Open-Set Semi-Supervised Object Detection

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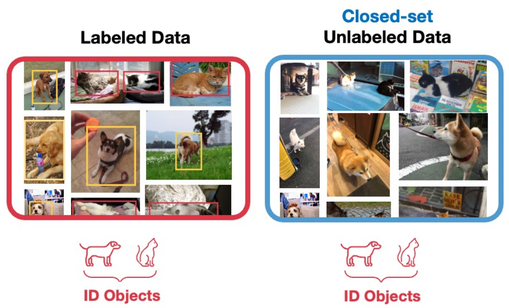
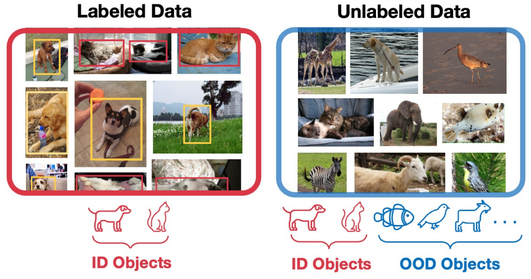
Motivation

1. Existing Semi-Supervised Object Detection (SSOD) works implicitly assumes closed-set setting
   - Label spaces of labeled and unlabeled data are identical

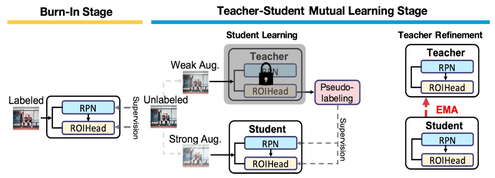


2. A more practical setting is Open-Set Semi-Supervised Object Detection (OSSOD)
   - Open-set unlabeled data have out-of-distribution (OOD) objects, which are unseen, undefined, and unknown in labeled data



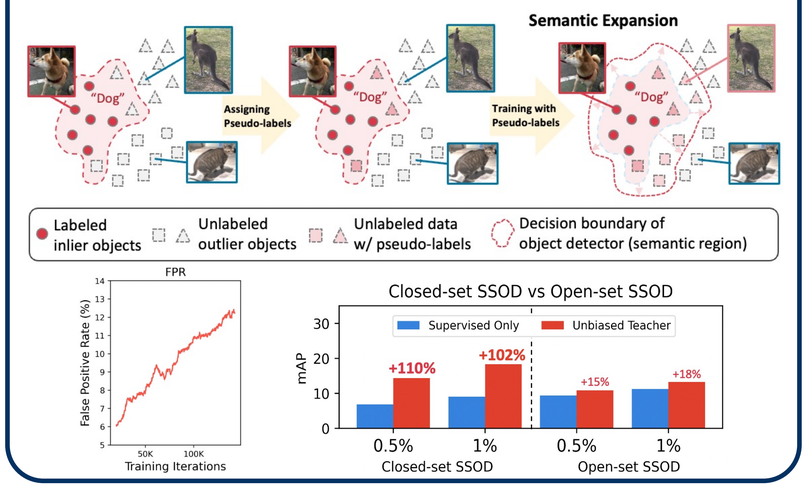
Analysis & Challenges

1. Applying existing SSOD method leads to unsatisfactory results due to semantic expansion



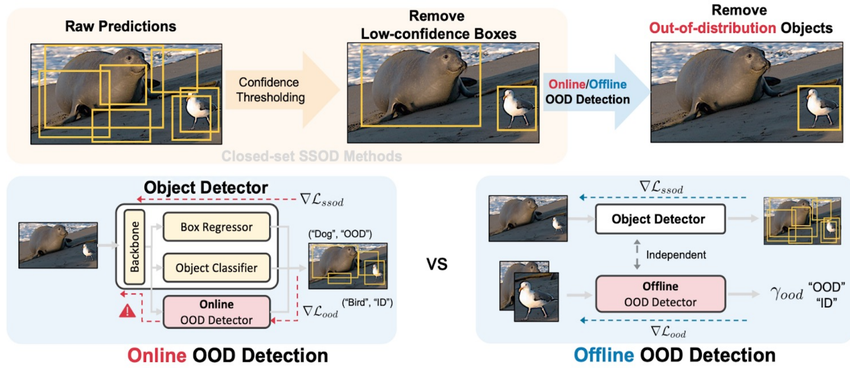
▲ Existing SSOD method (Unbiased Teacher)

2. Semantic expansion: OOD objects are mis-predicted as ID objects with high confidence and used as pseudo-labels
   - Lower accuracy in open-set settings



Methods

1. To address this issue, we propose to detect and remove OOD objects in pseudo-labels by using online/offline OOD detectors



✓ Online OOD Detectors

- Add a new head on object detector and apply existing OOD methods
- Jointly train OOD detector and SSOD

Results:

- SSOD and OOD affect each others
- Both SSOD and OOD performance are bad

✓ Offline OOD Detectors

- Apply a pretrained DINO
- Individually Fine-tune DINO using labeled data

Results:

- **Offline** detectors are much better than **online** detectors

✓ Performance Comparison

OOD Models	Methods	OoD Scores γ_{ood}	AUROC ↑	FPR75↓	FPR95↓
Online (ROIhead)	Vanilla	MSP [8]	67.0 / 71.0	58.4 / 52.4	92.3 / 91.1
		Energy [20]	75.5 / 68.2	36.8 / 49.0	83.6 / 87.8
		Entropy	75.9 / 68.4	38.5 / 51.1	83.1 / 87.7
		Mahalanobis [17]	50.2 / 61.6	83.0 / 65.7	98.1 / 93.7
		Euclidean	56.3 / 61.5	74.3 / 66.9	96.1 / 94.1
	OE [9]	MSP	67.0 / 73.3	55.0 / 45.9	89.1 / 85.6
	OVA [29]	MSP	73.0 / 76.0	45.7 / 40.2	90.0 / 84.8
	GODIN [11]	Cosine $h(x)$	77.8 / 73.5	33.8 / 45.0	77.4 / 84.5
	GSD [38]	Feat. angle	78.7 / 71.3	32.1 / 48.8	73.9 / 83.4
Offline (DINO)	AC [24]	IAC [37]	83.6 / 86.0	22.4 / 18.7	61.7 / 57.9
		Energy	89.6 / 85.9	12.2 / 18.8	47.5 / 56.8
		Entropy	88.9 / 84.7	12.6 / 20.3	51.1 / 59.9
		Mahalanobis [17]	81.8 / 75.7	25.6 / 35.9	57.6 / 68.9
		Euclidean	**90.8 / 86.1**	**10.7 / 18.5**	**38.6 / 51.6**

Experiments

- Adding an OOD detector in SSOD frameworks **significantly improves** the results in all open-set conditions

✓ Varying num. of labeled images

Num. of Labeled Images	1,000	2,000	4,000
Label-only	10.20± 0.34	11.84± 0.33	16.35± 0.28
UT	11.77±0.38 (+1.57)	13.87±0.68 (+2.03)	18.23±0.47 (+1.88)
UT + OF-DINO	**16.80±0.53 (+6.60)**	**18.10±0.71 (+6.26)**	**22.56±0.51 (+6.21)**
UT + OF-ViT	17.10±0.46 (+6.90)	19.32±0.53 (+7.48)	23.01±0.67 (+6.66)

✓ Varying num. of ID/OOD classes

Num. of ID/OOD objects	20/60	40/40	60/20
Label-only	16.89±2.6	15.98±0.49	16.64±0.59
UT	18.37±1.67 (+1.48)	20.28±0.85 (+4.29)	23.09±0.25 (+6.45)
UT + OF-DINO	**23.43±2.19 (+6.54)**	**22.91±0.28 (+6.93)**	**24.89±0.34 (+8.25)**
UT + OF-ViT	25.20±2.00 (+8.31)	25.10±1.01 (+9.12)	26.11±0.40 (+9.47)

✓ Large-scale unlabeled data

	mAP
Supervised	40.90
Proposal Learning [34]	38.40
CSD [14]	38.82
STAC [32]	39.21
Instant-Teaching [46]	40.20
MOCOv2 + Instagram-1B [35]	41.10
Humble Teacher [35]	42.37
SoftTeacher[3] [40]	44.05
Unbiased Teacher* [21]	44.06
Unbiased Teacher* + OF-DINO	**45.14**
Unbiased Teacher* + OF-ViT	45.16

✓ Large-scale unconstrained unlabeled data

	OpenImage GT labels	mAP
COCO		40.90
COCO + OpenImage	✓	42.91
Unbiased Teacher* [21]		41.81
Unbiased Teacher* + OF-DINO		**43.14**
Unbiased Teacher* + OF-ViT		43.48

ECCV EUROPEAN CONFERENCE ON COMPUTER VISION TEL AVIV 2022
October 23-27, 2022, Tel Aviv