

Problem Formulation

Course 3, Module 4, Lesson 1



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FACULTY OF APPLIED SCIENCE & ENGINEERING

Learning Objectives

- In this module...
 - Define the 2D object detection problem
 - Apply ConvNets to 2D object detection
 - Challenges of object detection
 - 2D object tracking problem

Learning Objectives

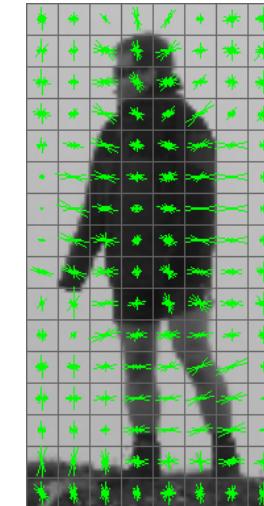
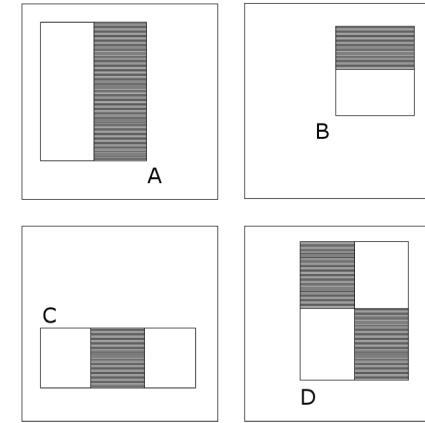
- Learn the 2D object detection task problem formulation.
- Learn to determine how good a 2D object detector is through evaluating performance measures.

Brief History of Object Detection

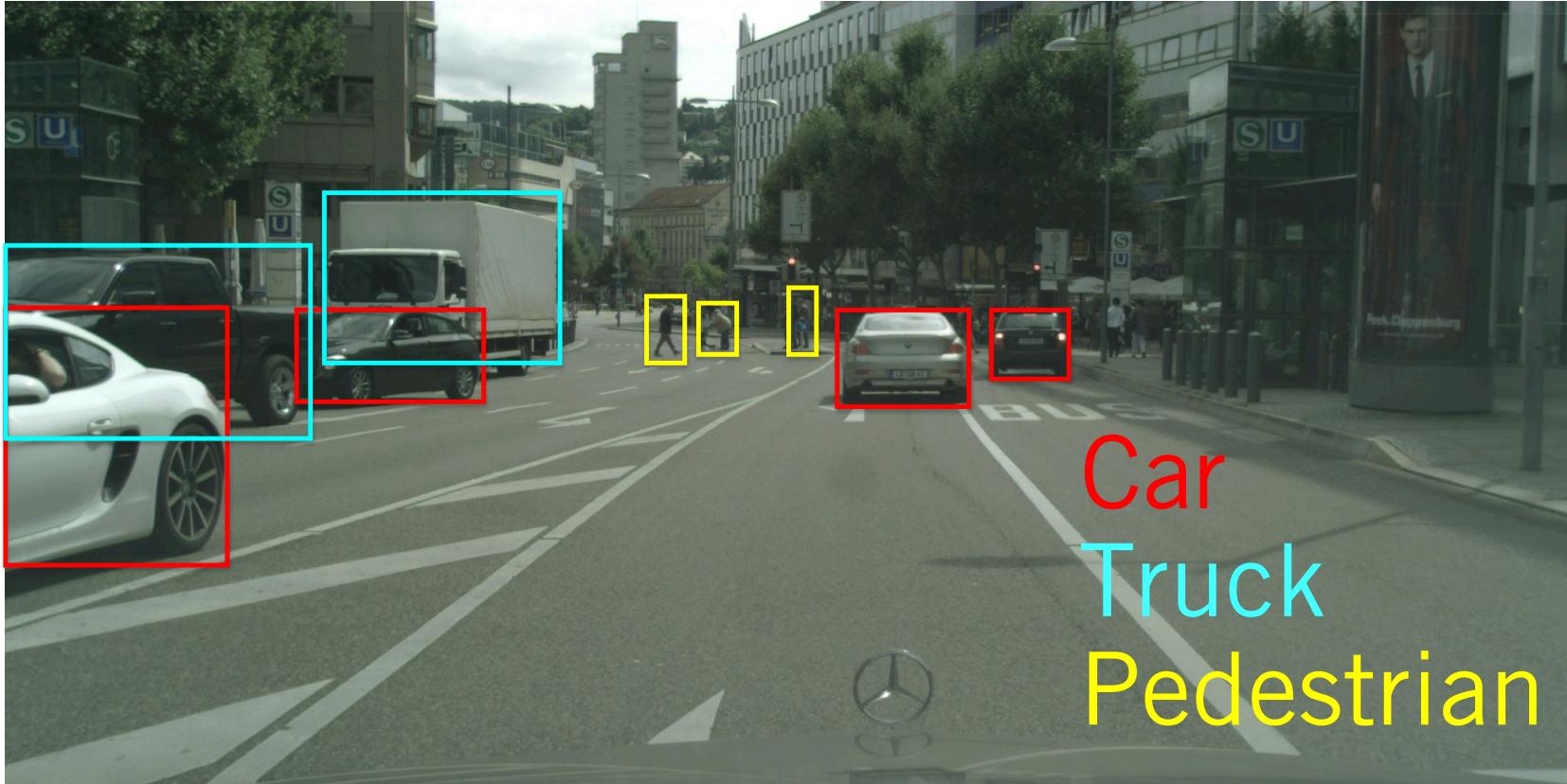
- 2001 – Viola, Jones – Viola Jones Object Detection Framework
- 2005 – Dalal, Triggs – Histogram of Oriented Gradients
- 2012 – Krizhevsky, Sutskever, Hinton - Alexnet



ImageNet

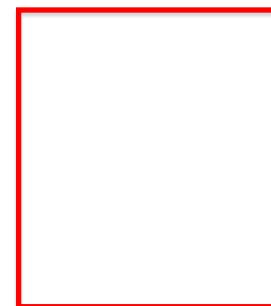


The Object Detection Problem

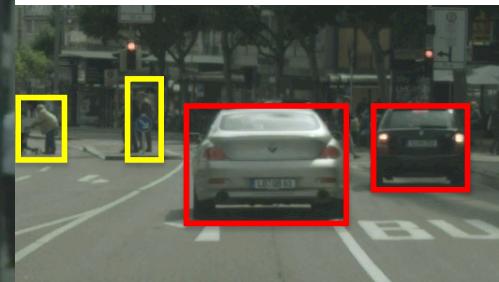
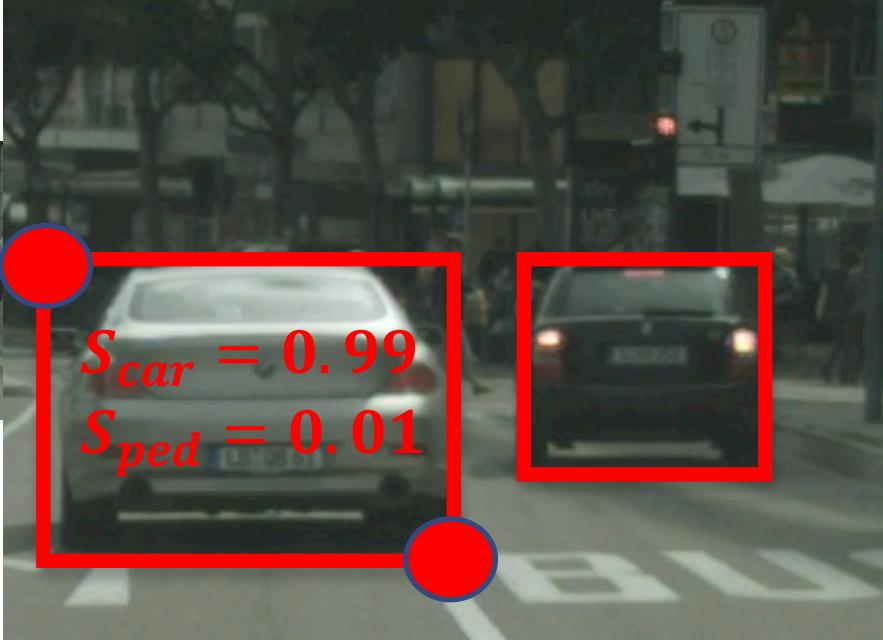


Object Detection Is Not Trivial !

- **Extent of objects is not fully observed!**
 - **Occlusion:** Background objects covered by foreground objects
 - **Truncation:** Objects are out of image boundaries
- **Scale:** Object size gets smaller as the object moves farther away
- **Illumination Changes:**
 - **Too bright**
 - **Too dark**



Mathematical Problem Formulation

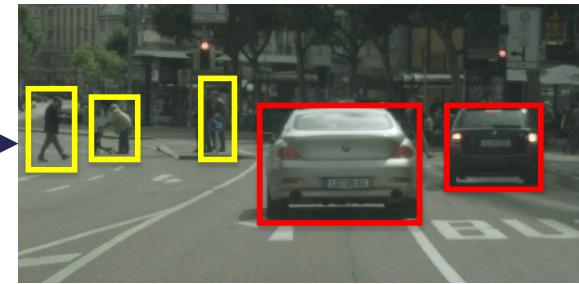


$$f(x; \theta) = [x_{min}, y_{min}, x_{max}, y_{max}, S_{class_1}, \dots, S_{class_k}]$$

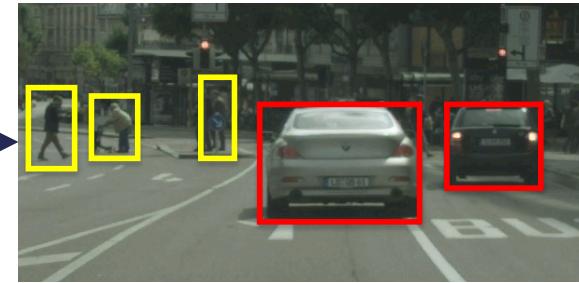
ConvNets For Object Detection



$$f(x; \theta)$$

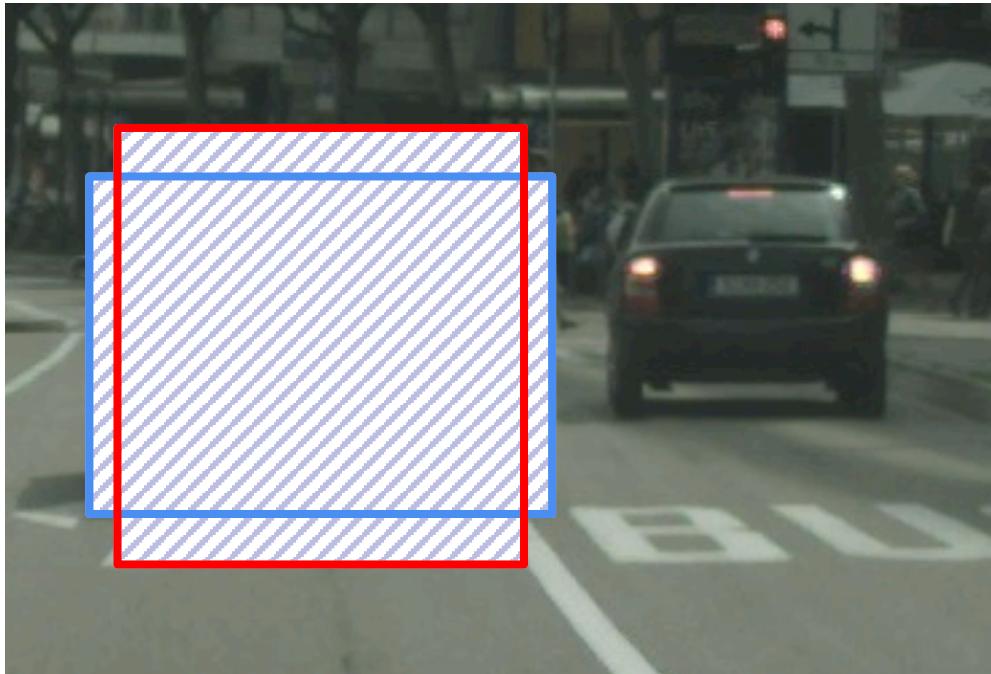


ConvNet



Evaluation Metrics

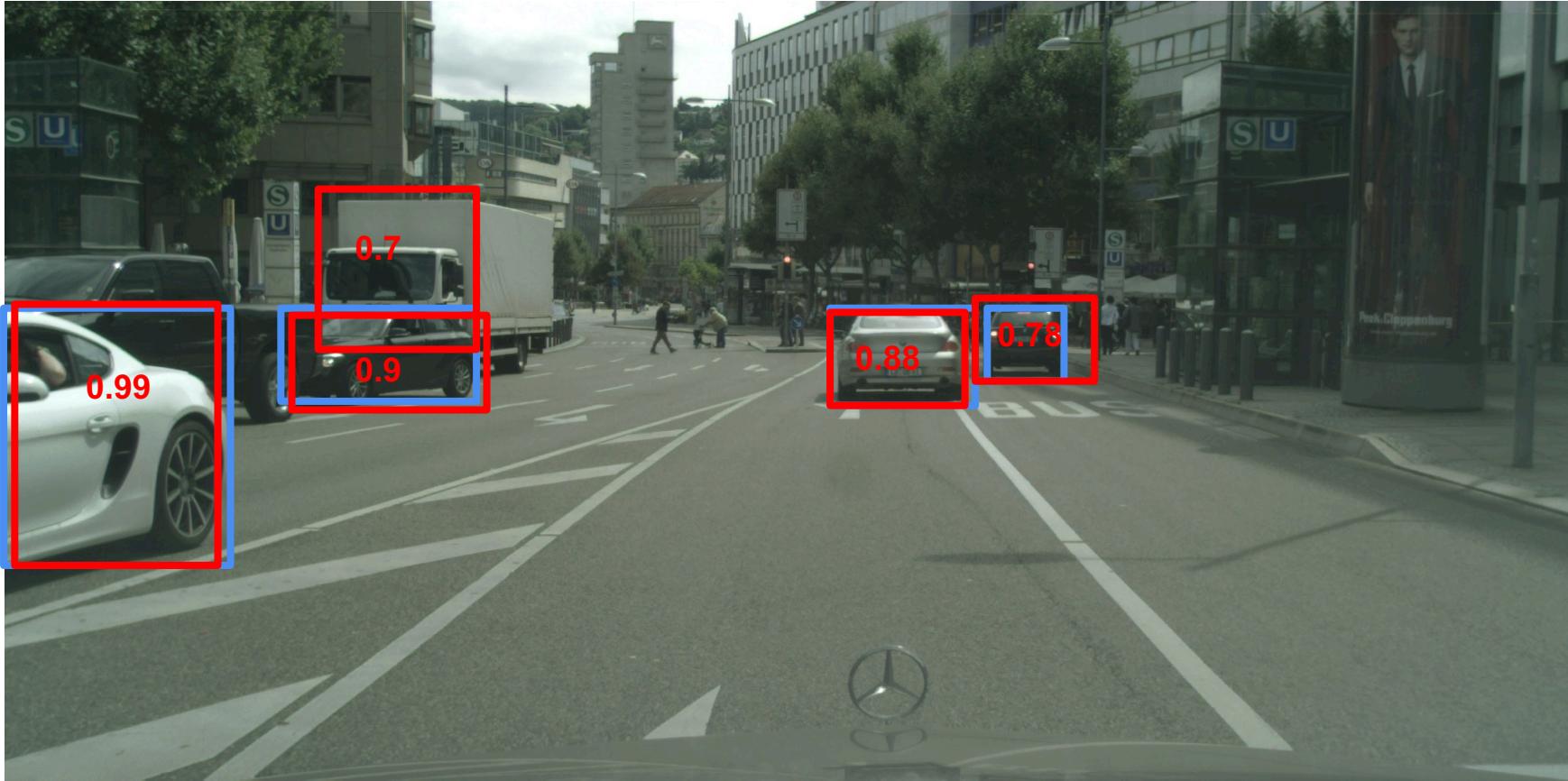
- **Intersection-Over-Union (IOU):** area of intersection of **predicted box** with a **ground truth box**, divided by the area of their union



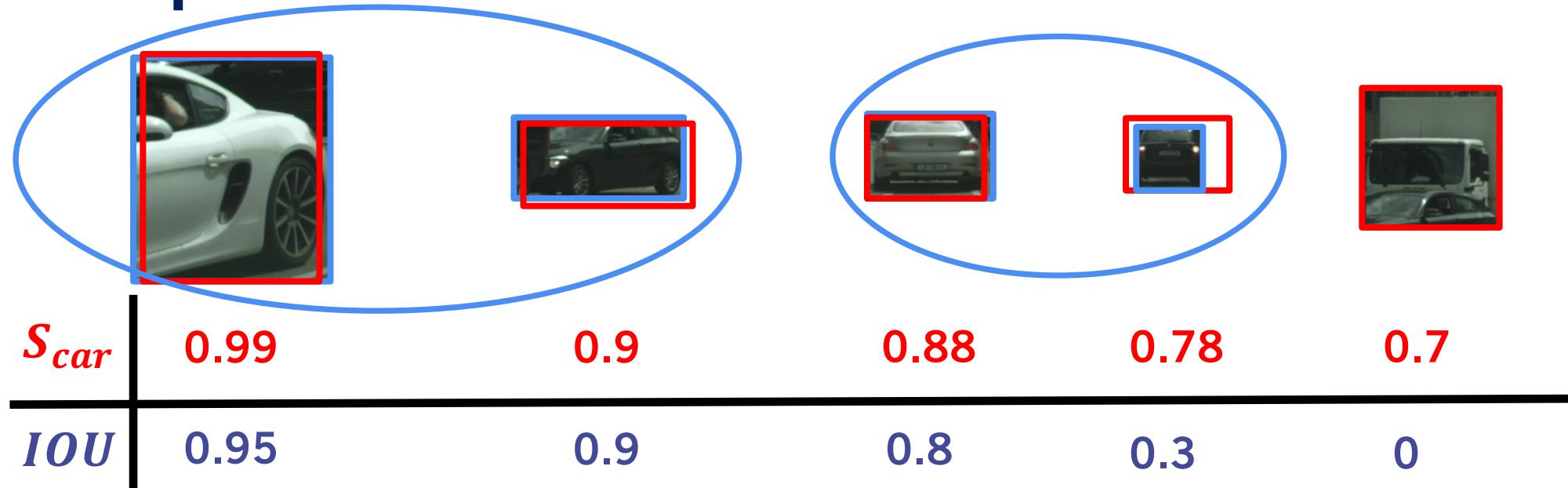
Evaluation Metrics

- **True Positive (TP):** Object class score > score threshold, and $\text{IOU} > \text{IOU threshold}$
- **False Positive (FP):** Object class score > score threshold, and $\text{IOU} < \text{IOU threshold}$
- **False Negative (FN):** Number of ground truth objects not detected by the algorithm
- **Precision:** $\text{TP} / (\text{TP} + \text{FP})$
- **Recall:** $\text{TP} / (\text{TP} + \text{FN})$
- **Precision Recall Curve (PR-Curve):** Use multiple object class score thresholds to compute precision and recall. Plot the values with precision on y-axis, and recall on x-axis
- **Average Precision (AP):** Area under PR-Curve for a single class. Usually approximated using 11 recall points

Example



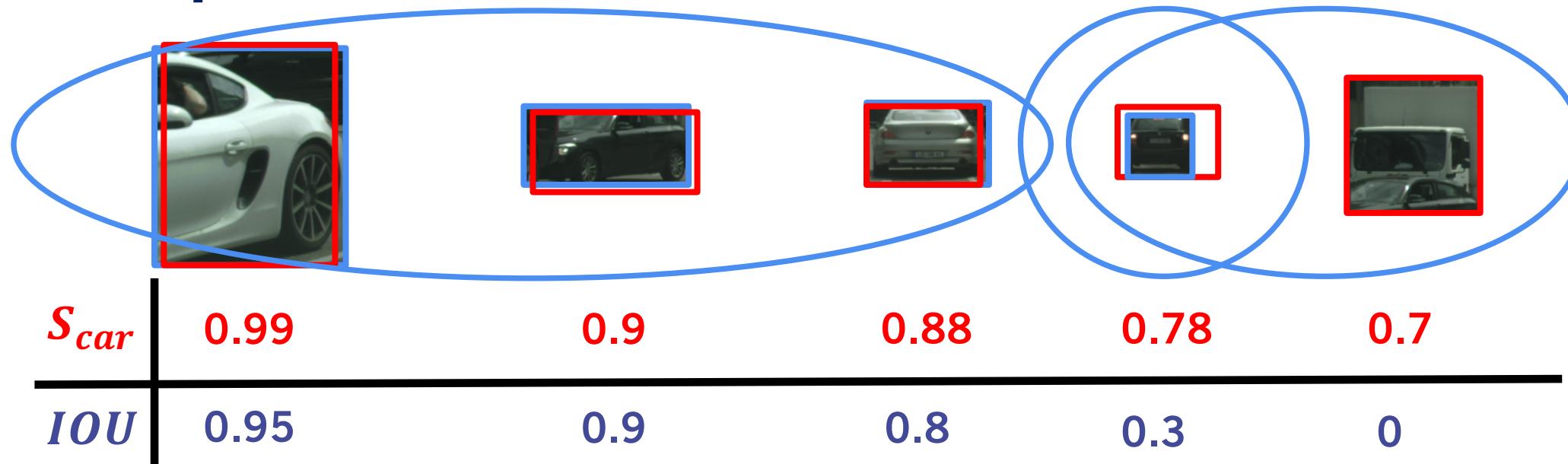
Example



- Score Threshold: 0.9
- IOU Threshold: 0.7

- TP = 2
- FP = 0
- FN = 2
- Precision = $2/2 = 1$
- Recall = $2/4 = 0.5$

Example



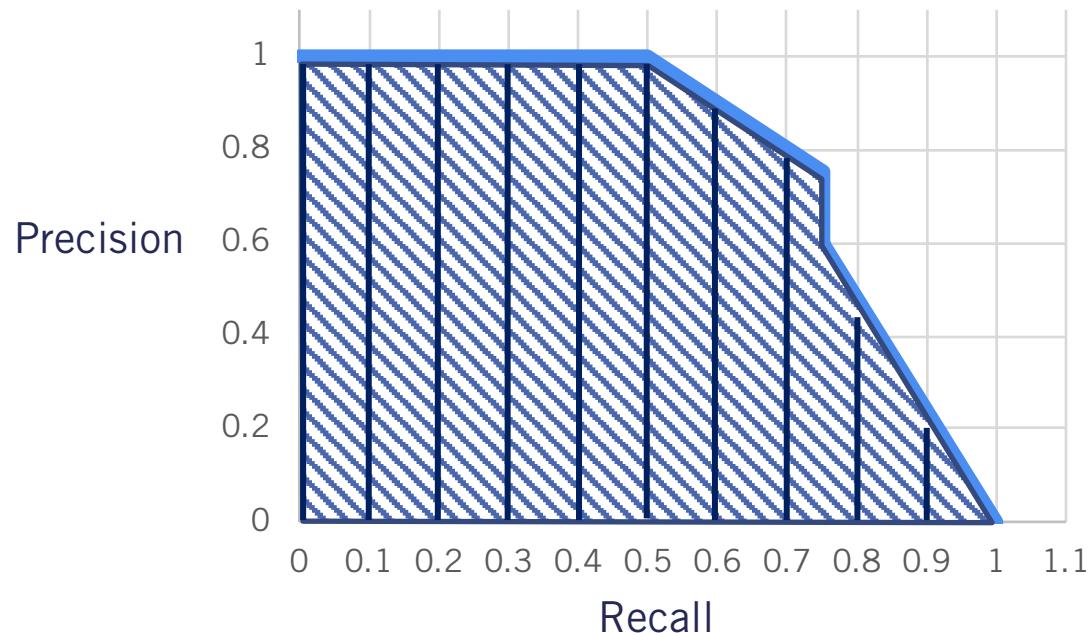
- Score Threshold: 0.7
- IOU Threshold: 0.7

- TP = 3
- FP = 2
- FN = 1
- Precision = $3/5 = 0.6$
- Recall = $3/4 = 0.75$

Example

Score threshold	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Precision	1	0.75	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Recall	0.5	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75

Precision-Recall Curve



$$AP = \frac{1}{11} \sum_{r=0}^{11} p_r \approx 0.75$$

Summary

- 2D object detection comprises of localizing an object and determining what the object is
- 2D object detectors are evaluated using the Average Precision metric, at a specific IOU threshold
- **Next: 2D object detection using ConvNets**