Comparative Analysis of YOLO Versions: YOLOv1 to YOLOv5

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1 Introduction

The YOLO (You Only Look Once) family, introduced in 2015, revolutionized object detection by enabling real-time processing with high accuracy. From YOLOv1 to YOLOv5, each version has advanced architecture, performance, and applicability. This report compares YOLOv1 through YOLOv5, covering architecture, performance metrics, improvements, strengths, weaknesses, and use cases, with a summary table, drawing from sources like LabelVisor, 2023 and ArXiv, 2024.

2 Architecture Differences

The YOLO family has evolved significantly in its architecture, enhancing backbones and detection mechanisms. Table 1 summarizes the key features, based on ArXiv, 2024.

Version	Year	Key Architectural Features	Framework
YOLOv1	2015	Grid cell-based detection, Darknet with 24 conv layers or Fast YOLO with 9 layers, Non-Maximum Suppression, loss includes coordinates, confidence, class probability	Darknet
YOLOv2	2016	Darknet-19 (19 conv layers, 5 max pooling), 1x1 convolutions, no fully connected layers, Batch Normalization, anchor boxes via K-means, skip connections, Word-Tree for 9418 classes	Darknet
YOLOv3	2018	Darknet-53 (53 conv layers, stride convolutions, residual connections), Spatial Pyramid Pooling, multi-scale feature maps (13x13, 26x26, 52x26), 8 prior boxes, binary cross-entropy	Darknet
YOLOv4	2020	CSPDarknet53, PANet, Cross mini-Batch Normalization, Spatial Attention Module, CIoU loss, multiple anchors per ground truth, bag-of-freebies	Darknet
YOLOv5	2020	CSPNet, SPP blocks, PAN module with upsampling, anchor-based predictions, Binary Cross-Entropy and CIoU loss, variants: s (7.5M params), m, l, x (86.7M params)	PyTorch

Table 1: Architectural Differences of YOLO Versions

3 Performance Metrics

Performance is evaluated using mean Average Precision (mAP) and Frames Per Second (FPS). Table 2 summarizes metrics, sourced from PyImageSearch, 2022.

Model	mAP	FPS	Dataset, Resolution, GPU
YOLOv1	63.4%	45	Pascal VOC, Titan X
YOLOv2	76.8%	67	Pascal VOC 2007, 416x416, Titan X
YOLOv3	28.2%	45	MS COCO, 320x320, Titan X
YOLOv4	43.5%	∼65	MS COCO, Tesla V100
YOLOv5l	67.2%	100	MS COCO, 640x640, Volta 100

Table 2: Performance Metrics of YOLO Versions

4 Improvements Introduced

Each YOLO version addresses limitations of its predecessor:

- YOLOv1: Pioneered single-stage detection, treating detection as regression (Redmon et al., 2016).
- YOLOv2: Added anchor boxes, batch normalization, multi-scale training (Redmon and Farhadi, 2017).
- YOLOv3: Adopted Darknet-53, feature pyramid networks for small objects (Redmon and Farhadi, 2018).
- YOLOv4: Integrated CSPDarknet53, PANet, CIoU loss for better accuracy (Bochkovskiy et al., 2020).
- YOLOv5: Scalable models, PyTorch framework, adaptive anchors (Ultralytics, 2020).

5 Strengths and Weaknesses

Table 3 summarizes strengths and weaknesses, based on PyImageSearch, 2022.

Model	Strengths	Weaknesses
YOLOv1	High speed, end-to-end trainable	Poor small object detection, localization issues
YOLOv2	Better speed/accuracy, multi-scale training	Limited small object detection
YOLOv3	Improved small object detection, accurate	Increased complexity
YOLOv4	SOTA performance, advanced features	Resource-intensive
YOLOv5	Scalable, PyTorch, easy deployment	Initial lack of formal paper

Table 3: Strengths and Weaknesses of YOLO Versions

6 Typical Use Cases

YOLO applications vary by version, as noted in LabelVisor, 2023 and ArXiv, 2024:

- YOLOv1: Autonomous vehicles, security systems.
- YOLOv2: Agriculture (crop monitoring), manufacturing.
- YOLOv3: Precision farming, UAV-based detection.
- YOLOv4: Manufacturing defect detection, quality control.
- YOLOv5: Medical diagnostics, general object detection.

7 Comparison Table

Table 4 consolidates key differences.

Aspect	YOLOv1	YOLOv2	YOLOv3	YOLOv4	YOLOv5
Year	2015	2016	2018	2020	2020
Backbone	Darknet-24	Darknet-19	Darknet-53	CSPDarknet53	CSPNet
mAP	63.4%	76.8%	28.2%	43.5%	67.2%
FPS	45	67	45	∼65	100
Key Improvements	Single-stage	Anchor boxes	FPN	PANet, CIoU	Scalability
Strengths	Speed	Speed, accuracy	Accuracy	SOTA	Scalability
Weaknesses	Small objects	Small objects	Complexity	Resources	Paper controversy
Use Cases	Vehicles	Agriculture	Farming	Manufacturing	General

Table 4: Comparison of YOLO Versions

8 References

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