMD



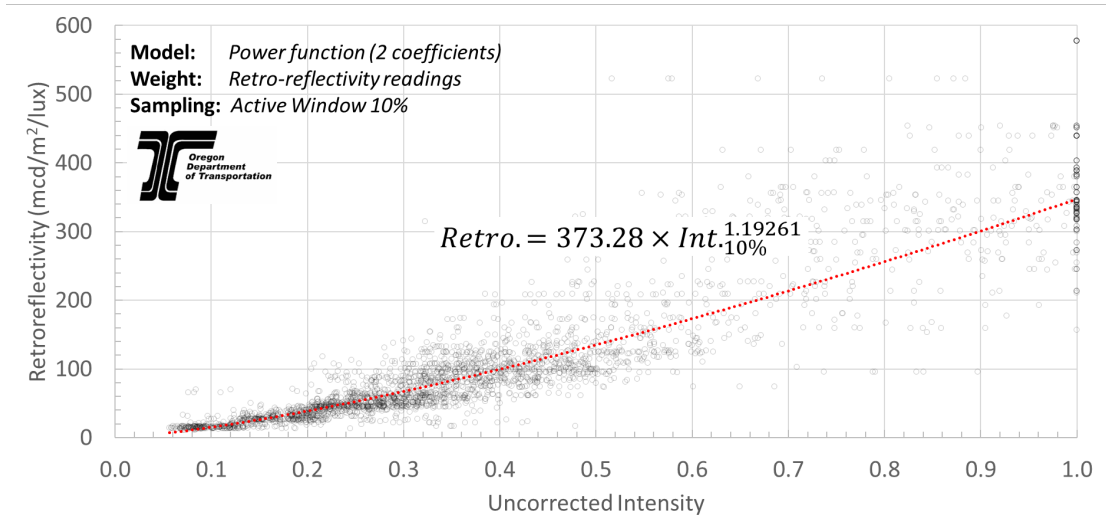
NSF Road and curb detection



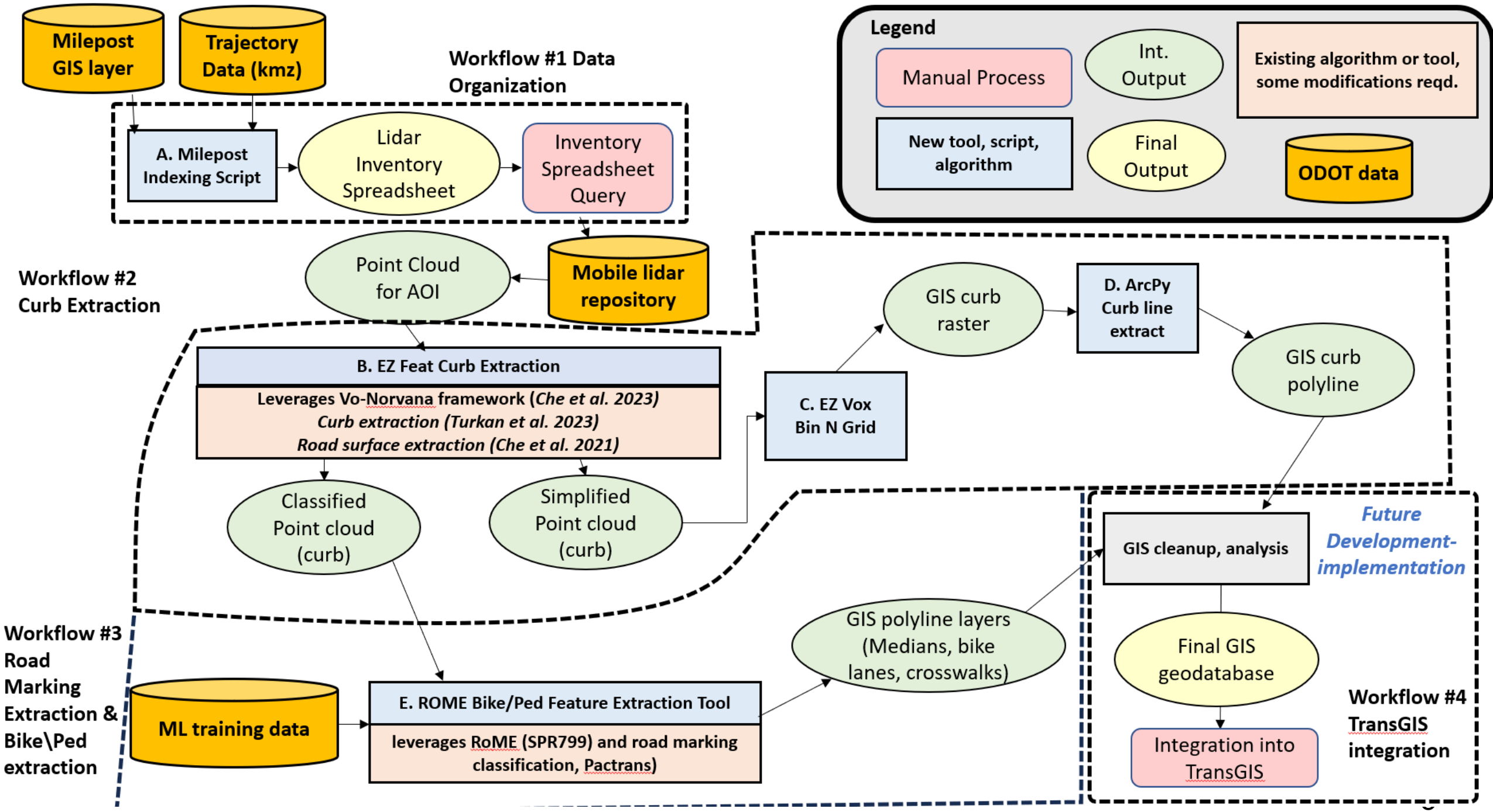

NSF urban object classification



ODOT / PacTrans ROME v1 and v2




ODOT Retroreflectivity evaluation


Milepost GIS layer
Trajectory Data (kmz)
Workflow #1 Data Organization
A. Milepost Indexing Script
Lidar Inventory Spreadsheet
Inventory Spreadsheet Query
Legend
Manual Process
Int. Output
Existing algorithm or tool, some modifications reqd.
New tool, script, algorithm
Final Output
ODOT data
Workflow #2 Curb Extraction
Point Cloud for AOI
Mobile lidar repository
B. EZ Feat Curb Extraction
Leverages Vo-Norvana framework (Che et al. 2023)
Curb extraction (Turkan et al. 2023)
Road surface extraction (Che et al. 2021)
Classified Point cloud (curb)
Simplified Point cloud (curb)
C. EZ Vox Bin N Grid
GIS curb raster
D. ArcPy Curb line extract
GIS curb polyline
Future Development-implementation
GIS cleanup, analysis
Final GIS geodatabase
Integration into TransGIS
Workflow #4 TransGIS integration
Workflow #3 Road Marking Extraction & Bike\Ped extraction
ML training data
E. ROME Bike/Ped Feature Extraction Tool
leverages RoME (SPR799) and road marking classification, Pactrans)
GIS polyline layers (Medians, bike lanes, crosswalks)

# Data Labeling

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- 5 sites selected to support the algorithm training and testing
- Started with larger area and narrow down to most relevant sections for data labeling

| Site ID | Location | Setting | Highways | Approximate Length (Miles) | Social Equity Rating (ODOT, 2022) |
|---|---|---|---|---|---|
| 1 | Downtown Salem (Figure 3.2) | Urban | • HWY 221 (MP16–21), • HWY 99EB (MP0-8.5) | 13.5 | Medium-high /high disparity |
| 2 | Tigard and King City (Figure 3.3) | Busy Suburban | • HWY 99W (MP8–13) • HWY 141 (MP2–7) | 10.0 | Medium-high /high disparity |
| 3 | Hillsborough (Figure 3.4) | Less dense suburban with some near rural | • HWY 029 (MP 0–18) • HWY 102 (MP 88–91) | 21.0 | High disparity |
| 4 | Albany (Figure 3.5) | Moderate size city | • HWY 99E (MP0–8) | 8.0 | Medium-high /high disparity |
| 5 | Newport (Figure 3.5) | Small Coastal Community | • HWY 101 (MP 134-140) | 6.0 | Medium-high /high disparity |

# Features

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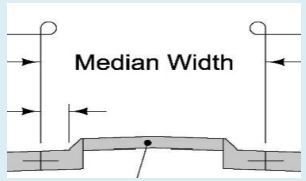
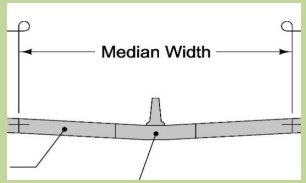
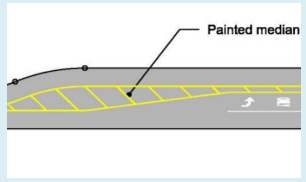
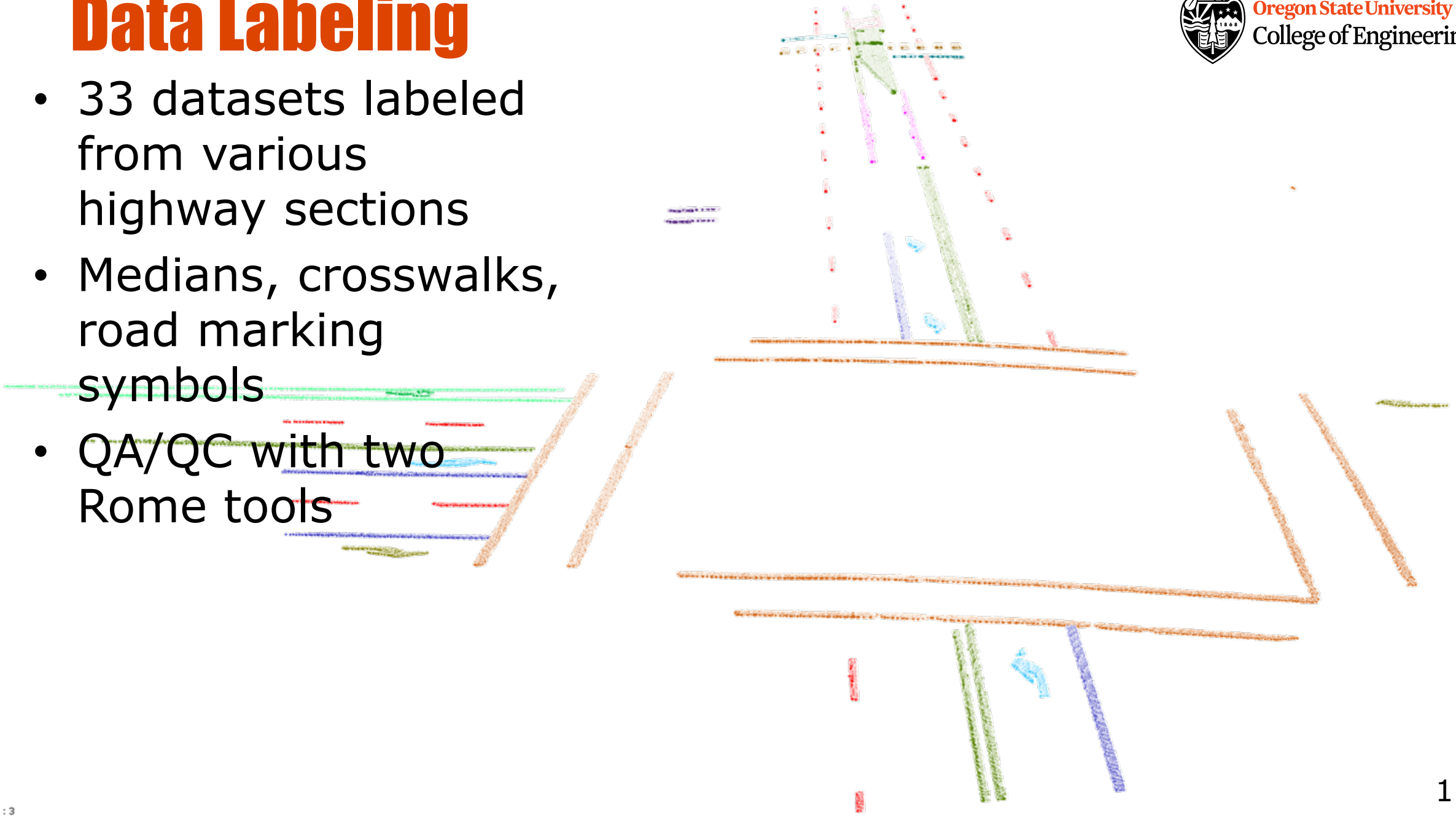
| Crosswalk | | Bikelane | | Median | |
|---|---|---|---|---|---|
| **Standard parallel**  | • Deep learning<br>• Angle constraint<br>• (104) | **Bike symbol**   | • Deep learning<br>• (91) | **Raised**   | • Curb extraction<br>• (29) |
| **Staggered continental**  | • Deep learning<br>• (14) | **Shoulder**  | • Lane marking + curb extraction<br>• (N/A) | **Closed**   | • Norvana segmentation<br>• (0) |
| **Ladder**  | • Deep learning<br>• Angle constraint<br>• Size<br>• (9) | **Buffered**  | • Deep learning<br>• Distinguish from painted median<br>• (0) | **Painted**   | • Deep learning<br>• Distinguish from Buffered bikelane markings<br>• (14) |

High-priority features | Low-priority features

# Data Labeling

- 33 datasets labeled from various highway sections
- Medians, crosswalks, road marking symbols
- QA/QC with two Rome tools



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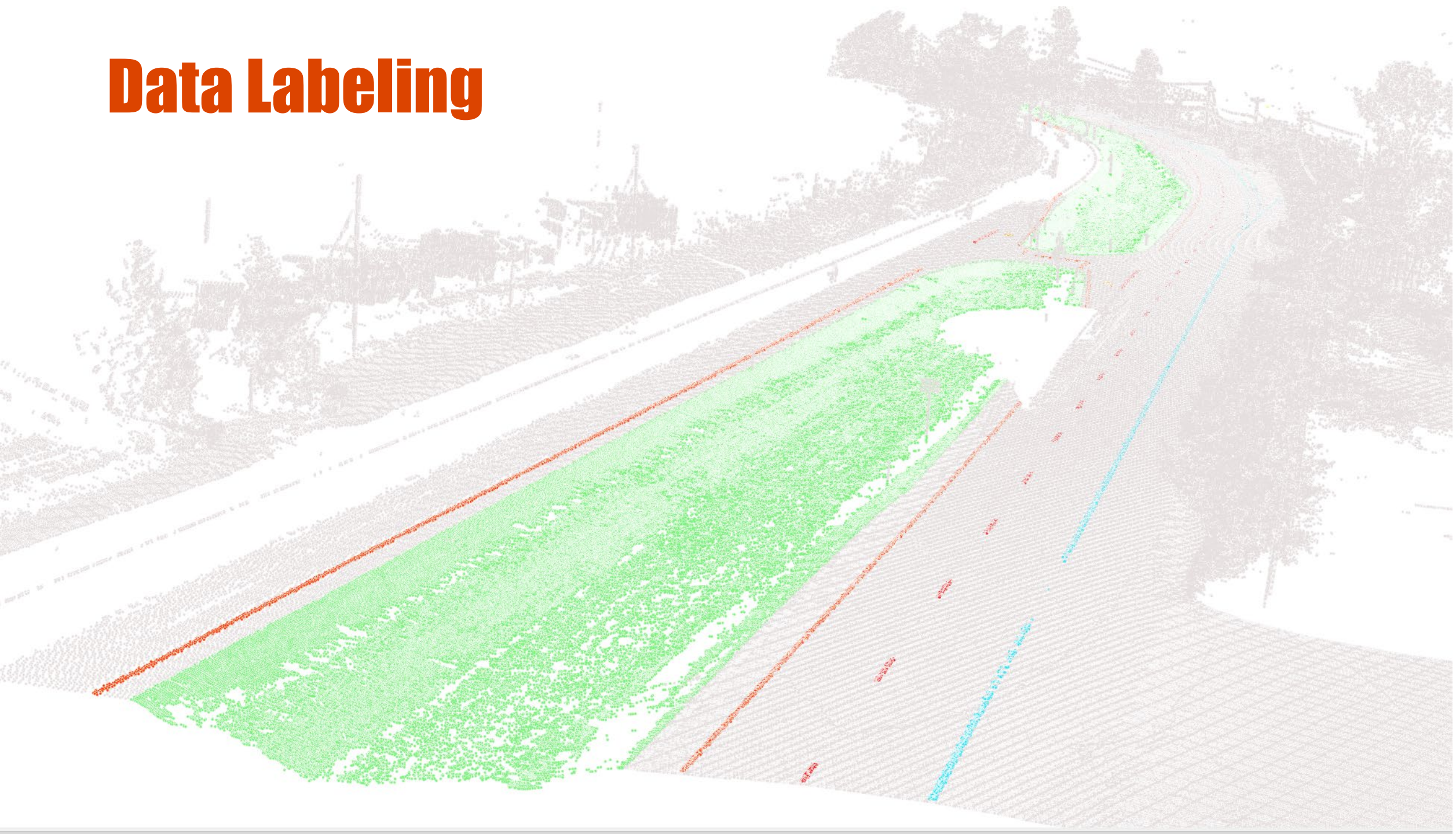
# Data Labeling



# Data Labeling

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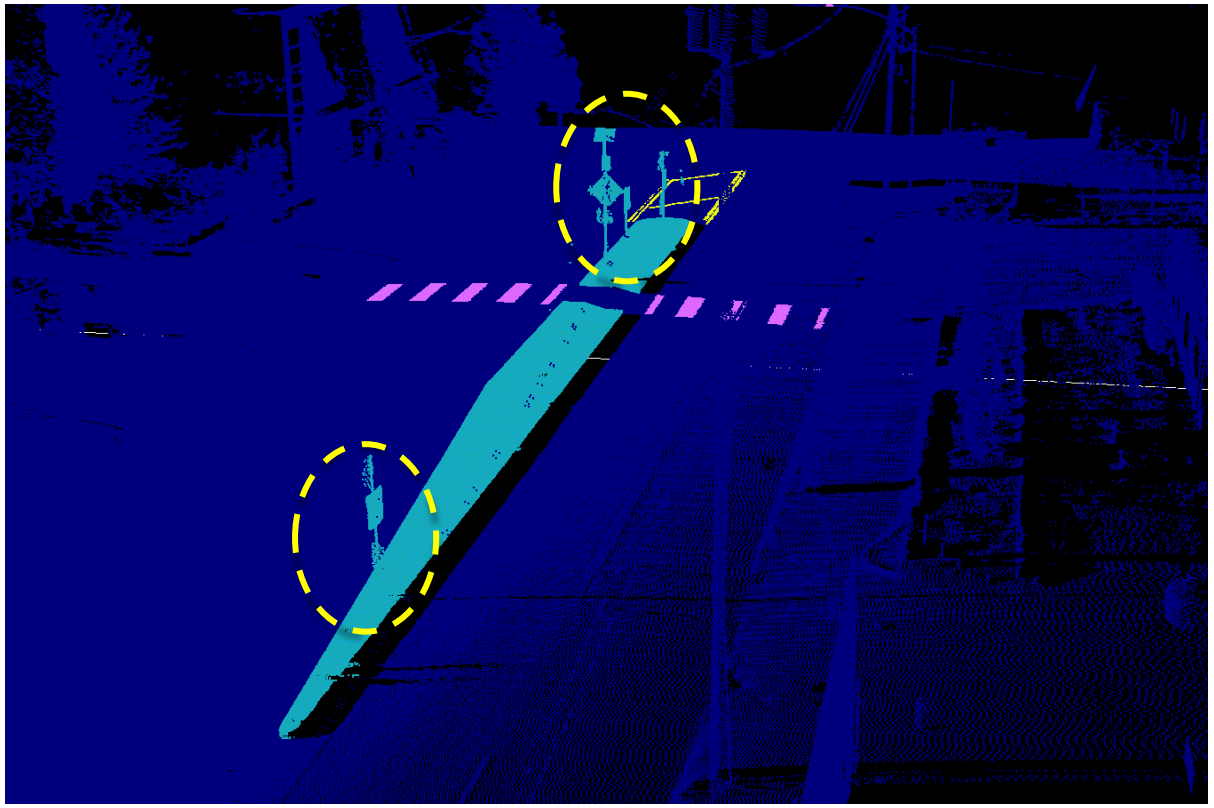

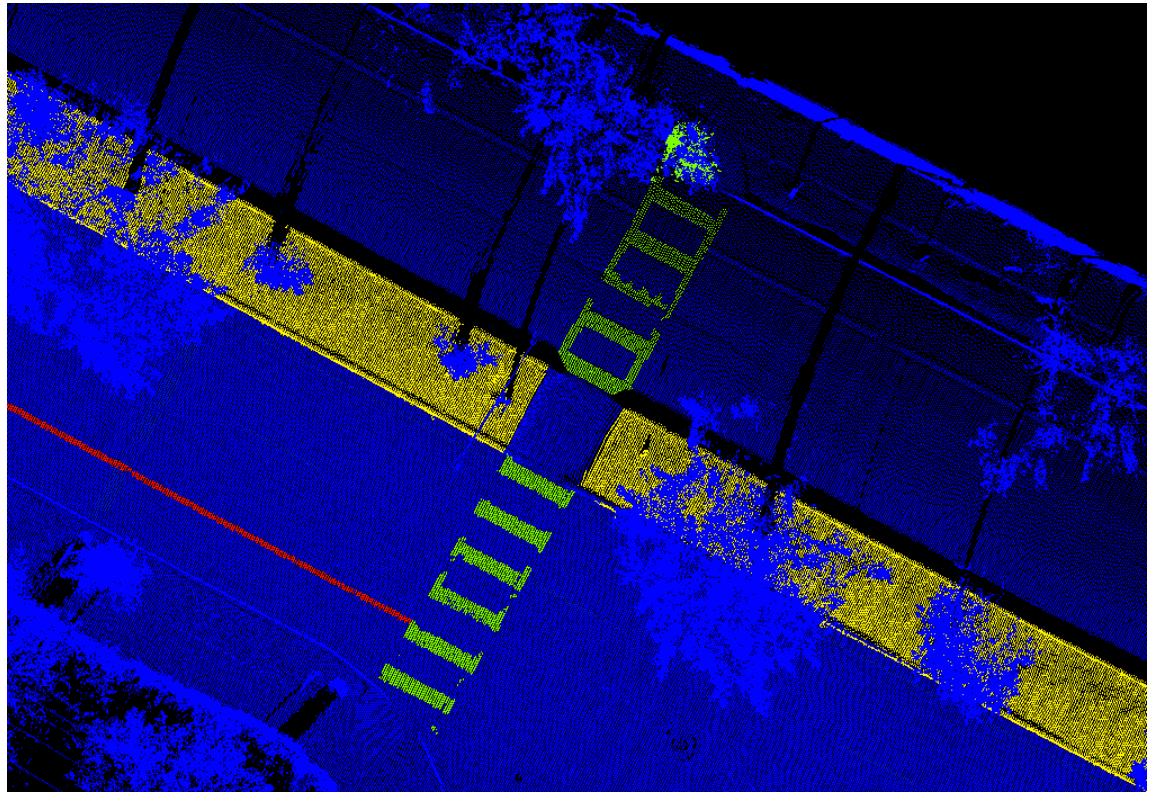

- Fixed issues of labeling done in plan view resulting in signs labeled as medians.
- Added additional datasets to improve samples of objects such as ladder cross walks.

# B-D. Road Surface and Curb Extraction

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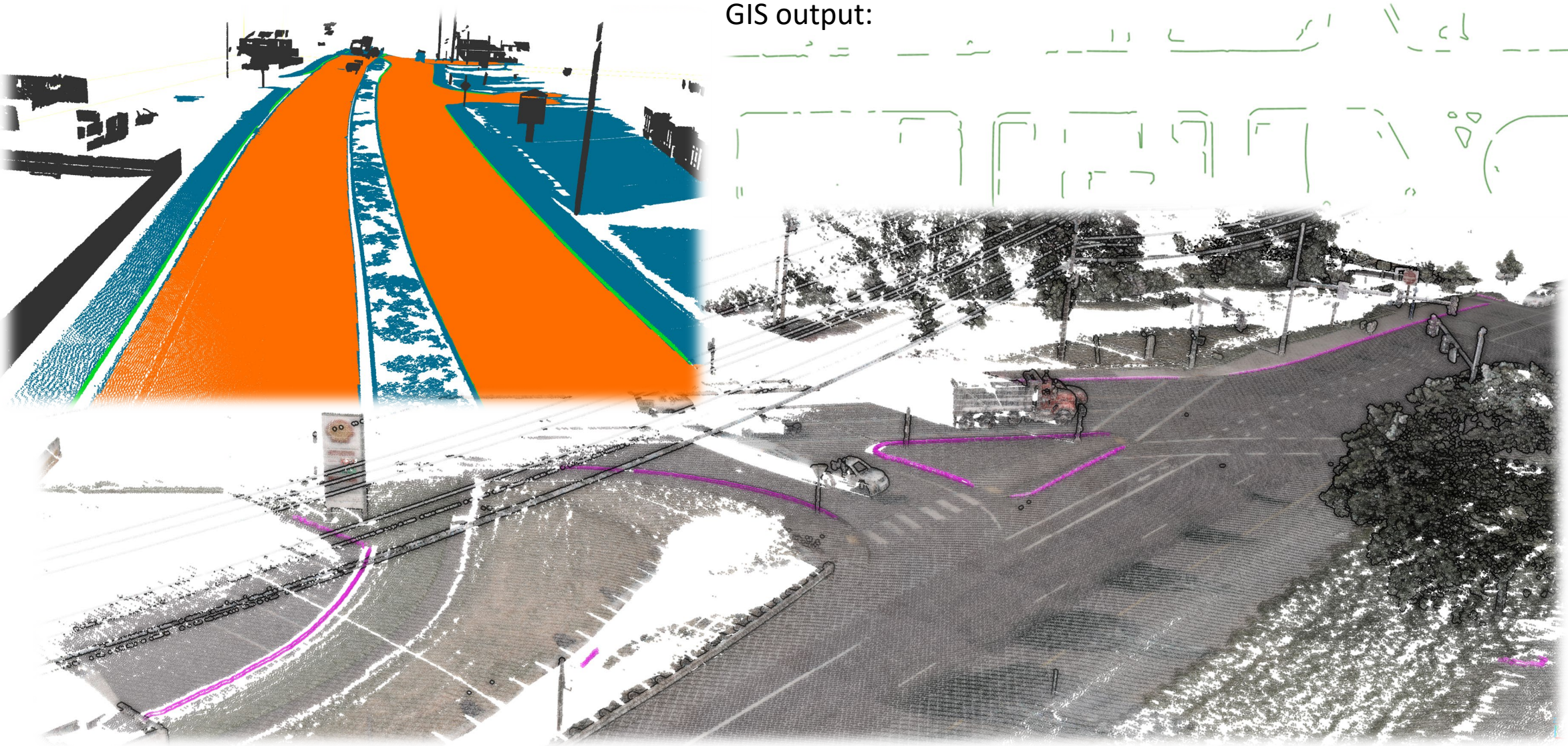
GIS output:



# E. Feature Extraction- Road Markings

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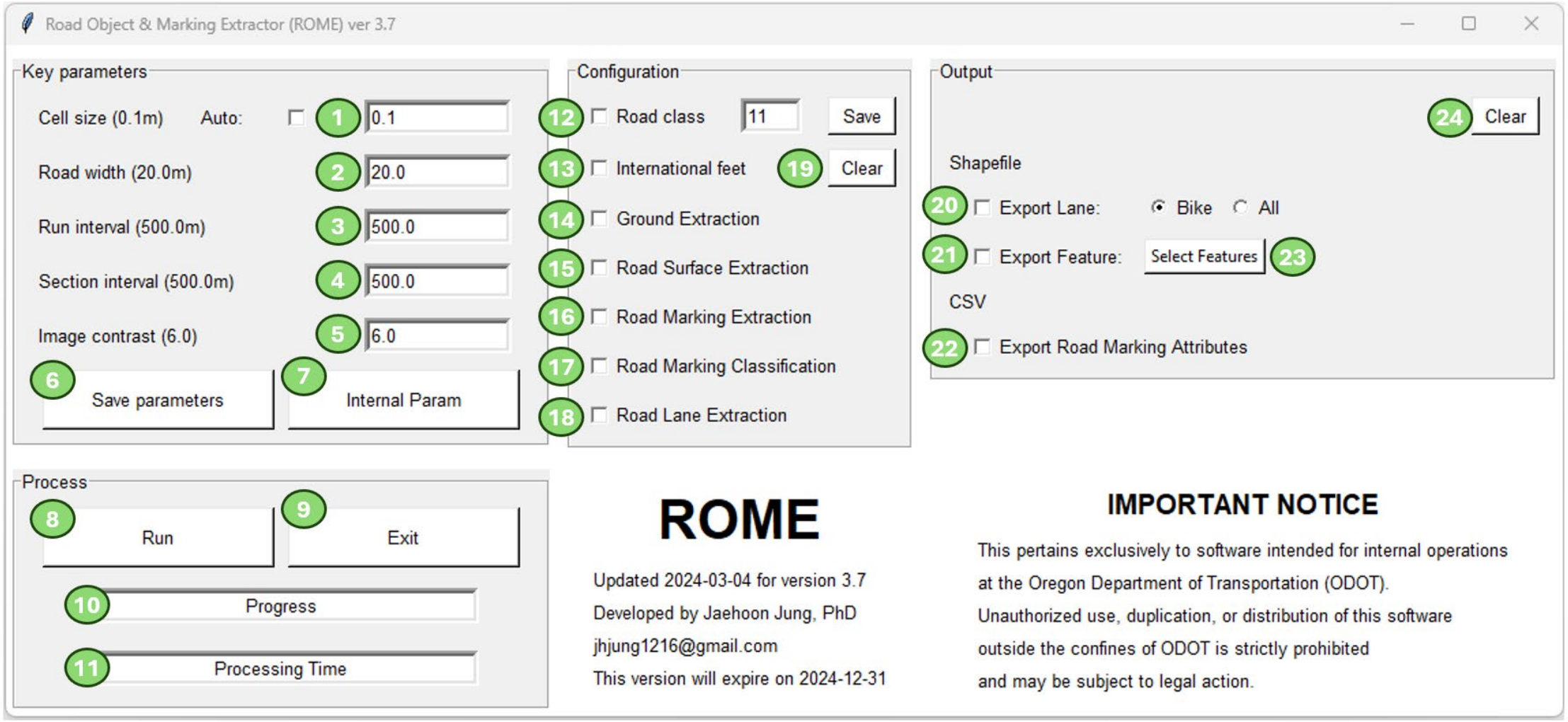


ROME
Road Object & Marking Extractor

# Road Marking Extraction

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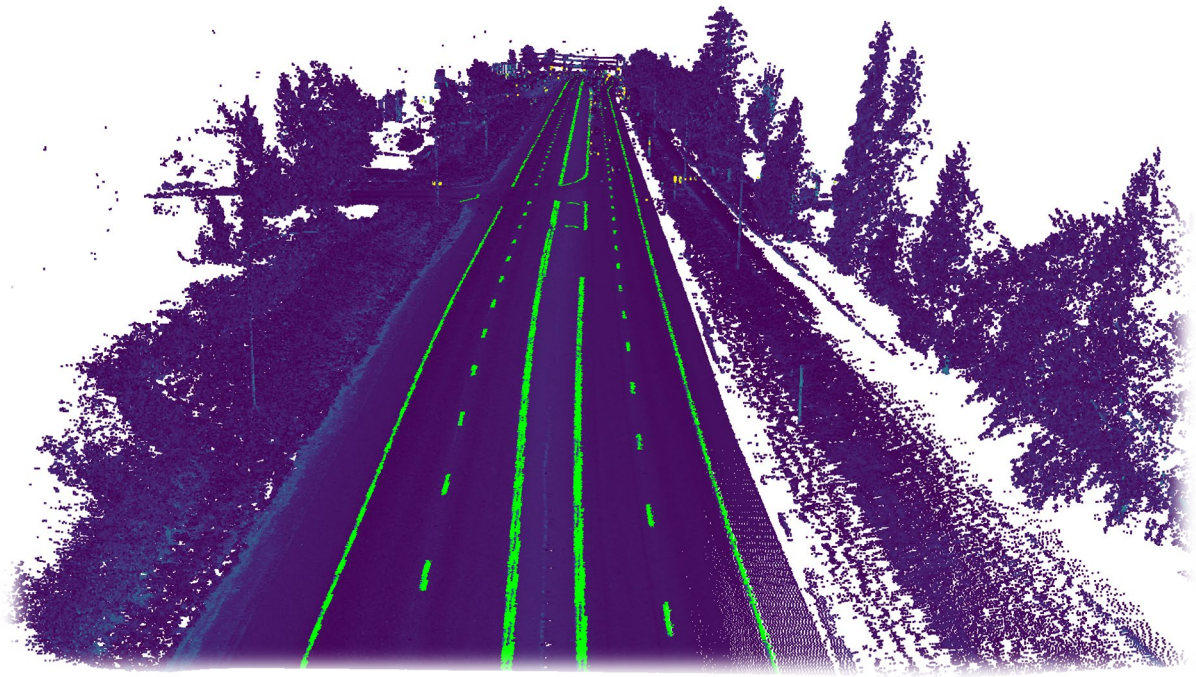
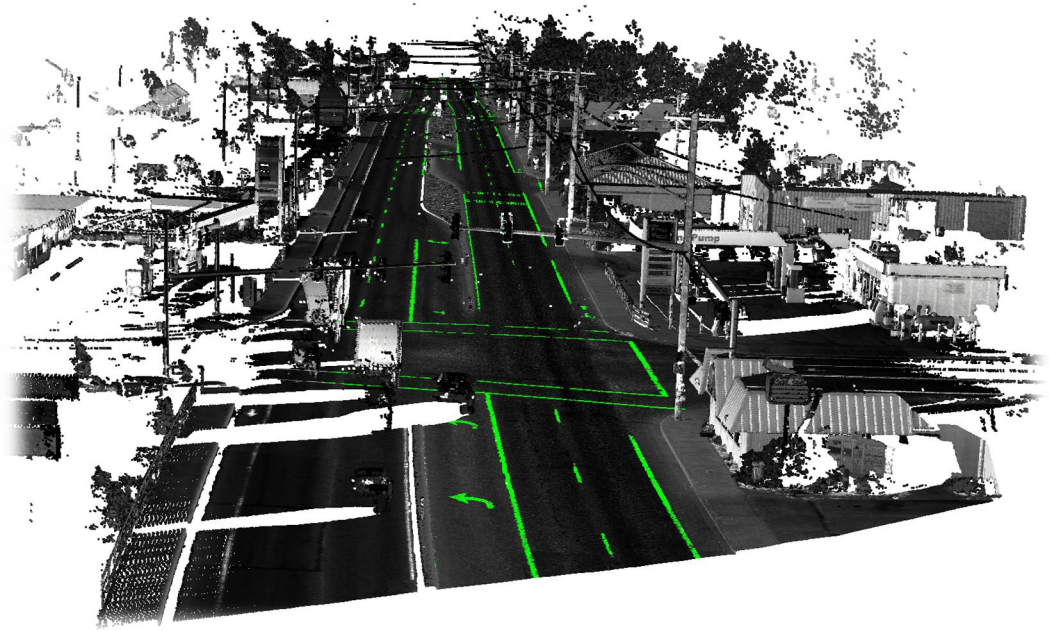
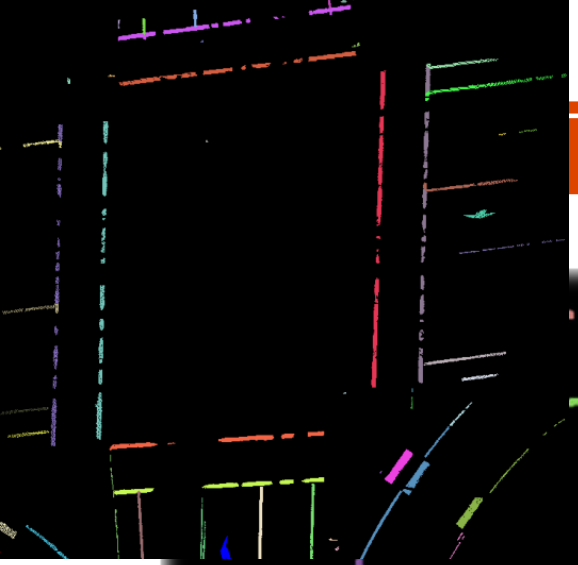
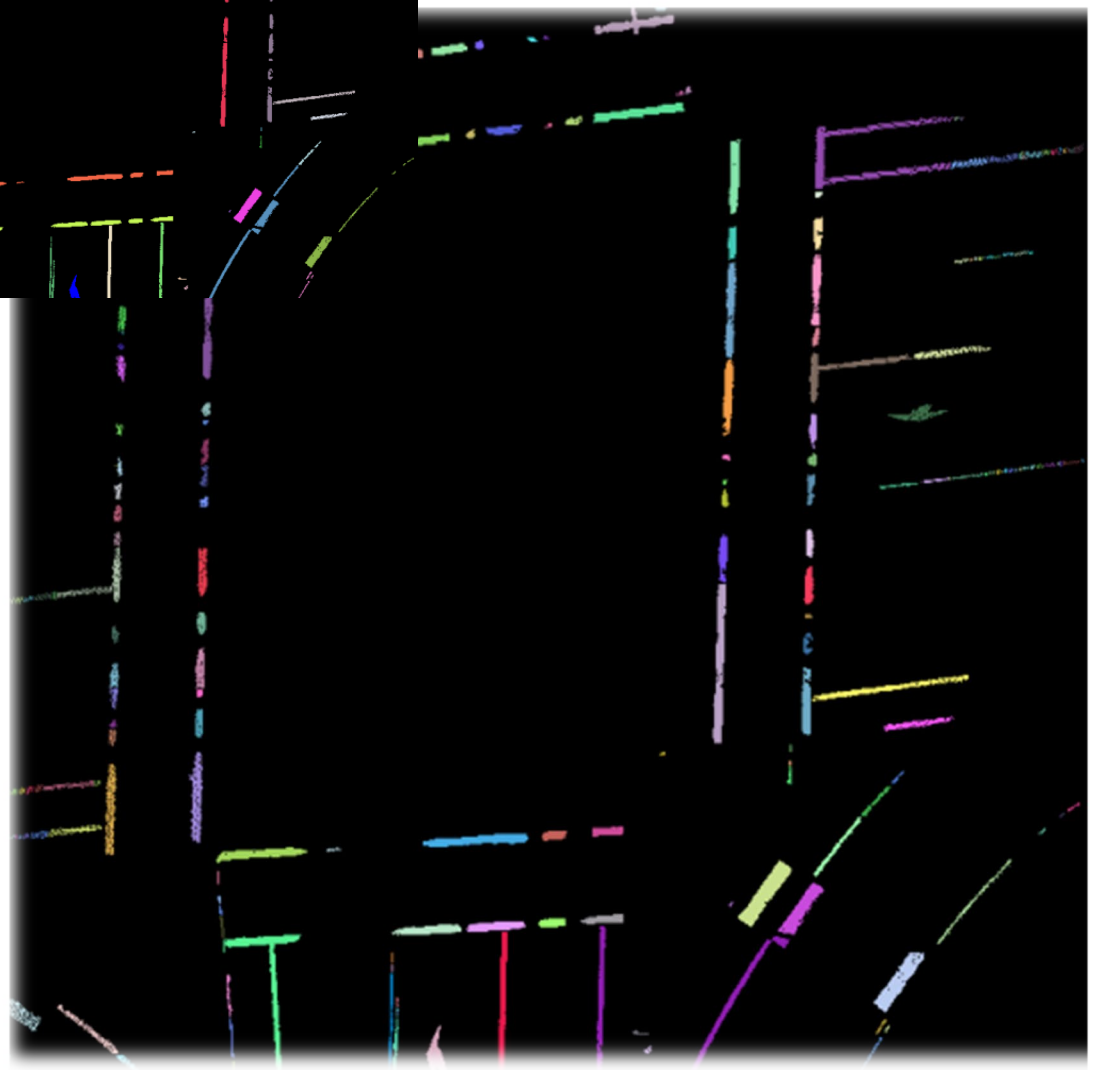


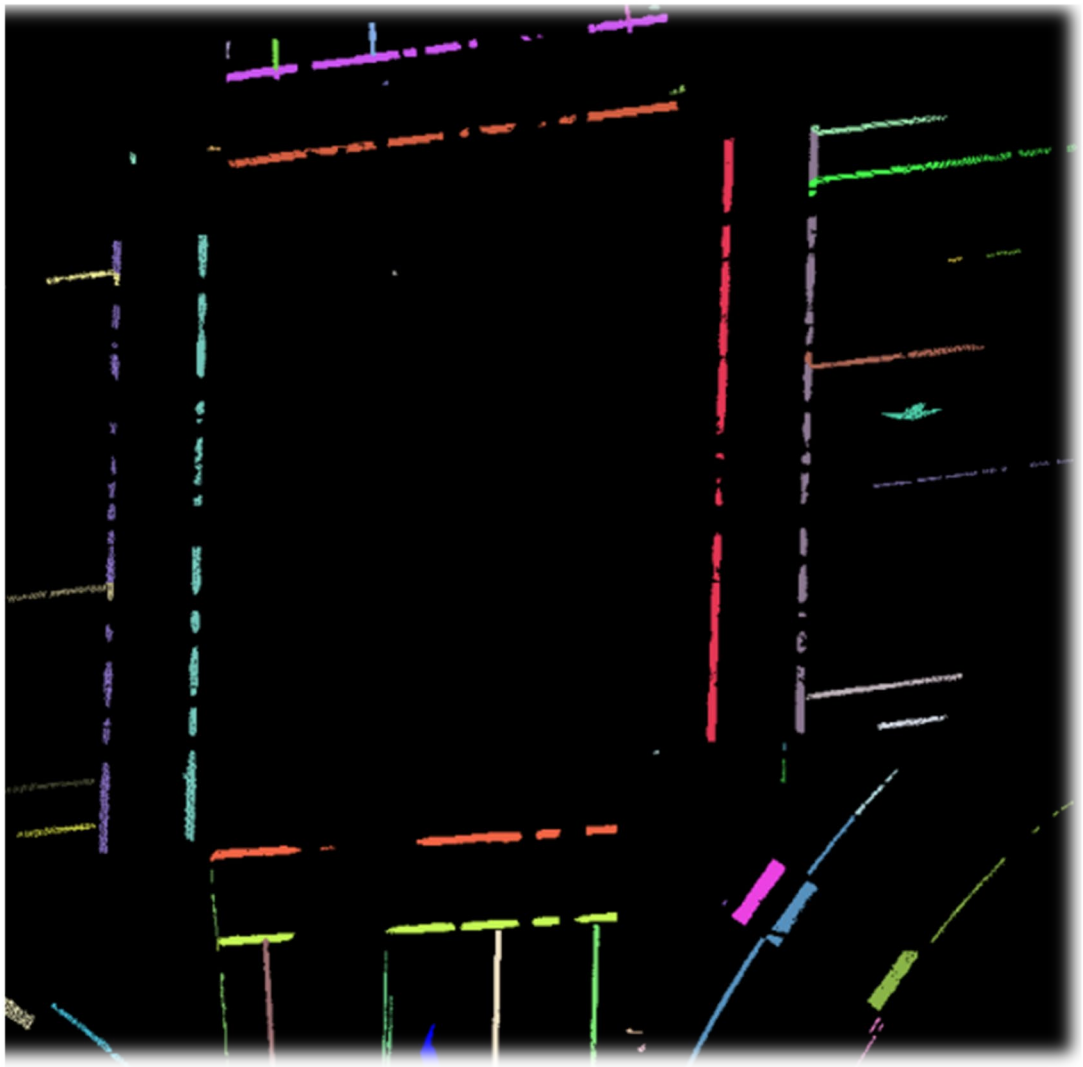


- 2023 AASHTO Sweet 16 High Value Research Award
- High ROI: One project using RoME to estimate striping costs saved more $$ than research cost.

# ing







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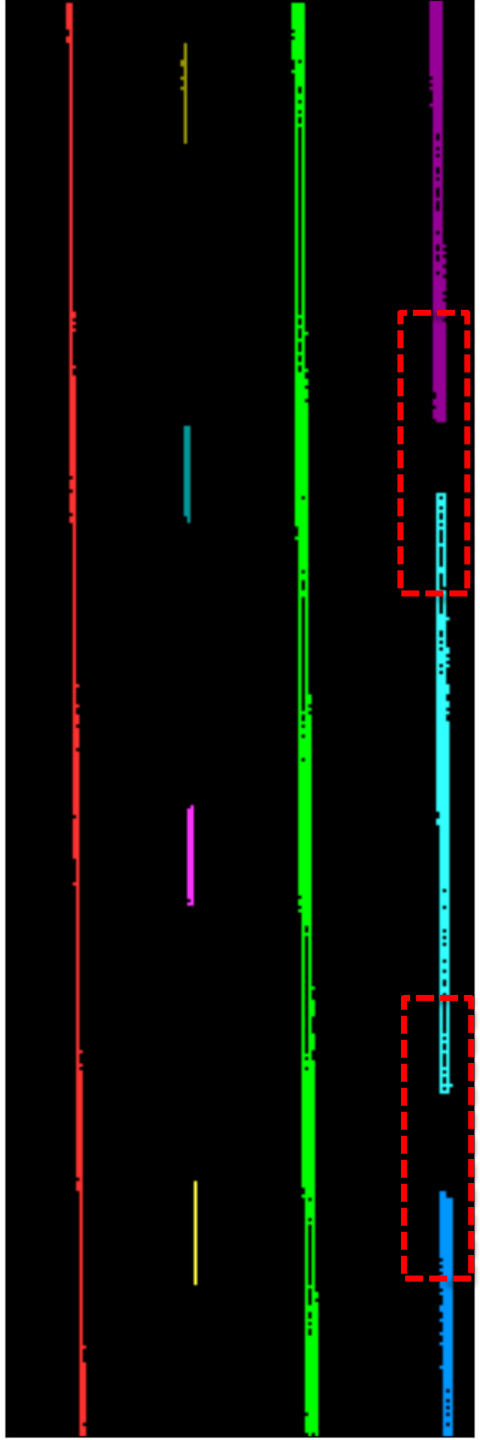

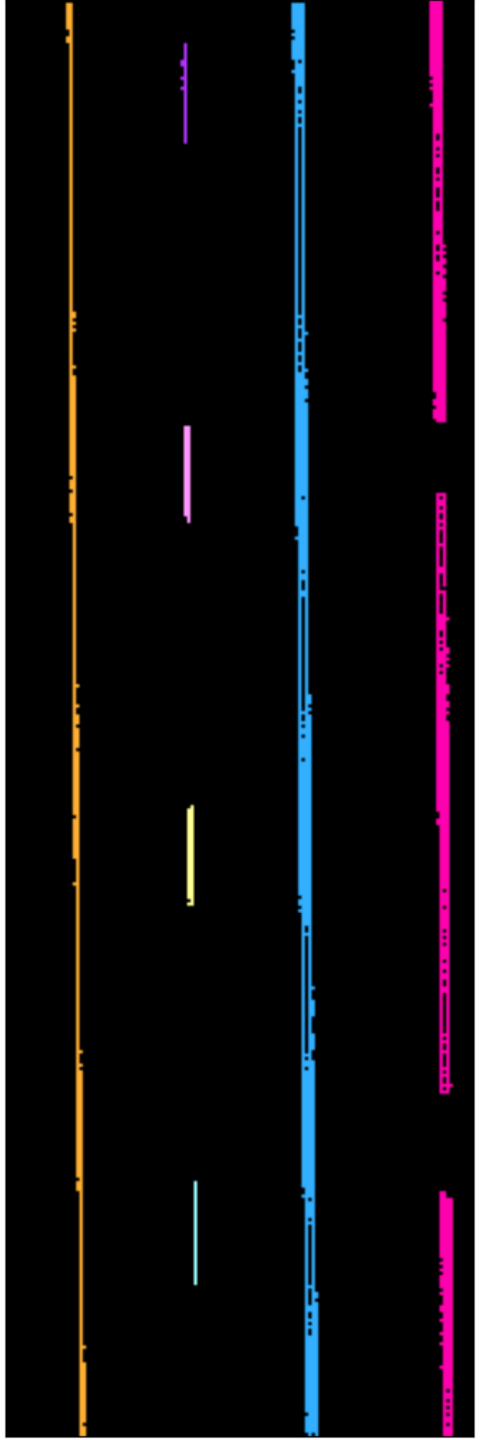

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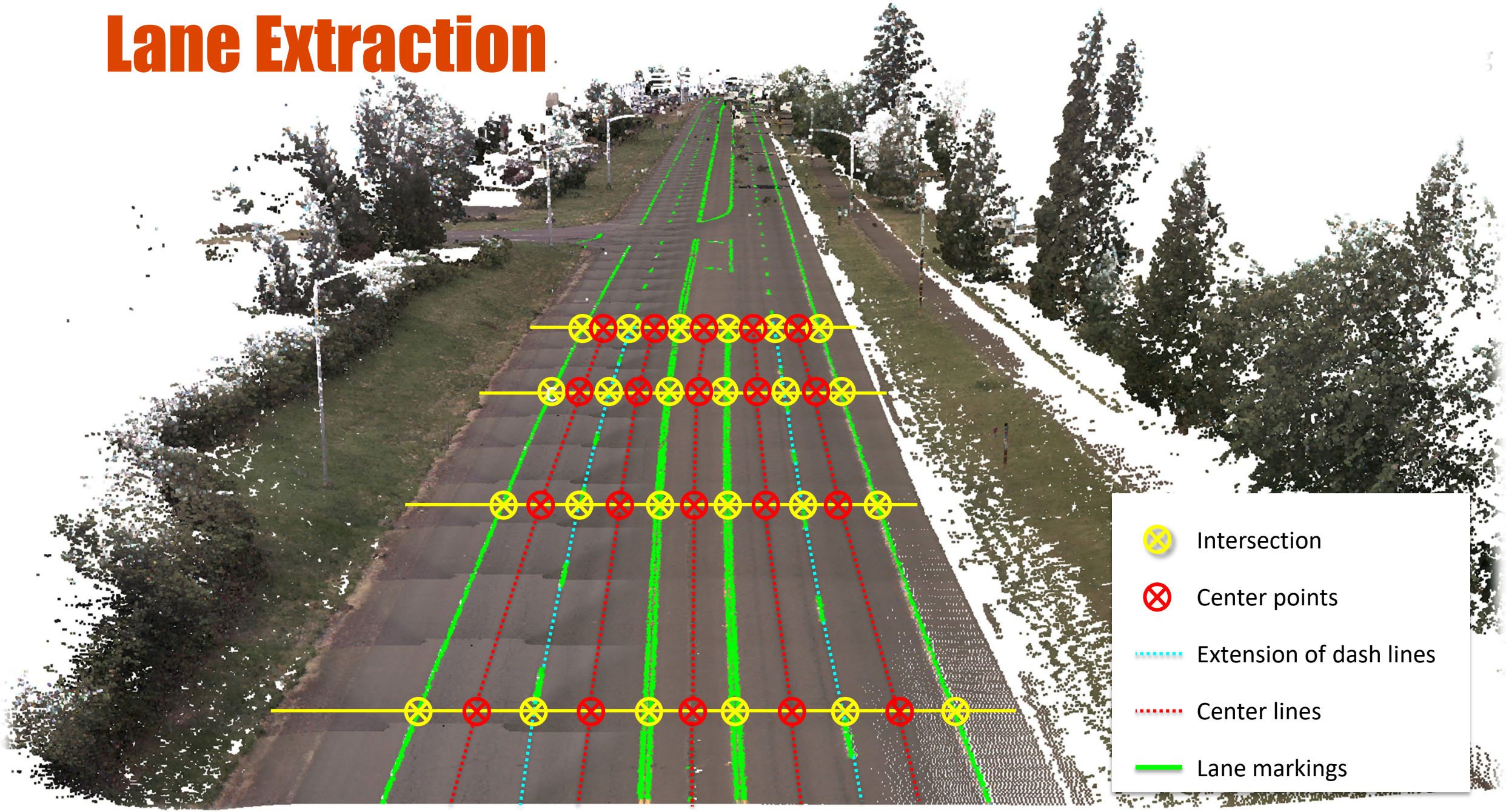
# Lane Extraction



# Lane Extraction

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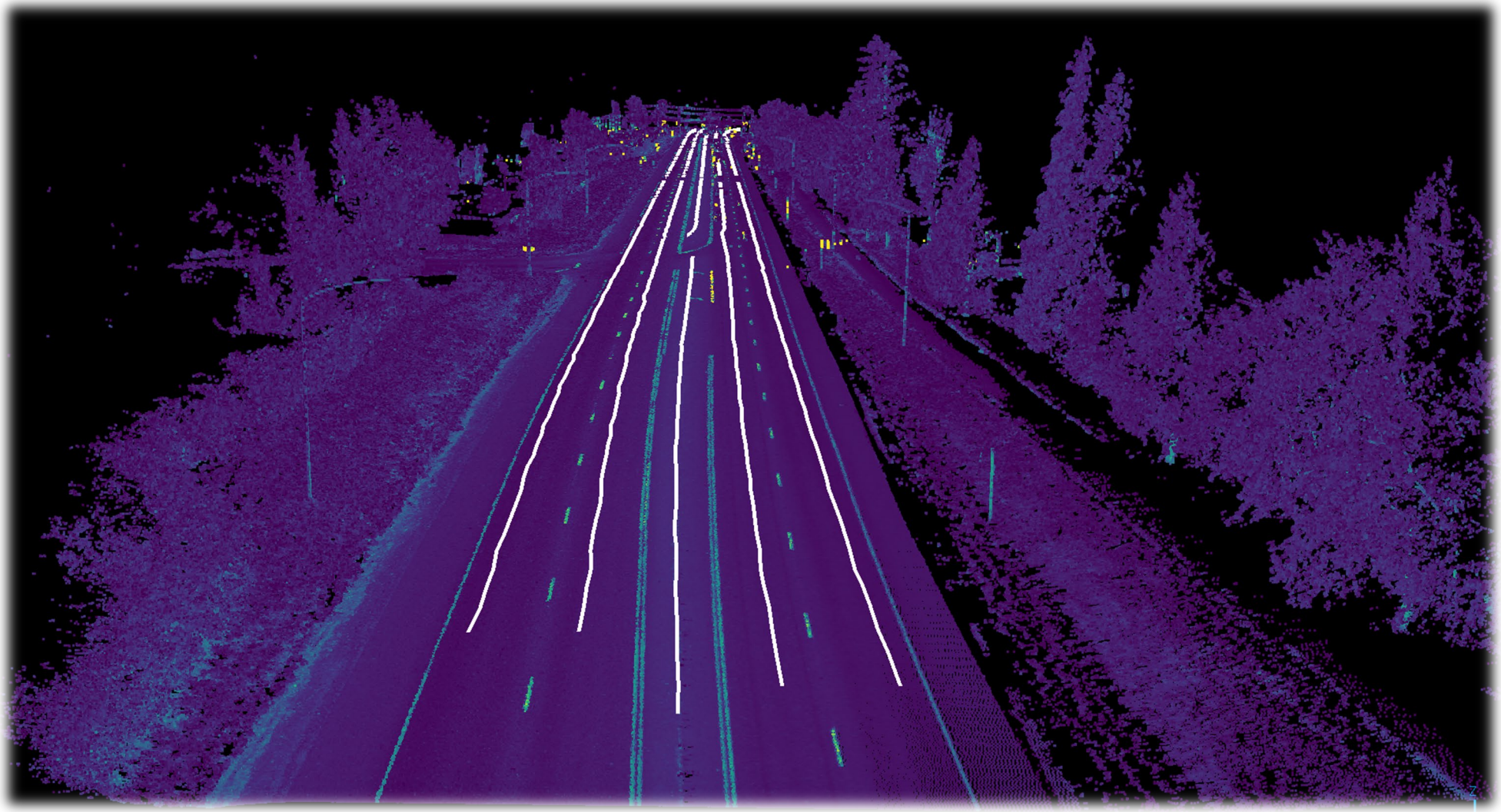

# Staggered Continental Crosswalk \Median

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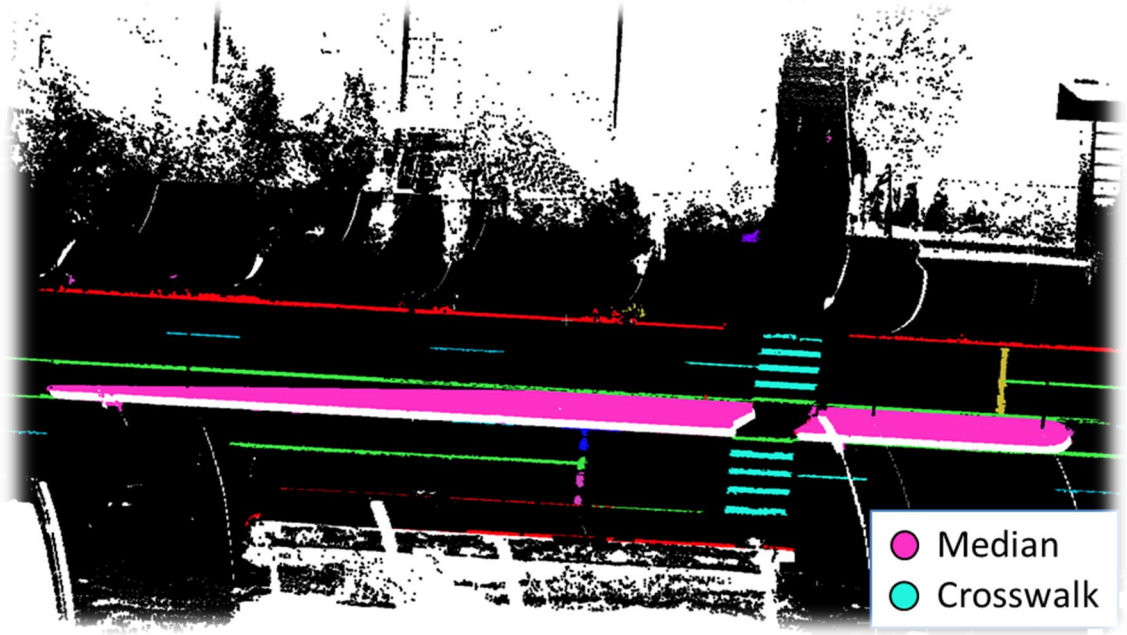


- Medians
  - Often removed in ground filtering. Algorithm uses those gaps to help identify.
  - Rules: Length>Width, Elev-Median > Elev-Roadway
- Staggered continental
  - Found by Convolutional Neural Network (CNN) with a modified VGG6 architecture
  - Geometric rules , clustering, and least squares fitting for worn markings

# Feature extraction

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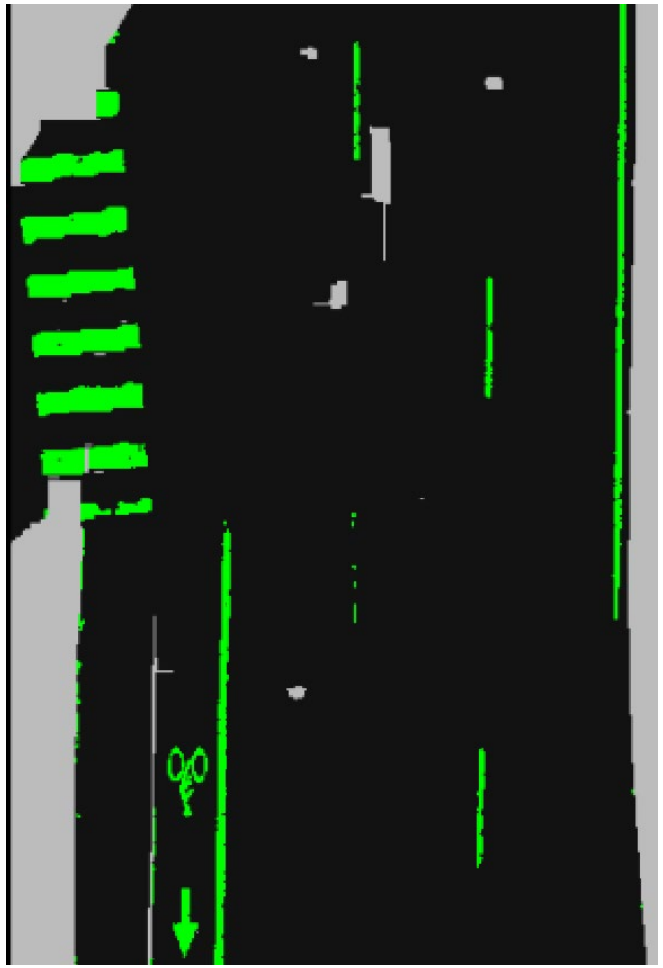
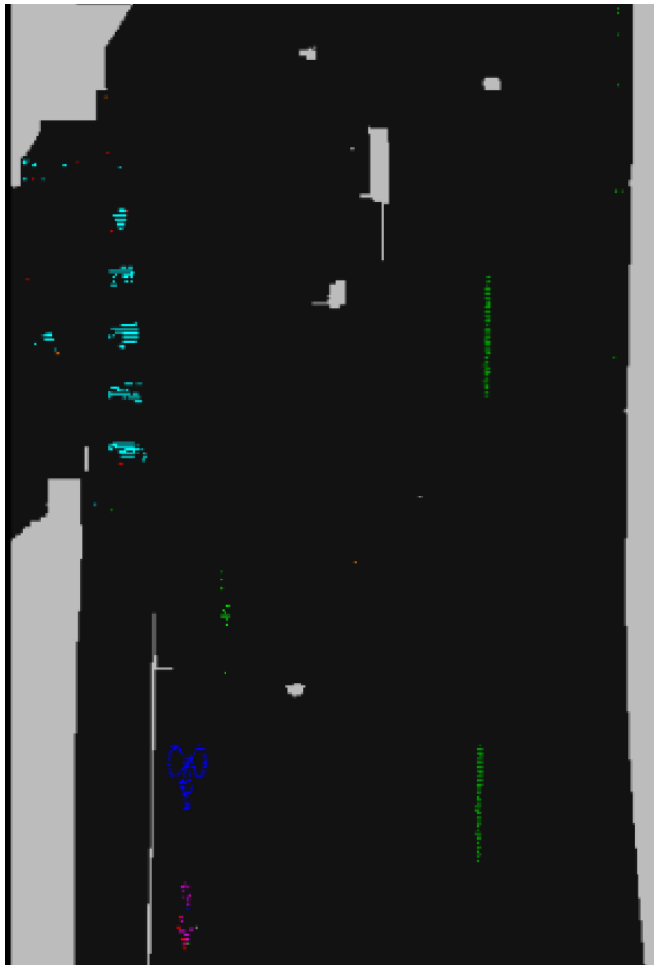
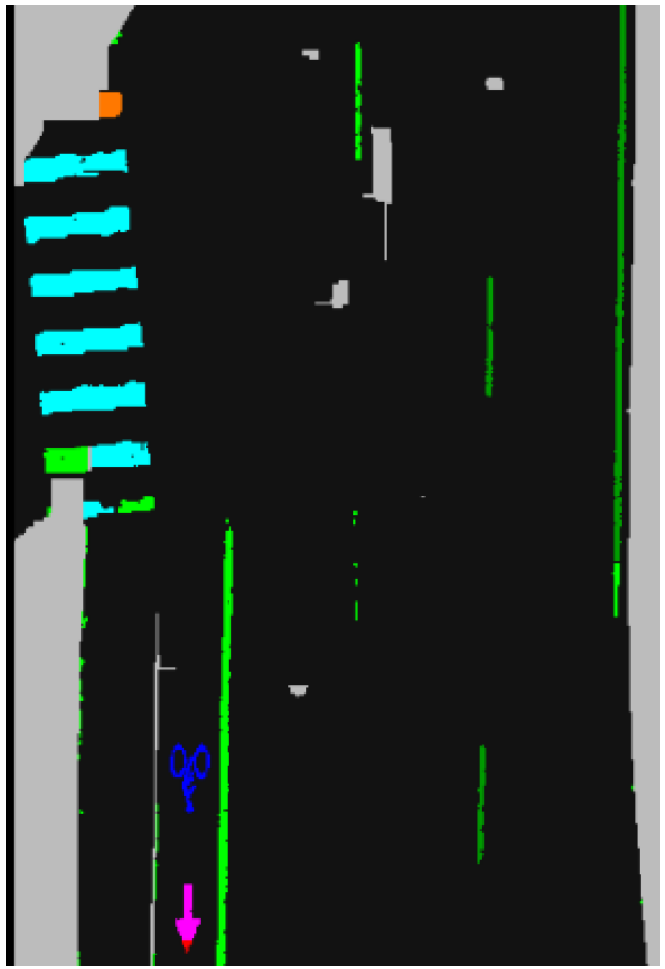
- Staggered continental & bike symbol



Rome extraction



Pixel-based classification



Object based classification

# Standard Parallel Crosswalk

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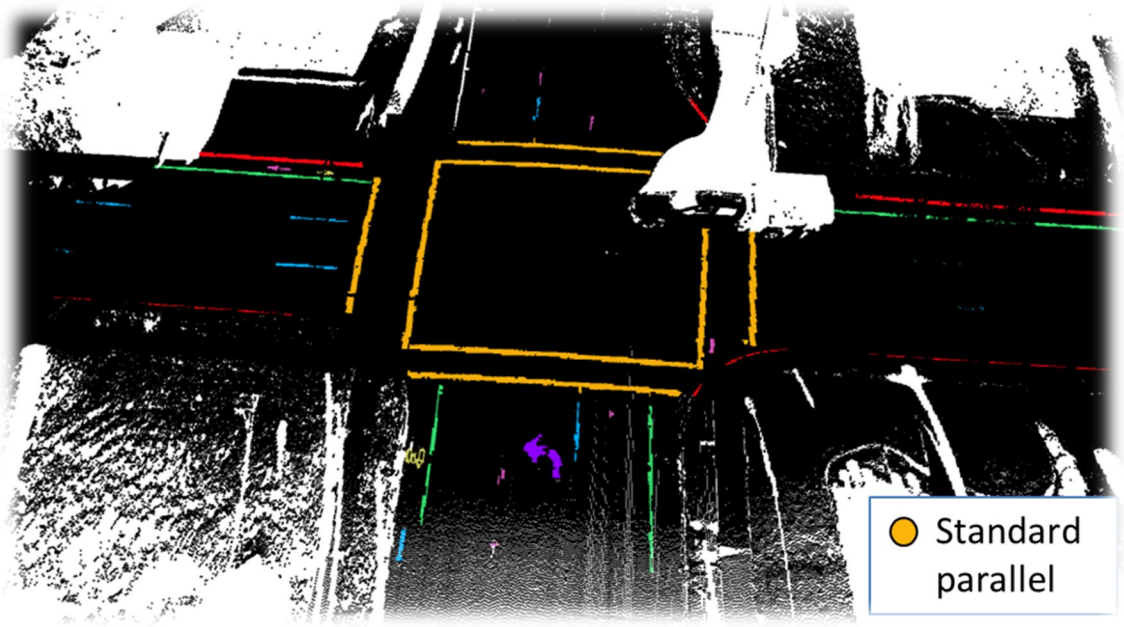


- Stop lines identified by intersection with vehicle trajectory data.
- Then evaluation longitudinal stop lines parallel to trajectory.

# Bikelanes

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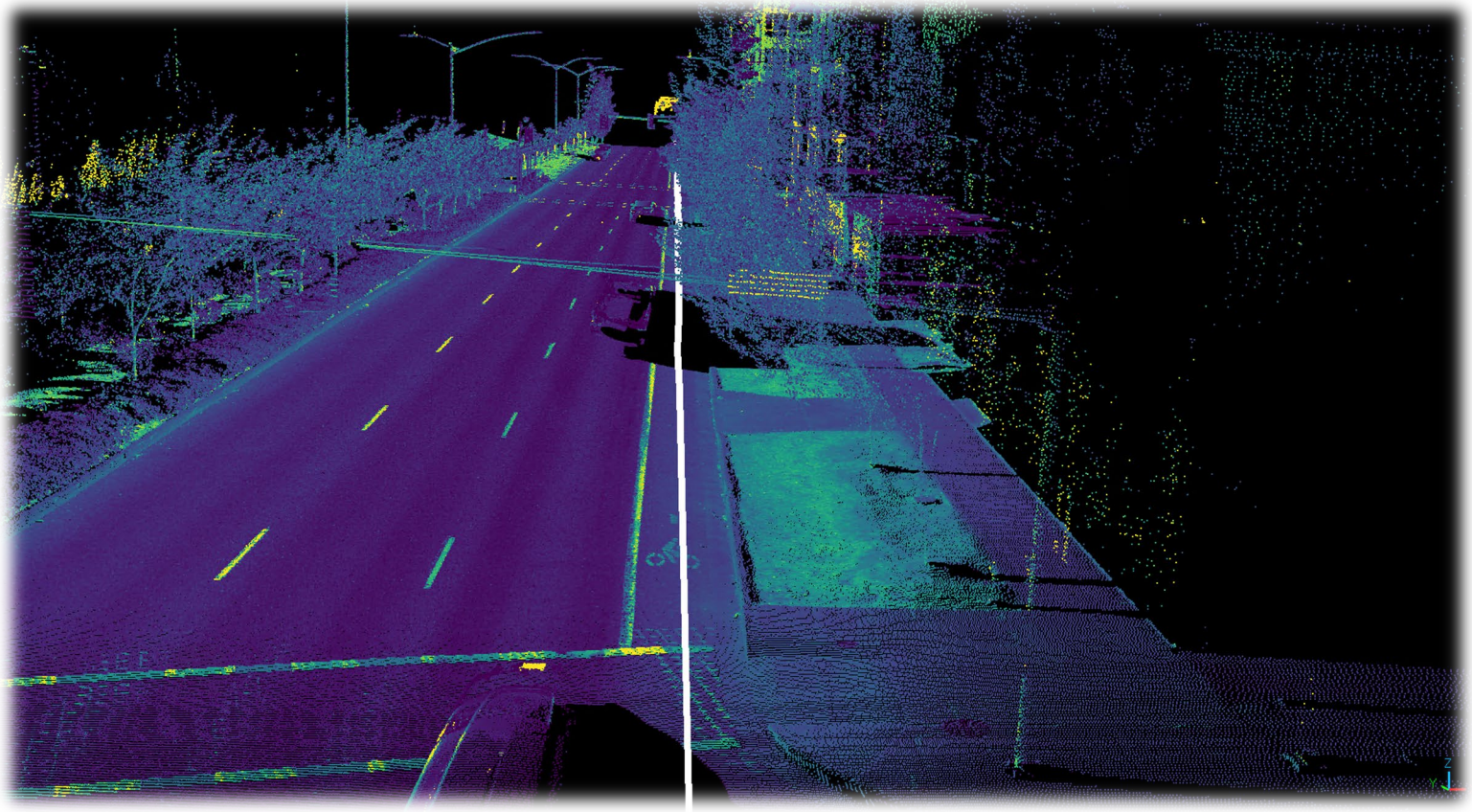
- Modified VGG6 deep learning model
- Lane with bike symbol
- Adjacent to curb



# GIS

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# Incorporation into GIS

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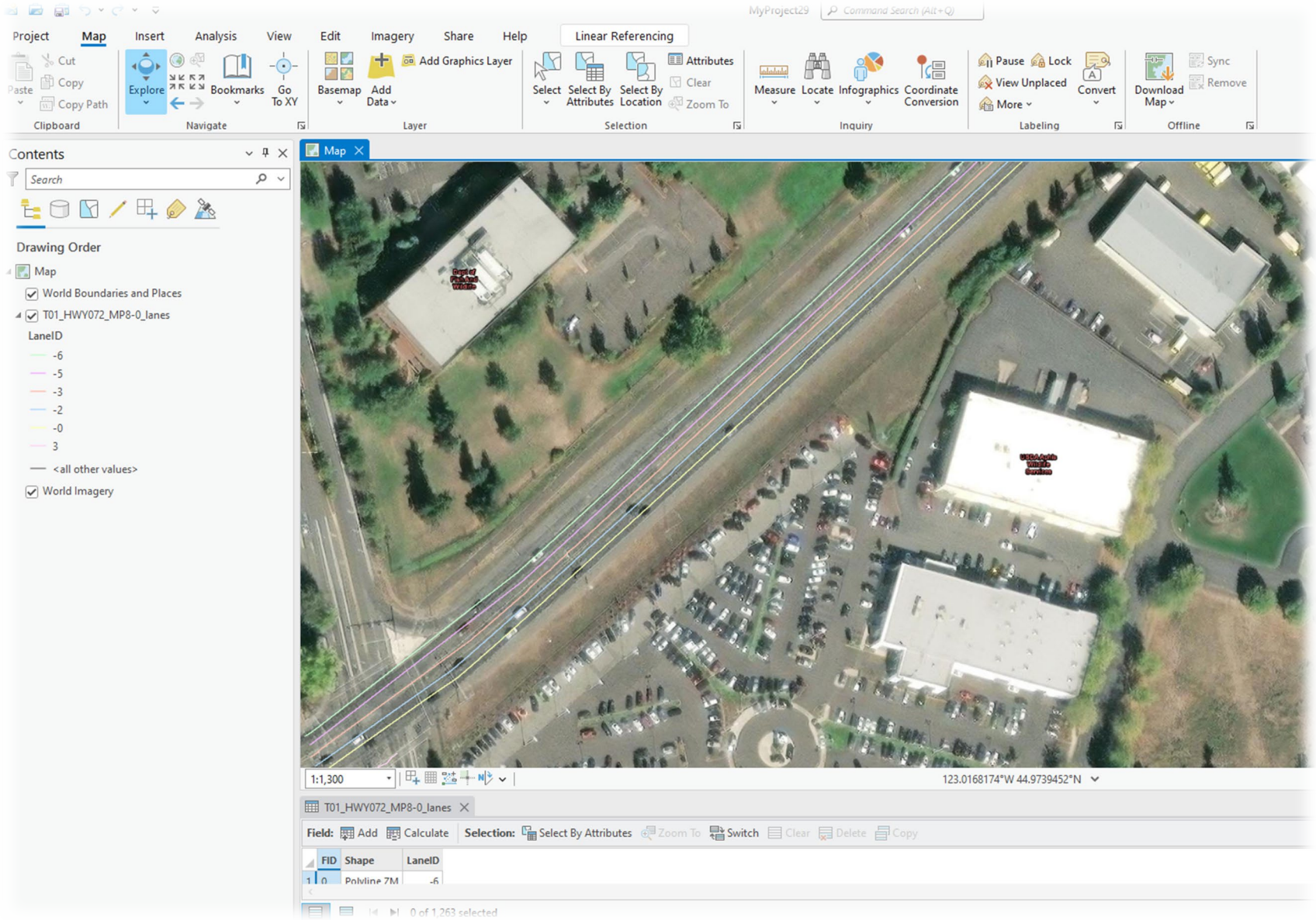

# Conclusions

- New approaches to extract:
  - Curb
  - Crosswalks
  - Bikelanes
  - Medians
- Less manual effort in extraction
- Helps ensure completeness
- High ROI has been demonstrated for RoME
- Stay tuned for SPR866
  - Road lanes
  - Road characteristics (e.g., grade, curvature)


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# Questions?

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# TransGIS: Shoulder

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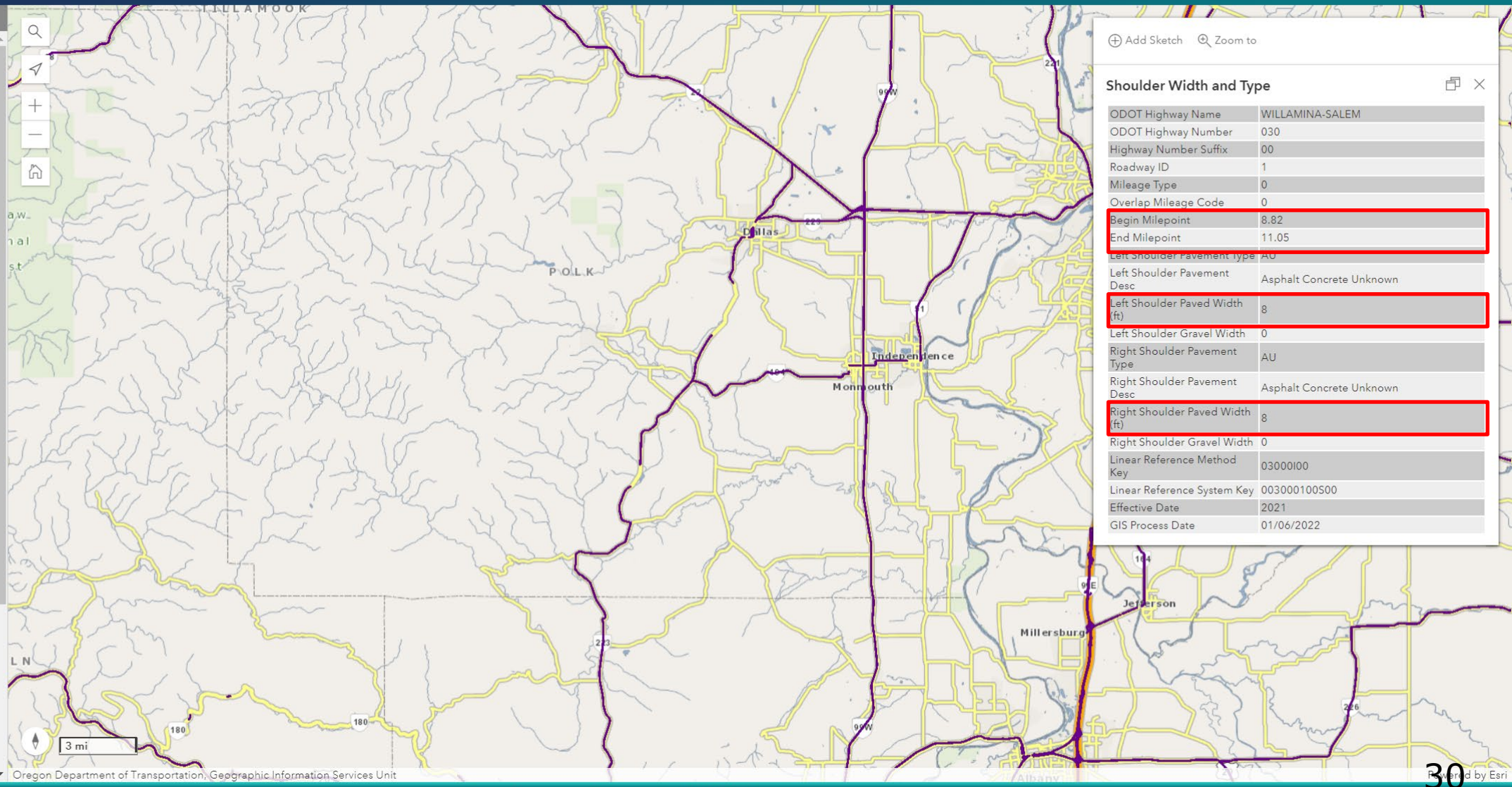
ODOT TransGIS

METADATA HELP ABOUT CONTACT FACS-STIP

Layers | Basemaps | Legend

- ODOT Streets
- ODOT Aerial Hybrid
- Aerial Imagery
- ODOT Terrain Hybrid
- ODOT Terrain
- Light Gray Canvas
- Dark Gray Canvas
- Streets
- World Street Map (Night)
- World Navigation Map
- Topographic




Add Sketch | Zoom to

**Shoulder Width and Type**

| | |
|---|---|
| ODOT Highway Name | WILLAMINA-SALEM |
| ODOT Highway Number | 030 |
| Highway Number Suffix | 00 |
| Roadway ID | 1 |
| Mileage Type | 0 |
| Overlap Mileage Code | 0 |
| Begin Milepoint | 8.82 |
| End Milepoint | 11.05 |
| Left Shoulder Pavement Type | AU |
| Left Shoulder Pavement Desc | Asphalt Concrete Unknown |
| Left Shoulder Paved Width (ft) | 8 |
| Left Shoulder Gravel Width | 0 |
| Right Shoulder Pavement Type | AU |
| Right Shoulder Pavement Desc | Asphalt Concrete Unknown |
| Right Shoulder Paved Width (ft) | 8 |
| Right Shoulder Gravel Width | 0 |
| Linear Reference Method Key | 03000I00 |
| Linear Reference System Key | 003000100S00 |
| Effective Date | 2021 |
| GIS Process Date | 01/06/2022 |

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# TransGIS: Marked crosswalk (no ADA ramps)

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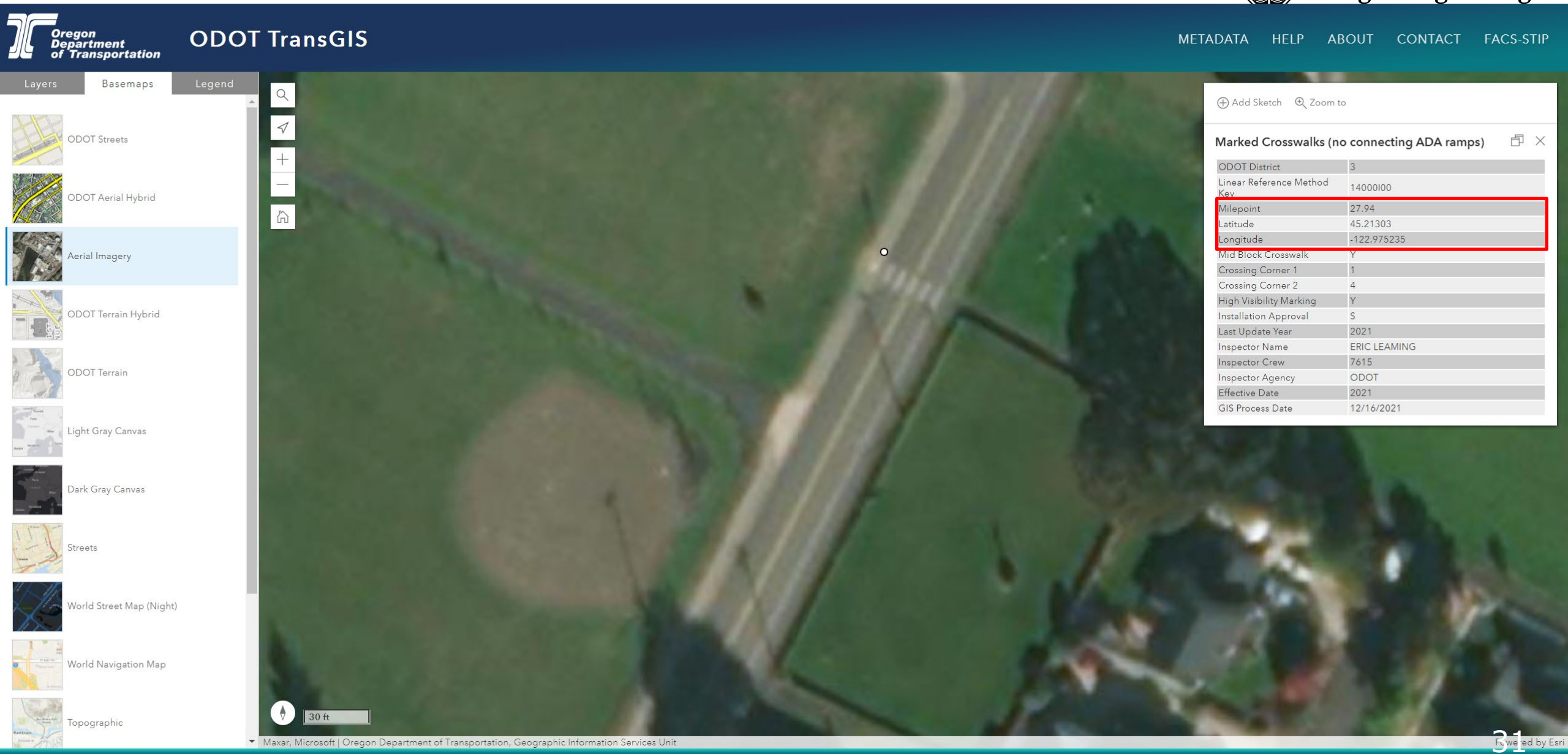




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# TransGIS: Marked crosswalk (ADA ramps)

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# TransGIS: Bicycle facilities (BL: Bikelane, SH: Shoulder, SL: Shared lanes)

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# TransGIS: Traffic Barriers (Cable, Concrete, Guardrail)

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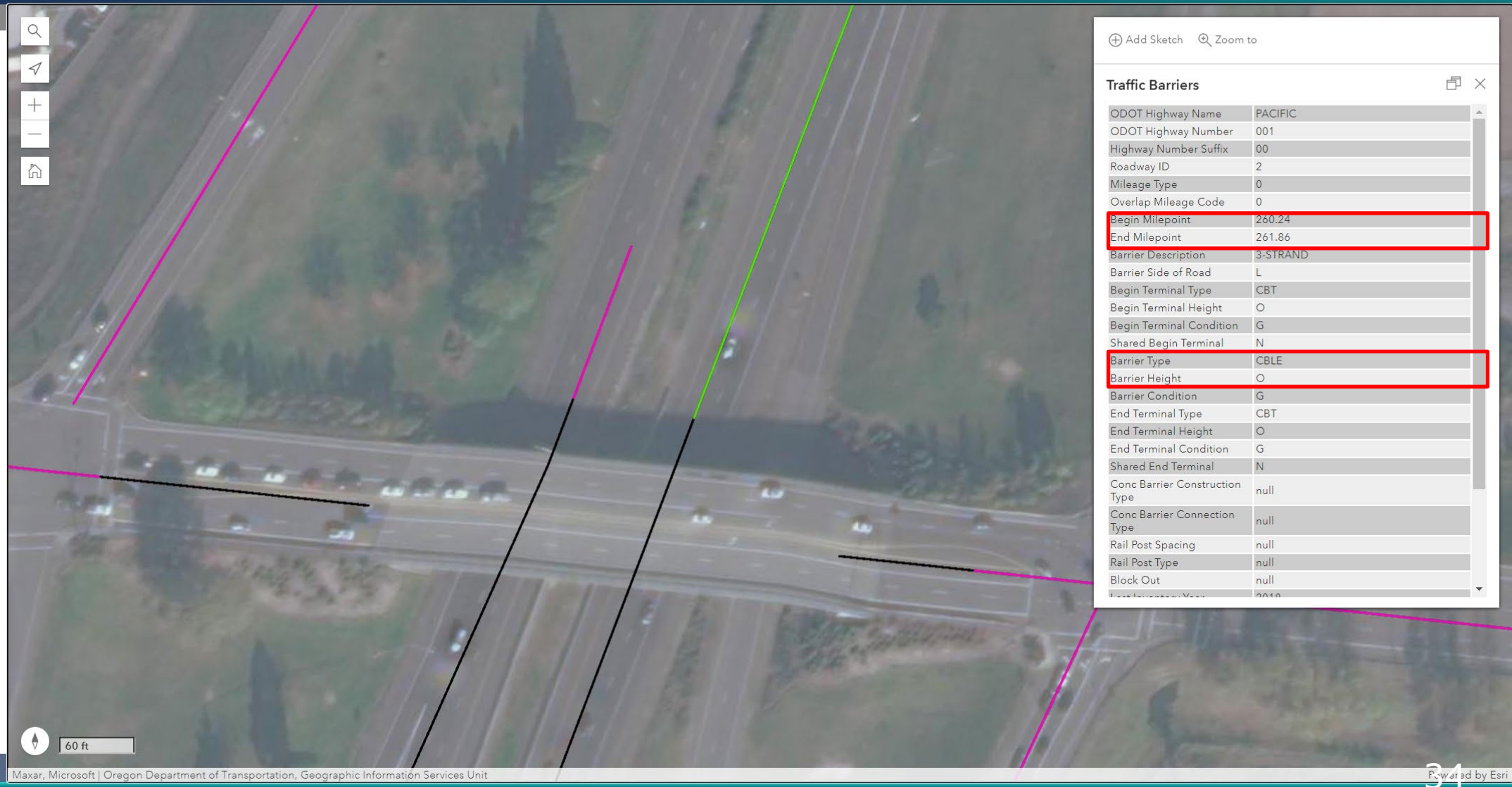
ODOT TransGIS

METADATA HELP ABOUT CONTACT FACS-STIP

Layers | Basemaps | Legend

Active Layers

Traffic Barriers




Add Sketch | Zoom to

**Traffic Barriers**

| | |
|---|---|
| ODOT Highway Name | PACIFIC |
| ODOT Highway Number | 001 |
| Highway Number Suffix | 00 |
| Roadway ID | 2 |
| Mileage Type | 0 |
| Overlap Mileage Code | 0 |
| Begin Milepoint | 260.24 |
| End Milepoint | 261.86 |
| Barrier Description | 3-STRAND |
| Barrier Side of Road | L |
| Begin Terminal Type | CBT |
| Begin Terminal Height | O |
| Begin Terminal Condition | G |
| Shared Begin Terminal | N |
| Barrier Type | CBLE |
| Barrier Height | O |
| Barrier Condition | G |
| End Terminal Type | CBT |
| End Terminal Height | O |
| End Terminal Condition | G |
| Shared End Terminal | N |
| Conc Barrier Construction Type | null |
| Conc Barrier Connection Type | null |
| Rail Post Spacing | null |
| Rail Post Type | null |
| Block Out | null |

Add New | Clear All

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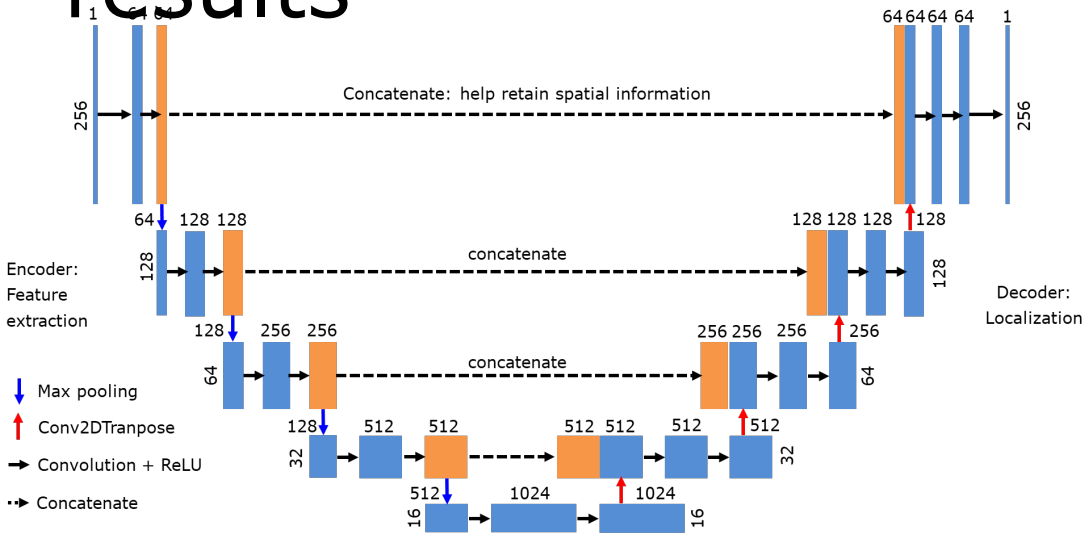
# Methods

- Deep learning + rule-based approach
- Object-based classification based on the clustering results




U-net deep learning architecture for semantic classification