

# Automated and Connected Driving Challenges

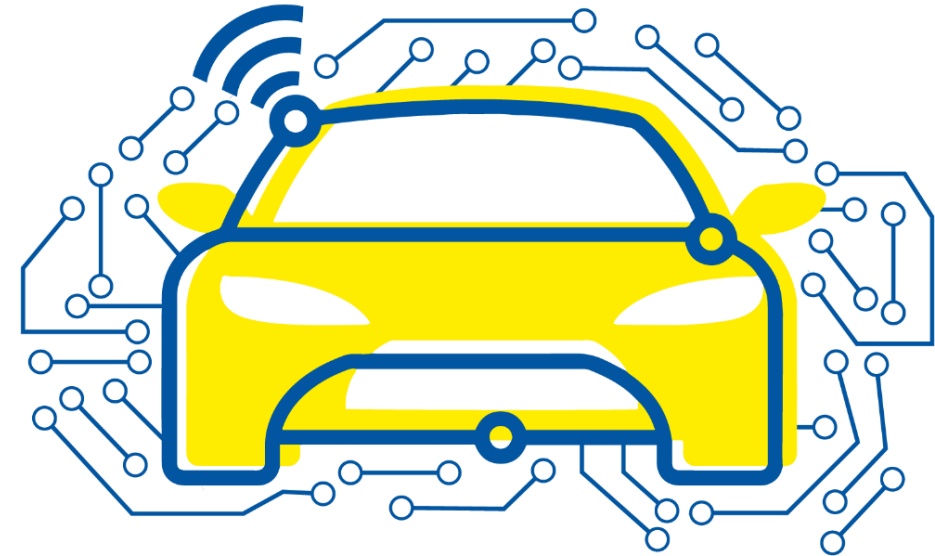
Section 2 – Sensor Data Processing

Object Detection

Evaluation

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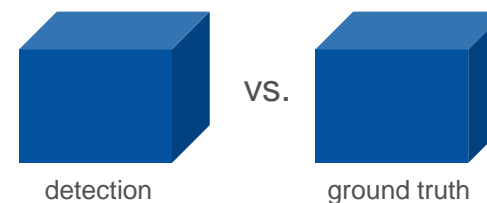




# Object Detection – Evaluation

## *Intersection over Union*

- Metric for evaluating the **localization**
- Compare each detection with its ground truth



$$IoU(b_1, b_2) = \frac{|b_1 \cap b_2|}{|b_1 \cup b_2|} = \frac{\text{Intersection}}{\text{Union}} \in [0,1]$$

- **Final hypotheses** with  $IoU_{pred}^{true} > \min IoU_{pred}^{true}$  are considered as **TP**
- All other predictions are false positives (**FP**) or false negatives (**FN**)

		actual	
		positive	negative
predicted	positive	True Positives (TP)	False Positives (FP)
	negative	False Negatives (FN)	True Negatives (TN)



# Object Detection – Evaluation

## Average Precision

- Confusion matrix



		actual	
		positive	negative
predicted	positive	True Positives (TP)	False Positives (FP)
	negative	False Negatives (FN)	True Negatives (TN)

- $\text{Precision} = \frac{TP}{TP+FP}$  (Positive Predictive Value)
- $\text{Recall} = \frac{TP}{TP+FN}$  (True Positive Rate)

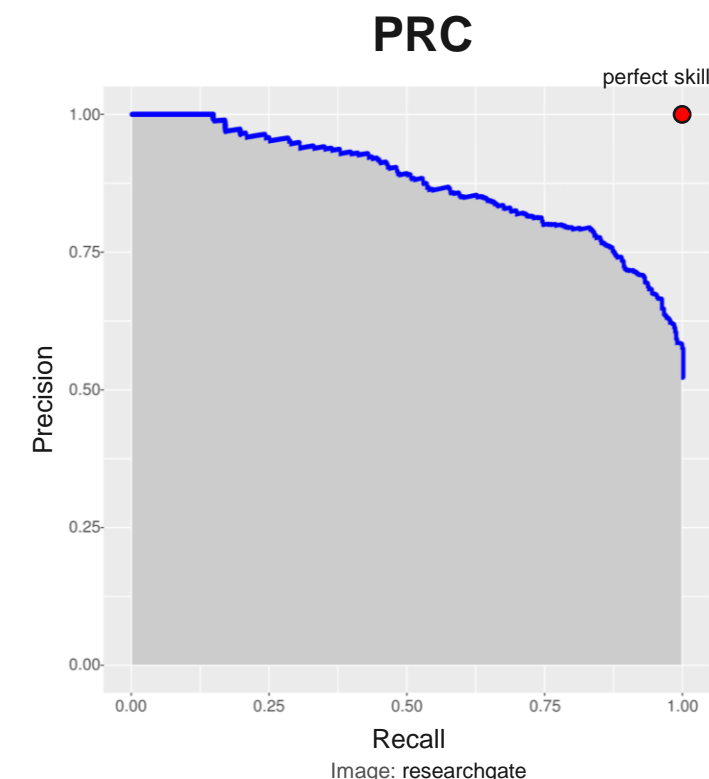
- Precision-Recall pairs

- Variable confidence score thresholds  $^{min}CS$
- Fixed  $^{min}IoU_{pred}^{true}$  threshold (often 50%)



- Average Precision (AP) is integrated area under curve

- e.g.  $AP_{50}$  /  $AP@50\%$   $AP \in [0,1]$





# Object Detection – Evaluation

## Average Precision

- Average Precision can be computed at **different IoU Prediction Thresholds** ( $AP_{50}$ ,  $AP_{75}$ , ...)  
→ **average of AP scores**  $AP_{\emptyset} = AP@[0.5:0.95:0.05]$
- **Mean Average Precision (mAP)** is **average** over all **class-specific** AP scores
- Model evaluation matrix looks similar to this table

Model	$mAP_{50}$	$mAP_{75}$	$mAP_{\emptyset}$	$c_1$			...			$c_N$		
				$AP_{50}$	$AP_{75}$	$AP_{\emptyset}$	$AP_{50}$	$AP_{75}$	$AP_{\emptyset}$	$AP_{50}$	$AP_{75}$	$AP_{\emptyset}$
Model 1	<b>0.8</b>	0.4	<b>0.6</b>	...	...	...	...	...	...	...	...	...
Model 2	0.7	<b>0.6</b>	0.5	...	...	...	...	...	...	...	...	...
Model 3	0.5	0.4	0.3	...	...	...	...	...	...	...	...	...

**Bold numbers**  
indicate the  
best score  
across models



# Object Detection – Evaluation

## Datasets and Benchmarks

### 2D Datasets

- ImageNet
- CIFAR
- COCO
- Cityscapes
- KITTI
- PASCAL VOC
- nuScenes



Image: [cv.gluon](http://cv.gluon)

### 3D Datasets

- Waymo Open Dataset
- Ford Campus Vision
- nuScenes
- KITTI
- KITTI 360



Image : [cvlibs](http://www.cvlibs.net/datasets/kitti-360)

### Benchmarks challenges

enable comparison between different models

- main **influencing factors**
  - Average Precision
  - runtime for inference



always tradeoff between runtime and accuracy!

	Method	Setting	Code	Moderate	Easy	Hard	Runtime
1	DRF			83.21 %	91.02 %	78.20 %	0.08 s
2	Anonymous			82.99 %	91.64 %	78.02 %	0.1 s
3	BtcDet	☑		82.86 %	90.64 %	78.09 %	0.09 s
4	HIKVISION-ADLab-HZ			82.83 %	89.00 %	76.00 %	0.1 s
5	SPG_mini	☑		82.66 %	90.64 %	77.91 %	0.09 s
6	SE-SSD	☑	code	82.54 %	91.49 %	77.15 %	0.03 s

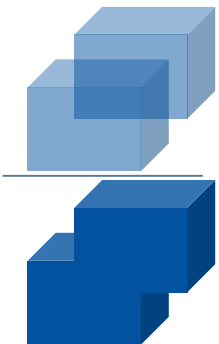
Image : [cvlibs](http://www.cvlibs.net/datasets/kitti-360)



# Object Detection – Evaluation

## Summary

- Intersection over Union
- Average Precision
- Datasets and Benchmarks



		actual	
		positive	negative
predicted	positive	True Positives (TP)	False Positives (FP)
	negative	False Negatives (FN)	True Negatives (TN)

