Interactive Deep Clustering via Value Mining

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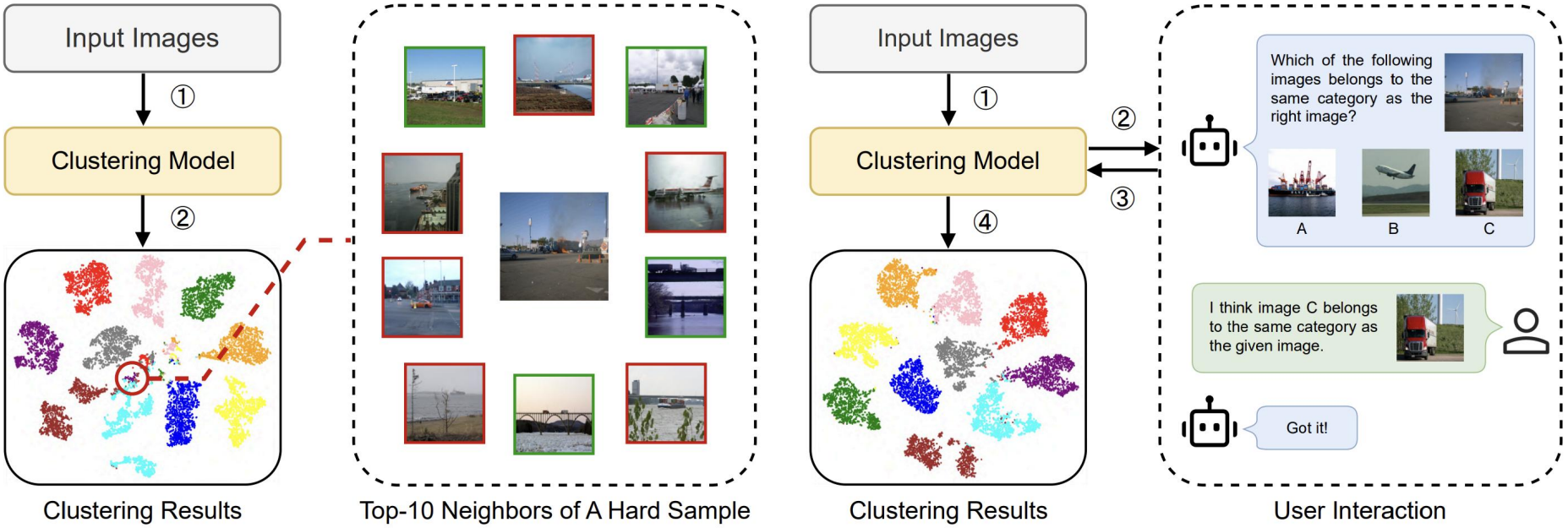
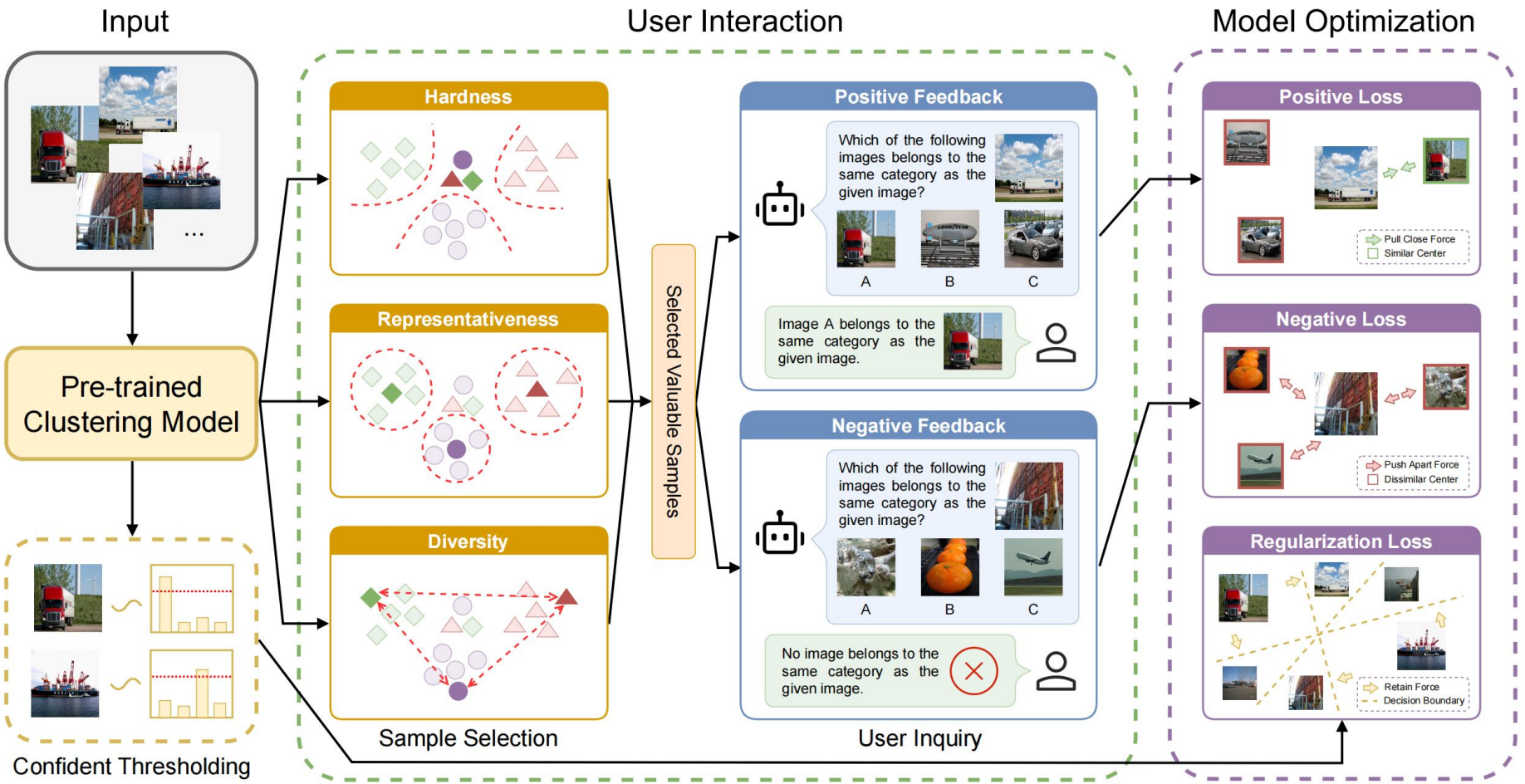
Key Idea



(a) Existing Deep Clustering Pipeline

(b) Our Interactive Deep Clustering Pipeline

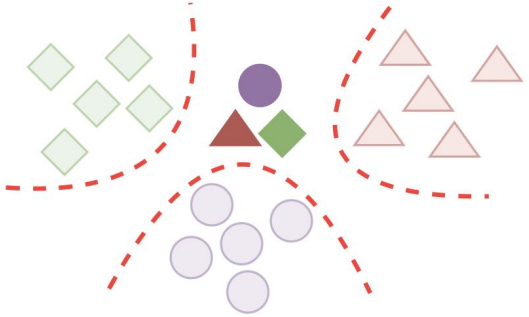
Framework


Input
User Interaction
Model Optimization
...
Pre-trained Clustering Model
Confident Thresholding
Hardness
Representativeness
Diversity
Sample Selection
Selected Valuable Samples
Positive Feedback
Which of the following images belongs to the same category as the given image?
A
B
C
Image A belongs to the same category as the given image.
Negative Feedback
Which of the following images belongs to the same category as the given image?
A
B
C
No image belongs to the same category as the given image.
User Inquiry
Positive Loss
Pull Close Force
Similar Center
Negative Loss
Push Apart Force
Dissimilar Center
Regularization Loss
Retain Force
Decision Boundary

Method

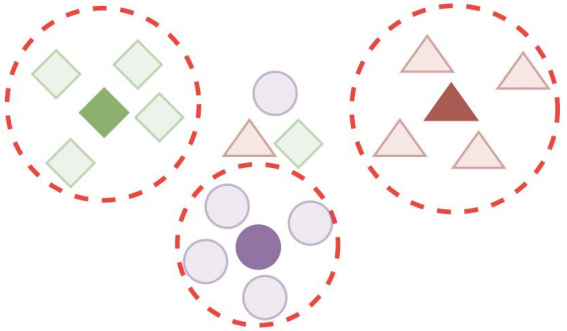
Hardness

$$h_i = \log(1 - z_i \cdot c_{g_1} + z_i \cdot c_{g_2})$$



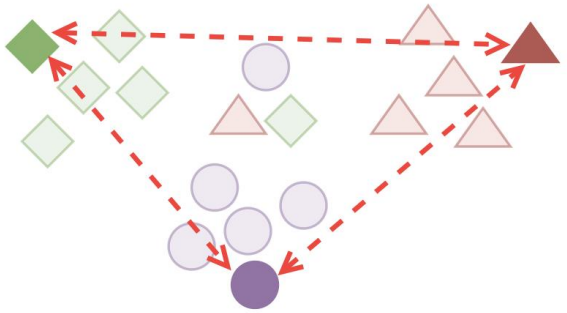
Representativeness

$$r_i = -\log \sum_{j=1}^{K} \| z_i - z_{i(j)} \|_2^2$$



Diversity

$$d_i = \min_{j \in \mathbf{S}} \log(1 - z_i \cdot z_j)$$



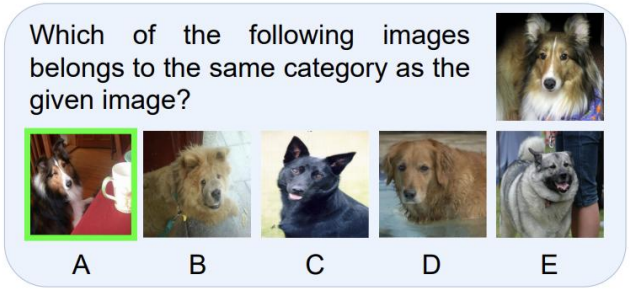
Method

Algorithm 1 Valuable Sample Selection

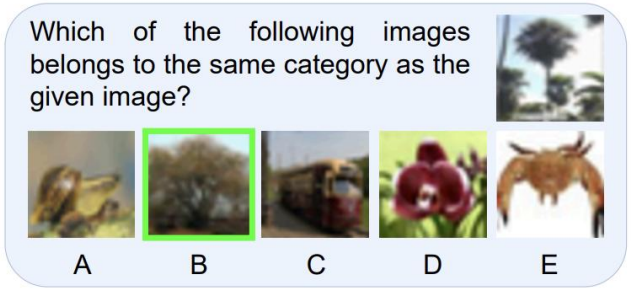
Input: Sample features $\mathbf{Z} = \{\mathbf{z}_1, \ldots, \mathbf{z}_N\}$, number of samples to be selected M
Output: Selected sample indices $\mathbf{S} = \{s_1, \ldots, s_M\}$

Initialize the selected indices $\mathbf{S} = \{\}$ and the remaining indices $\mathbf{R} = \{1, \ldots, N\}$
Compute cluster centers of $\mathbf{Z}$ by k-means
for $i \in [1, N]$ **do**
    Compute the hardness score h_i by Eq. (2)
    Compute the representativeness score r_i by Eq. (3)
    Initialize the diversity score $d_i = 0$, since no sample has been selected
    Compute the value score v_i by Eq. (1)
end for
for $j \in [1, M]$ **do**
    Select the s_j-th sample with the highest value from $\mathbf{Z}_\mathbf{R}$
    $\mathbf{S} = \mathbf{S} \cup \{s_j\}$, $\mathbf{R} = \mathbf{R} \setminus \{s_j\}$
    Update the diversity score d for $\mathbf{Z}_\mathbf{R}$ by Eq. (4)
    Update the value score v for $\mathbf{Z}_\mathbf{R}$ by Eq. (1)
end for

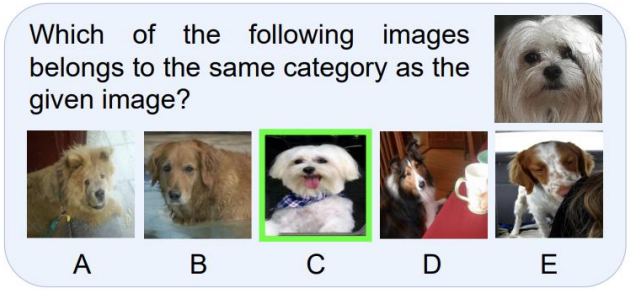
Method



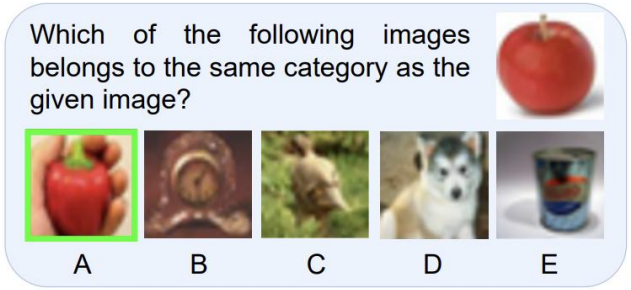
(a) A Positive Feedback on ImageNet-Dogs



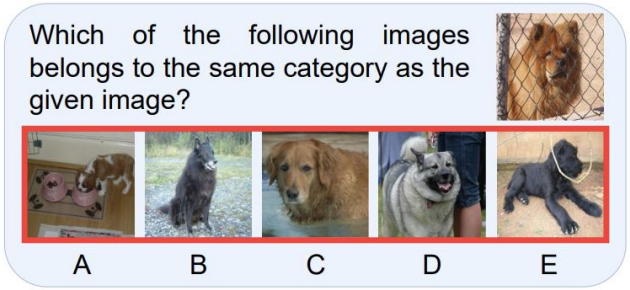
(b) A Positive Feedback on CIFAR-20



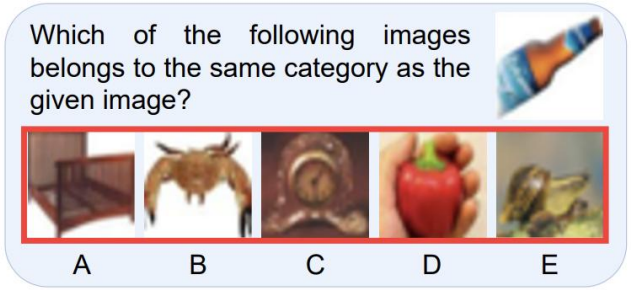
(c) A Positive Feedback on ImageNet-Dogs



(d) A Positive Feedback on CIFAR-20



(e) A Negative Feedback on ImageNet-Dogs

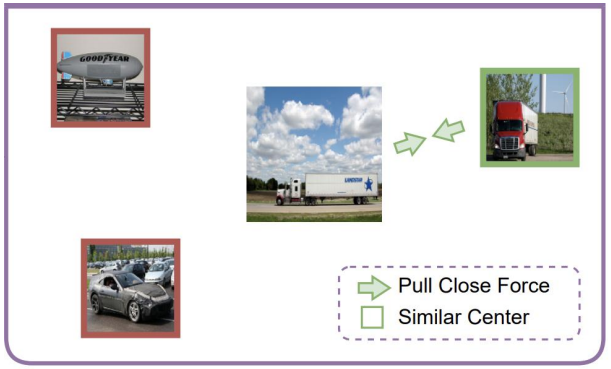


(f) A Negative Feedback on CIFAR-20

Method

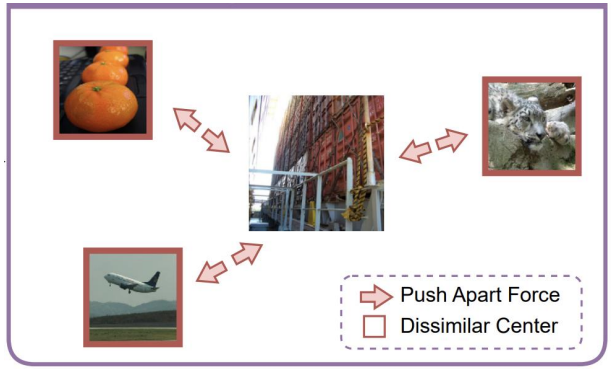
Positive Loss

$$\mathcal{L}_{pos} = -\frac{1}{M_{pos}} \sum_{i=1}^{M_{pos}} \sum_{j=1}^{C} y_{ij} \log p_{ij}$$



Negative Loss

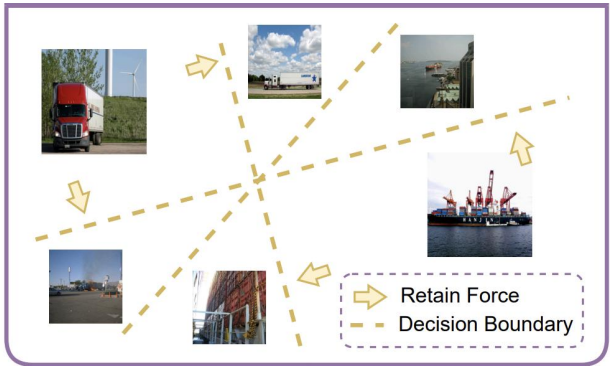
$$\mathcal{L}_{neg} = -\frac{1}{M_{neg}} \sum_{i=1}^{M_{neg}} \sum_{j=1}^{C} \tilde{y}_{ij} \log(1 - p_{ij})$$



Regularization Loss

$$\mathcal{L}_{reg} = -\frac{1}{N} \sum_{i=1}^{N} \mathbb{1}[p_{i\hat{j}} > \tau] \log p_{i\hat{j}},$$

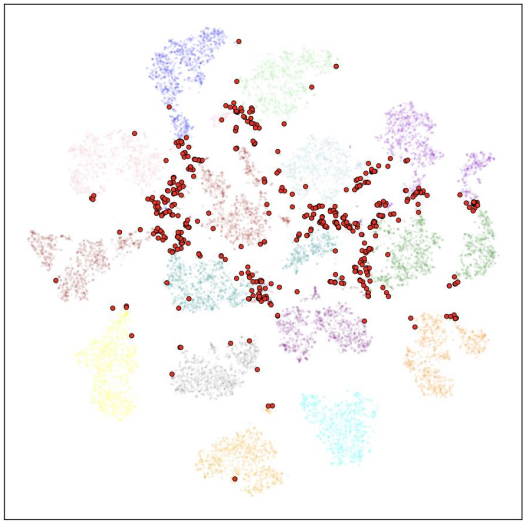
$$\hat{j} = \operatorname{argmax} p_i$$



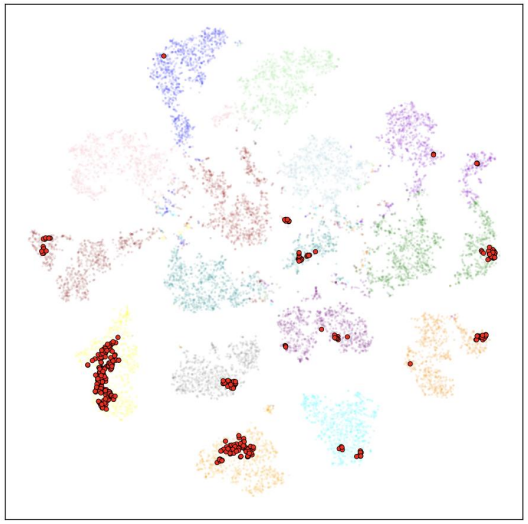
Experiments

Method	CIFAR-10			CIFAR-20			STL-10			ImageNet-10			ImageNet-Dogs		
	NMI	ACC	ARI	NMI	ACC	ARI	NMI	ACC	ARI	NMI	ACC	ARI	NMI	ACC	ARI
CC [18]	70.5	79.0	63.7	43.1	42.9	26.6	76.4	85.0	72.6	85.9	89.3	82.2	44.5	42.9	27.4
SCAN [38]	79.7	88.3	77.2	48.6	50.7	33.3	69.8	80.9	64.6	-	-	-	-	-	-
NMM [9]	74.8	84.3	70.9	48.4	47.7	31.6	69.4	80.8	65.0	-	-	-	-	-	-
MiCE [37]	73.7	83.5	69.8	43.6	44.0	28.0	63.5	75.2	57.5	-	-	-	42.3	43.9	28.6
BYOL [10]	81.7	89.4	79.0	55.9	56.9	39.3	71.3	82.5	65.7	86.6	93.9	87.2	63.5	69.4	54.8
GCC [46]	76.4	85.6	72.8	47.2	47.2	30.5	68.4	78.8	63.1	84.2	90.1	82.2	49.0	52.6	36.2
SPICE [29]	73.4	83.8	70.5	44.8	46.8	29.4	81.7	90.8	81.2	82.8	92.1	83.6	57.2	64.6	47.9
IDFD [36]	71.1	81.5	66.3	42.6	42.5	26.4	64.3	75.6	57.5	89.8	95.4	90.1	54.6	59.1	41.3
TCC [34]	79.0	90.6	73.3	47.9	49.1	31.2	73.2	81.4	68.9	84.8	89.7	82.5	55.4	59.5	41.7
DivClust [26]	72.4	81.9	68.1	44.0	43.7	28.3	-	-	-	89.1	93.6	87.8	51.6	52.9	37.6
SeCu [32]	86.1	93.0	85.7	55.1	55.2	39.7	73.3	83.6	69.3	-	-	-	-	-	-
CoNR [45]	87.1	93.3	86.5	60.3	59.0	44.8	84.6	92.2	83.8	89.8	95.8	90.9	74.2	80.2	67.6
FixMatch [35]	86.8	92.8	85.4	57.2	67.2	47.3	61.7	68.6	49.2	84.2	92.5	84.4	50.0	57.9	33.7
Cop-Kmeans [40]	82.3	89.0	78.6	52.2	52.4	34.7	78.1	85.4	73.1	85.5	88.6	81.0	61.5	63.5	49.7
TCL [21]	81.9	88.7	78.0	52.9	53.1	35.7	79.9	86.8	75.7	87.5	89.5	83.7	62.3	64.4	51.6
TCL†	82.2	88.9	78.4	53.2	53.5	36.1	82.0	88.6	78.5	88.6	90.4	85.0	62.8	65.6	52.3
IDC$_{\text{TCL}}$(Ours)	84.4	92.7	84.8	58.1	69.4	48.7	**85.3**	**92.7**	**84.6**	93.2	97.2	93.9	69.1	78.8	63.6
ProPos [14]	87.7	93.6	87.1	59.1	59.1	43.6	75.8	86.7	73.7	88.9	95.2	89.6	73.0	76.9	66.9
ProPos†	87.9	93.7	87.3	59.3	59.4	43.8	-	-	-	89.6	95.5	90.3	73.8	77.8	67.8
IDC$_{\text{ProPos}}$(Ours)	**90.5**	**95.7**	**90.9**	**69.2**	**78.3**	**61.4**	-	-	-	**93.2**	**97.3**	**94.1**	**77.6**	**86.1**	**74.8**

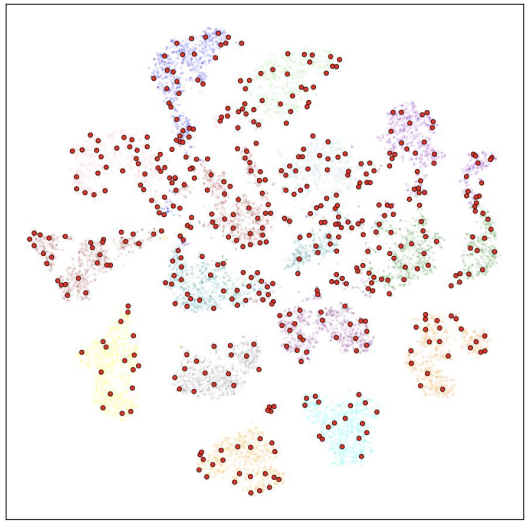
Experiments



(a) Hard



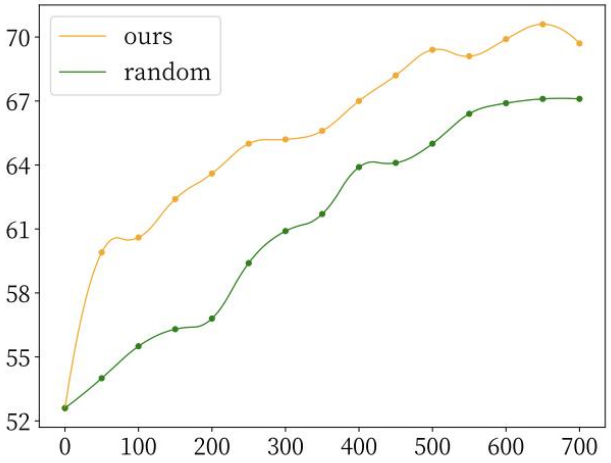
(b) Hard+Rep



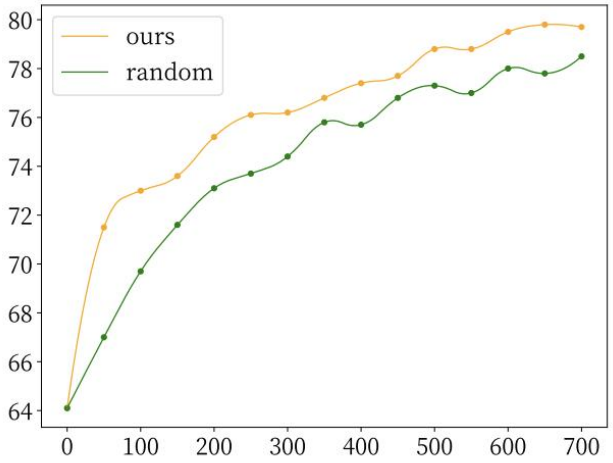
(c) Hard+Rep+Div

Selection Strategy	CIFAR-20			ImageNet-Dogs		
	NMI	ACC	ARI	NMI	ACC	ARI
None (Pre-trained Model)	52.2	52.6	34.9	61.8	64.1	50.9
Hard	51.3	57.7	37.0	68.2	75.9	60.2
Hard+Rep	35.8	36.3	12.6	59.7	65.3	49.4
Hard+Rep+Div	**58.1**	**69.4**	**48.7**	**69.1**	**78.8**	**63.6**

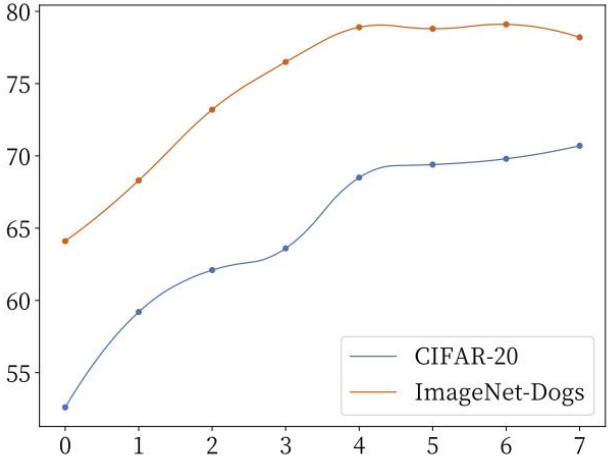
Experiments



(a) M on CIFAR-20



(b) M on ImageNet-Dogs



(c) T on both datasets

Experiments

$\mathcal{L}_{pos}$	$\mathcal{L}_{neg}$	$\mathcal{L}_{reg}$	CIFAR-20			ImageNet-Dogs		
			NMI	ACC	ARI	NMI	ACC	ARI
✓			56.8	65.8	46.2	68.3	76.9	62.5
	✓		7.0	9.6	2.4	26.8	24.1	3.1
		✓	50.9	52.9	35.2	61.7	64.9	51.8
✓	✓		55.0	66.2	44.1	67.9	77.5	61.6
✓		✓	**58.7**	67.6	47.8	68.8	77.5	62.7
	✓	✓	36.7	39.2	17.3	53.1	59.7	34.8
✓	✓	✓	58.1	**69.4**	**48.7**	**69.1**	**78.8**	**63.6**

Thanks

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