

10^{MECO}

years outgrowing the science

Risk Ranked Recall

Collision Safety Metric for Object Detection Systems in Autonomous Vehicles



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Problem definition



		Detection	
		Exists	Does not Exist
Ground Truth	Exists	True Positive (TP)	False Negative (FN)
	Does not Exist	False Positive (FP)	True Negative

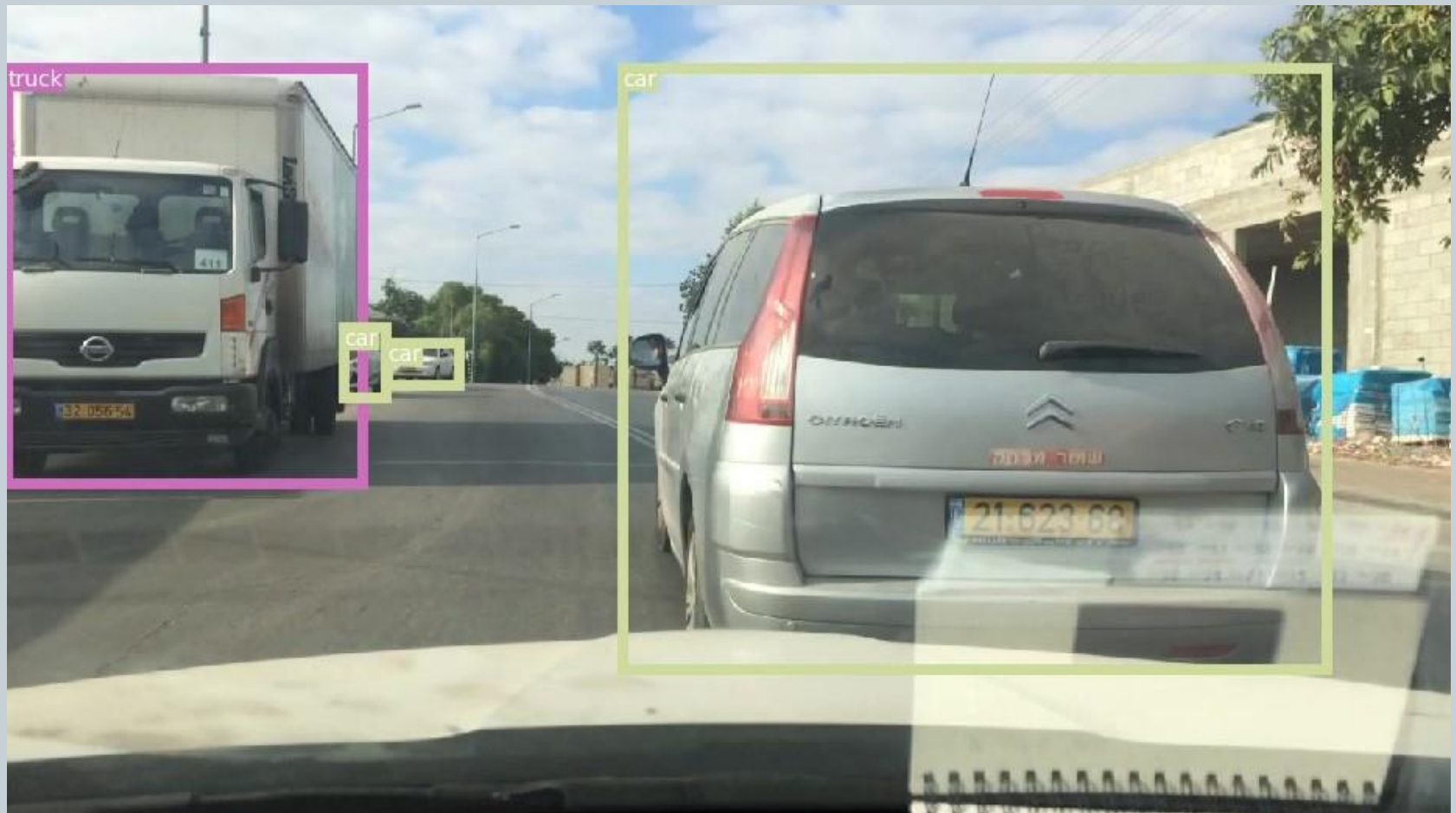
Problem definition



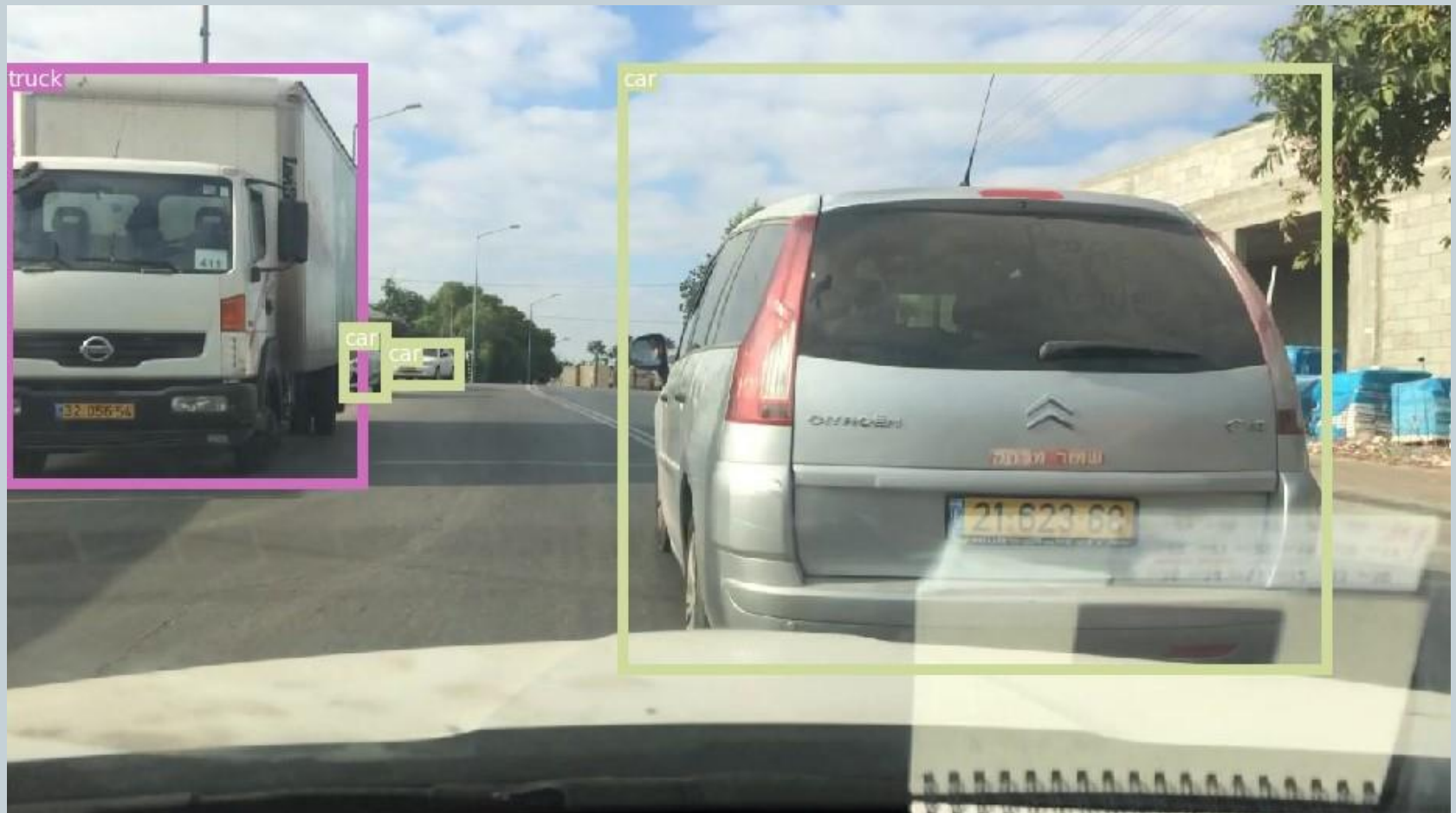
- The current metrics
 - Precision = $TP / (TP + FP) = TP / \text{All Detected}$
 - Recall = $TP / (TP + FN) = TP / \text{All Exists}$
 - ✦ FN *i.e.*, not detecting obstacles that exist, safety issue

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Problem definition



Problem definition



State of the art



- **Object Importance**
 - Ohn-Bar E, Trivedi MM. “Are all objects equal? Deep spatio-temporal importance prediction in driving videos.”
 - ✦ User annotated object importance
 - Refaat KS, Ding K, Ponomareva N, Ross S. Agent prioritization for autonomous navigation.
 - ✦ Agent prioritization by impact on planning
- **Neural Network based scene Risk Annotation**
 - Wang Y, Kato J. Collision risk rating of traffic scene from dashboard cameras.
 - Feth P, Akram MN, Schuster R, Wasenmüller O. Dynamic Risk Assessment for Vehicles of Higher Automation Levels by Deep Learning.

State of the art



- Object Importance

- Ohn-Bar E, Trivedi MM. “Are all objects equal? Deep spatio-”

Approximate or subjective determinations
not suitable for Safety Analysis

Need an Objective Safety Performance Indicator

Assessment for Vehicles of Higher Automation Levels by Deep Learning.

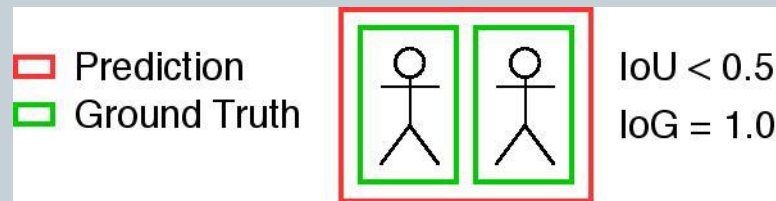
Design Choices I

- Time Horizon
 - For any risk analysis what time frame should be considered?
 - ✦ We choose Time to Stop (TTS)
 - Emergency stop acceptable default safety response [1].
 - Time to stop includes
 - ✦ reaction time of the AV
 - ✦ physical conditions of the scene (safe deceleration)
 - *i.e.*, more information about ground truth and AV system, more accurate the risk evaluation.

[1] Meder B, Fleischhut N, Krumnau NC, Waldmann MR. How should autonomous cars drive? A preference for defaults in moral judgments under risk and uncertainty.

Design Choices II

- IoU vs IoG
 - IoU : Intersection over Union
 - IoG : Intersection over GroundTruth



- SuperSet existence detection is enough to avoid collision.
- Truncated and Occluded objects are also handled with this

Design Choices III

- Flexible Options

- TP determination

- ✦ Class match

- Classification provides additional information, but unclassified obstacles should also be avoided.
- Class match is not used as a requirement for TP determination.

- ✦ Depth

- ✦ Volume IoG

- Sensor / System type

- ✦ Vision

- ✦ Lidar

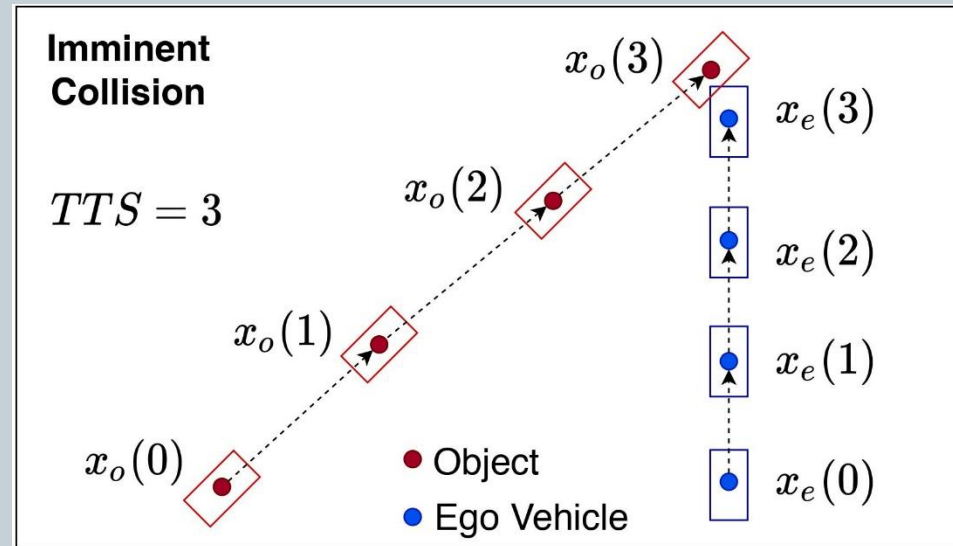
- ✦ Radar

- ✦ Vision was primarily used in this work.

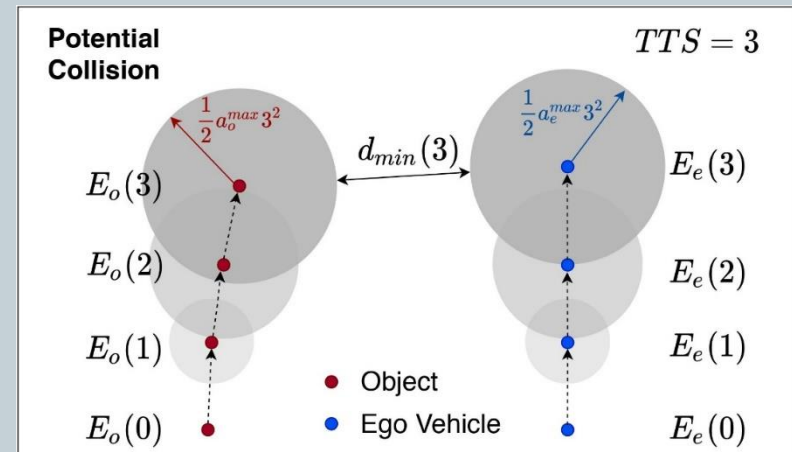
- Risk Ranked Recall

- R_1^3 : Recall for objects that pose an imminent risk of collision
- R_2^3 : Recall for objects that pose a potential risk of collision
- R_3^3 : All other objects in the environment.

- Imminent Collision
 - Collisions that will happen without any corrective action
 - Trajectories with current heading and velocity over TTS
 - Check for any collision
 - Such scenarios are not present in real world datasets



- Potential Collisions
 - Collisions that can potentially happen
 - Existence Region $E(t)$ [2]
 - ✦ Area where an object's center point may exist at time t
 - ✦ Center = $x(o) + v(o)t$
 - ✦ Area = $\frac{1}{2} a^{max} t^2$
 - ✦ $d_{min}(t)$ = Min distance between $E(t)$ of objects at time t
 - ✦ d_{crit} = Max distance between center of objects where their edges still touch, for rectangles that's sum of half diagonals.
 - ✦ Considers a_{max} for each object
 - $d_{min}(t) < d_{crit} \rightarrow$ Potential Collision



[2] Schmidt C, Oechsle F, Branz W. Research on trajectory planning in emergency situations with multiple objects.

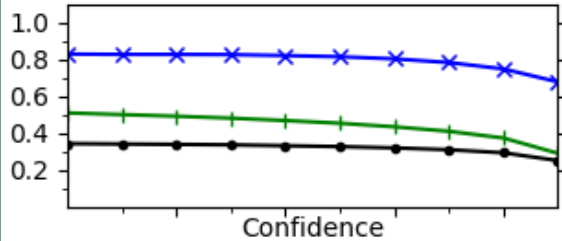
Usage

- Object Detection DNN, Pretrained
 - Yolo v3, FasterRCNN, MaskRCNN
 - Input resolutions 320x320, 416x416, 608x608 pixels
- Waymo Open Dataset, 24 sequences, 10 Hz
 - R_1^3 : 0 objects in GroundTruth
 - R_2^3 : 952 objects in GroundTruth
 - R_3^3 : 27021 objects in GroundTruth

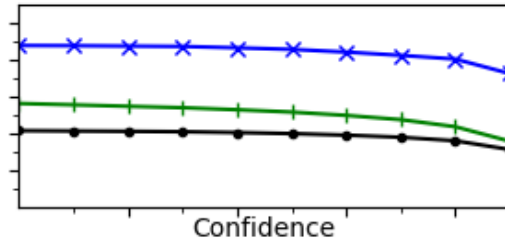
Usage Results



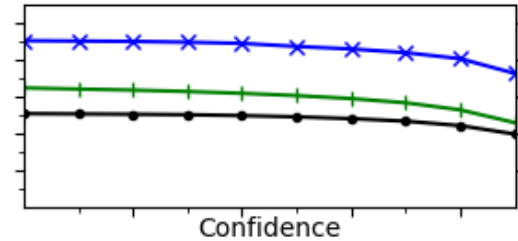
fasterrcnn 320



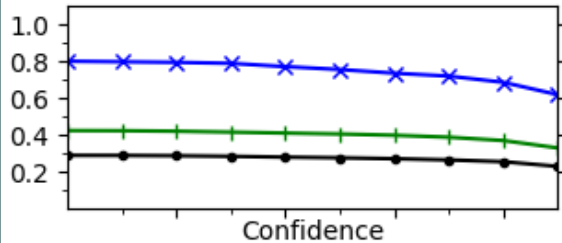
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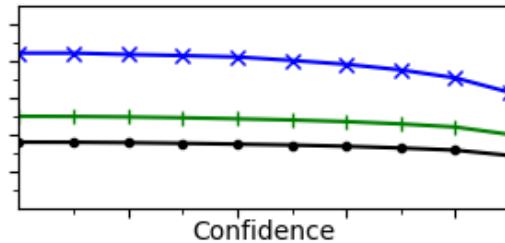
fasterrcnn 608



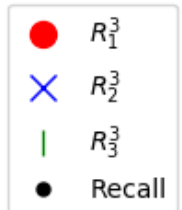
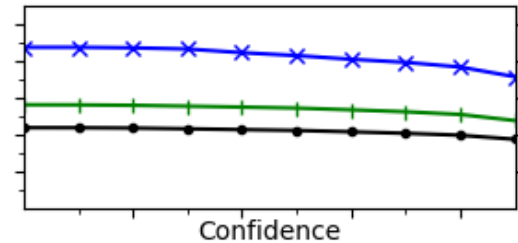
yolov3 320



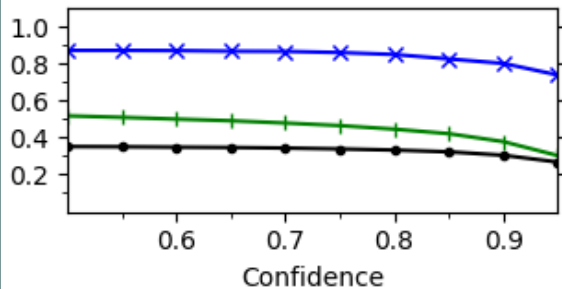
yolov3 416



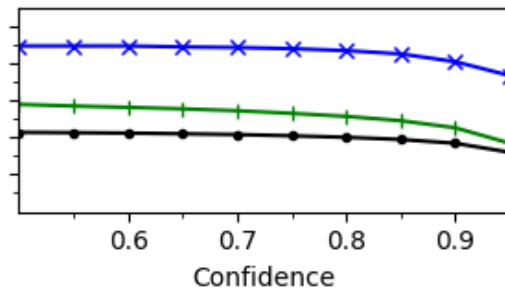
yolov3 608



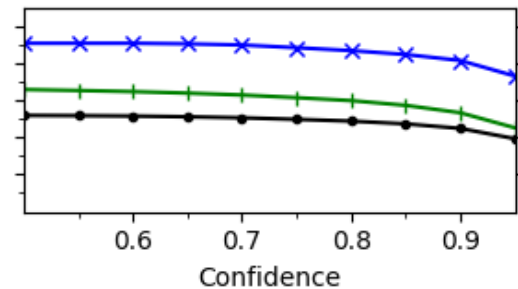
maskrcnn 320



maskrcnn 416



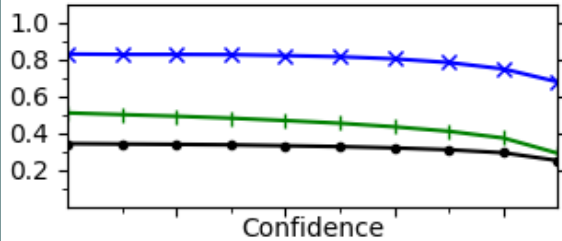
maskrcnn 608



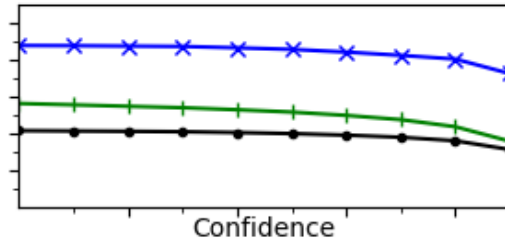
Usage Results



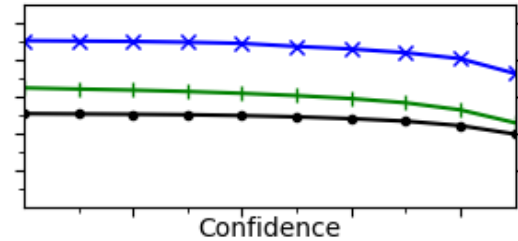
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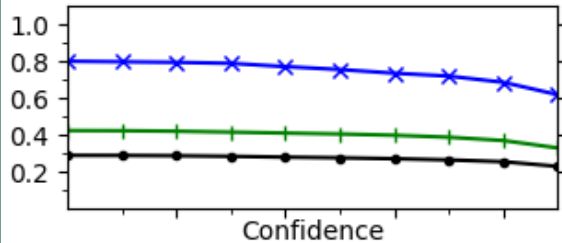
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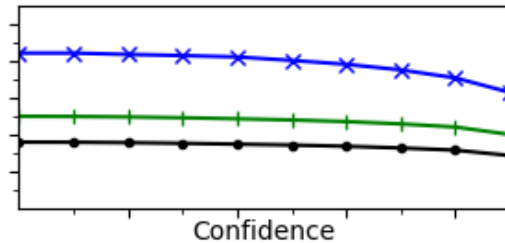
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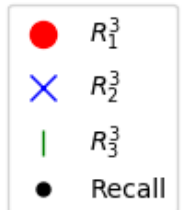
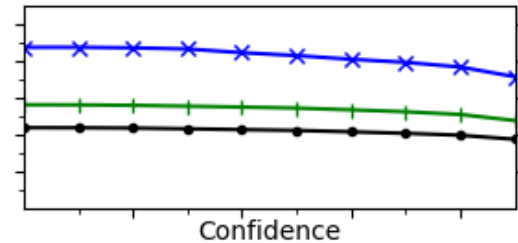
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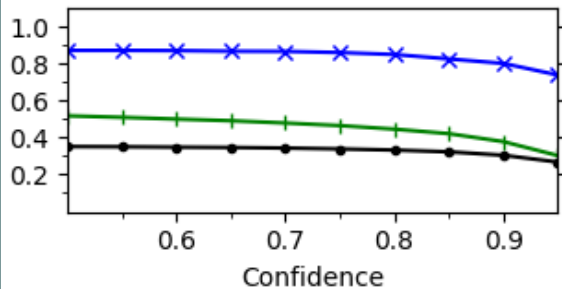
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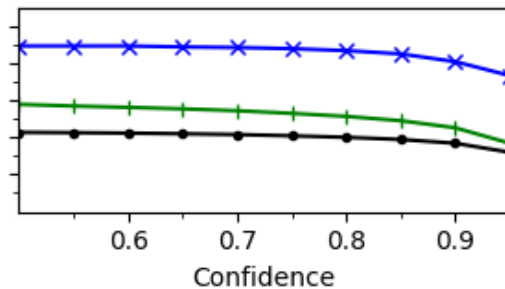
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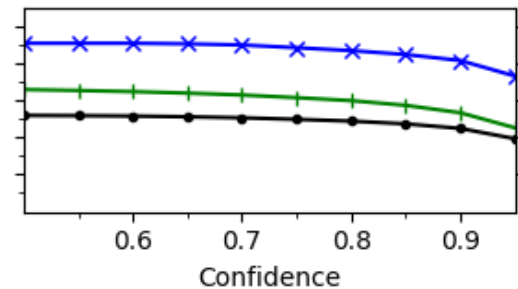
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maskrcnn 416



maskrcnn 608



Conclusions



- Existing metrics are incomplete
- Need for an objective safety performance indicator
- Risk Ranked Recall bridges the gap
- Additional information to existing metrics
- Future work will explore object detection system design and evaluation using the new metrics