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Supervised Exploratory Learning for Long-Tailed Visual Recognition

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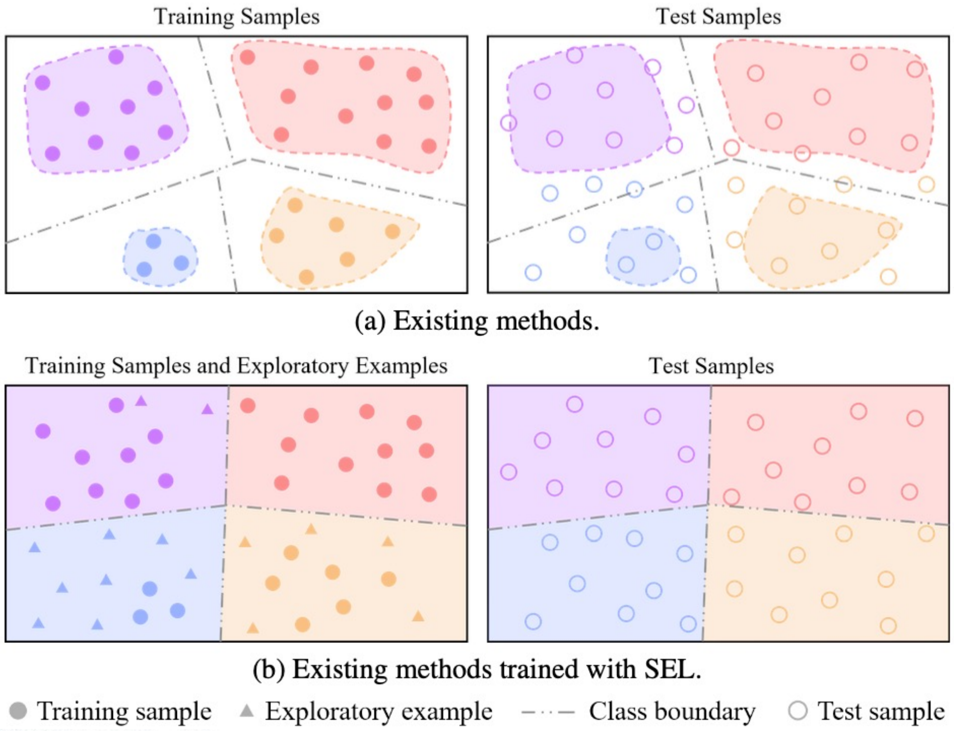
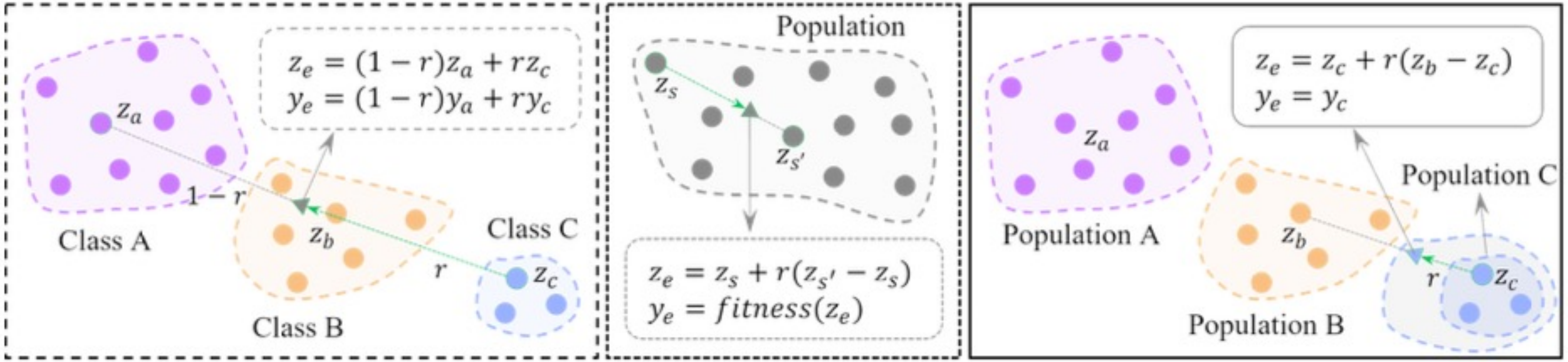
Motivation



This discrepancy erodes the well-defined margins of the classifier [25], leading to the misclassification of samples from tail classes as head classes, as shown in Fig. 1(a).

SEL leverages an adaptive OFA operator to synthesize exploratory examples, compensating for insufficient tail-class data and enabling balanced decision regions and boundaries, as shown in Fig. 1(b).

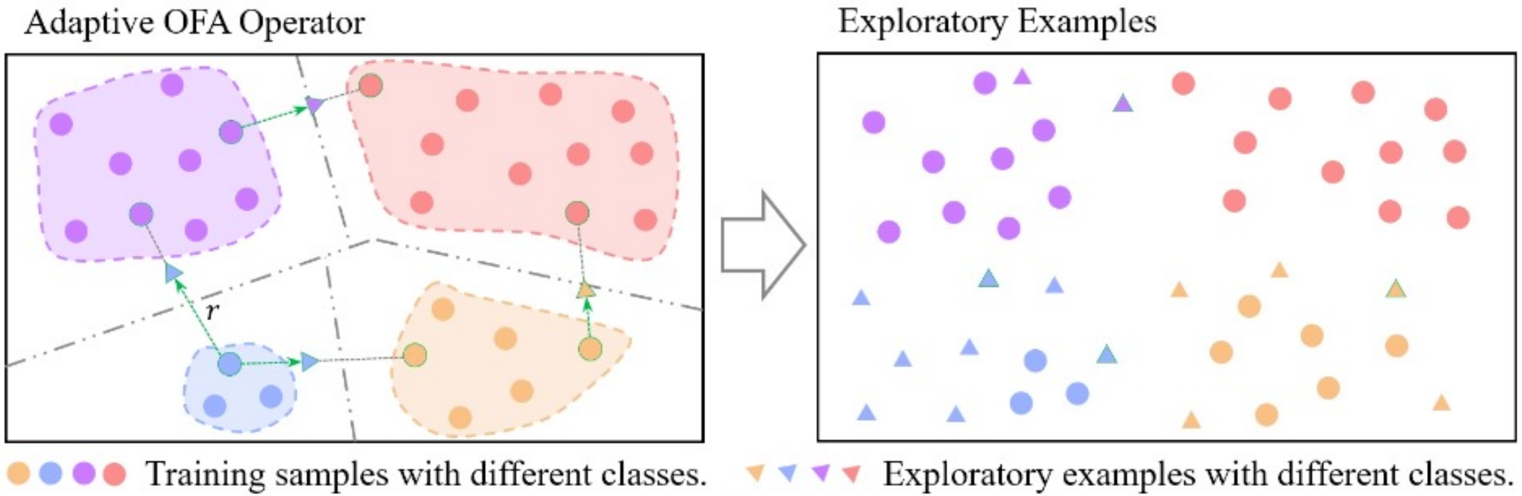
Method



(a) MixUp (b) OFA (c) SEL

The differences and relationships among MixUp, OFA, and SEL. MixUp linearly interpolates two random samples (typically from different classes, such as z_a and z_c) to create a new sample, while OFA leverages the better individual ($z_{s'}$) to guide weaker individuals (z_s) toward better evolution. Combining their strengths, SEL gradually expands and reinforces minority decision regions by synthesizing adjacent exploratory examples.

Method



$$z_e = z_s + r(z_{s'} - z_s)$$

$$\mathcal{L}_{SEL} = -\frac{1}{C}\sum_{c=1}^{C}(\frac{1}{k_c}\sum_{i=1}^{k_c}\log(\hat{y}_i^c))$$

Rational

$$\hat{y}^c = \frac{e^{w_c^T z}}{\sum_{c'=1}^{C} e^{w_{c'}^T z}}$$

Case	z_s	$z_{s'}$	z_e	Goal
1	z_t	z_h	$z_t + r(z_h - z_t)$	$\hat{y}_e^t > \hat{y}_e^h$
2	z_h	z_t	$z_h + r(z_t - z_h)$	$\hat{y}_e^h > \hat{y}_e^t$

Table 1. Two types of synthesized exploratory examples.

For the first case, the goal of $\hat{y}_e^t > \hat{y}_e^h$ is equivalent to:

$$\begin{aligned} w_t^T z_e - w_h^T z_e > 0 \Rightarrow \\ w_t^T(z_t + r(z_h - z_t)) - w_h^T(z_t + r(z_h - z_t)) > 0 \end{aligned} \tag{8}$$

After expanding and transforming the inequality, we have:

$$\begin{aligned} w_t^T z_t - w_h^T z_t > \frac{r}{1-r}(w_h^T z_h - w_t^T z_h) \\ \Rightarrow \hat{y}_t^t - \hat{y}_t^h > \frac{r}{1-r}(\hat{y}_h^h - \hat{y}_h^t) \end{aligned} \tag{9}$$

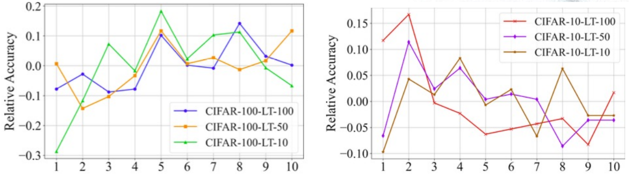
For the second case:

$$\hat{y}_h^h - \hat{y}_h^t > \frac{r}{1-r}(\hat{y}_t^t - \hat{y}_t^h)$$

Experiments

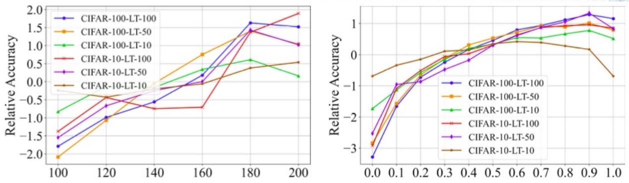
Methods		CIFAR-100-LT			CIFAR-10-LT		
Avenue	Imbalance Ratio ρ	100	50	10	100	50	10
-	ResNet-32 [9]	39.96	46.01	56.66	71.96	75.95	85.92
	+ MixUp [45]	$41.55_{\uparrow 1.59}$	$47.11_{\uparrow 1.10}$	$57.18_{\uparrow 0.52}$	$73.43_{\uparrow 1.47}$	$77.19_{\uparrow 1.24}$	$86.37_{\uparrow 0.45}$
	+ SEL	$44.53_{\uparrow 4.57}$	$49.64_{\uparrow 3.85}$	$59.17_{\uparrow 2.51}$	$75.84_{\uparrow 3.88}$	$79.81_{\uparrow 3.86}$	$86.78_{\uparrow 0.86}$
ICCV 2021	IB [31]	40.50	46.31	56.75	75.11	79.95	88.01
	+ SEL	$42.34_{\uparrow 1.84}$	$47.95_{\uparrow 1.64}$	$57.57_{\uparrow 0.82}$	$75.04_{\downarrow 0.07}$	$79.81_{\downarrow 0.14}$	$88.13_{\uparrow 0.12}$
CVPR 2022	BCL [52]	51.76	56.51	67.90	83.61	86.13	90.10
	+ SEL	$52.30_{\uparrow 0.54}$	$57.25_{\uparrow 0.74}$	$68.43_{\uparrow 0.53}$	$84.44_{\uparrow 0.83}$	$86.31_{\uparrow 0.18}$	$90.26_{\uparrow 0.16}$
CVPR 2022	GCL [23]	46.50	51.72	61.79	80.56	84.74	89.65
	+ SEL	$47.89_{\uparrow 1.39}$	$52.74_{\uparrow 1.02}$	$62.41_{\uparrow 0.62}$	$81.86_{\uparrow 1.30}$	$85.13_{\uparrow 0.39}$	$89.78_{\uparrow 0.13}$
CVPR 2023	FCC+CE [22]	40.20	45.93	57.80	73.80	79.57	87.75
	+ SEL	$42.33_{\uparrow 2.13}$	$48.05_{\uparrow 2.12}$	$58.75_{\uparrow 0.95}$	$77.88_{\uparrow 4.08}$	$82.10_{\uparrow 2.53}$	$88.80_{\uparrow 1.05}$
CVPR 2023	GLMC [7]	53.91	58.87	68.07	83.68	86.90	91.16
	+ SEL	$56.48_{\uparrow 2.57}$	$61.13_{\uparrow 2.26}$	$70.75_{\uparrow 2.68}$	$85.40_{\uparrow 1.72}$	$88.57_{\uparrow 1.67}$	$92.83_{\uparrow 1.67}$
TPAMI 2023	KPS [24]	41.97	47.92	59.59	82.32	84.29	89.10
	+ SEL	$44.01_{\uparrow 2.04}$	$47.80_{\downarrow 0.12}$	$60.03_{\uparrow 0.44}$	$83.48_{\uparrow 1.16}$	$84.49_{\uparrow 0.20}$	$89.34_{\uparrow 0.24}$
AAAI 2024	H2T+CE [25]	42.27	47.58	58.24	79.91	82.80	88.77
	+ SEL	$42.45_{\uparrow 0.18}$	$47.80_{\uparrow 0.22}$	$58.66_{\uparrow 0.42}$	$80.43_{\uparrow 0.52}$	$82.80_{\downarrow 0.00}$	$88.79_{\uparrow 0.02}$

Table 2. Comparisons between raw methods and their SEL-enhanced counterparts on CIFAR-LT datasets.



(a) CIFAR-100-LT (b) CIFAR-10-LT

Figure 5. Changes with different neighboring class numbers.



(a) start epochs (b) weight (λ)

Figure 6. Changes with different parameters.

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Thank You for Listening

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