

# Uncertainty-Aware Road Obstacle Identification

Computer Vision / Project 11 - Prof. Amerini



Andrea Pizzi  
Simone Turco  
Federico Urbini

# Outline:

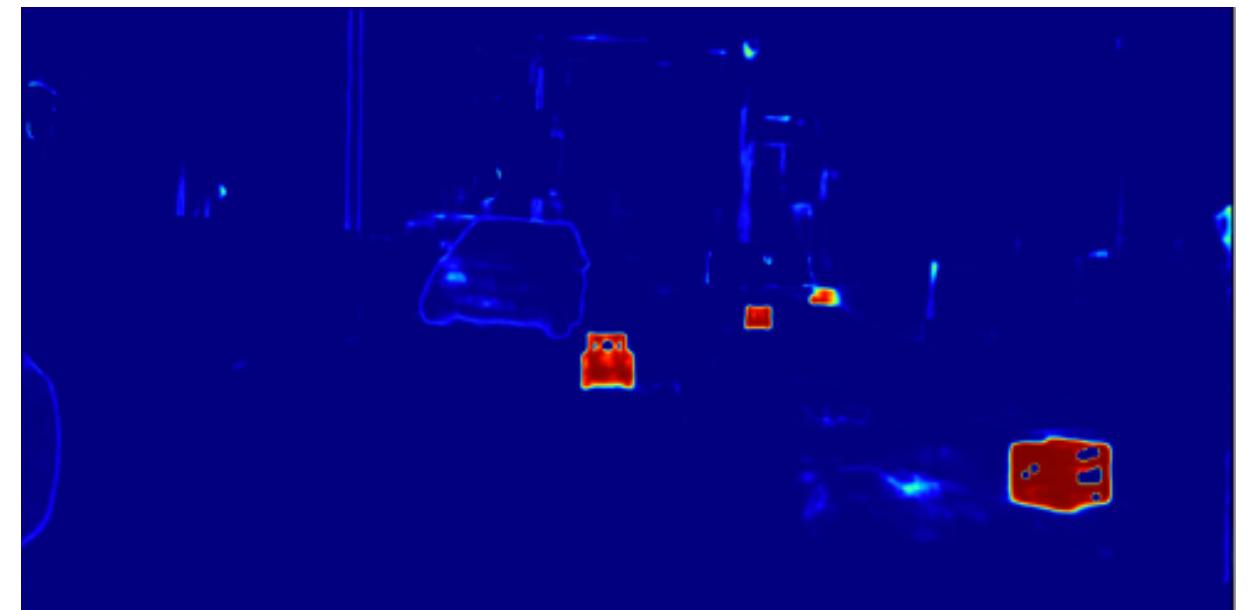
- Introduction
- Challenges
- Related Works
- Datasets
- Proposed Method
- Evaluation and Results
- Conclusions & Future Work

# Why Uncertainty-Aware Road Obstacle Detection?

**Traditional semantic segmentation** models **assume** all objects belong to **known classes**.

**Real-world** driving involves **unexpected obstacles** (debris, boxes, unusual vehicles), so misclassifying unknowns as background leads to critical safety failures.

A model must understand what it doesn't know, **uncertainty** is key.



# Why Add Uncertainty Awareness?

**Uncertainty awareness** means that a model not only makes **predictions** (e.g., where the road is) but also knows **how confident** it is in those **predictions**.

This **method** helps to:

- Improve **Safety**
- Highlights **low-confidence** regions
- Improve **Robustness**
- Adapt model to **Real Scenarios**

# Challenges & Limitations in Semantic Segmentation

- **Small** or **distant** objects often lack sufficient pixel area to be detected reliably.



- **Domain shifts** like weather changes or unseen environments reduce generalization.



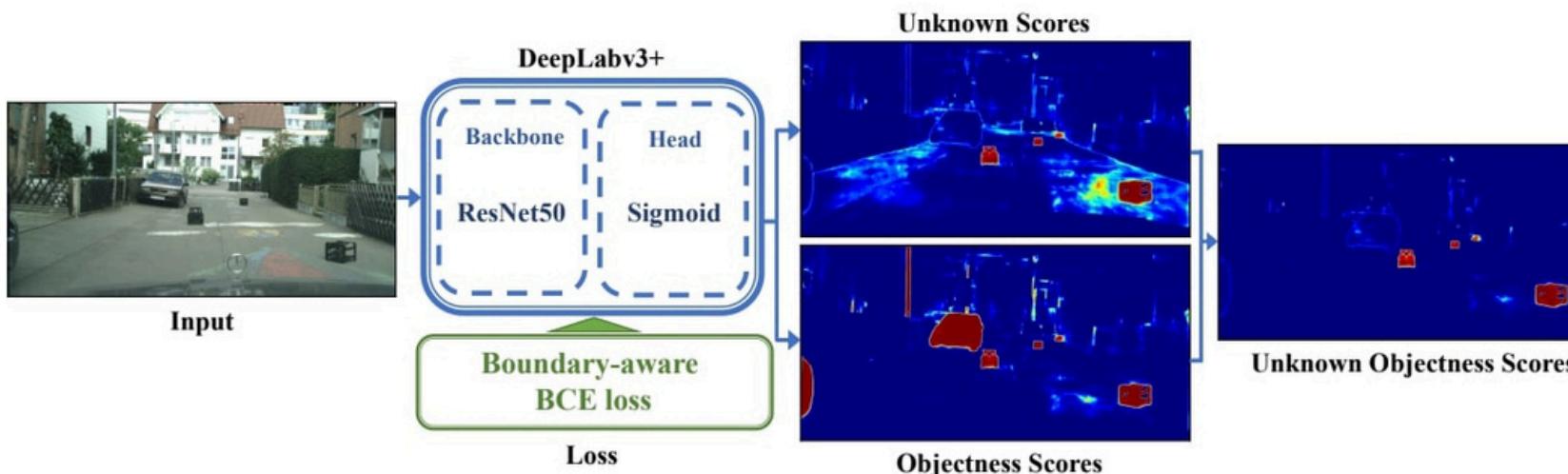
- **Unknown objects** may be misclassified as background.



# Related Works – Unknown Objectness and CP

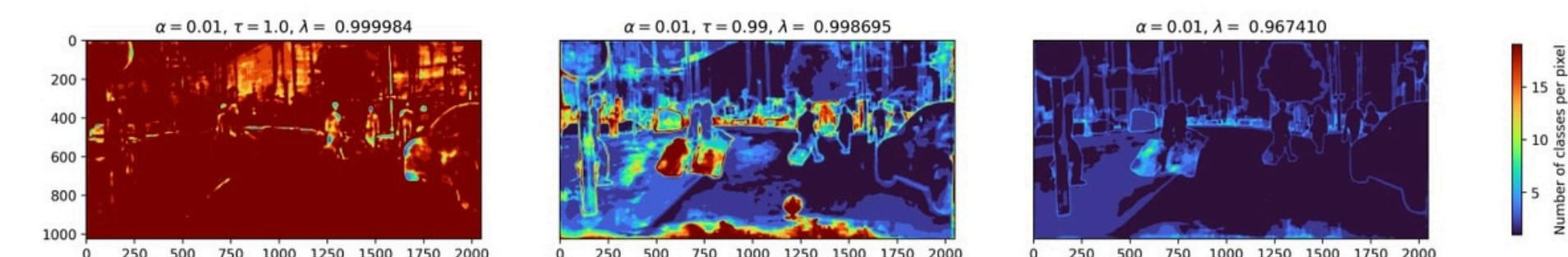
**Noguchi** et al. (2024) introduced UOS to improve OOD detection.

- Works independently of softmax thresholds.
- Highlights limitations of temperature scaling.



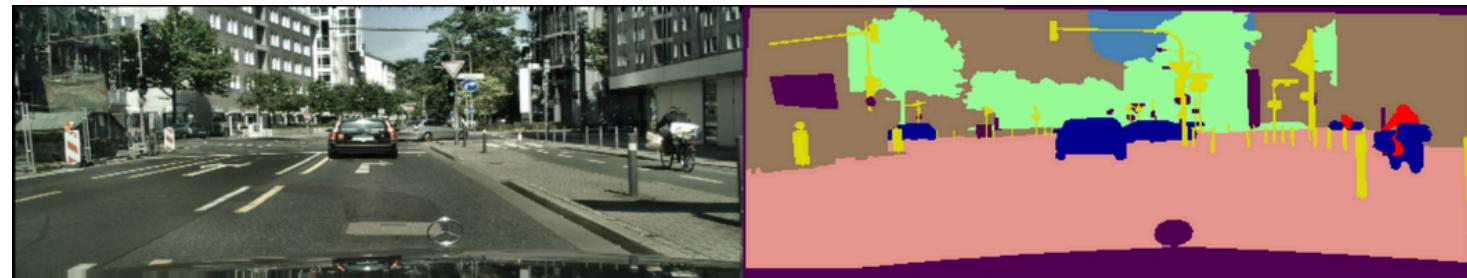
**Mossina** et al. (2024) proposed pixel-wise Conformal Prediction for semantic segmentation.

- Ensures a formal coverage guarantee (e.g., 95%) per pixel.
- Improves trust under distributional shift.



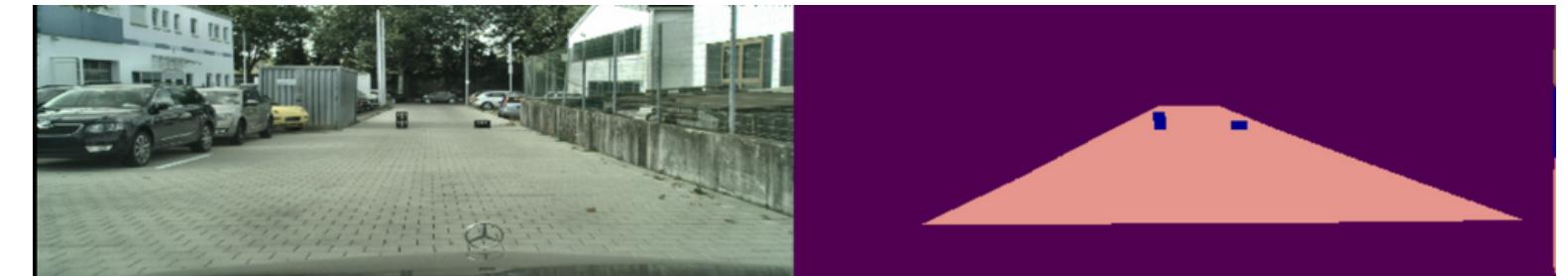
# Datasets

## Cityscapes



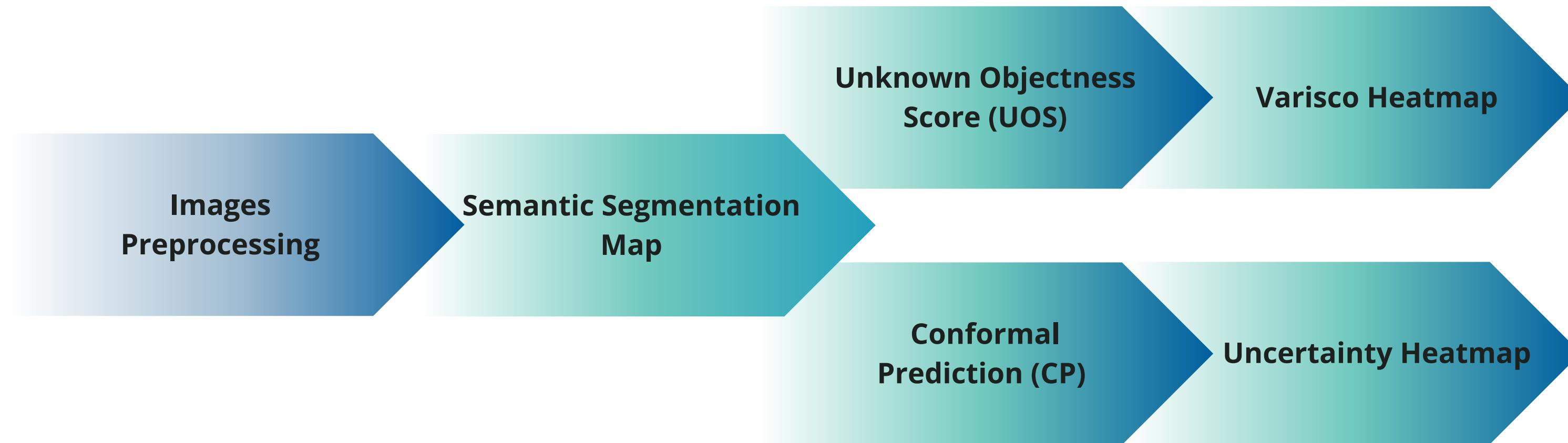
- Urban Scenes
- High-Quality/Corse Annotations.
- High Resolution ( $2048 \times 1024$  px)
- Large (more than 10.000)

## LostAndFound



- Urban Scenes
- Very Small Obstacles
- High-Quality Annotations.
- High Resolution ( $2048 \times 1024$  px)

# Proposed Method Overview



# Image Preprocessing

- **Downscaling Dataset Images on a fixed size (512x256, )**  
Standardize input dimension and reduce memory usage and computational cost during training
- **Contrast and brightness enhancement using CLAHE**  
CLAHE enhances visual clarity, especially in shadowed or overexposed regions
- **Implemented color-to-label mapping and reverse label-to-color mapping on the target image**  
Converts color-coded ground truth images into numerical class labels for training and enable reverse transformation to visualize prediction in colors
- **Transform intermediate mapping in one-hot encoding to match model logits**  
Aligns ground truth format with the model's softmax/logit output

# Semantic Segmentation and Object Class

We collapsed the original dataset classes into a reduced set of 8:

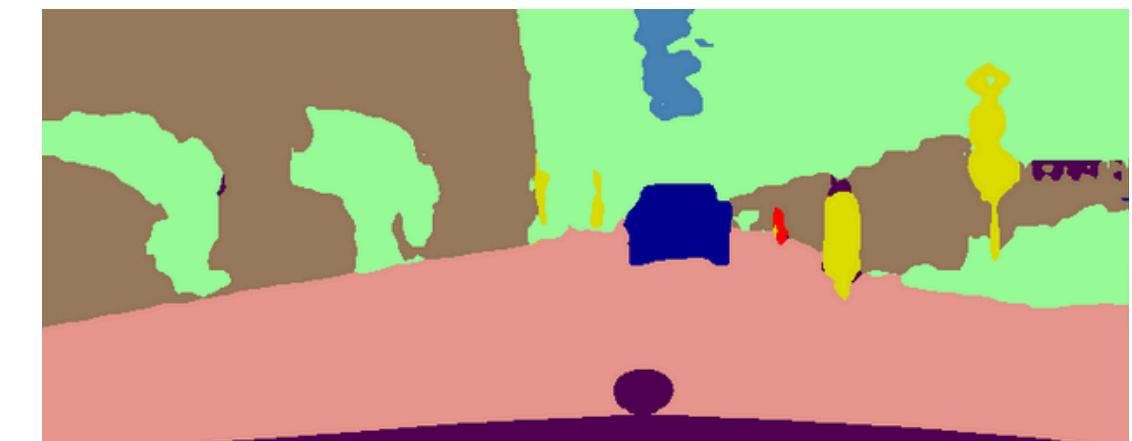
- simplify the segmentation task and help the model learn more effectively by focusing on fewer, more meaningful categories.

Introduced an 'object' class:

- Binary mask, where each pixel is assigned a value of 1 if it corresponds to an object of interest (e.g., vehicles, traffic signs, or road obstacles), and 0 otherwise.

Three steps for segmentation:

1. **Pre-training** on Extended Cityscapes with Coarse Annotations
2. **Training** on Cityscapes with Fine Annotations
3. **Fine-Tuning** on Lost and Found Dataset for Obstacle Detection



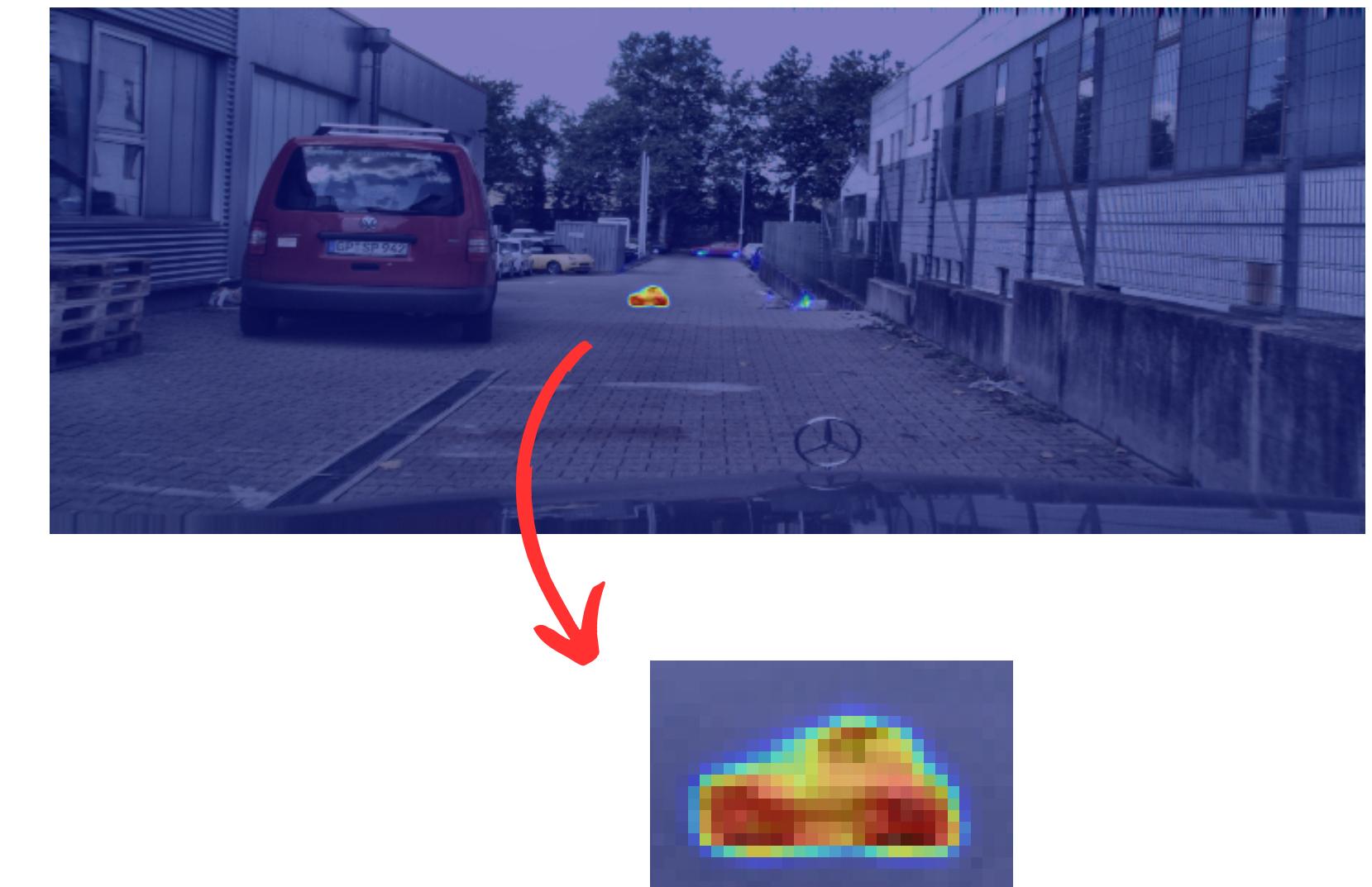
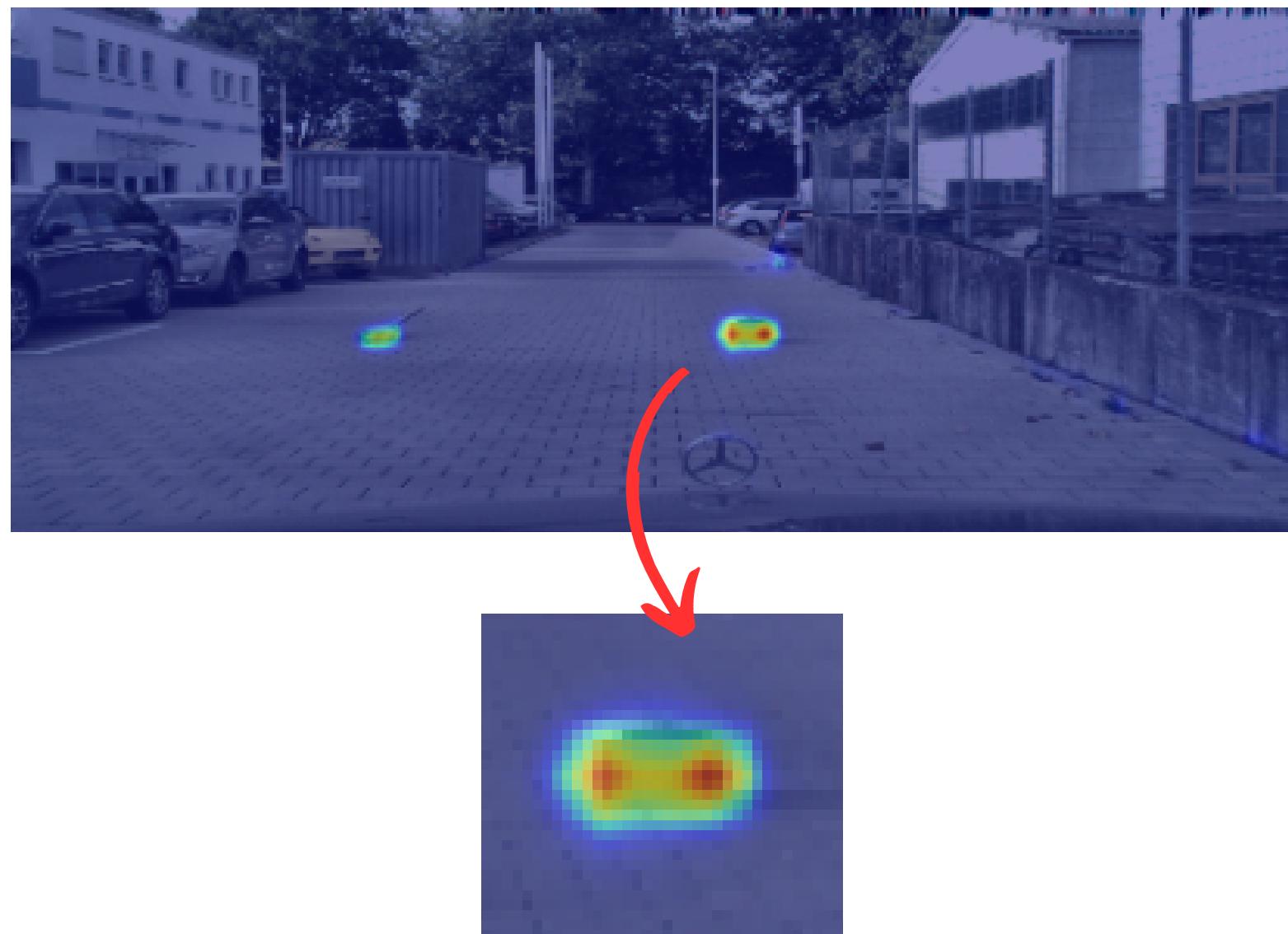
# Unknown Objectness Score (uOS)

**UOS** is computed from softmax outputs as:

$$S_i = p_i^o \prod_{k=1}^K (1 - p_{ik}).$$

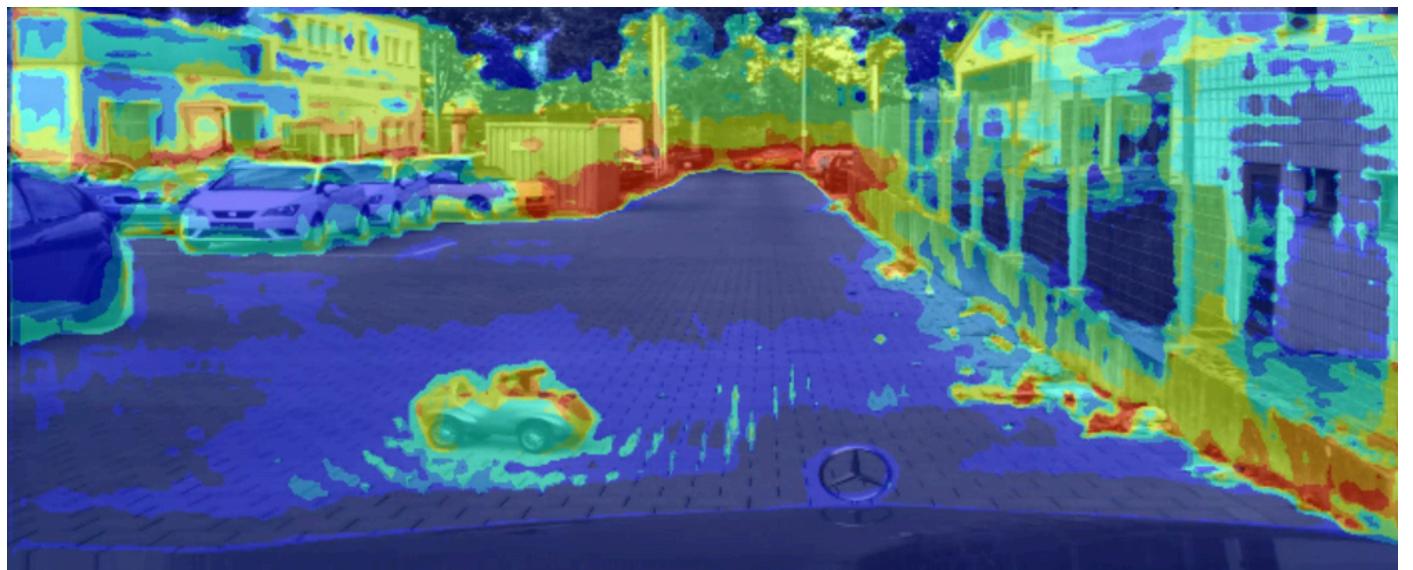
- Highlights pixels that do not belong confidently to any known class.
- Independent of softmax threshold → detects rare and out-of-distribution (OOD) objects.
- We used the Varisco heatmap to visualize Unknown Objectness Scores (UOS) as a color-coded overlay on RGB images.

# Varisco Heatmap for Unknown Objectness Score



# Conformal Prediction (CP)

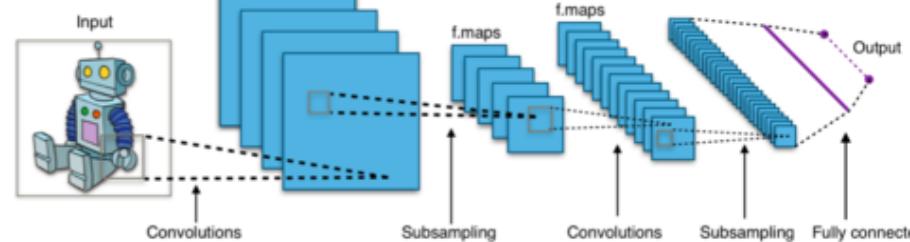
Conformal Prediction estimates how reliable a prediction is by comparing it to past examples. It helps identify uncertain regions where the model might be wrong.



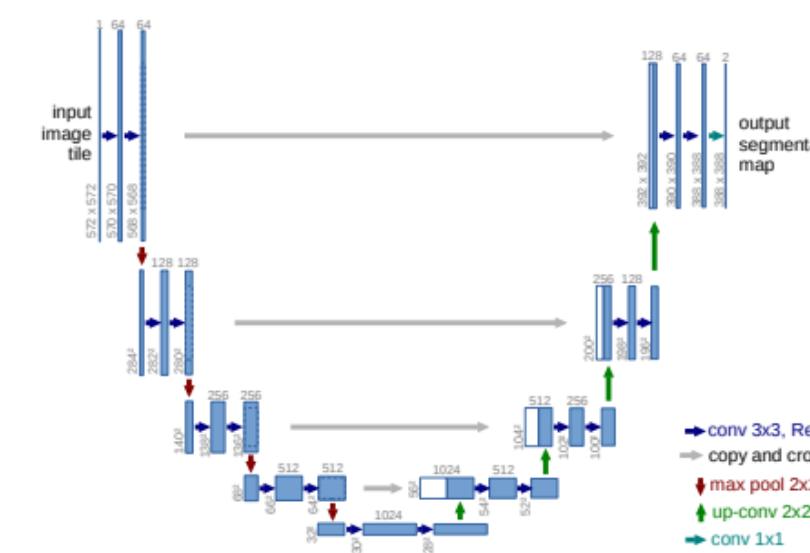
**lambda = 0.995**

# Proposed Networks

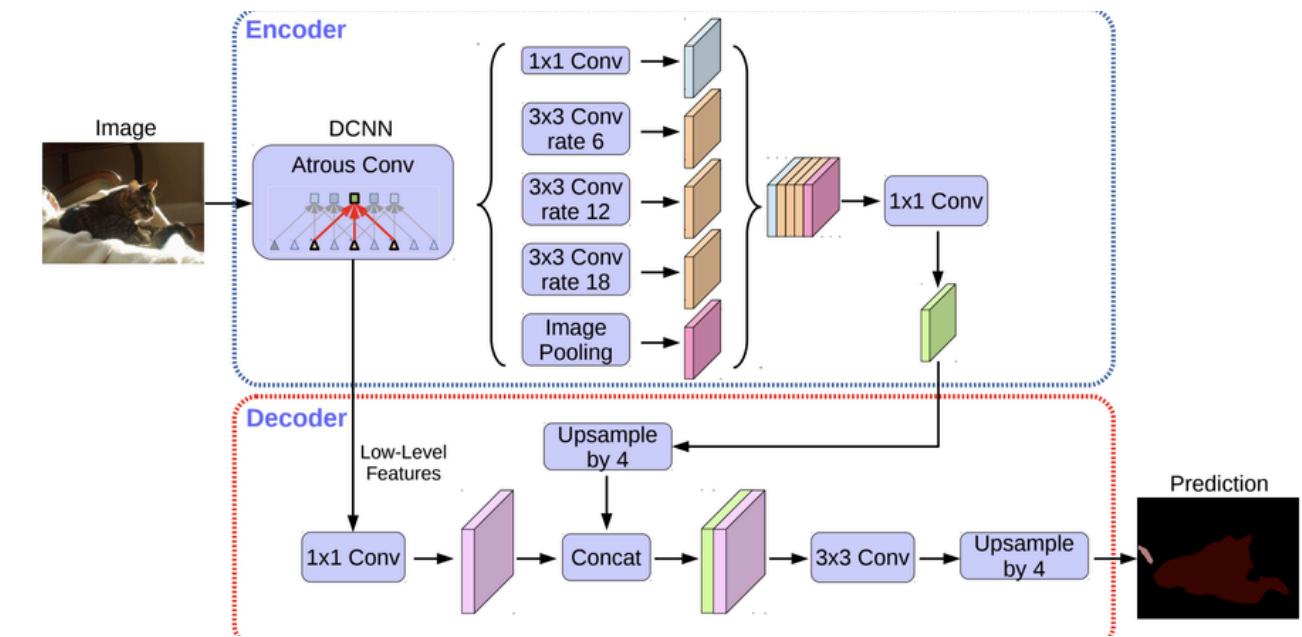
## FCN Vgg-19 based



## U-Net



## DeepLabV3+



- **Full Convolutional** Network
- Standard Structure
- No Advance Features

- **Encoder-Decoder** architecture
- **Weights share** at same level

- **Multi-scale** segmentation
- Efficient dilatate convolution
- Network **State-Of-Art** for Segmentation Task

# Evaluation Metrics, Benchmark

## Train Metrics

- Segmentation: IoU, DiceScore

## Benchmark procedure

1. Test the model on LostAndFound Dataset
2. Repeate test 3 times
3. Estimate Uncertain
4. Collect Average results

## Benchmark metrics

- OOD Detection: AUROC, AP
- Uncertainty: Conformal coverage

# Results

	optimizer	lr	Backbone	Atrous rates	stride	Decoder Depth	IoU	mAP	AUROC	Dice Score
DeepLab3+	SGD	0.01	ResNet50	[3,6,12]	16	5	0.554	0.2	0.93	0.62
U-Net	SGD	0.001	ResNet50	-	-	5	<b>0.57</b>	<b>0.46</b>	<b>0.96</b>	<b>0.65</b>
DeepLab3+	SGD	0.01	ResNet101	[3,6,12]	16	5	0.56	0.19	0.86	0.64

Among the tested architectures, U-Net consistently achieved the best performance on our task. It proved highly effective, resulting in the highest scores across all evaluation metrics.

# Conclusion & Future Work

Our integration of UOS and Conformal Prediction improves robustness under domain shift and enhances reliability. The framework is lightweight, modular, and generalizable.

## Future Directions:

- Real-time deployment of UOS & CP
- Fusion with multi-modal data (RGB + depth, LiDAR) and network
- Use UOS maps to guide refinement: when the model is uncertain, activate a second-stage module to reprocess those regions and improve the final segmentation."

## **Contacts:**

**Andrea Pizzi**, [pizzi.1995517@studenti.uniroma1.it](mailto:pizzi.1995517@studenti.uniroma1.it)

**Simone Turco**, [turco.1987712@studenti.uniroma1.it](mailto:turco.1987712@studenti.uniroma1.it)

**Federico Urbini**, [urbini.2007465@studenti.uniroma1.it](mailto:urbini.2007465@studenti.uniroma1.it)