Object Detection Basics

Deep Learning for Computer Vision

Lecture by [Your Name]

Inspired by Andrew Ng's teaching style

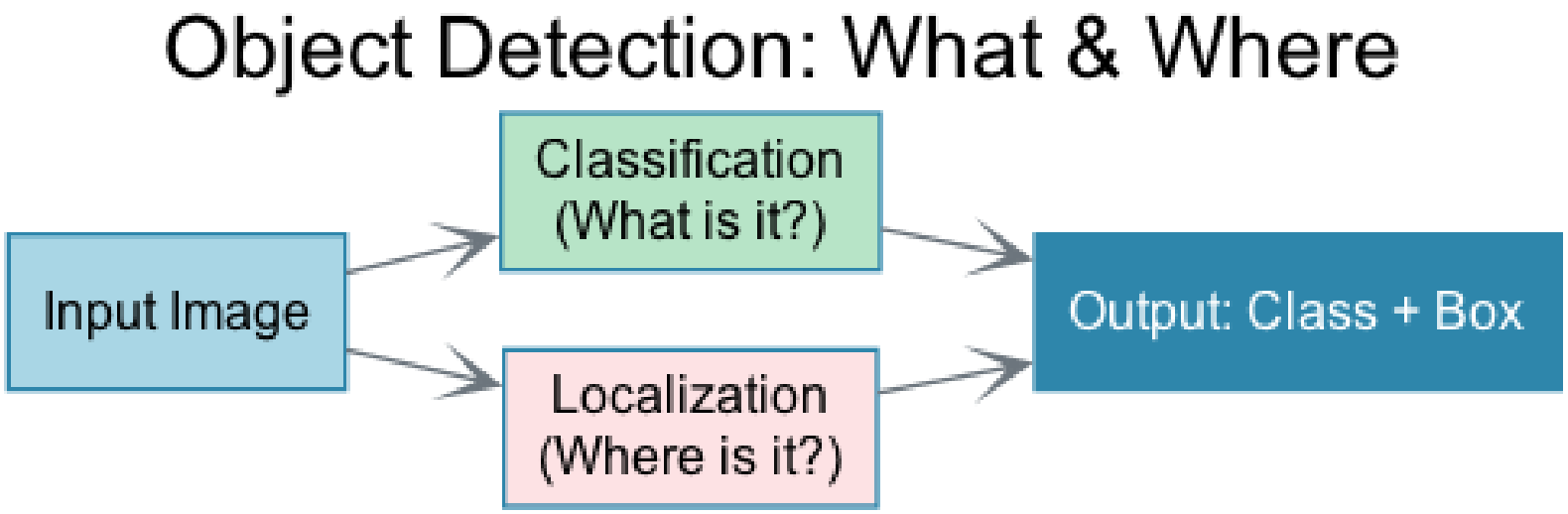
What You Will Learn Today

1. **The Core Problem**: Classification vs. Detection
2. **The Tools**: Bounding Boxes, Confidence, IoU
3. **The Algorithm**: How NMS cleans up results
4. **The Architectures**: YOLO vs. Faster R-CNN
5. **The Metrics**: How do we measure success? (mAP)
6. **Practical Tips**: Training & Data Augmentation

1. Understanding the Goal

Classification answers "What is this?"

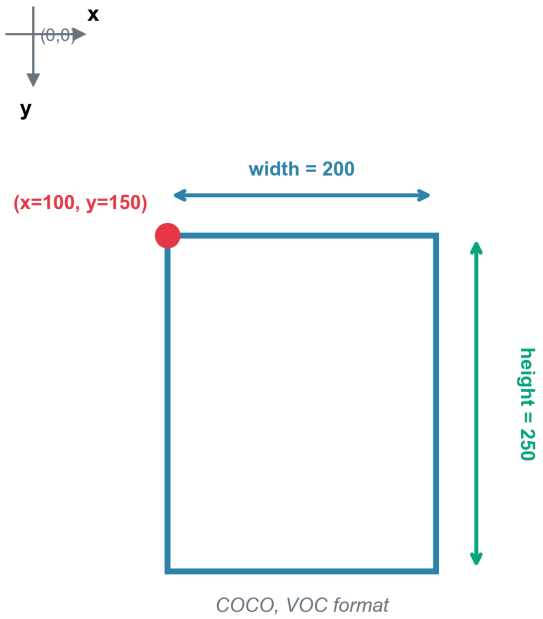
Detection answers "What is this **AND** Where is it?"



The Bounding Box (BBox)

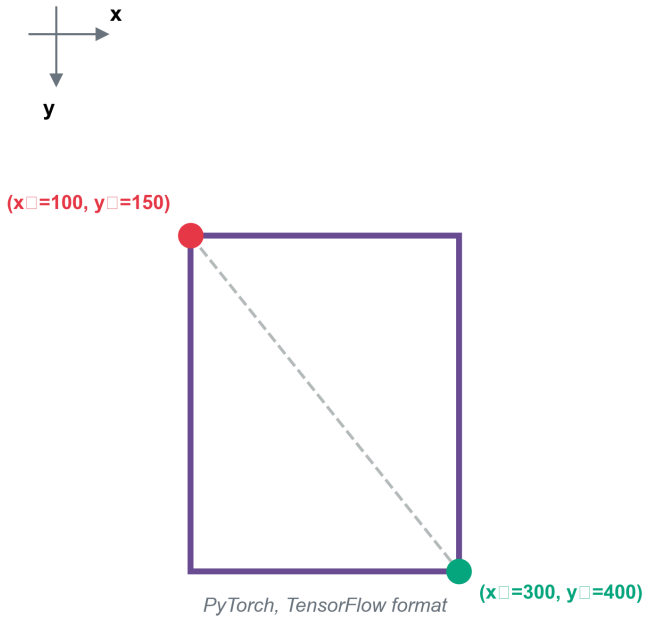
A BBox defines the object's location. It is crucial to understand the format because datasets vary!

Format 1: (x, y, w, h)
Top-Left Corner + Dimensions



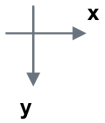
COCO, VOC format

Format 2: (x□, y□, x□, y□)
Two Corner Points



PyTorch, TensorFlow format

Format 3: (cx, cy, w, h)
Center Point + Dimensions



Format Conversions

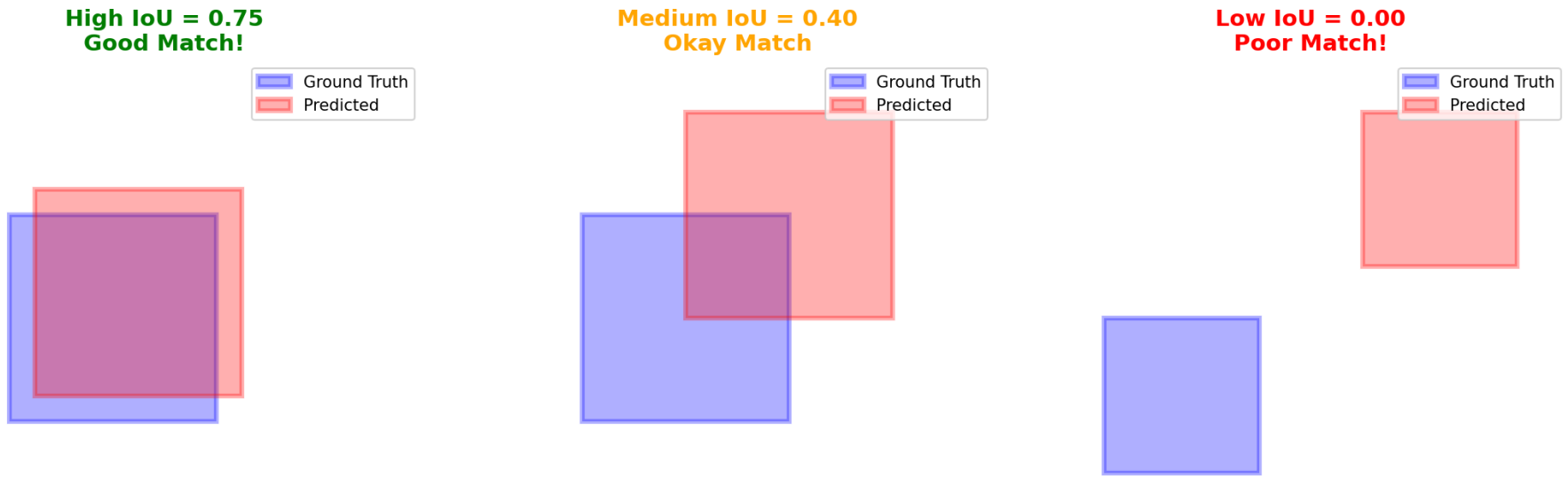
2. Key Concept: IoU (Intersection over Union)

How do we know if a detection is "correct"? We compare it to the Ground Truth.

Intuition:

- **Intersection:** The shared area (overlap).
- **Union:** The total combined area.
- **Ratio:** 0 (No overlap) to 1 (Perfect match).

IoU Visualized



3. The Problem of Multiple Detections

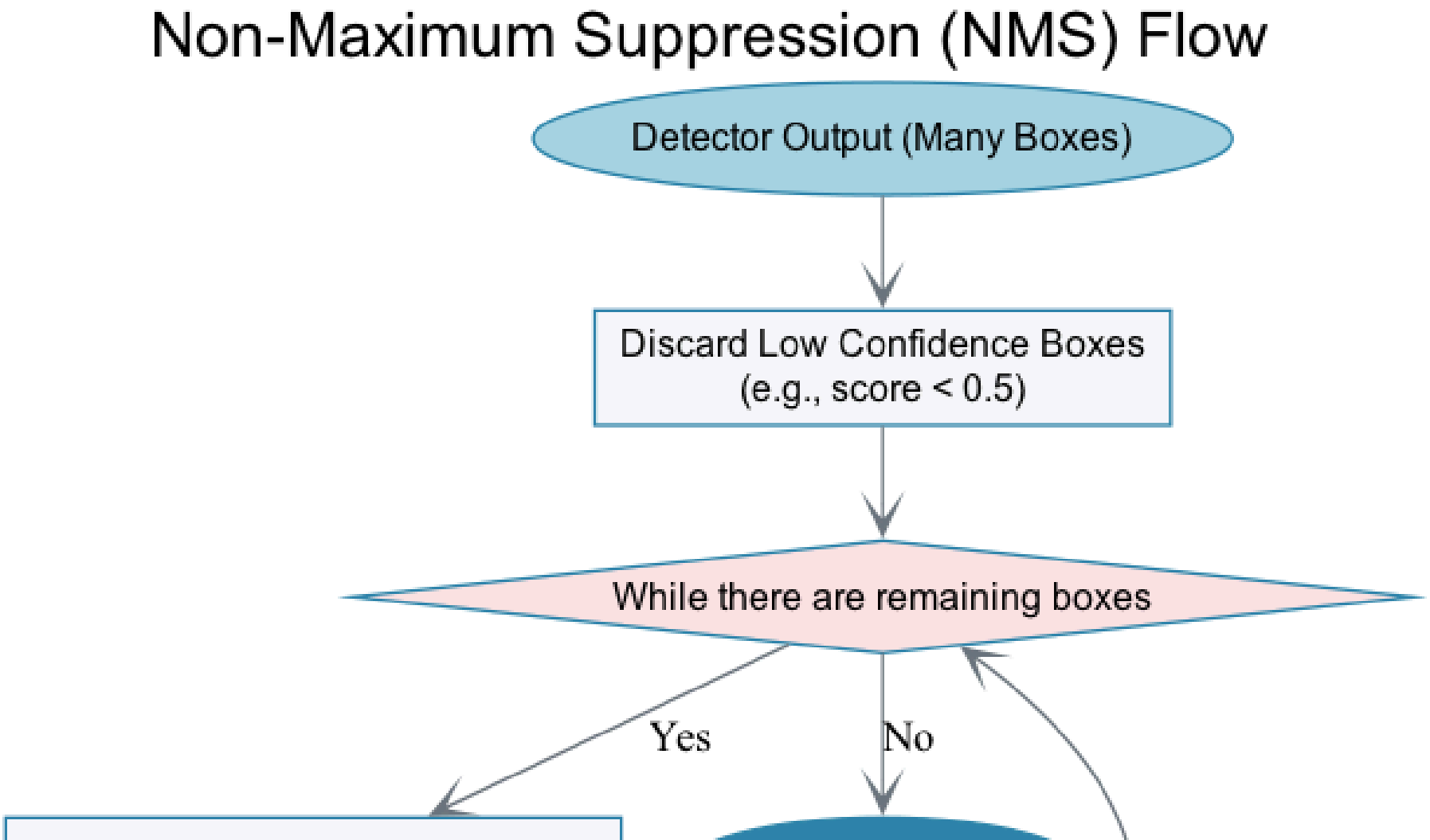
Detectors often find the same object multiple times.

- "Is this a car?" -> Yes (90%)
- "Is this slightly shifted box a car?" -> Yes (85%)

We need a way to clean this up.

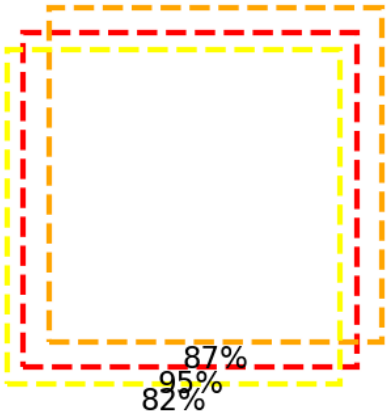
Non-Maximum Suppression (NMS)

The Algorithm to clean up duplicate boxes:

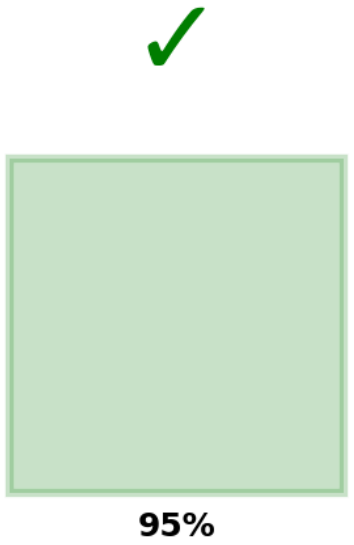


NMS in Action

Before NMS
Multiple Overlapping Detections

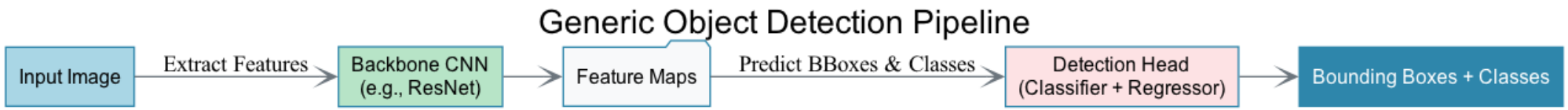


After NMS
Single Best Detection

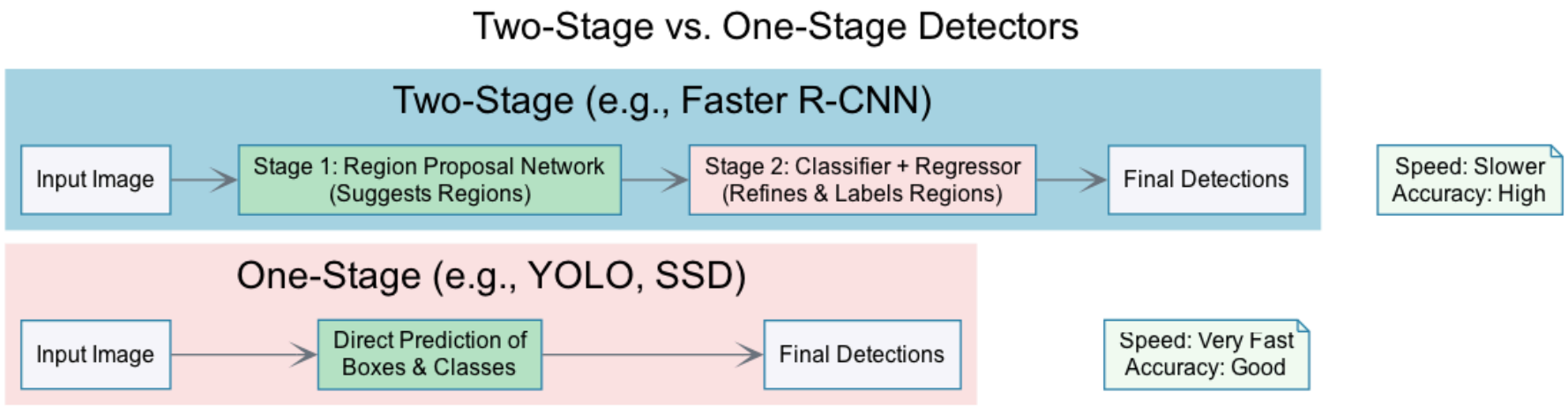


4. How Detection Models Work

Most modern detectors follow a similar pipeline:

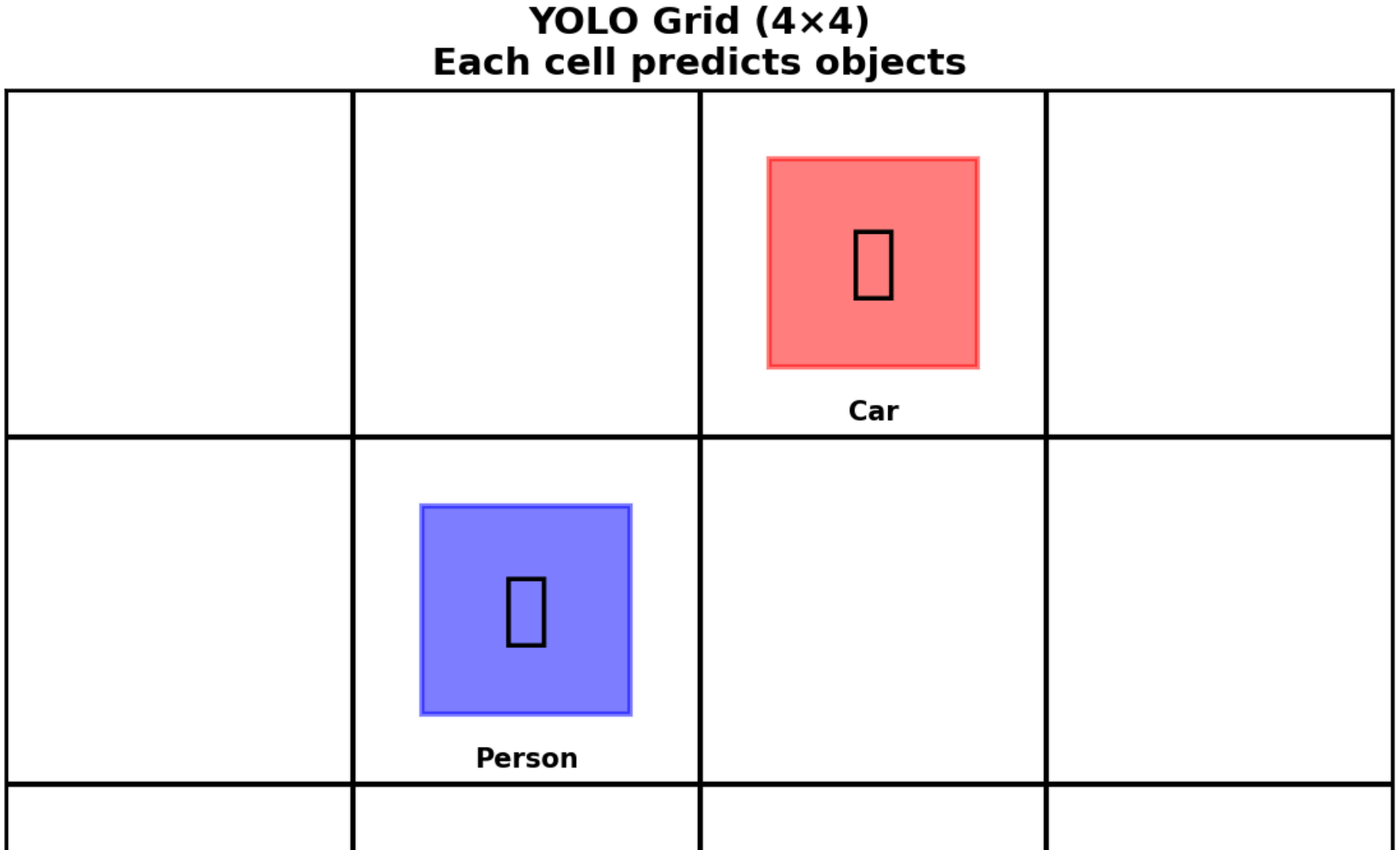


Two Main Approaches

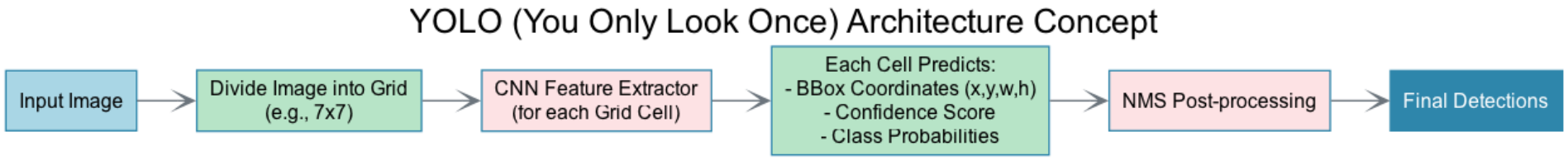


Deep Dive: YOLO (You Only Look Once)

YOLO divides the image into a **grid**. Each cell is responsible for detecting objects whose center falls inside it.

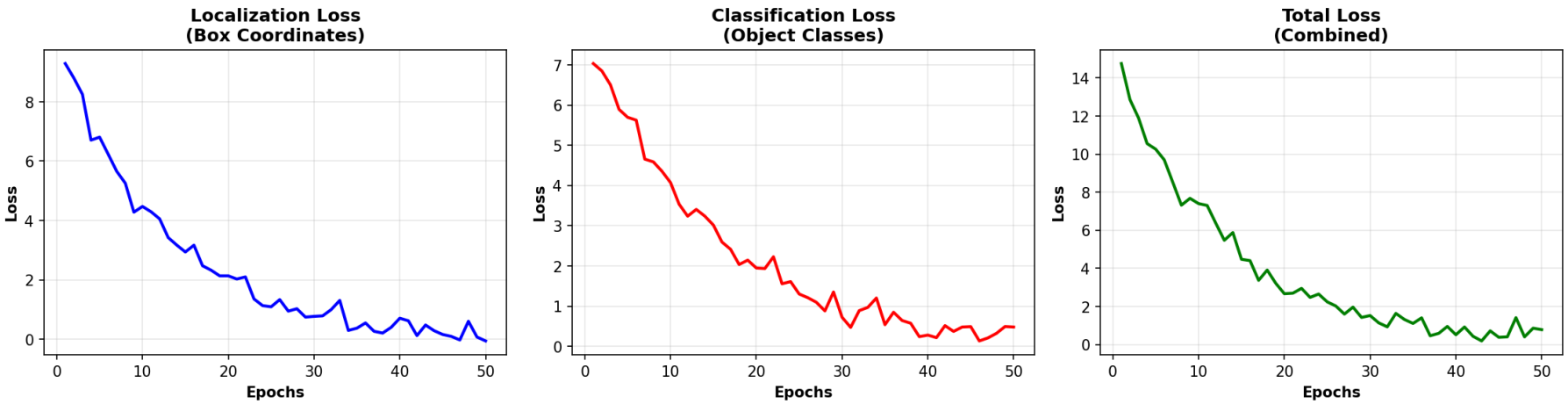


YOLO Architecture Explained



5. Loss Functions (How the Model Learns)

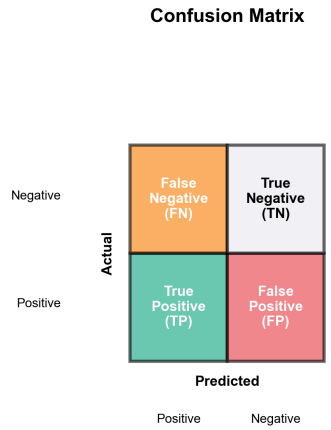
The model needs to minimize errors in three things simultaneously:



6. Evaluation Metrics: mAP

Accuracy is not enough! We use **Mean Average Precision (mAP)**.

- **Precision:** When you predict a car, is it actually a car?
- **Recall:** Did you find all the cars?
- **mAP:** Area under the Precision-Recall curve, averaged over all classes.



Precision

Precision = TP / (TP + FP)

"Of all detections, how many were correct?"

Example:

Model detects 100 cars

90 are actually cars (TP)

10 are not cars (FP)

Precision = 90/100 = 0.90 (90%)

High precision:

Few false alarms

Important when FP is costly

Recall (Sensitivity)

Recall = TP / (TP + FN)

"Of all actual objects, how many did we find?"

Example:

Image has 100 cars

Model finds 85 cars (TP)

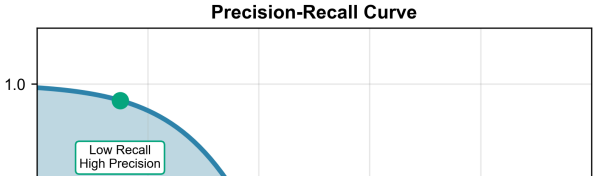
Misses 15 cars (FN)

Recall = 85/100 = 0.85 (85%)

High recall:

Few missed detections

Important when FN is costly



Average Precision (AP)

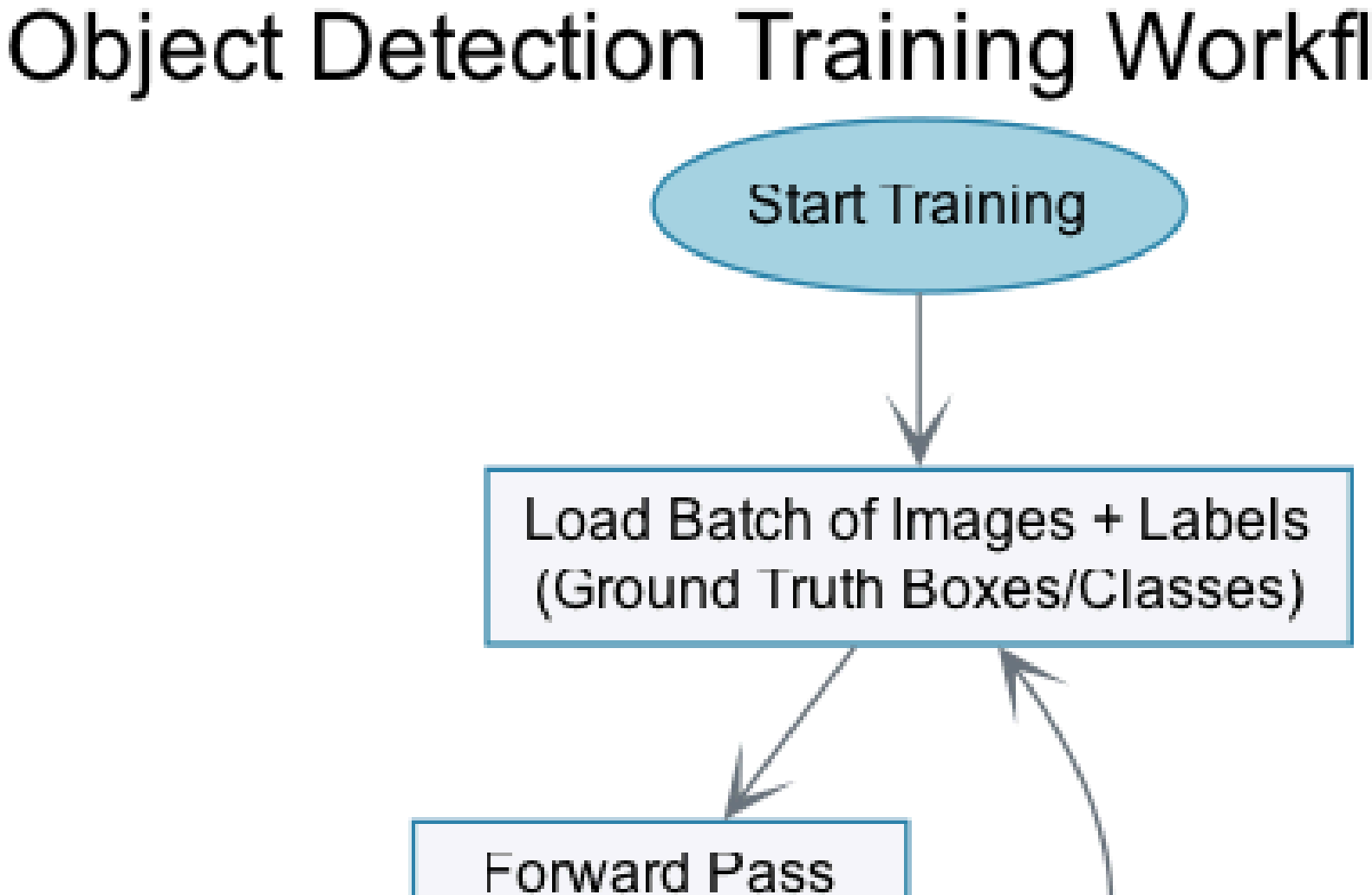
AP = Area Under PR Curve

mean Average Precision (mAP)

mAP = Average of AP across all classes

7. Practical Training Tips

Training a robust detector requires more than just code.



Summary & Key Takeaways

1. **Object Detection** = Localization + Classification.
2. **IoU** measures how good a box is.
3. **NMS** removes duplicate boxes.
4. **YOLO** is fast (one-stage), **Faster R-CNN** is accurate (two-stage).
5. **mAP** is the gold standard metric.

Next Steps:

- Download a dataset (e.g., COCO128).
- Run YOLOv8 on your webcam.
- Inspect the "loss curves" to see learning in action!

Thank You

"AI is the new electricity." - Andrew Ng

Questions?

Slides generated with Marp, Matplotlib & Graphviz