Uncertainty-Aware Road Obstacle Identification

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PROJECT OVERVIEW

1. Problem Statement

Exploring the approaches of current road obstacle detectors

2. State of the Art

Review of anomaly detection, objectness and conformal prediction

3. Proposed Method

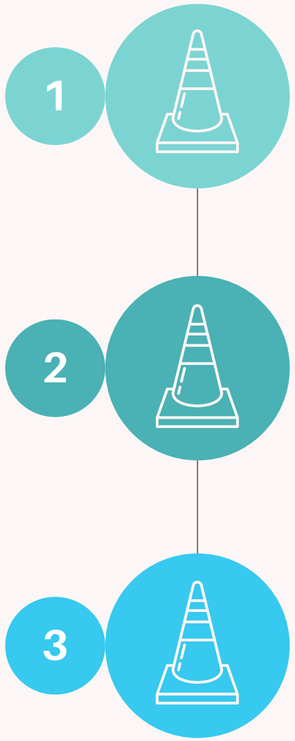
Segmentation, inference and interpretation

4. Conclusions

Key findings, limitations, and next research directions

PROBLEM STATEMENT

The Challenge of Unknown Obstacles



Traditional object detectors are limited to identifying objects belonging to a fixed set of predefined classes.

They are unable to recognize unknown road dangers —like fallen debris, construction materials, or lost cargo.

These unknown obstacles are often misclassified as background, leading to potential safety hazards.

STATE OF THE ART

current landscape of road obstacle detection

Road Obstacle Detection based on Unknown Objectness Scores [1]

- Introduces Unknown Objectness Score (UOS)
- Pixel-wise approach with strong results
- Sensitive to boundary noise

Conformal Semantic Image Segmentation [2]

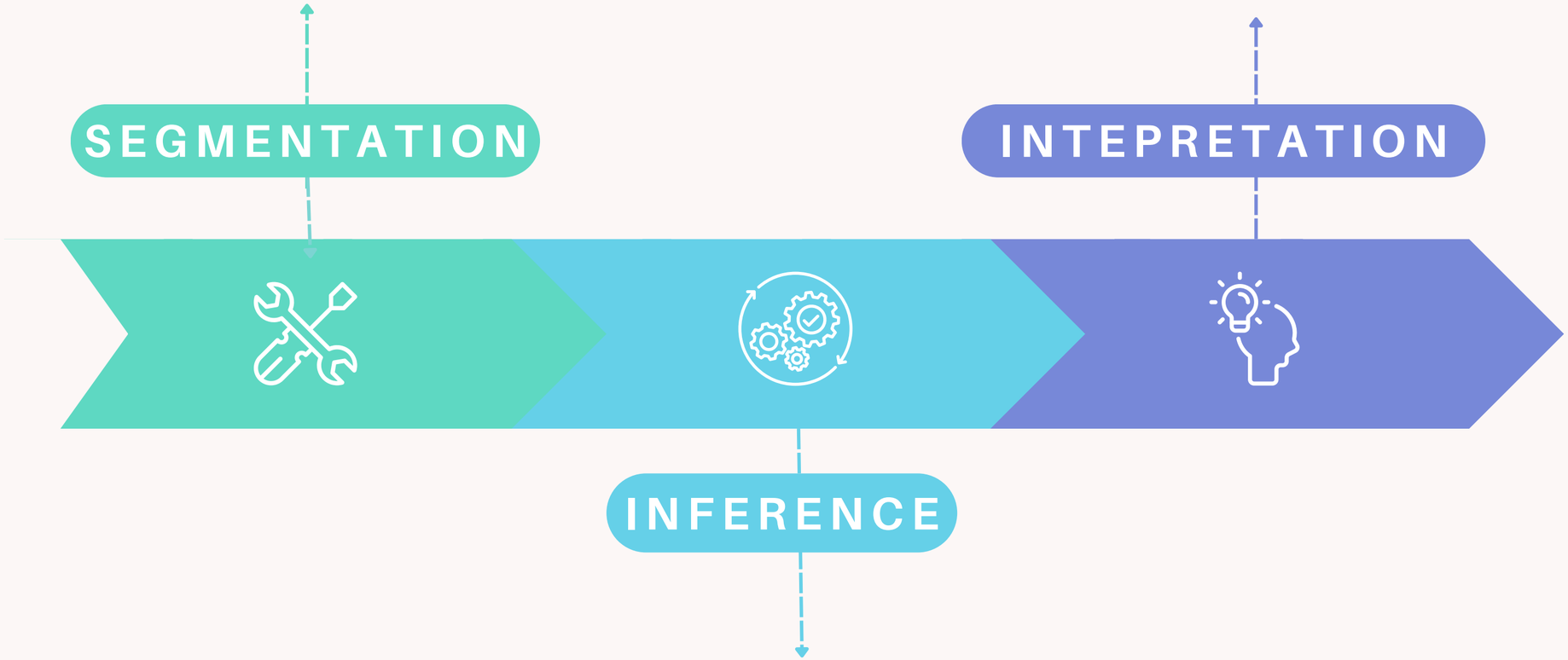
- Proposed a dual-decoder RGB-D architecture using conformal prediction.
- Needs depth sensors and is less effective for irregular obstacles

A Gentle Introduction to Conformal Prediction and Distribution-Free Uncertainty Quantification [3]

- Conformal prediction for uncertainty estimation with statistical guarantees.
- Theory-focused, not directly designed for vision tasks.

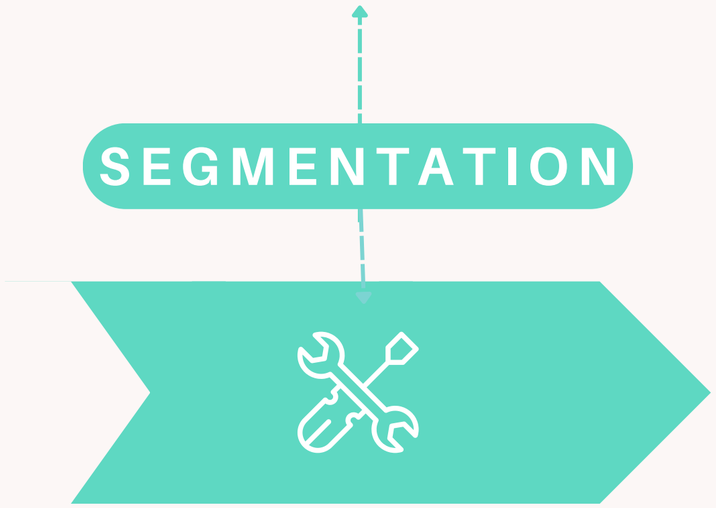
[1] Noguchi, C., Ohgushi, T., & Yamanaka, M. (2024)
[2] Mossina, L., Dalmau, J., & Andéol, L. (2024)
[3] Angelopoulos, A. N., & Bates, S. (2022)

PROPOSED METHOD



PROPOSED METHOD

DeepLabV3+ with ResNet50 backbone



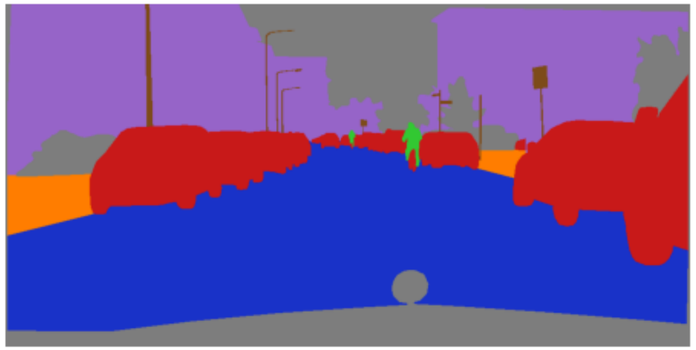
- Dual-Head Model
  - Softmax Head
  - Sigmoid Head
- Training Dataset: CityScapes remapped from 19 to 7 macro-classes*
- Data Augmentation: Horizontal Flip
- Loss functions:
  - CE for segmentation
  - BCE with logits loss for objectness

*road, flat, human, vehicle, construction, object, and background

SEGMENTATION PREDICTIONS

Input RGB

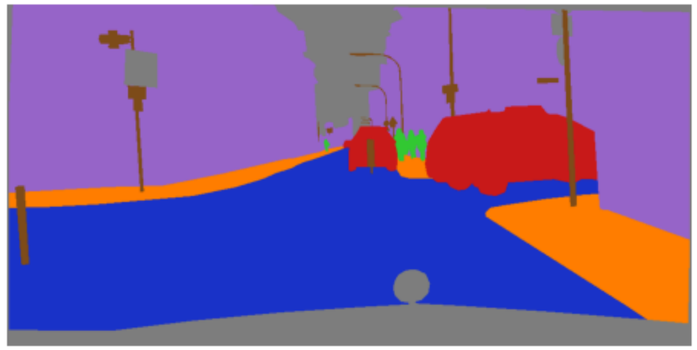
SEG Ground Truth



SEG Prediction

Input RGB

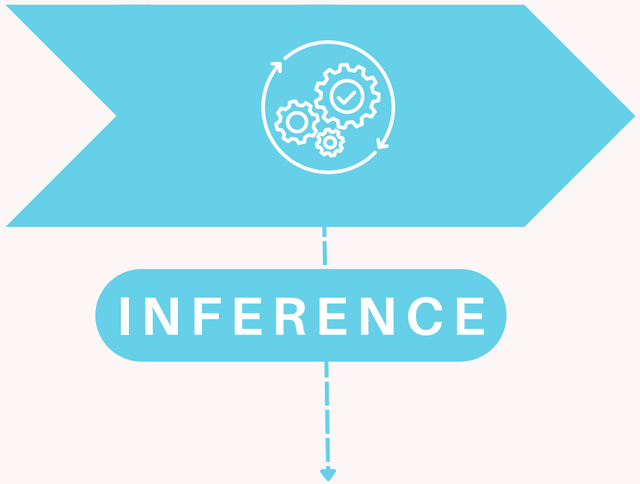
SEG Ground Truth



SEG Prediction

Avg IoU: 0.64

PROPOSED METHOD



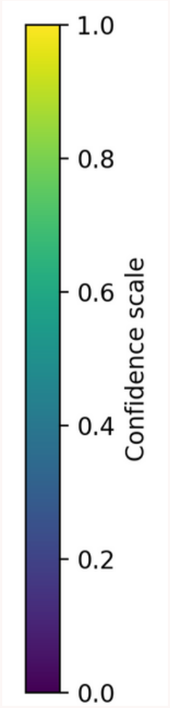
- Obstacle detection rule:
  - softmax confidence is low for every class
  - objectness score is above a threshold
- Uncertainty estimation via conformal prediction
  - Calibration
  - Threshold

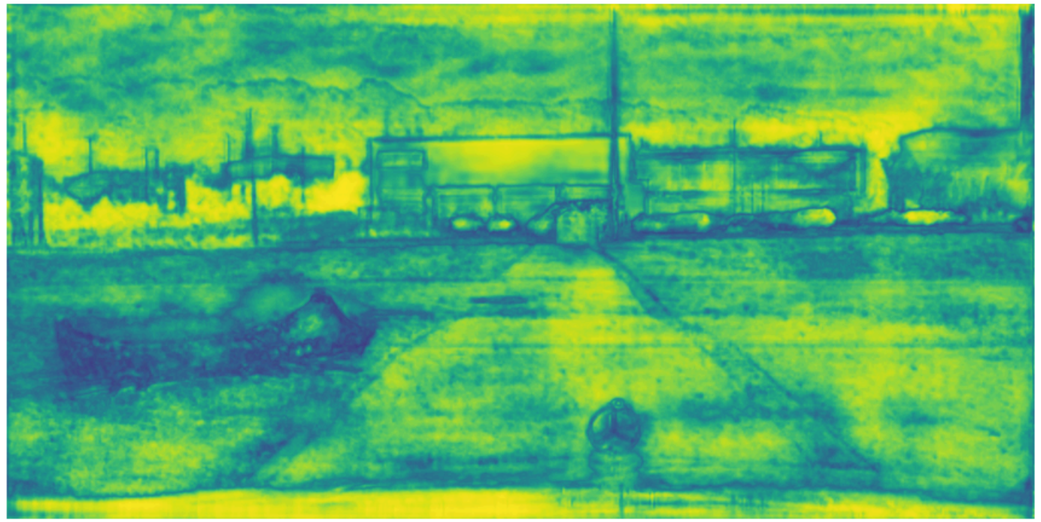
$$1 \quad - [max(softmax \quad outputs)]$$

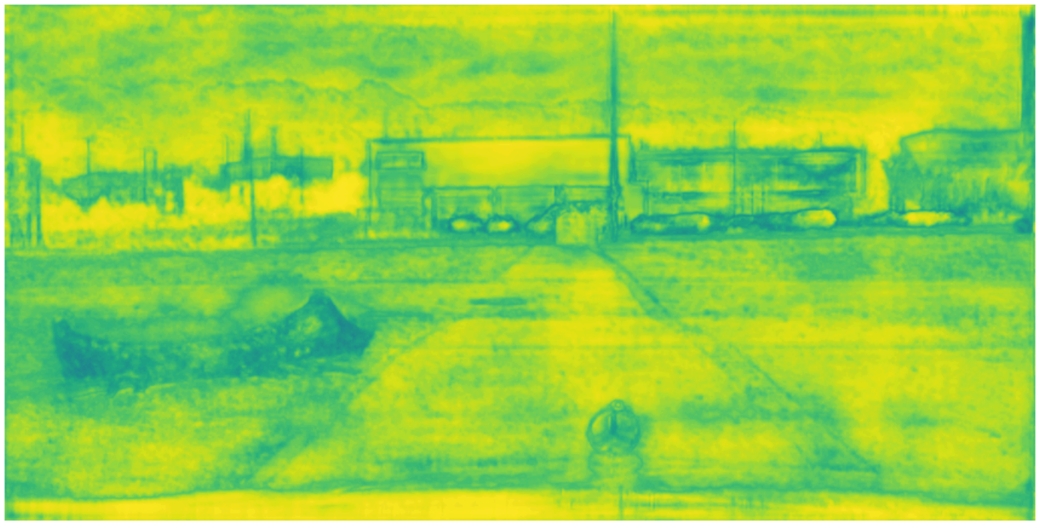
- Datasets: LostAndFound, RoadAnomaly

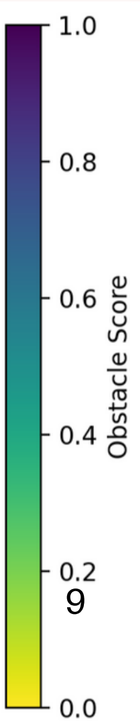
LOST AND FOUND INTERPRETATION

Metric	Avg
Precision	0.297769
Recall	0.492834
F1 Score	0.317349
IoU	0.198677
AUROC	0.6812
FP@95TPR	81.29%



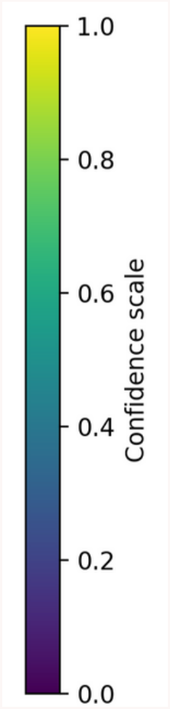


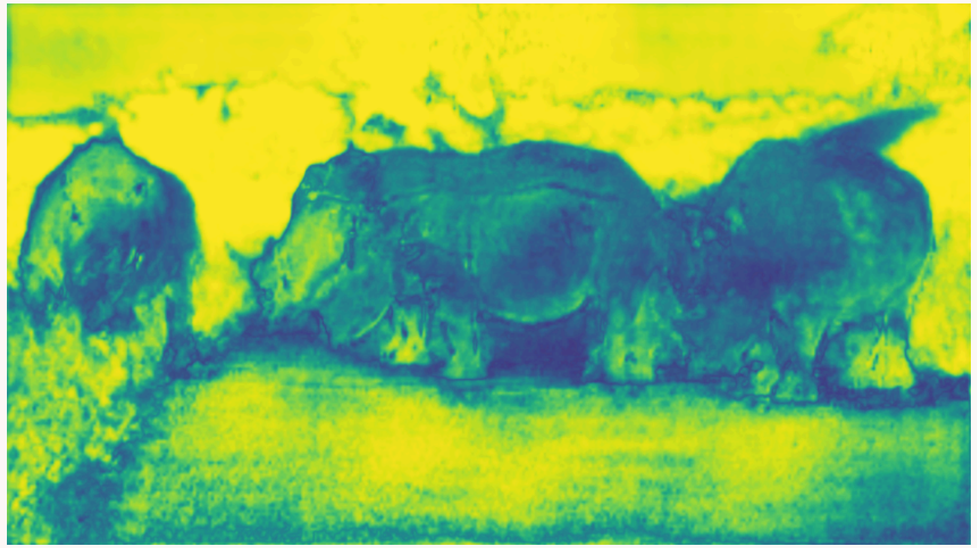


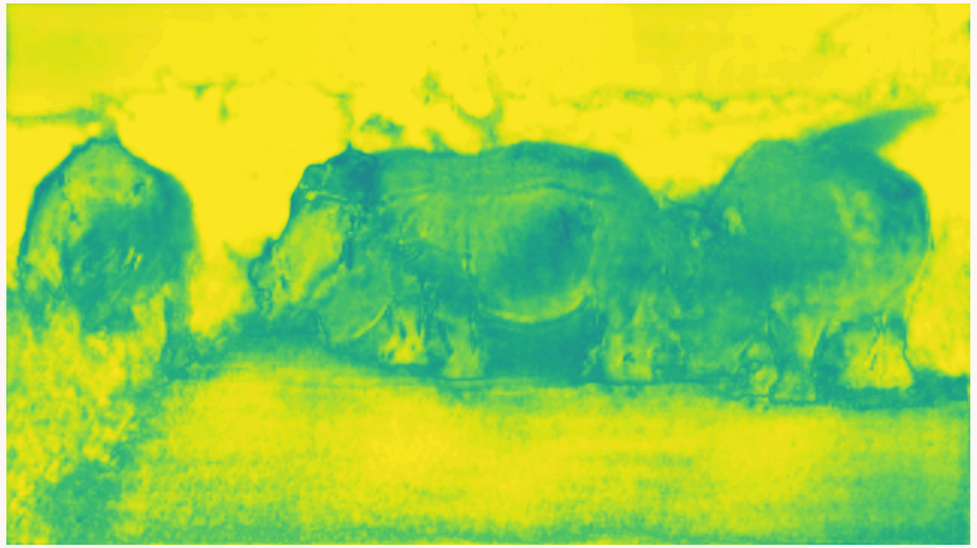


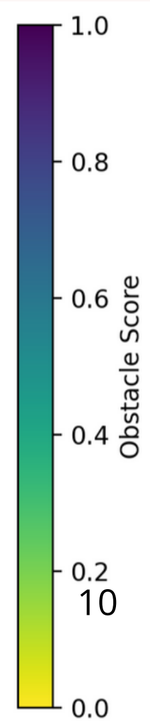
ROAD ANOMALY INTERPRETATION

Metric	Avg
Precision	0.007024
Recall	0.700488
F1 Score	0.013409
IoU	0.006931
AUROC	0.8421
FP@95TPR	54.11%







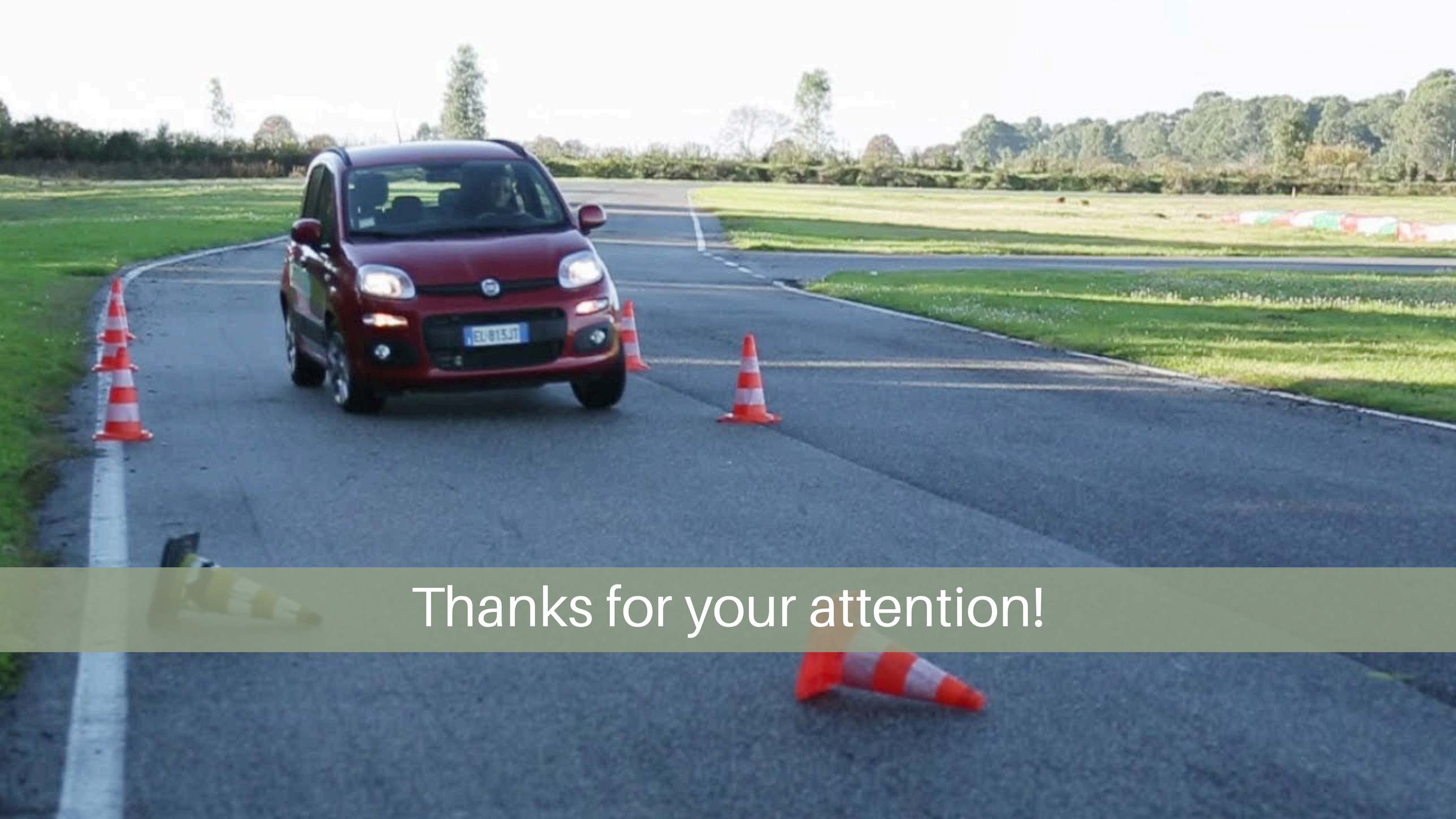


CONCLUSIONS

Custom traits introduced
(segmentation head override, data augmentation attempts)

Segmentation-independent approach achieved

However, directly shifting domains comes with drawbacks
Precision drops, false positives rise, instability on unseen data


Thanks for your attention!