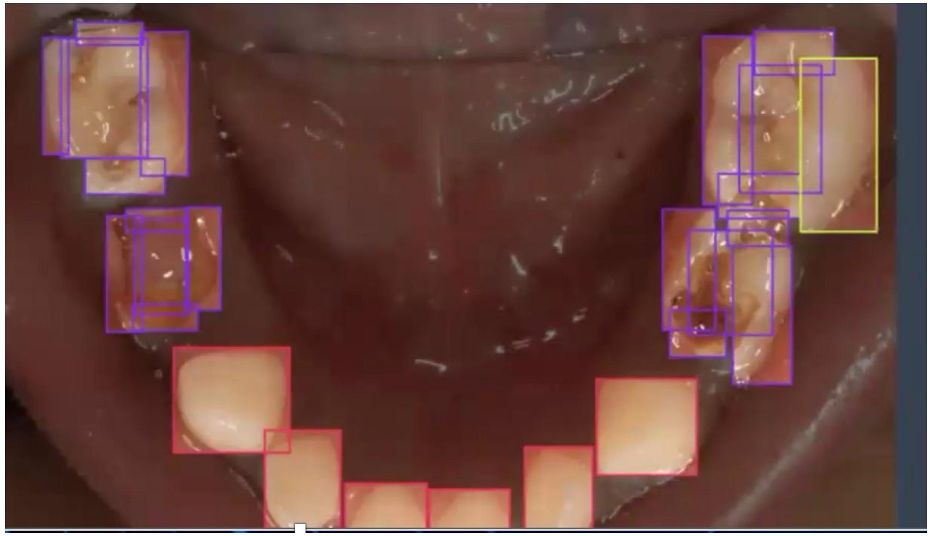
Dent.py: Training Dental Models from Zero to Hero

Part 4 of 5

YOLO: You Only Look Once – Deep Dive

Object Detection

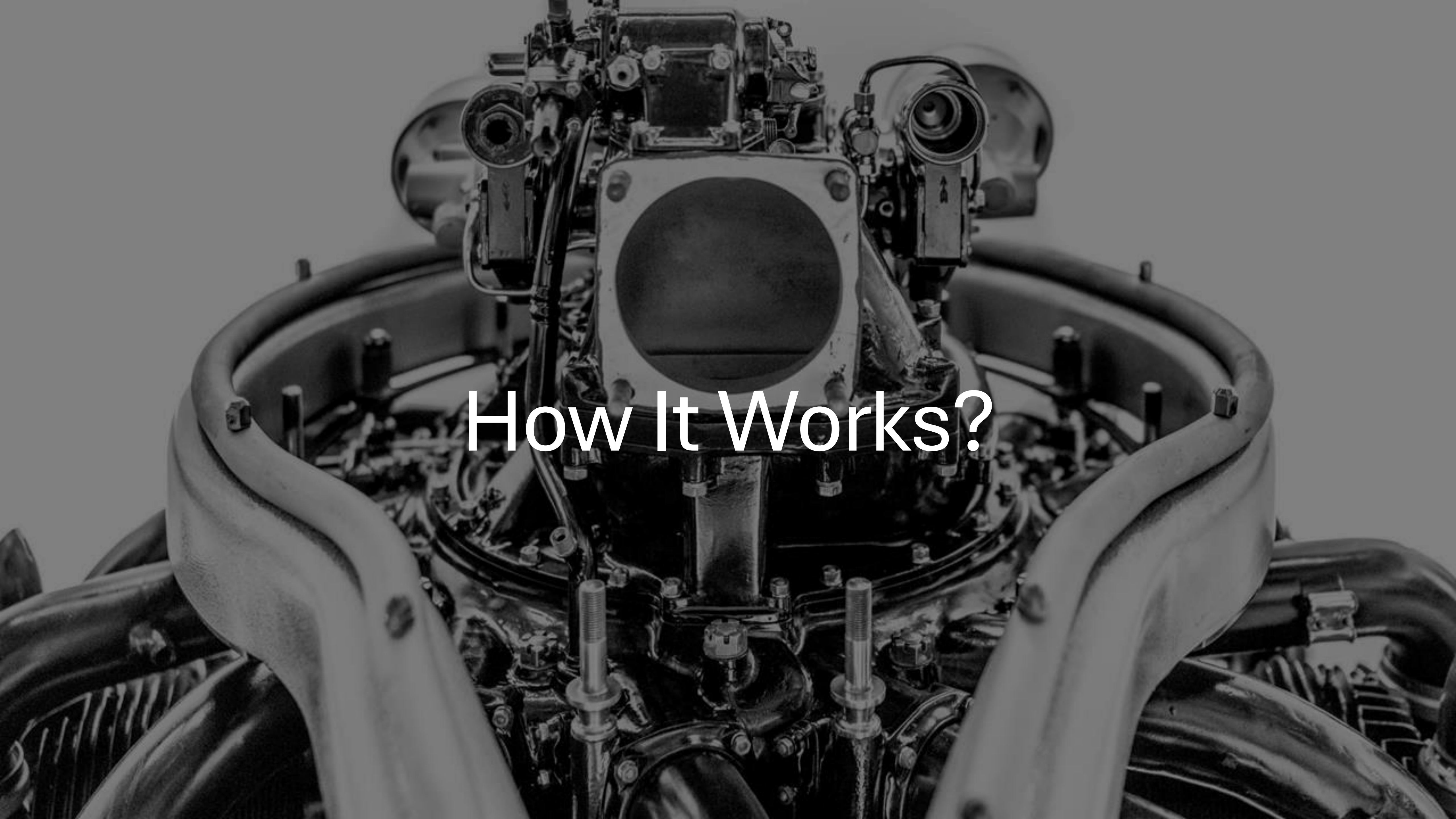
- What is object detection?
  - Identifying and locating objects in an image.
  - Used in various applications like autonomous driving, security, retail, etc…



YOLO

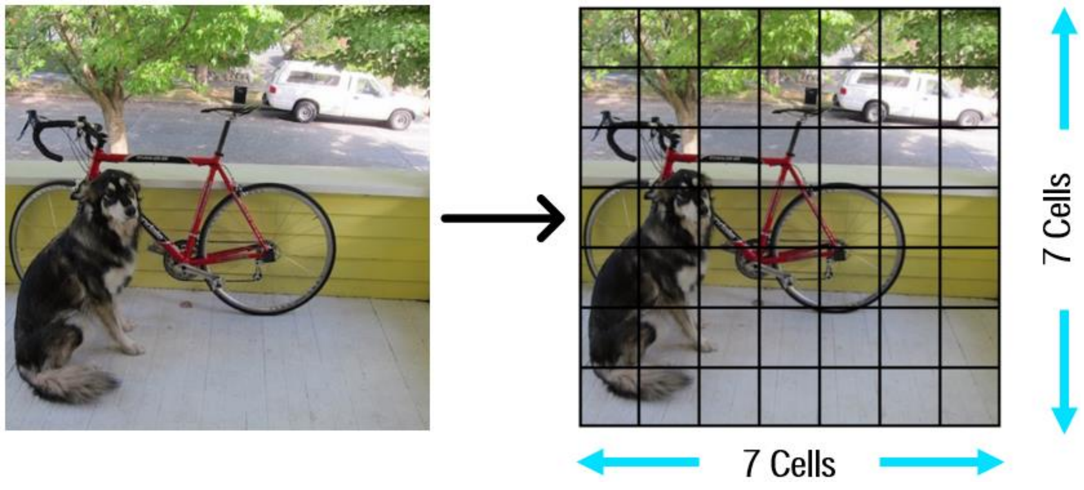
- YOLO
  - You Only Look Once
- Overview
  - A fast and efficient object detection algorithm.
  - Processes an image in a single pass, unlike traditional methods.
- Why YOLO is important
  - Real-time processing capability.
  - High accuracy and efficiency.

How It Works?



Grid-based prediction

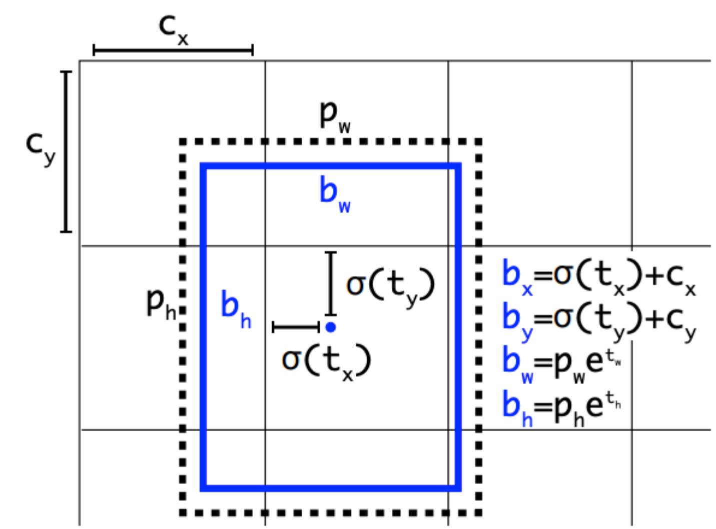
- The image is divided into an S × S grid (e.g., 7×7, 19×19).
- Each grid cell predicts bounding boxes, confidence scores, and class probabilities.
- A grid cell is responsible for detecting objects whose center falls within it.

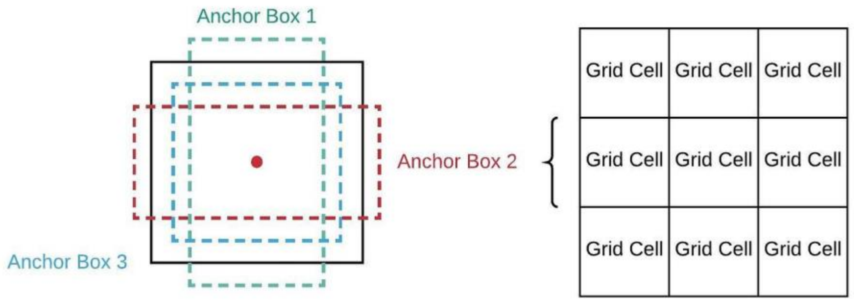


Yajnik, A. (2023, September 7). *Computer vision: Yolo: Grid cells and anchor boxes*. Medium. https://medium.com/@ayushyajnik2/computer-vision-yolo-grid-cells-and-anchor-boxes-57b8a33cb25b

Bounding box prediction

- Each grid cell predicts multiple bounding boxes with (x, y, w, h) coordinates.
- Predefined boxes of different aspect ratios and sizes improve detection.
- Helps in detecting objects of various scales and shapes.
- Each grid cell predicts adjustments to these anchor boxes rather than free-form bounding boxes.

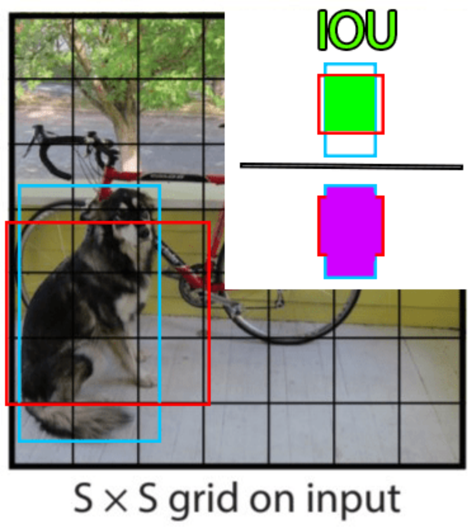


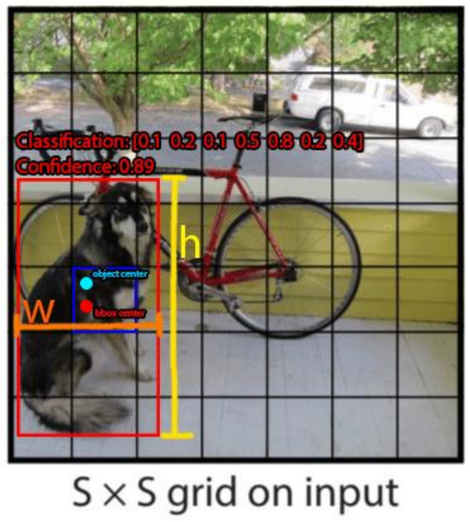


Li, E. Y. (2023, June 15). *Dive really deep into Yolo V3: A beginner's guide*. Medium. https://medium.com/data-science/dive-really-deep-into-yolo-v3-a-beginners-guide-9e3d2666280e

Confidence Scores

- Represents how likely an object is present and the accuracy of the bounding box.
- Confidence score = Object probability × IoU (Intersection over Union).
- Higher confidence scores indicate more reliable predictions.

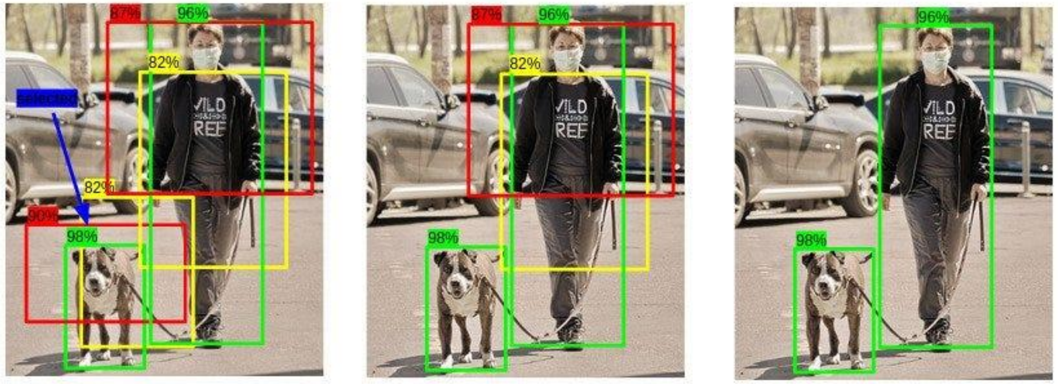




Yolo for Object Detection. GUVI Geeks Network. (n.d.-b). https://forum.guvi.in/posts/6991/yolo-for-object-detection

Non-Maximum Suppression

- Removes overlapping boxes to keep only the most relevant detections.
- Ensures that the best bounding box for each object is retained.



Step 1: Selecting Bounding box with highest score

Step 3: Delete Bounding box with high overlap

Step 5: Final Output

kamal_DS. (2023, March 14). *Non-max suppression*. Medium. https://korlakuntasaikamal10.medium.com/non-max-suppression-b0569e89e9e7

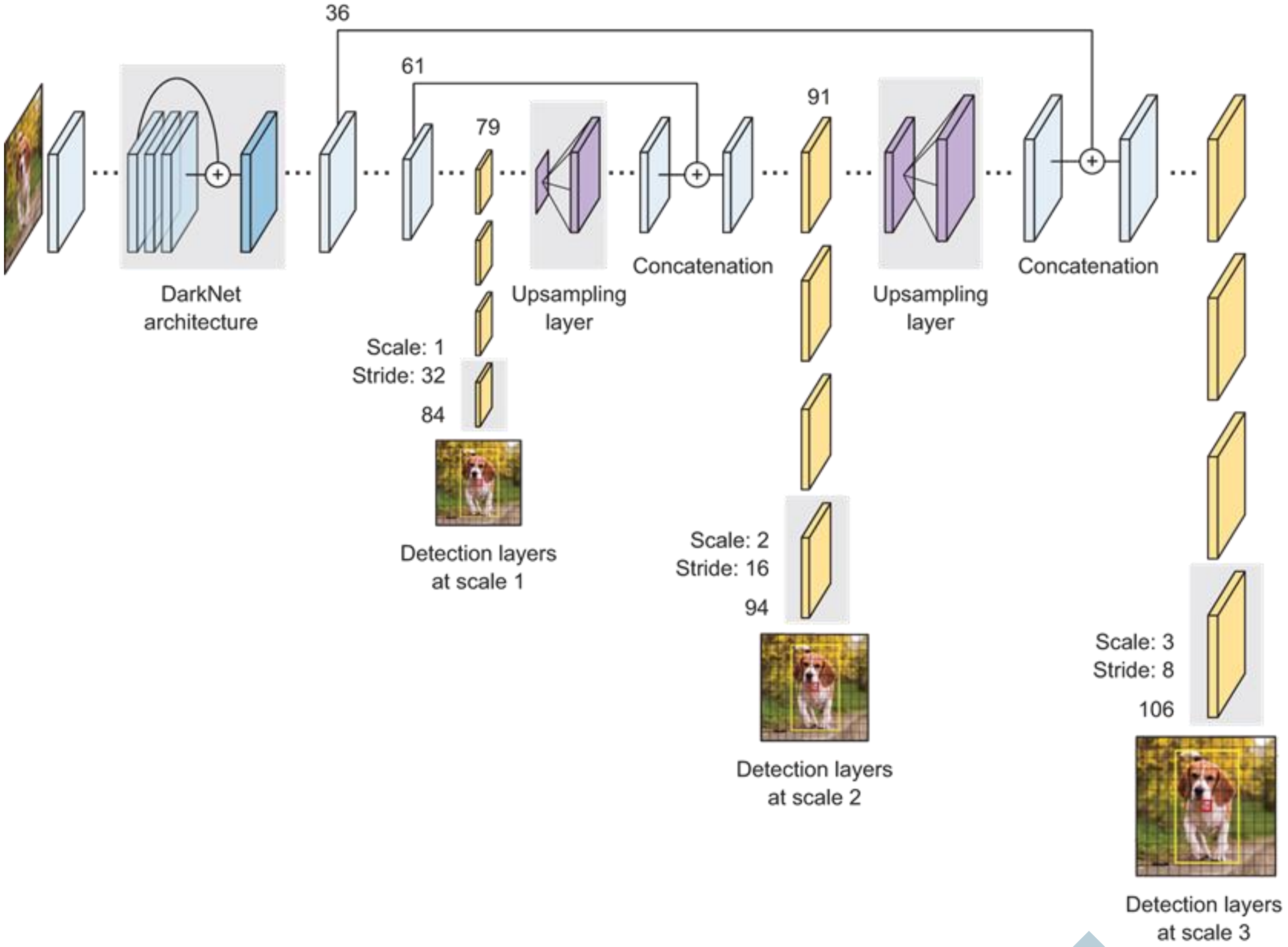
Architecture

Overview

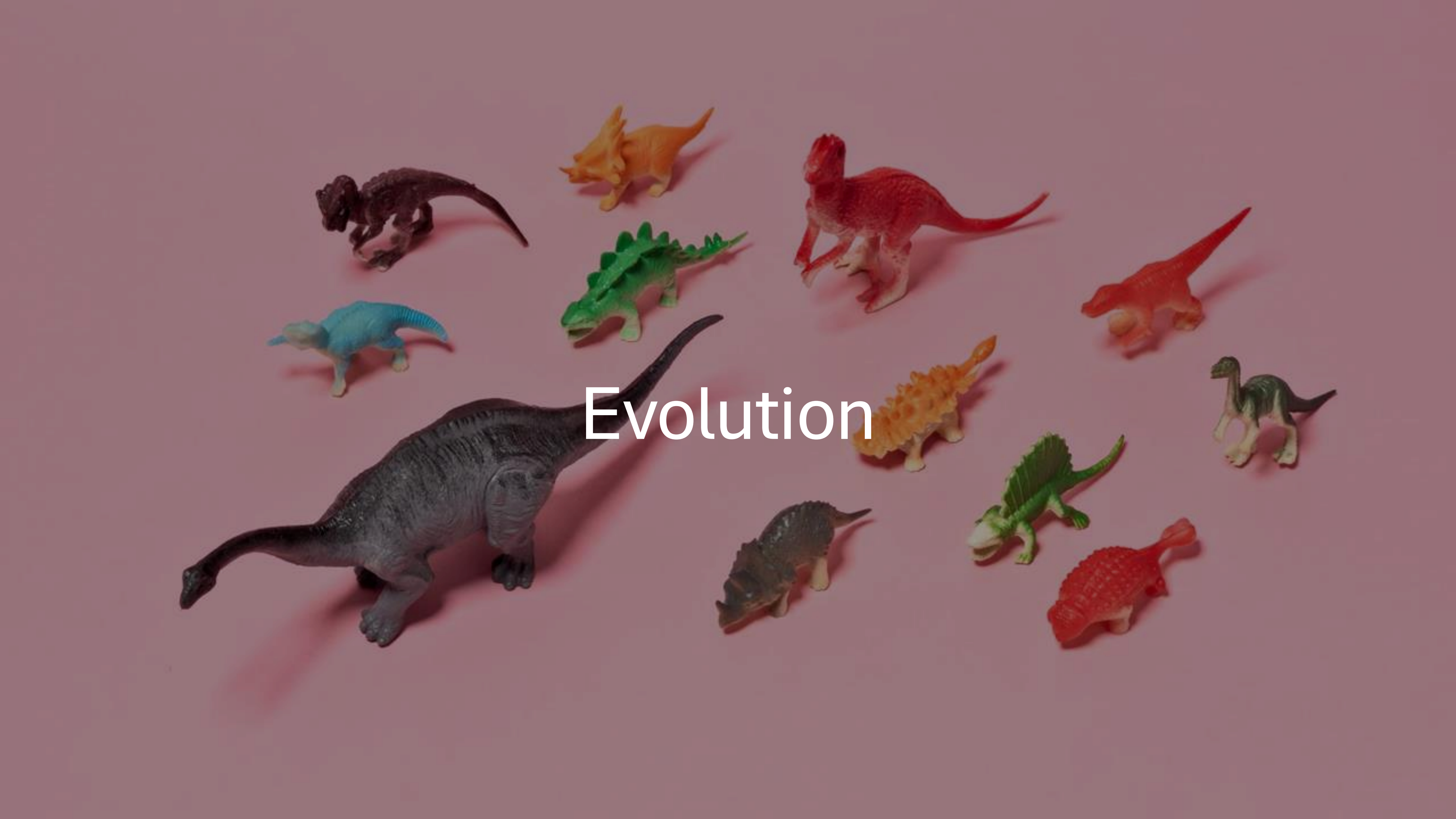
- Input and Feature Extraction
  - Uses a CNN backbone (e.g., Darknet-53 in YOLOv3) to extract hierarchical features.
  - Processes input images through convolutional layers with increasing depth.
- Detection Head
  - Splits into multiple scales for multi-scale detection (FPN-like structure in YOLOv3).
  - Outputs bounding box coordinates, objectness score, and class probabilities.

Building Blocks

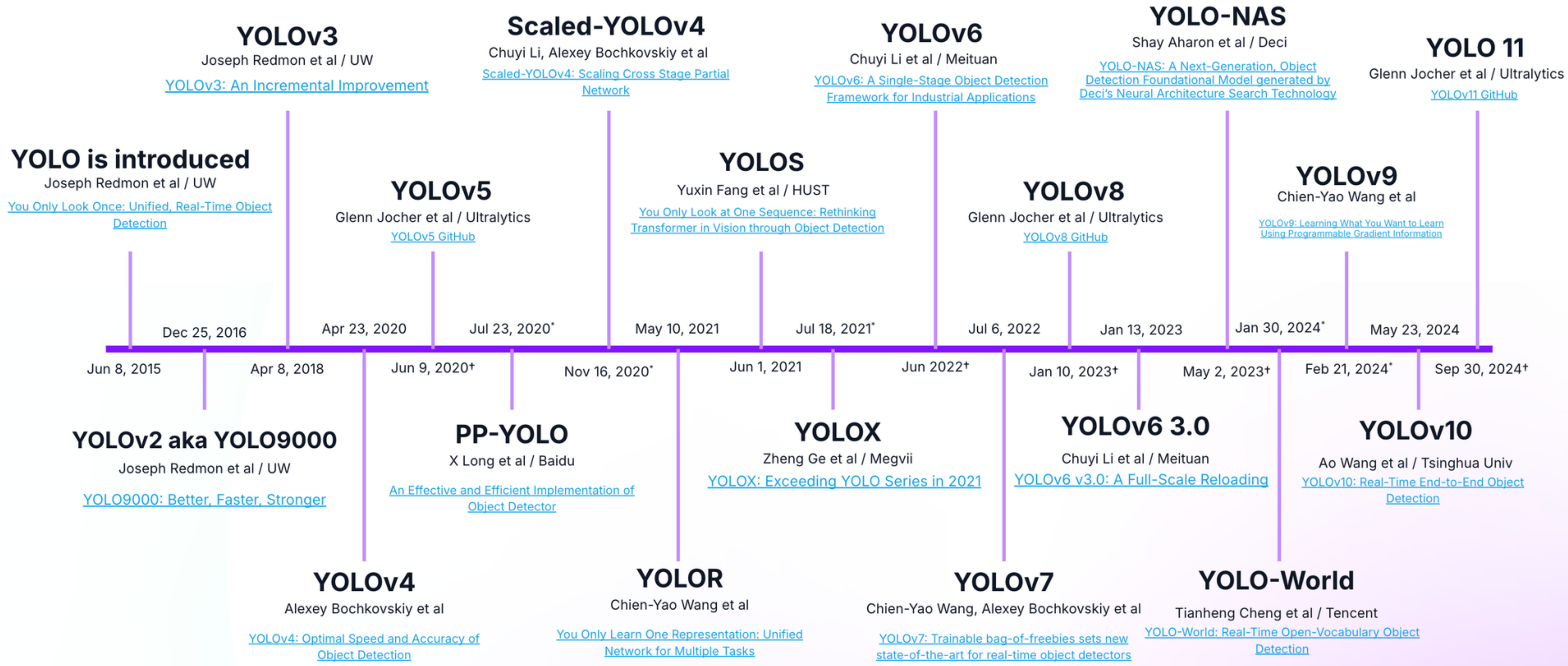
- Convolutional Layers
  - Extract spatial features from images.
- Batch Normalization
  - Speeds up training and stabilizes learning.
- Residual Connections
  - Help gradient flow and improve learning efficiency.
- Leaky ReLU Activation
  - Prevents vanishing gradients and speeds up training.


36
61
79
91
DarkNet architecture
Upsampling layer
Concatenation
Upsampling layer
Concatenation
Scale: 1
Stride: 32
84
Detection layers at scale 1
Scale: 2
Stride: 16
94
Detection layers at scale 2
Scale: 3
Stride: 8
106
Detection layers at scale 3

Evolution



YOLO Greatest Hits



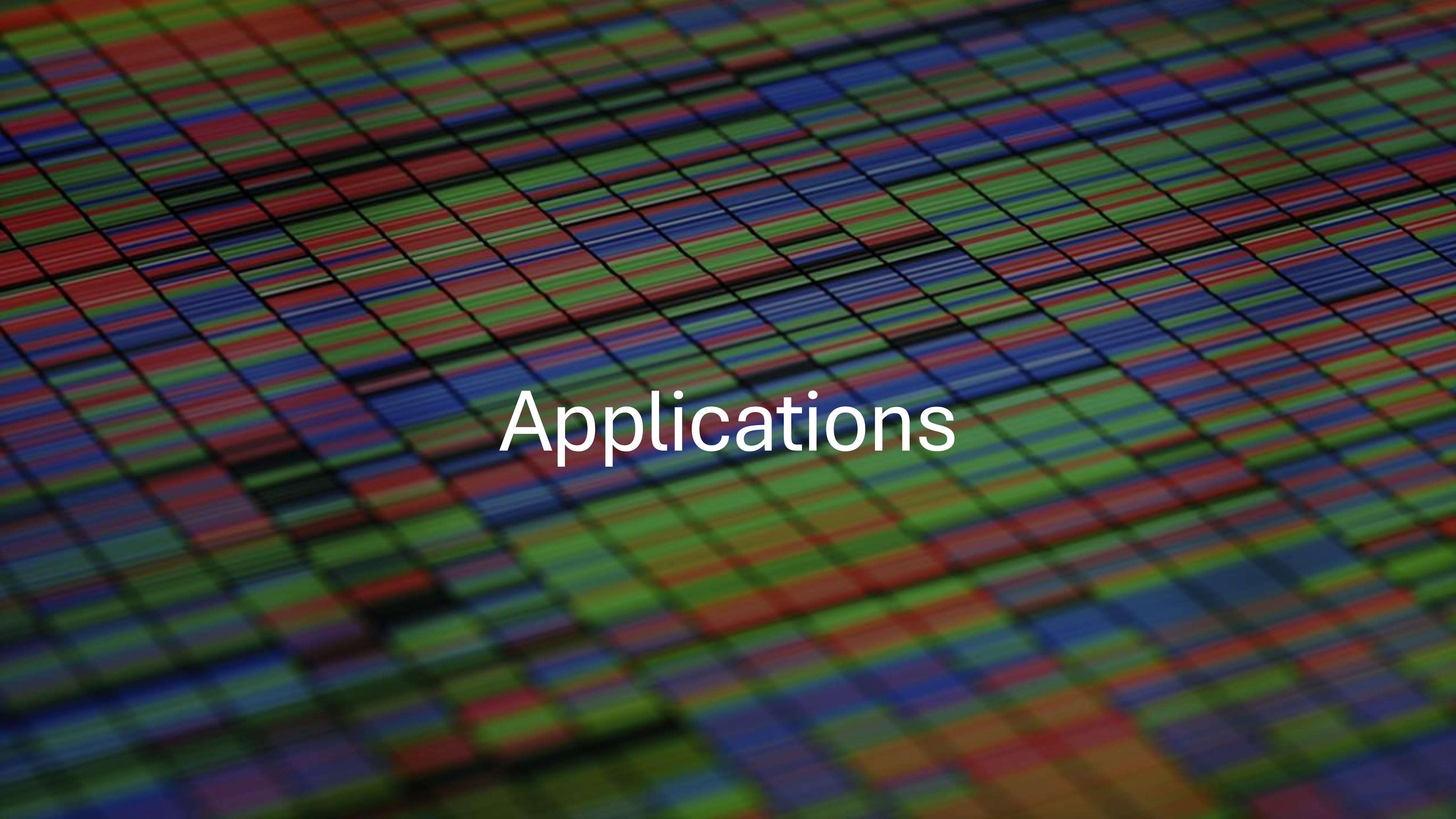
* Denotes paper updated after first publication date

† Denotes repository predates paper publication date

Joseph Nelson. (Jan 9, 2025). What is YOLO? The Ultimate Guide [2025]. Roboflow Blog: https://blog.roboflow.com/guide-to-yolo-models/

YOLOv12

- Released on February 18, 2025
- Introduced in the paper “YOLOv12: Attention-Centric Real-Time Object Detectors.”
- **Key Features**
  - Incorporates advanced attention mechanisms for improved detection accuracy.
  - Optimized for real-time applications with lower latency.
  - Open-source implementation available for fine-tuning and customization.
- **Performance**
  - Benchmarked on the Microsoft COCO dataset.
  - Achieves higher mean Average Precision (mAP) while reducing computational overhead.



Applications

General

Autonomous Vehicles

Detects pedestrians, vehicles, traffic signs in real-time.

Security & Surveillance

Identifies objects in CCTV footage.

Medical Imaging

Used for detecting tumors, anomalies in medical scans.

Retail & Logistics

Automated checkout systems, inventory tracking.

Dentistry

Tooth Segmentation

Identifying individual teeth for orthodontic planning.

Caries and Cavity Detection

Detecting early-stage cavities in dental X-rays.

Root Canal Detection

Assisting endodontists in visualizing canal morphology.

IAN (Inferior Alveolar Nerve) Localization

Preventing nerve damage during surgeries.

Pros and Cons

Pros

- Fast and efficient, capable of real-time detection.
- Single-stage processing, end-to-end learning.
- Works well in real-world applications.

Cons

- Struggles with detecting small objects.
- May not be as accurate as two-stage methods like Faster R-CNN.
- Limited interpretability due to end-to-end learning.

Questions?

Workshop Activity

- Notebooks Link
  - https://github.com/KnightsLab/EMRA-Workshop