

# Boundary Contrastive Learning for

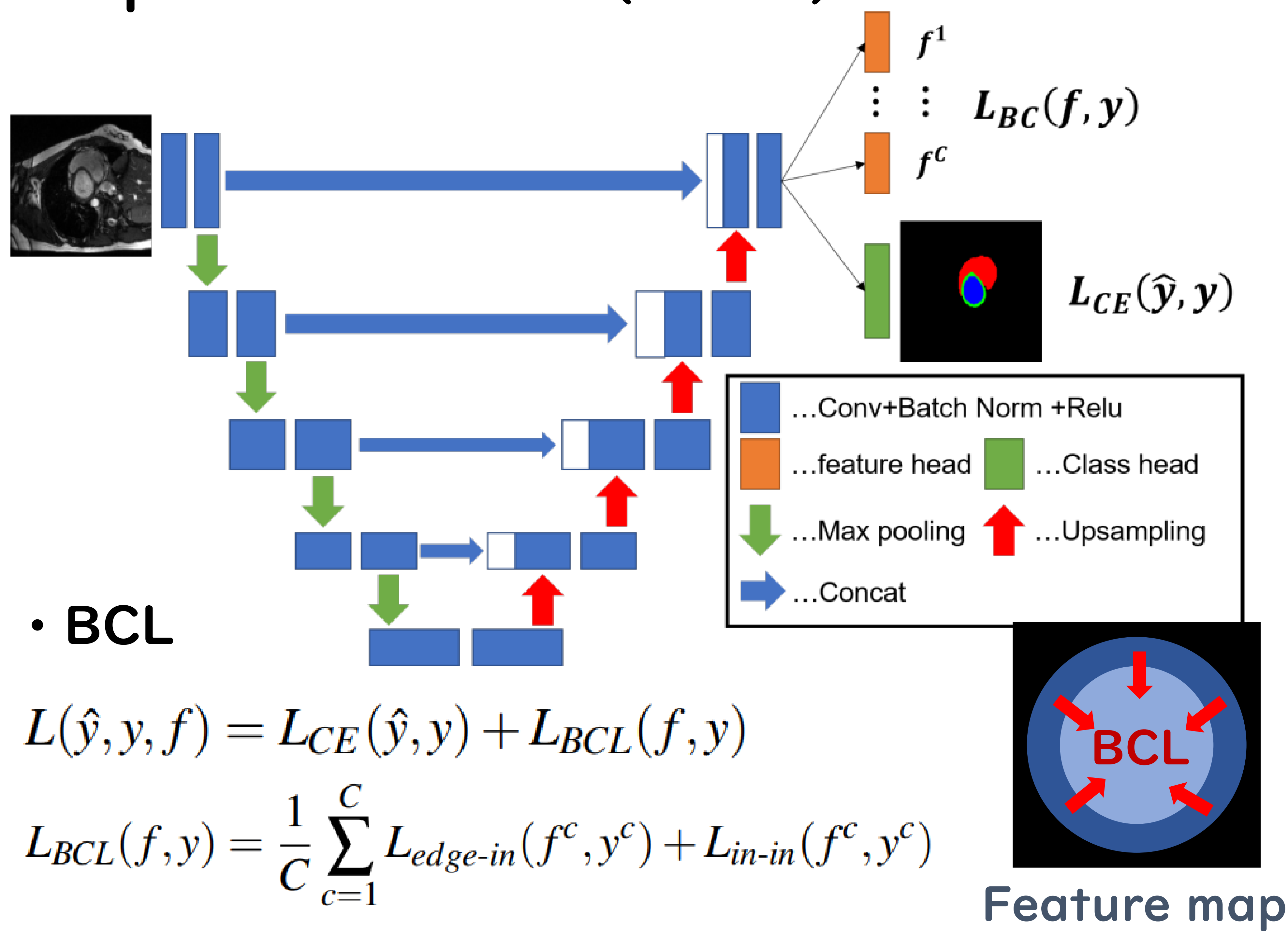
# Label-Efficient Medical Image Segmentation

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- The task uses only 5% or 10% of training images from the dataset.
- Contrastive Learning for Label Efficient Semantic Segmentation (CLLE) has two problems:
  1. Low accuracy for small objects in images
  2. In label-efficient tasks, low accuracy around complex object boundaries.

## Proposed Method (BCLL)



### • BCL

$$L(\hat{y}, y, f) = L_{CE}(\hat{y}, y) + L_{BCL}(f, y)$$

$$L_{BCL}(f, y) = \frac{1}{C} \sum_{c=1}^C L_{edge-in}(f^c, y^c) + L_{in-in}(f^c, y^c)$$

$$L_{edge-in}(f^c, y^c) = \frac{1}{N^2} \sum_{\substack{\{h,w\} \\ \sim S_{edge}^c}}^N \sum_{\substack{\{i,j\} \\ \sim S_{in}^c}}^N (\phi_{GGD}(f_{h,w}^c \cdot f_{i,j}^c; \kappa) - \mathbb{1}[y_{h,w}^c, y_{i,j}^c])^2$$

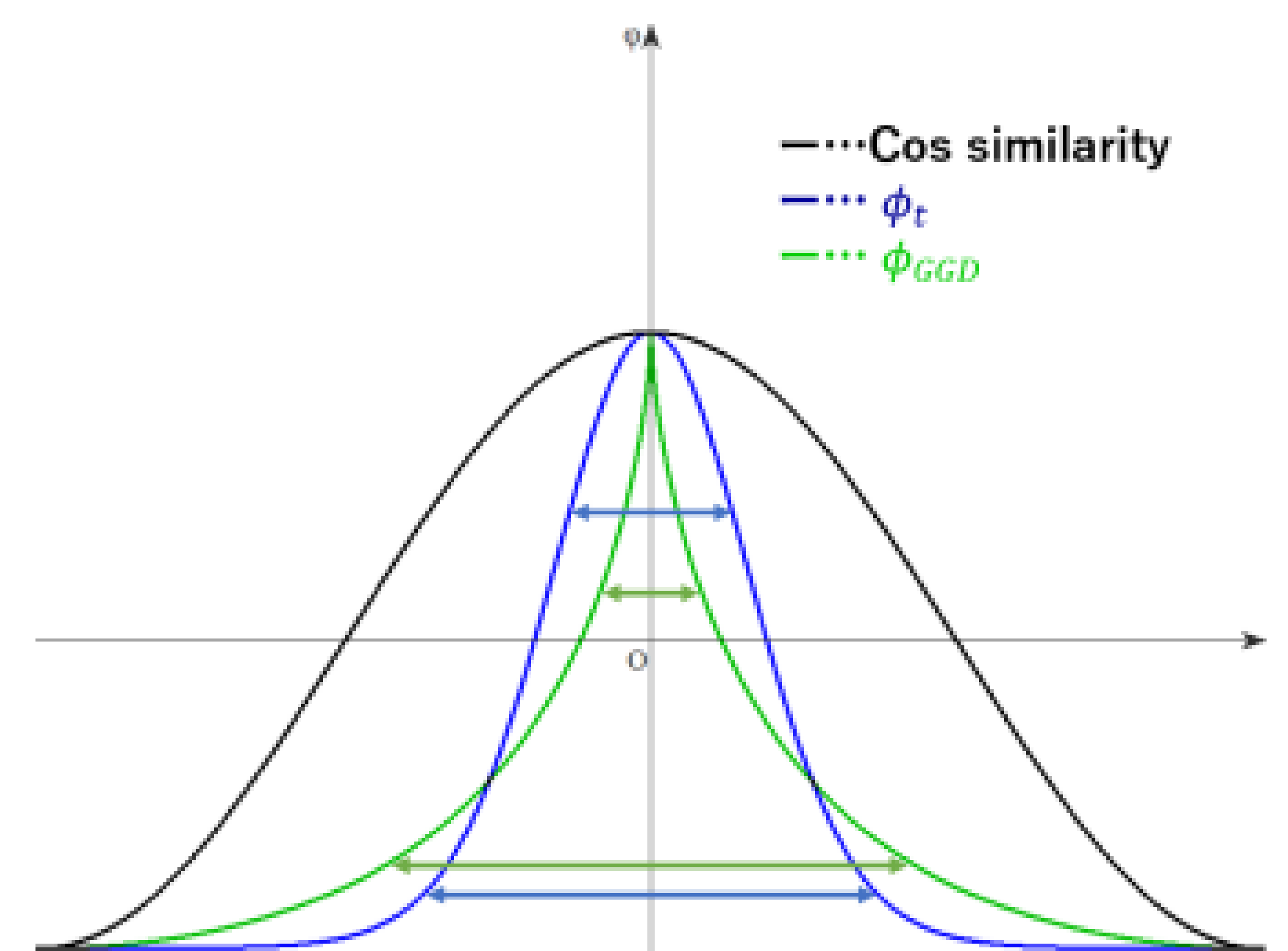
$$L_{in-in}(f^c, y^c) = \frac{1}{N^2} \sum_{\substack{\{h,w\} \\ \sim S_{in}^c}}^N \sum_{\substack{\{i,j\} \\ \sim S_{in}^c}}^N (\phi_{GGD}(f_{h,w}^c \cdot f_{i,j}^c; \kappa) - \mathbb{1}[y_{h,w}^c, y_{i,j}^c])^2$$

Feature map

### • GGD-vMF

$$\Psi_{GGD}(x; \kappa) = \exp(-(2 - 2x)^{\frac{1}{2\kappa}})$$

$$\phi_{GGD}(x; \kappa) = 2 \frac{\Psi_{GGD}(x; \kappa) - \exp(-2^{\frac{1}{\kappa}})}{1 - \exp(-2^{\frac{1}{\kappa}})} - 1$$



## 3. Experiments

dataset	method	5%	10%	30%	50%	100%
ACDC	baseline	64.97%	77.08%	81.17%	84.00%	86.96%
	CPC	66.45%	75.04%	80.97%	84.11%	
	CLLE	68.64%	77.22%	81.49%	84.59%	
	ours	<b>72.14%</b>	<b>77.30%</b>	<b>82.10%</b>	<b>85.89%</b>	
	SMO	baseline	39.33%	41.43%	53.74%	61.82%
SMO	CPC	40.14%	40.97%	56.36%	63.06%	
	CLLE	39.59%	40.93%	56.63%	62.25%	
	ours	<b>47.07%</b>	<b>52.28%</b>	<b>60.87%</b>	<b>68.09%</b>	
	Covid19	baseline	-	39.39%	43.89%	46.16%
CPC		-	38.52%	43.14%	46.27%	
CLLE		-	34.65%	41.15%	45.27%	
ours		-	<b>39.83%</b>	<b>47.07%</b>	<b>47.12%</b>	

w/L <sub>BCL</sub>	feature	similarity	mIoU
-	-	-	64.97%
✓	class imbalance	Cos	67.33%
✓	class balance	Cos	70.06%
✓	+ edge	Cos	70.78%
✓	+ edge	<i>t</i> -vMF ( $\kappa = 4$ )	71.30%
✓	+ edge	GGD-vMF ( $\kappa = 0.5$ )	<b>72.14%</b>

