Hyp-OW: Exploiting Hierarchical Structure Learning with Hyperbolic Distance Enhances Open World Object Detection

Thang Doan, Xin Li, Sima Behpour, Wenbin He, Liang Gou, and Liu Ren
Bosch Research North America, Bosch Center for Artificial Intelligence (BCAI)

The 38th Annual AAAI Conference on Artificial Intelligence
FEBRUARY 20-27, 2024 | VANCOUVER, CANADA
VANCOUVER CONVENTION CENTRE – WEST BUILDING

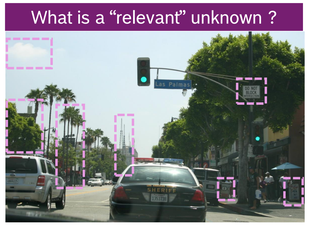
BOSCH
Invented for life

1 Motivations

Challenges

Open World Object Detection (OWOD):

- Classify known items
- Detect unknowns & integrate them
- Continuously learn



Ill-defined Problem

- What is an unknown?
- What is relevant to be detected?

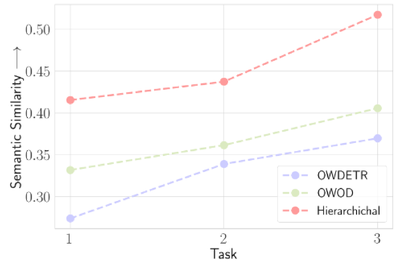
2 Methodology

Our Paradigm

Relevant unknowns must share similarities with known items

Contributions

- Learn Hierarchical Structure (SuperClass Regularizer)
- Adaptive Relabeling Scheme (Detect Unknowns)
- Design a Benchmark with Higher Known-Unknown Similarity degree

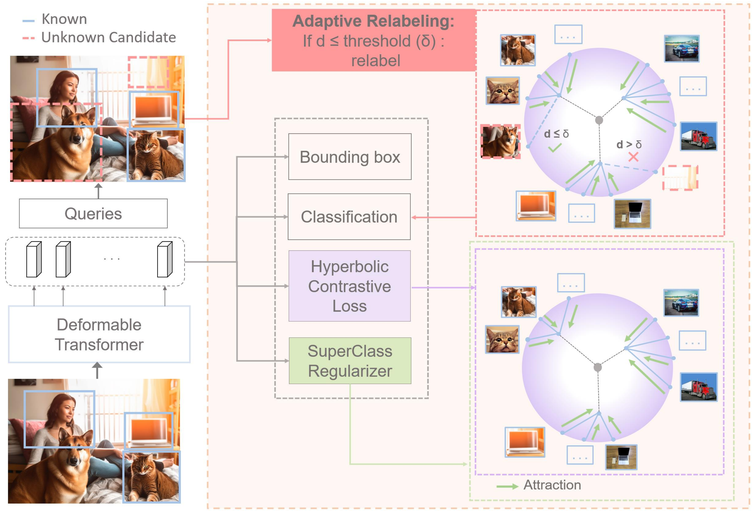


Better semantic similarity (y-axis) between knowns and unknowns in our proposed benchmark (Hierarchical)

Structure Learning | Known-Unknown Similarity
Adaptive Unkowns Detection | More Suitable Benchmark

3 Overview

Hyp-OW Architecture



4 Experiments

Benchmarks

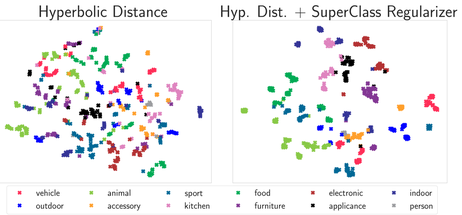
Regime	Methods	Task 1 U-Recall (↑)	Task 1 mAP (↑)	Task 2 U-Recall (↑)	Task 2 mAP (↑)	Task 3 U-Recall (↑)	Task 3 mAP (↑)	Task 4 mAP (↑)
Low	ORE - EBUI	1.5	61.4	3.9	40.6	3.6	33.7	31.8
	OW-DETR	5.7	71.5	6.2	43.8	6.9	38.5	33.1
	PROB	17.6	**73.4**	22.3	50.4	24.8	42.0	39.9
	Hyp-OW (Ours)	**23.9**	72.7	**23.3**	**50.6**	**25.4**	**46.2**	**44.8**
	Δ(Rel. Difference)	+6.3	≤ 1.0	+1.0	≤ 1.0	≤ 1.0	+4.2	+4.9
Medium	ORE - EBUI	4.9	56.0	2.9	39.4	3.9	29.7	25.3
	UC-OWOD	2.4	50.7	3.4	8.7	16.3	24.6	23.2
	OCPL	8.26	56.6	7.65	39.1	11.9	30.7	26.7
	2B-OCD	12.1	56.4	9.4	38.5	11.6	29.2	25.8
	OW-DETR	7.5	59.2	6.2	42.9	5.7	30.8	27.8
	PROB	19.4	**59.5**	17.4	44.0	19.6	36.0	31.5
	Hyp-OW (Ours)	**23.5**	59.4	**20.6**	**44.4**	**26.3**	**36.8**	**33.6**
	Δ(Rel. Difference)	+4.1	≤ 1.0	+3.2	≤ 1.0	+6.7	≤ 1.0	+2.1
High	OW-DETR	7.0	47.3	11.0	38.6	8.8	38.3	38.2
	PROB	29.4	49.6	43.9	42.9	52.7	41.3	41.0
	Hyp-OW (Ours)	**34.9**	**49.9**	**47.5**	**45.5**	**55.2**	**44.3**	**43.9**
	Δ(Rel. Difference)	+5.5	≤ 1.0	+3.6	+2.6	+2.5	+3.0	+2.9

Results on 3 different regimes of known-unknown similarity: Low, Medium, High

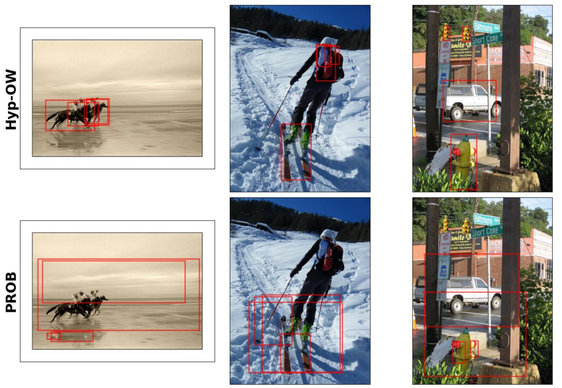
5 Qualitative Results

SuperClass Regularizer (right) allows:

- Hierarchical structure learning
- Move items from same class closer
- Repel away item from distinct classes



t-SNE plot of the learned class representations, with colors representing their respective categories



Hyp-OW (top):

- Finer-grained unknown detection
- Better visual cues understanding via family-based item clustering

PROB (bottom):

- Coarse-grained detection
- General learned features irrespective of item family

Unknowns detection highlighted with red boxes

6 Conclusion

- Derive a new paradigm to detect ‘relevant unknowns’
- Learn hierarchical structure of data
- Improve up to 6 pts for unknown detection compared to SOTA
- Introduce new benchmark to evaluate all baselines

Unknown Definition | ~ 6 pts Increase

Paper | Code