LUNA: Localizing Unfamiliarity Near Acquaintance for Open-set Long-Tailed Recognition

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Introduction

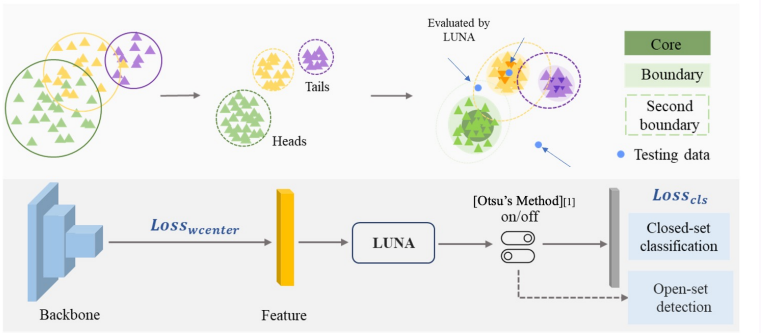
- No authentic collected open long-tailed dataset to evaluate the OLTR methodology.
- Most open-set methods decouples the open set challenges with long-tailed distribution.
- Most long-tail recognition methods ignore the open set issues.
- **Our Goal is to answer:**

(1) Whether the input is novel;
(2) If no, which class it is; if yes, what is the novelty level of the new class concerning the pretrained acquaintance classes.

- **Our Achievements are:**

(1) **The first natural OLTR dataset** in a fine-grained domain: we collect a new well-annotated real Marine Species open long-tailed (MS-LT) dataset.
(2) **A distribution-aware loss**: It centralizes the deep features of the head classes, while preserving the classification accuracy of the tails, resulting in more distinctive features.
(3) **A quantitative measurements of novelty** under the long-tailed distribution.
(4) LUNA significantly outperforms the sota methods by 4-6% on the closed set and in average 4% improvement of the F-measure under the open-set setting.

The Proposed Method



Weighted Center Loss

- Distribution-aware weights are applied on each class separately for accurate long-tailed recognition and clustering.

$$L_{wc} = \frac{1}{2}\sum_i \lambda_i \|x_i - c_j\|^2 = \frac{1}{2}\sum_i (\frac{\widetilde{n_j}}{\max_c \widetilde{n_c}} + 1)\|x_i - c_j\|^2$$

LUNA Factor

- Inside each cluster, the points are classified into **core and boundary points** by its sub local reachability density ($\boldsymbol{D}$)
- Define the **second boundary points** as the points which belong to other clusters but regard this cluster as their second-best choice by the distance to its center point.

$$D = \frac{1}{\frac{1}{K}\sum_i d_i}$$

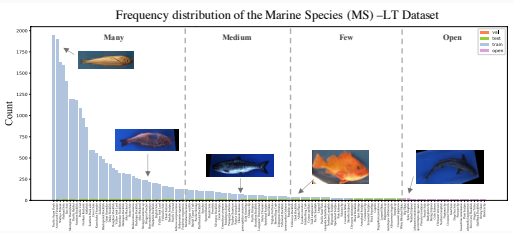
LUNA factor of $\mathbf{p_i}$

$$= \mathbf{min}(|\mathbf{1} - \mathbf{COF_i}|, |\mathbf{1} - \mathbf{BOF_i}|) + |\mathbf{1} - (\frac{\mathbf{1}}{\mathbf{M}}\sum_{\mathbf{j}}^{\mathbf{M}} \mathbf{sBOF_j})/\mathbf{sBOF_i}| + (\mathbf{1} - \mathbf{conf_i})$$

Results

Dataset	Model	Closed-set				Open-set			
		Many	Medium	Few	Overall	Many	Medium	Few	F-measure
ImageNet-LT (ResNet-10)	Base Model [15]	40.9	10.7	0.4	20.9	40.1	10.4	0.4	0.295
	Lifted Loss [29]	35.8	30.4	17.9	30.8	34.8	29.3	17.4	0.374
	Focal Loss [23]	36.4	29.9	16.0	30.5	35.7	29.3	15.6	0.371
	Range Loss [39]	35.8	30.3	17.6	30.7	34.7	29.4	17.2	0.373
	OpenMax [3]	-	-	-	-	35.8	30.3	17.6	0.368
	FSLwF [12]	40.9	22.1	15.0	28.4	40.8	21.7	14.5	0.347
	OLTR [25]	43.2	35.1	18.5	35.6	41.9	33.9	17.4	0.474
	IEM [43]	48.9	44.0	24.4	43.2	46.1	42.3	20.1	0.525
	LUNA (Ours)	**51.8**	**48.6**	**26.2**	**46.6**	**48.2**	**44.7**	**23.6**	**0.579**
Places-LT (ResNet-152)	Base Model [15]	45.9	22.4	0.4	27.2	45.9	22.4	0.4	0.366
	Lifted Loss [29]	41.1	35.4	24	35.2	41.0	35.2	23.8	0.459
	Focal Loss [23]	41.1	34.8	22.4	34.6	41.0	34.8	22.3	0.453
	Range Loss [39]	41.1	35.4	23.2	35.1	41.0	35.3	23.1	0.457
	OpenMax [3]	-	-	-	-	41.1	35.4	23.2	0.458
	FSLwF [12]	43.9	29.9	29.5	34.9	38.1	19.5	14.8	0.375
	OLTR [25]	44.7	37	25.3	35.9	44.6	36.8	25.2	0.464
	IEM [43]	46.8	39.2	28.0	39.7	**48.8**	**42.4**	28.9	0.486
	LUNA (Ours)	**48.7**	**42.4**	**30.2**	**42.1**	48.1	41.6	**29.0**	**0.491**
MS-LT (ResNet-32)	Base Model [15]	56.1	35.1	8.0	35.7	56.1	35.1	11.4	0.537
	Lifted Loss [29]	53.2	42.3	12.6	38.0	53.0	42.2	12.4	0.549
	Focal Loss [23]	57.3	44.6	18.5	42.1	57.0	42.8	15.4	0.576
	Range Loss [39]	55.8	43.8	15.7	40.5	55.8	43.6	15.6	0.575
	OpenMax [3]	-	-	-	-	54.2	44.9	12.8	0.564
	OLTR [25]	57.8	49.8	28.6	46.8	56.7	45.3	23.6	0.603
	LUNA (Ours)	**61.2**	**56.6**	**34.6**	**52.0**	**60.4**	**51.8**	**30.4**	**0.657**

Marine Species Dataset



$$\boldsymbol{COF} = \frac{\text{D of p}}{\text{Average D of core points}} = \frac{\sum_i^{N_c} D_p/D_C^i}{Nc}$$

$$\boldsymbol{BOF} = \frac{\text{D of p}}{\text{Average D of boundary points}} = \frac{\sum_i^{N_B} D_p/D_B^i}{N_B}$$

$$\boldsymbol{sBOF} = \frac{\text{D of p}}{\text{Average D of sb points}} = \frac{\sum_i^{N_{sB}} D_p/D_{sB}^i}{N_{sB}}$$