IVORY – AI for Vision Zero in Road Safety

Paper ID: 029

Impact of Camera vs. Lidar Data on Road Attribute Identification Using Deep Learning: An Empirical Investigation

Muhammad Shahid*, Amirhossein Hassani, Marko Ševrović

Faculty of Transport and Traffic Sciences
University of Zagreb

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ANNUAL GLOBAL ROAD CRASH STATISTICS

1.19 MILLION
die in Road Crashes each year with an average of **3,287 Deaths** per day.

20-25 MILLION
are injured or disabled.

More than **HALF** of all road traffic deaths occur among people **ages 15-44.**

$518 BILLION
per year and are predicted to become the **5th LEADING** overall cause of death by **2030**.

Around **1,000** People under the **age of 25** each year.

LEADING Cause of death For **ages 15-29**, and **SECOND LEADING** Cause of death for **ages 2-14**

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Making Roads and Roadsides Safer

Motivation & Context

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Road Infrastructure Analysis

Very narrow lanes (<2.8–3.0 m) or overly wide lanes (>3.6 m) can be hazardous

Medians can reduce crashes by 15–55%, depending on type and context.

Source: ERSO. (2018). Roads 2018; Mitra et al., (2022). Guide to Integrating Safety into Road Design; Tahir et al., (2022). A simulation-based empirical bayes approach: Incorporating unobserved heterogeneity in the before-after evaluation of engineering treatments

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Roadside Safety Attributes

Crash Into a Fixed Object

Hazardous Side Ditches

Hazardous safety barrier terminations

Source: La Torre, F., Saleh, P., Cesolini, E., & Goyat, Y. (2012). Improving Roadside Design to Forgive Human; Mitra et al., (2022). Guide to Integrating Safety into Road Design

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Forgiving Roadside Design

Remove the Obstacle
The safest option: eliminate the hazard entirely

Redesign the obstacle so it can be safely traversed
Example: Ditch and slope treatments

Relocate the obstacle to a point where it is less likely to be struck
Move it outside the clear zone

Reduce impact severity by using an appropriate breakaway device
Example: Fragile signposts or light poles

Shield the obstacle
The safest option: eliminate the hazard entirely

Delineate the obstacle
Marking or highlighting the hazard to increase driver awareness


Remove and Relocate


Side Slope Improvements


Fragile Light Poles

Source: AASHTO. (2011). Roadside Design; Mitra et al., (2022). Guide to Integrating Safety into Road Design

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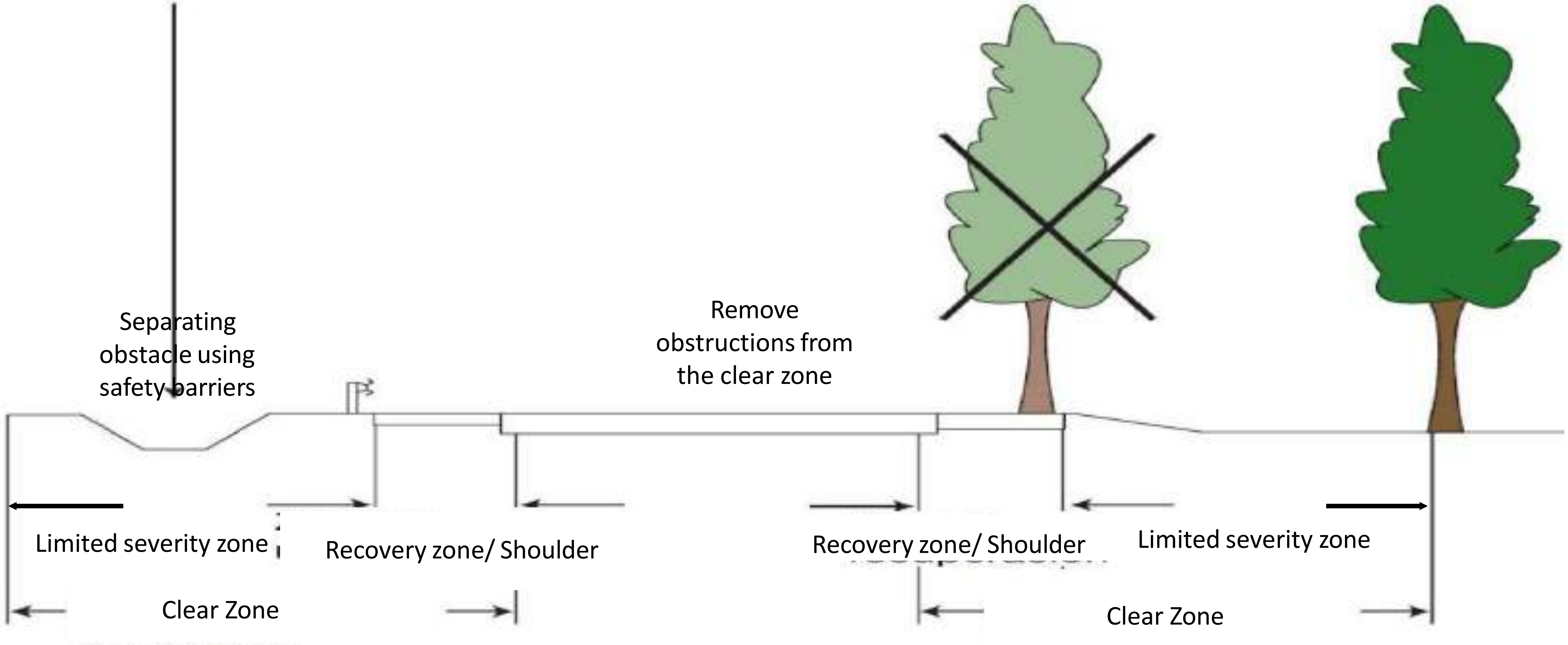
Clear Zones



Source: La Torre, F., Saleh, P., Cesolini, E., & Goyat, Y. (2012). Improving Roadside Design to Forgive Human; Mitra et al., (2022). Guide to Integrating Safety into Road Design

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METHODOLOGY OVERVIEW

Why Deep Learning for Roadside assessment?

🔍 **Scale & Speed**

🎯 **Accuracy**

📊 **Fast Road Assessments**

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Two Approaches

APPROACH 1

Camera-Based Classification

- CNN-based image classification
- 14 roadside object classes
- 4 distance categories
- Road image input

VS

APPROACH 2

LiDAR-Based YOLO Object Detection

- Two-stage YOLO pipeline
- 13 roadside object classes
- Metric distance estimation (m)
- LiDAR point cloud input

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Roadside Safety Attributes

Road-Side Object Type (13 classes)

1. Safety Barrier Metal
2. Safety Barrier Concrete
3. Rockface
4. Upward Slope Rollover
5. Upward Slope No Rollover
6. Drainage
7. Down Slope
8. Tree
9. Pole
10. Rigid
11. Semi Rigid
12. Safety Barrier End
13. Rock

Roadside object distance from Road Edge

- 0–1 m (immediate roadside)
- 1–5 m
- 5–10 m
- > 10 m (low risk)

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1st Approach

Classification Technique: Roadside objects & Distance classification

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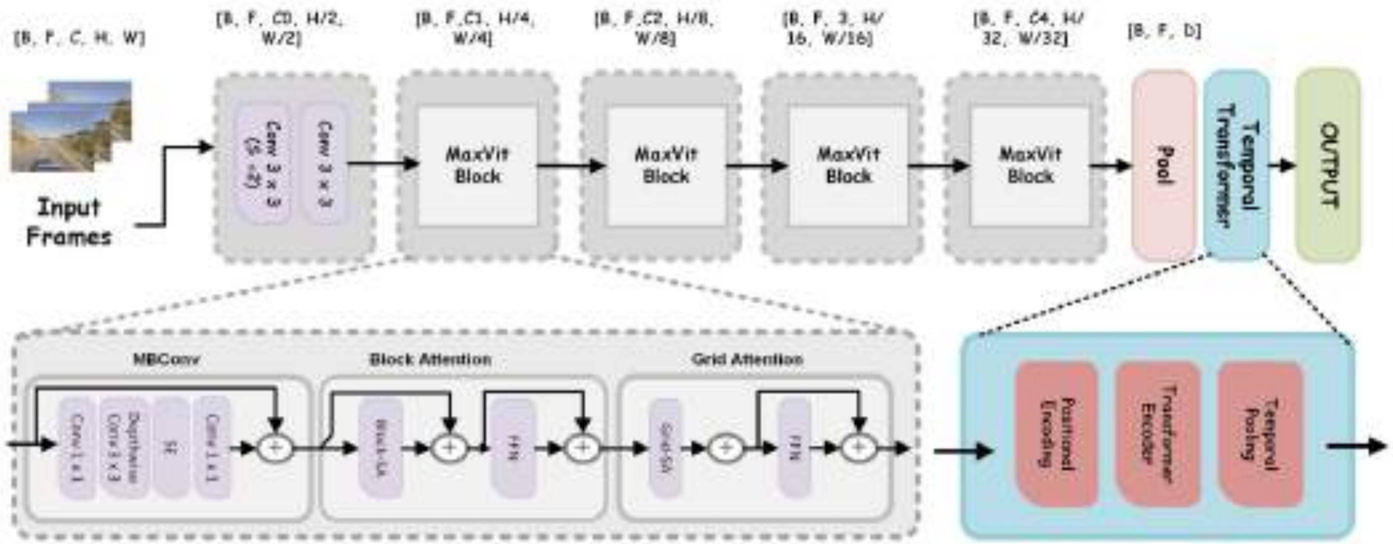
Deep Learning based multi-class classification using camera (RGB) images

1. Dataset was coded for classification problem (image have their labeled ground truth values)
2. A deep learning model is trained on road survey dataset
3. Model provide prediction as one roadside object class among 14-17 classes and one distance class among 3 distance classes (Wide ≥2.4m, Medium 1m to <2.4m, Narrow 0m to <1m)



Ref: Shahid, Muhammad, et al. "A Spatio-Temporal Multi-Task Framework for iRAP Road Attribute Classification from Street-Level Videos." *2025 8th International Conference on Algorithms, Computing and Artificial Intelligence (ACAI)*. IEEE, 2025.

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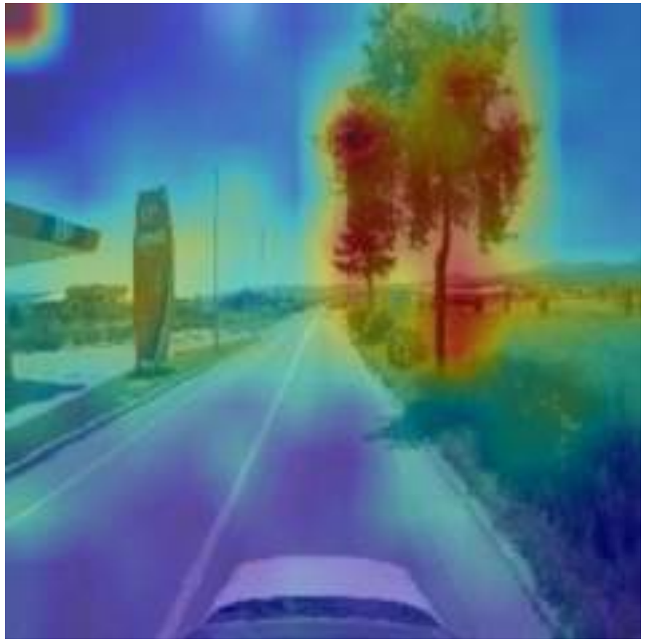
Classification Approach : Roadside Severity Object

Roadside Object: Semi-rigid structure or building



Roadside object: Tree

Roadside object: Tree

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2nd Approach

Object Detection Technique:

Roadside objects Detection & Distance Calculation

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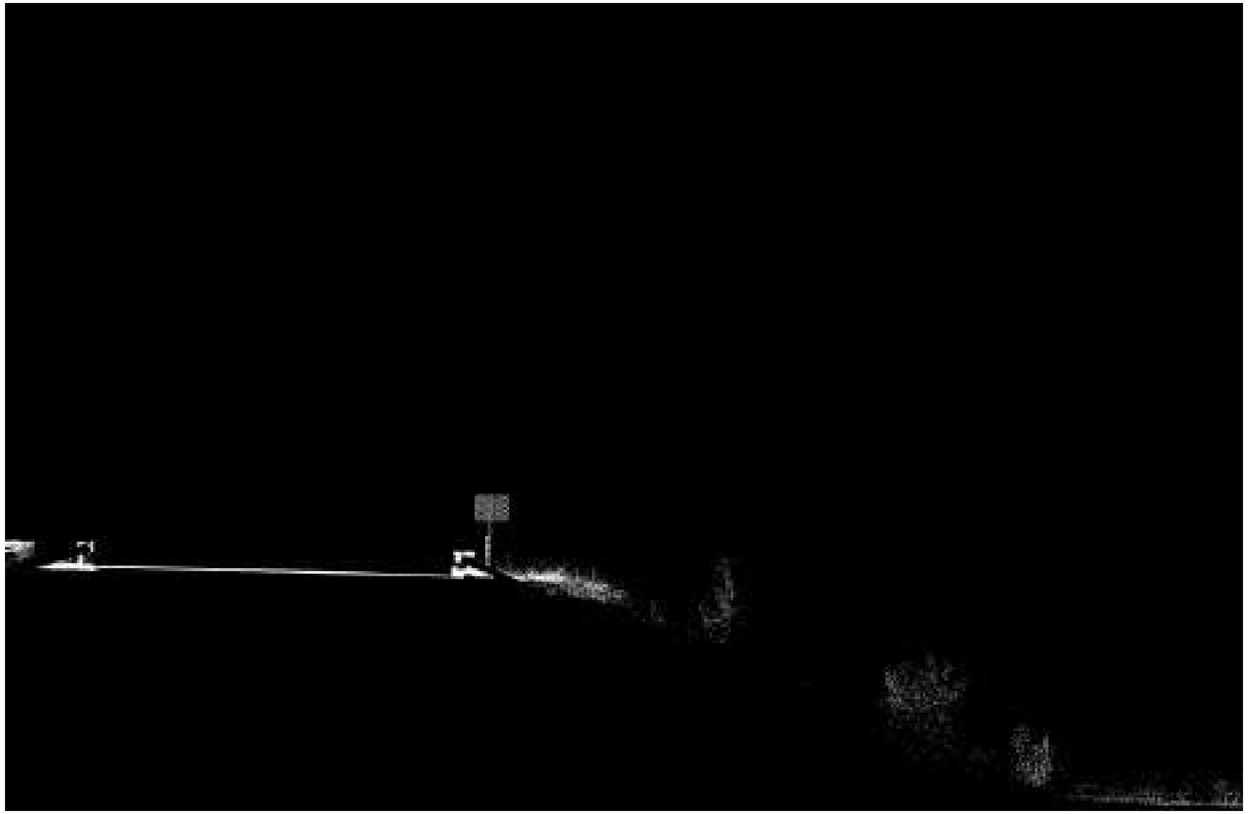
Roadside severity Objects detection using Lidar

RGB Image



LiDar Image

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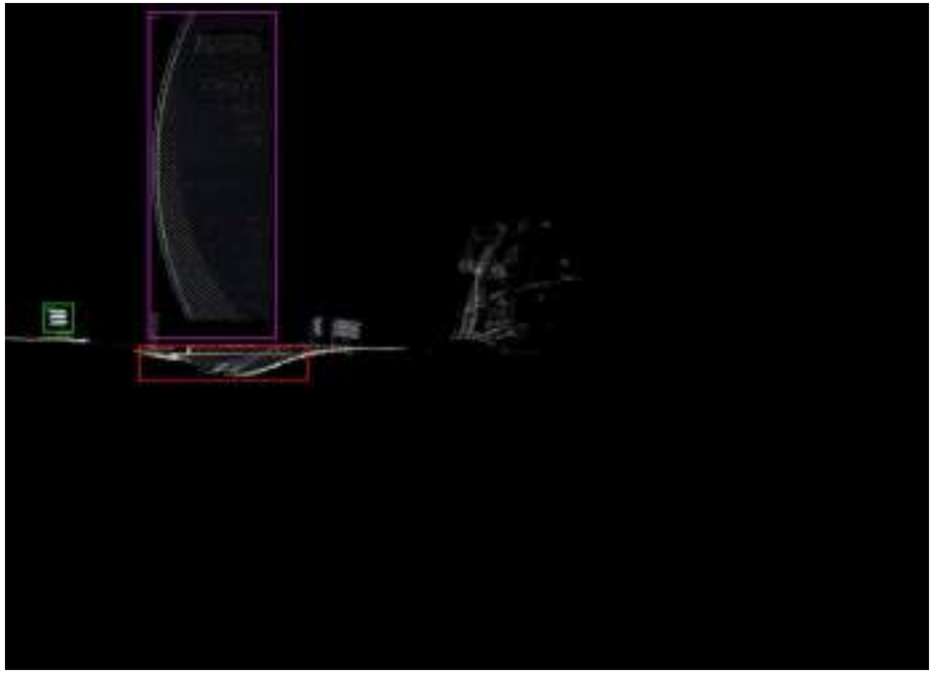
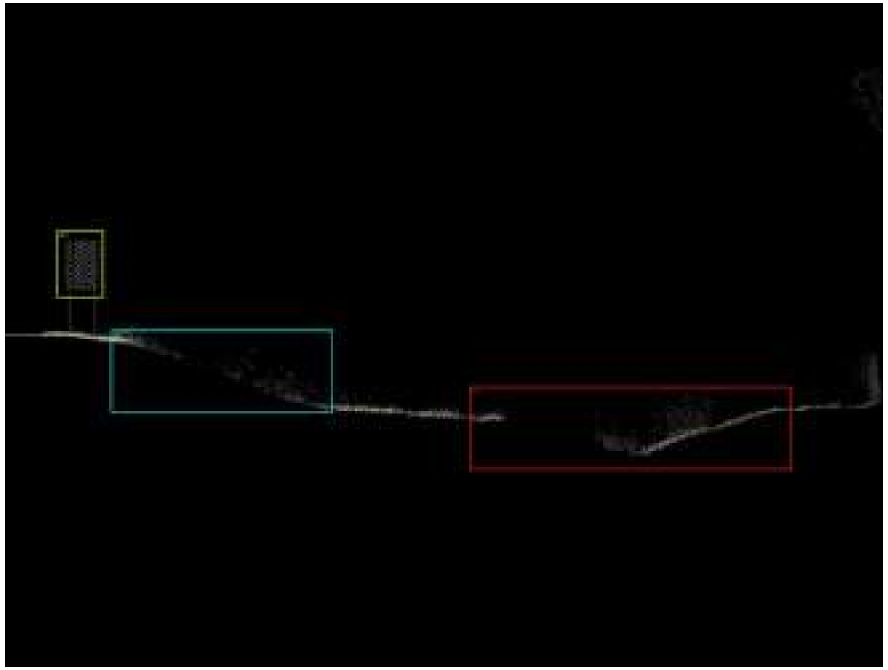
Dataset creation- bounding boxes





LiDar Image – Road Side Objects Bounding Boxes

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Two-Stage Detection Pipeline

Input Image → Stage 1 Road Detection → Road Edge Extraction → Stage 2 Object YOLO → RSS-O + RSS-D Output

Road Detection

Single-class YOLO model trained on road cross-section images · Outputs road bounding box + right edge X coordinate (road_edge_x)

Edge Extraction & Crop

Road right edge (Xmax) defines transition from road to roadside · Roadside crop defined relative to road_edge_x for Stage 2 input

Object Detection

13-class YOLO model identifies roadside hazard type (RSS-O) ·

Distance Calculation

Pixel distance from road_edge_x to object reference point

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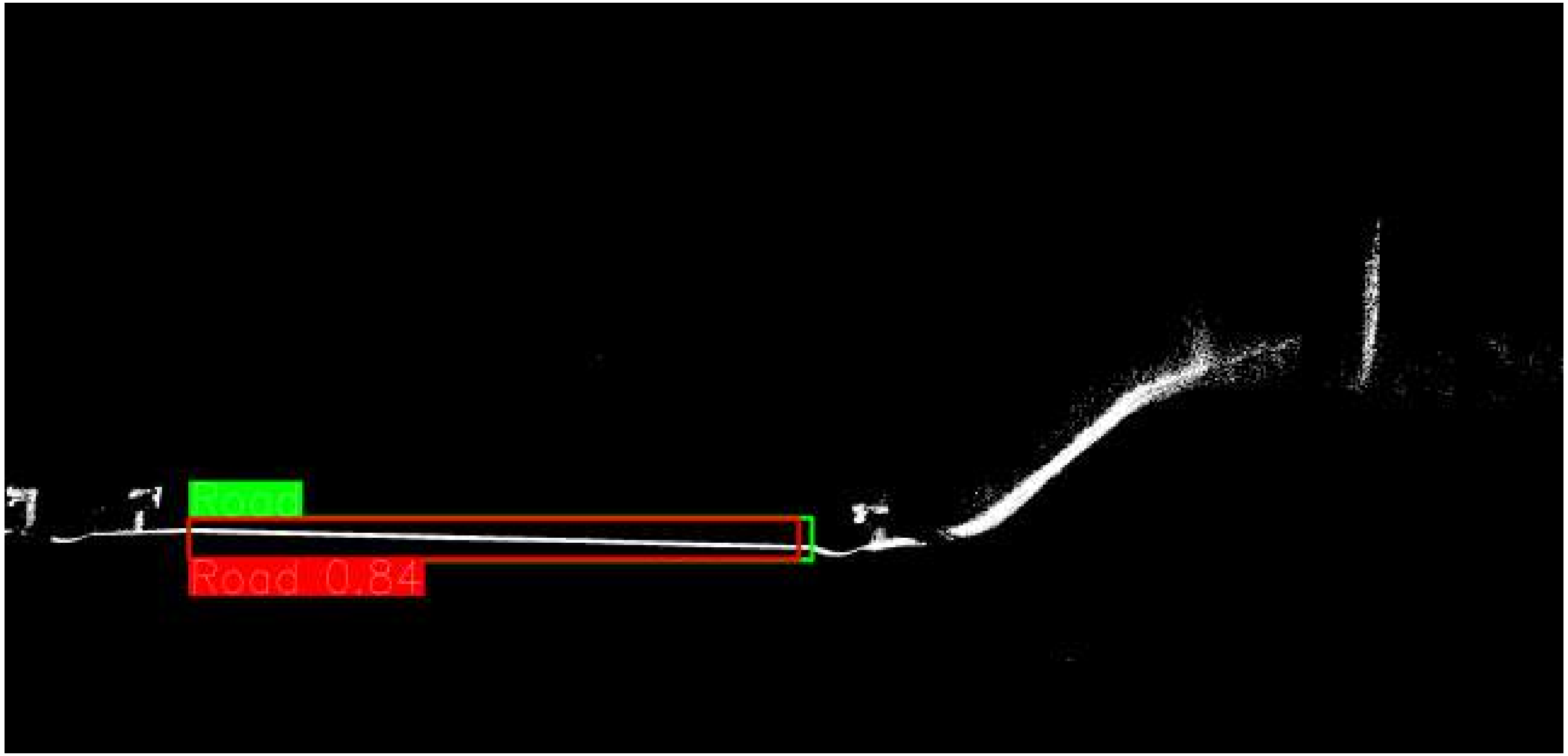
Stage1: Road detection



Ground truth

Prediction

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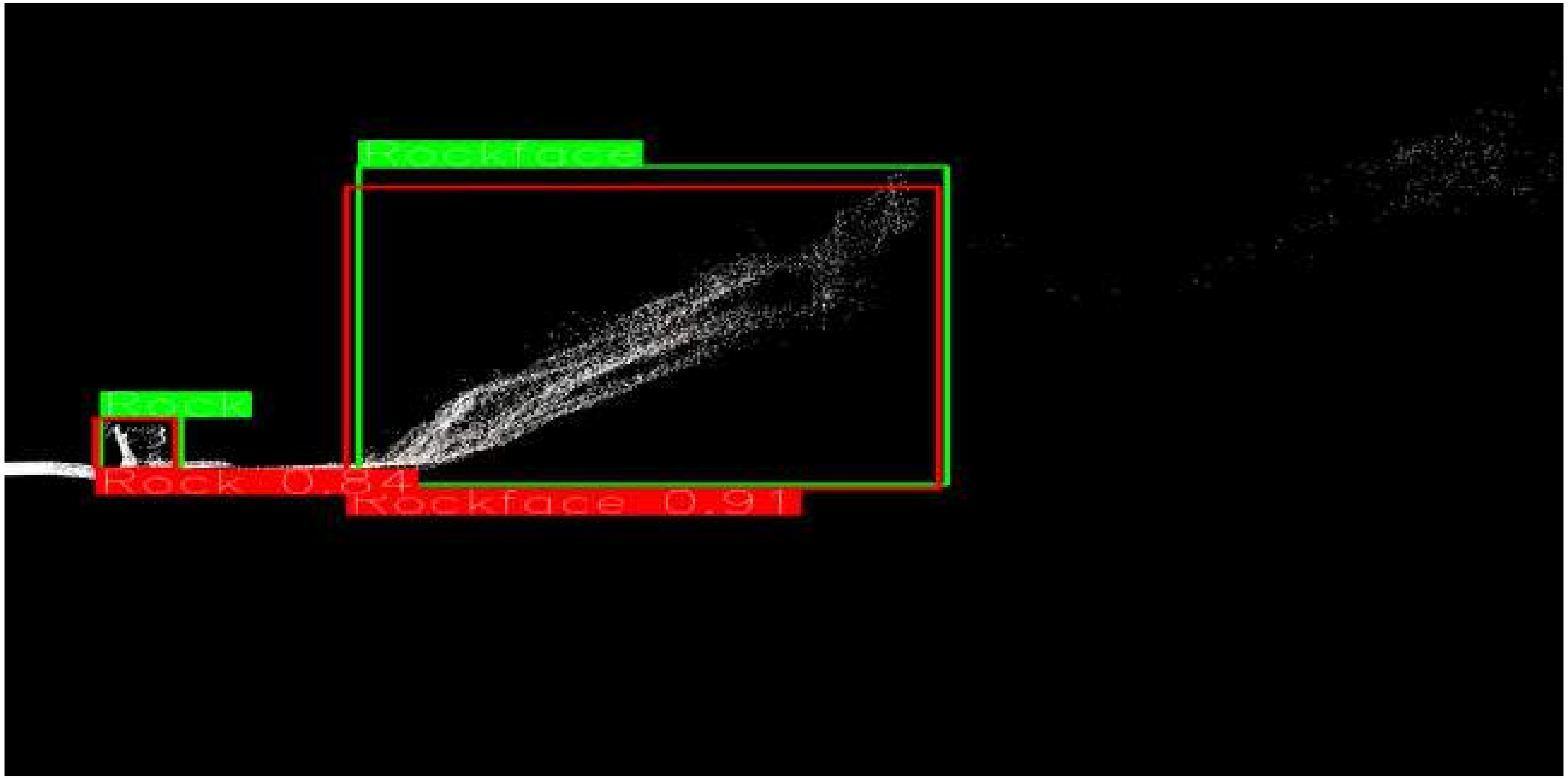
Stage 2: Roadside objects detection



Ground truth

Prediction

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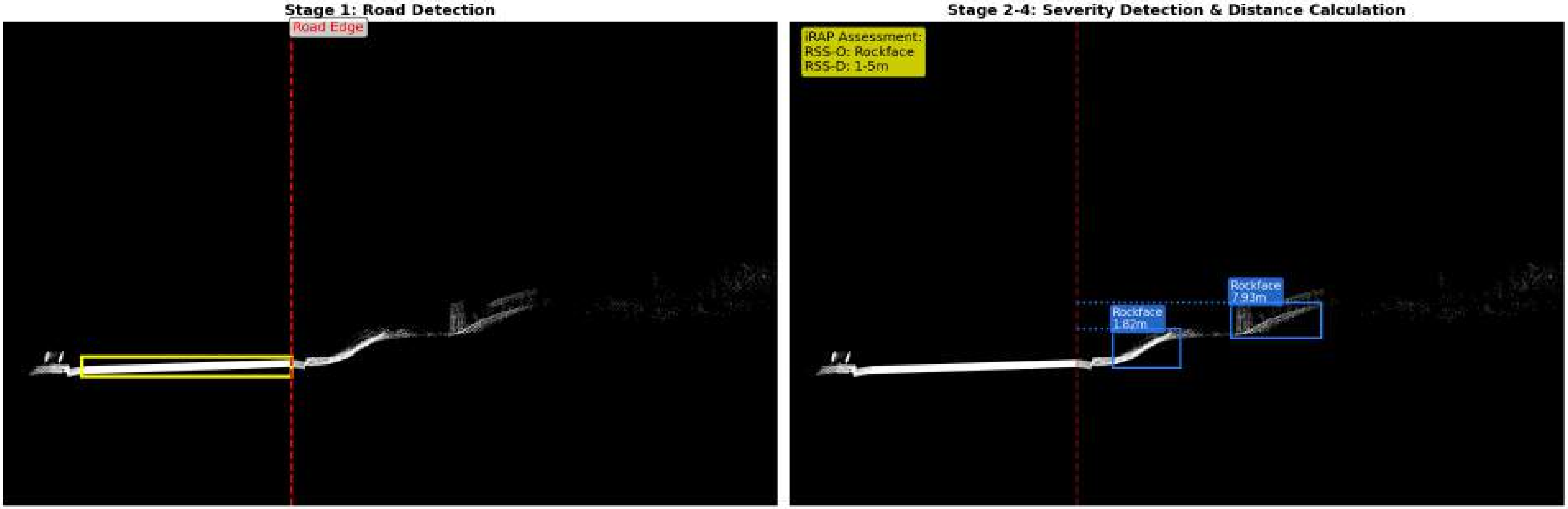
Model Inference on Test Dataset



Yolo model detected the road, then detected the roadside objects after that it calculated the distance of each roadside object to road edge line.

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Comparison of Results

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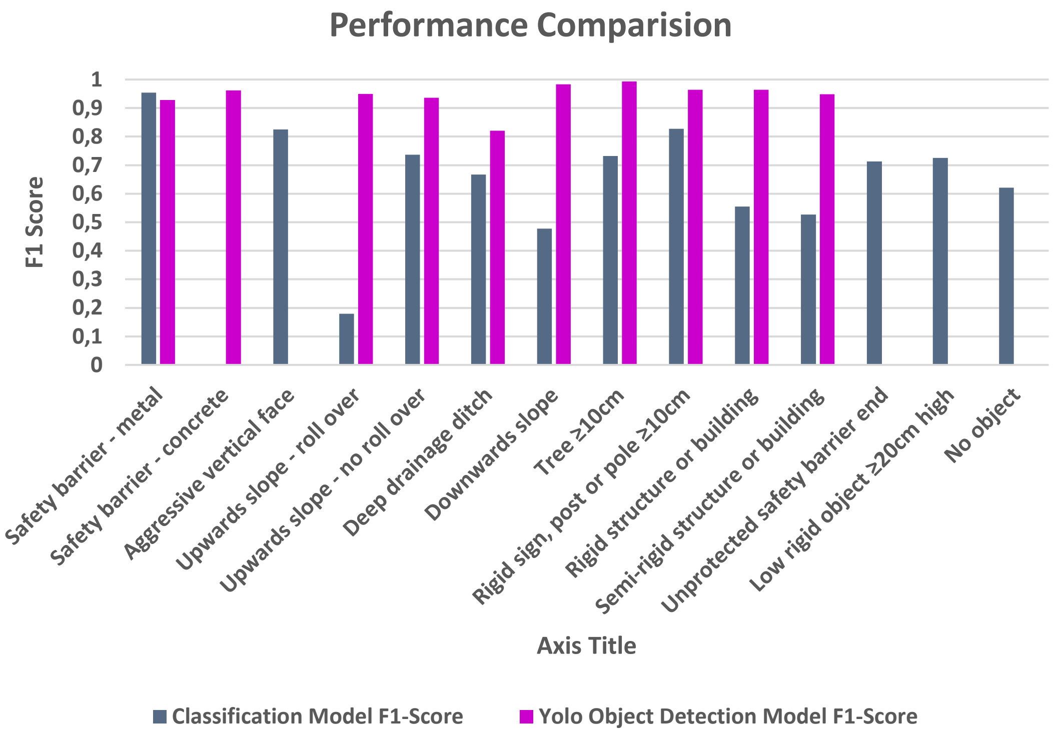
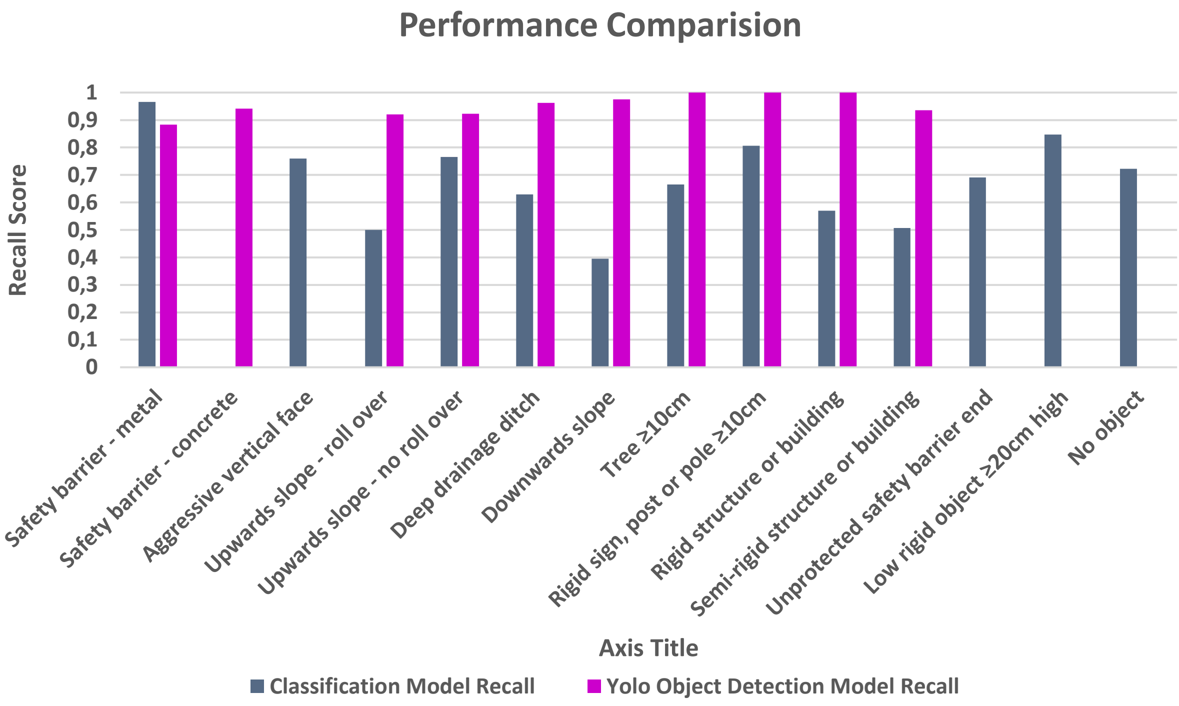
Roadside objects performance on Classification and Detection approaches





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Conclusion

Camera (RGB) imagery based Classification Model

Disadvantages:

- No precise distance estimation (e.g. distance will be classified in pre-defined categories)
- Data Imbalance issues
- Less accurate compared to object detection based approach

Advantages:

- Bounding box for each object is not required.

Lidar Yolo Based object detection Model

Disadvantages:

- Hard to create label each object with bounding boxes

Advantages:

- Highly accurate for roadside objects detection
- Highly accurate for dynamic distance calculation

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Thank you!

Muhammad Shahid, University of Zagreb

Contact: mshahid@fpz.unizg.hr

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