Geometric Imbalance in Semi-Supervised Node Classification

Liang Yan, Shengzhong Zhang, Bisheng Li, Menglin Yang, Chen Yang, Min Zhou, Weiyang Ding, Yutong Xie, Zengfeng Huang

https://divinyan.com/UNREAL/

Contact: yanliangfdu@gmail.com

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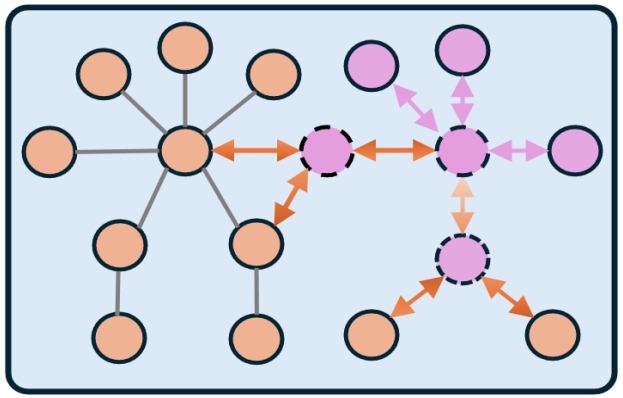
Class Imbalance on Graph



Minor Class
Major Class
Unlabeled (major)
Unlabeled (minor)

non-i.i.d. data

biases introduced by the message passing itself

Upsampling → Destroy topology

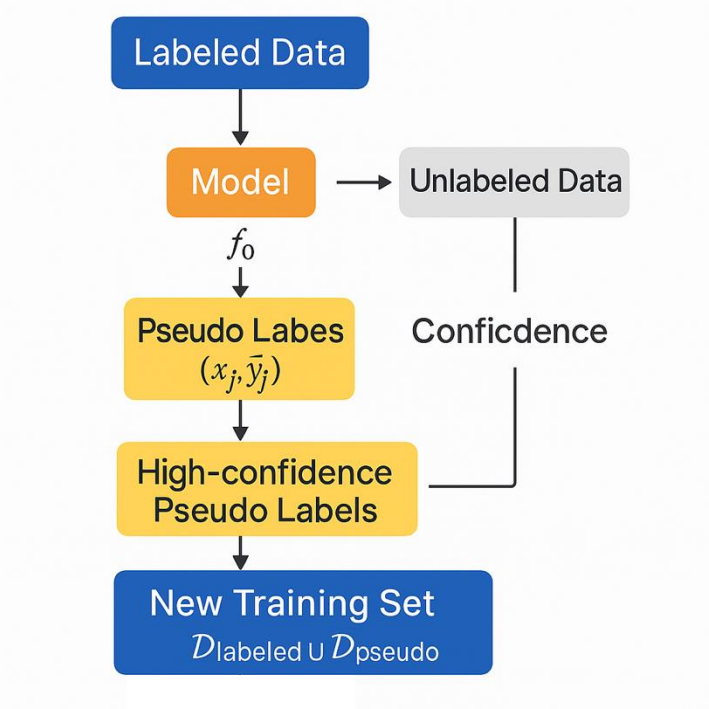
Undersampling → Destroy topology

Smote&GenAI → Building the topology

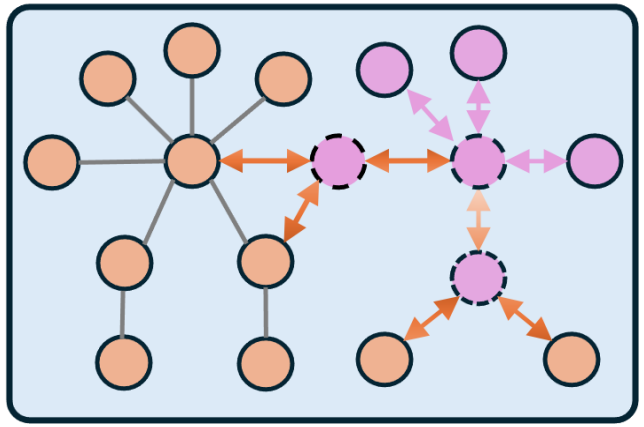
Loss Function Correction → Weighting of minority class

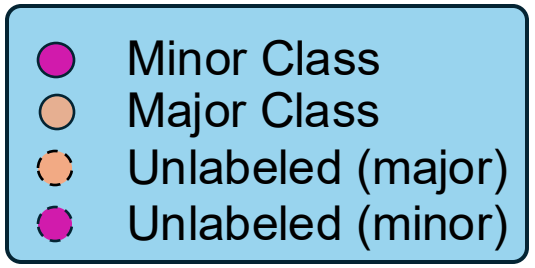
Traditional imbalanced learning solutions cannot be well transferred to graph data.

Self-Training for Graphs



Data augmentation can be performed without considering the topological structure !!!

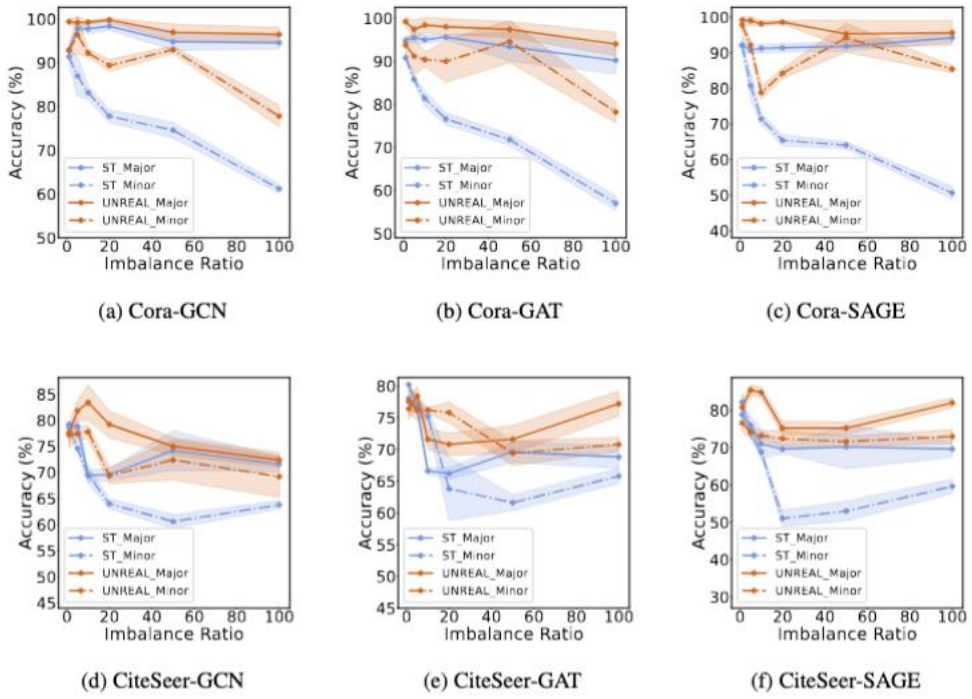




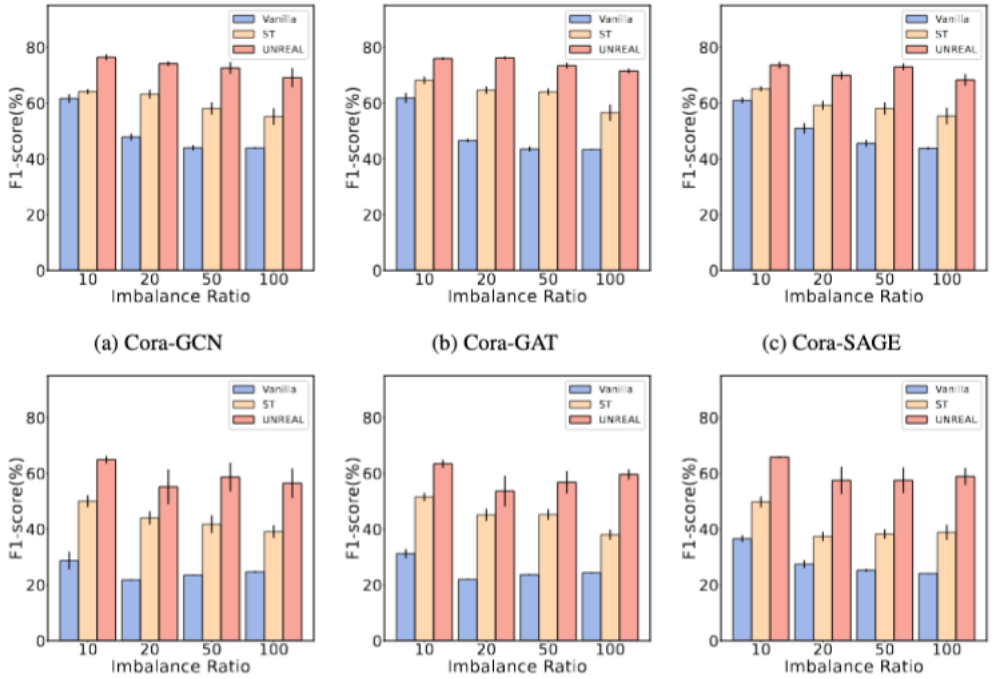
Self-training

Demo of Class Imbalance

The Performance of Vanilla Self-Training

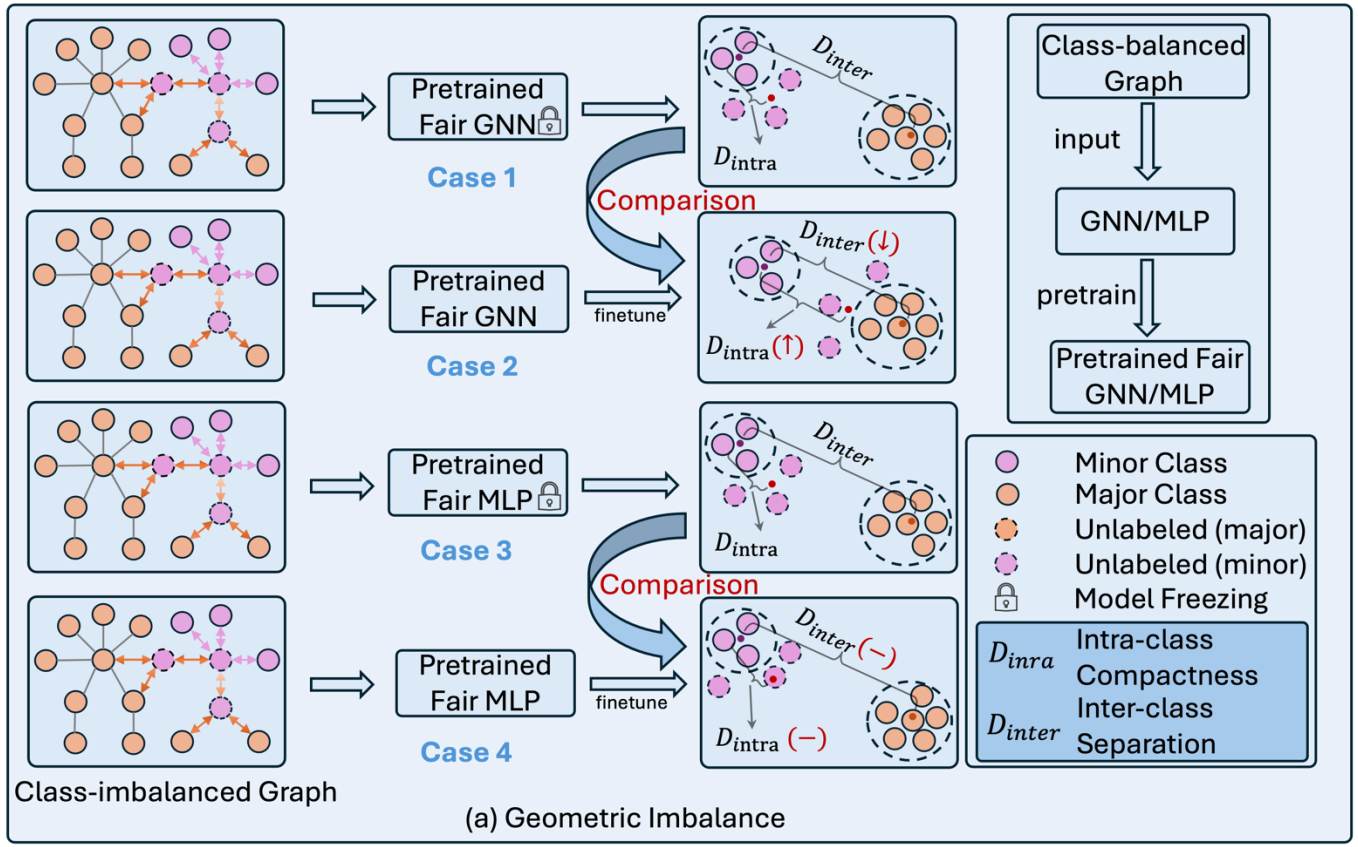


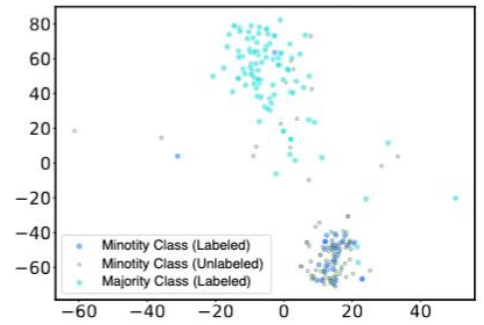
The graph shows the relationship between pseudo-label accuracy and dataset imbalance during training.



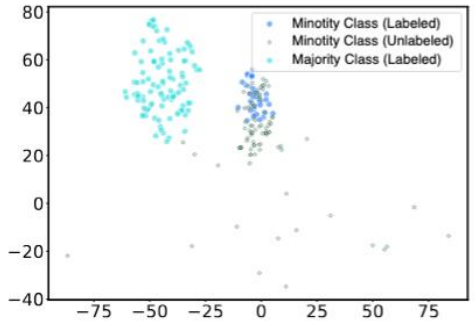
The graph shows the relationship between the specific training performance (F1 Score) and the dataset imbalance rate.

Geometric Imbalance

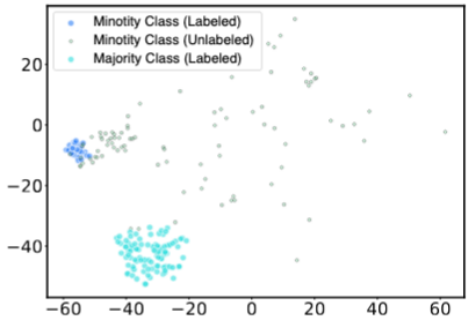




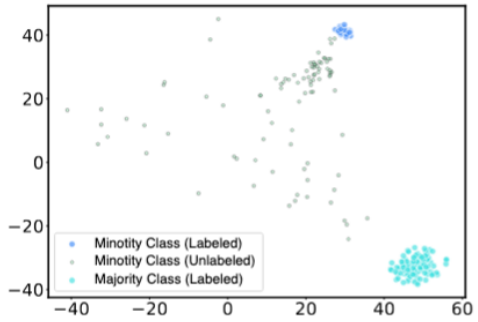
(a) GNN-Pretrained



(b) GNN-Fintune



(a) MLP-Pretrained

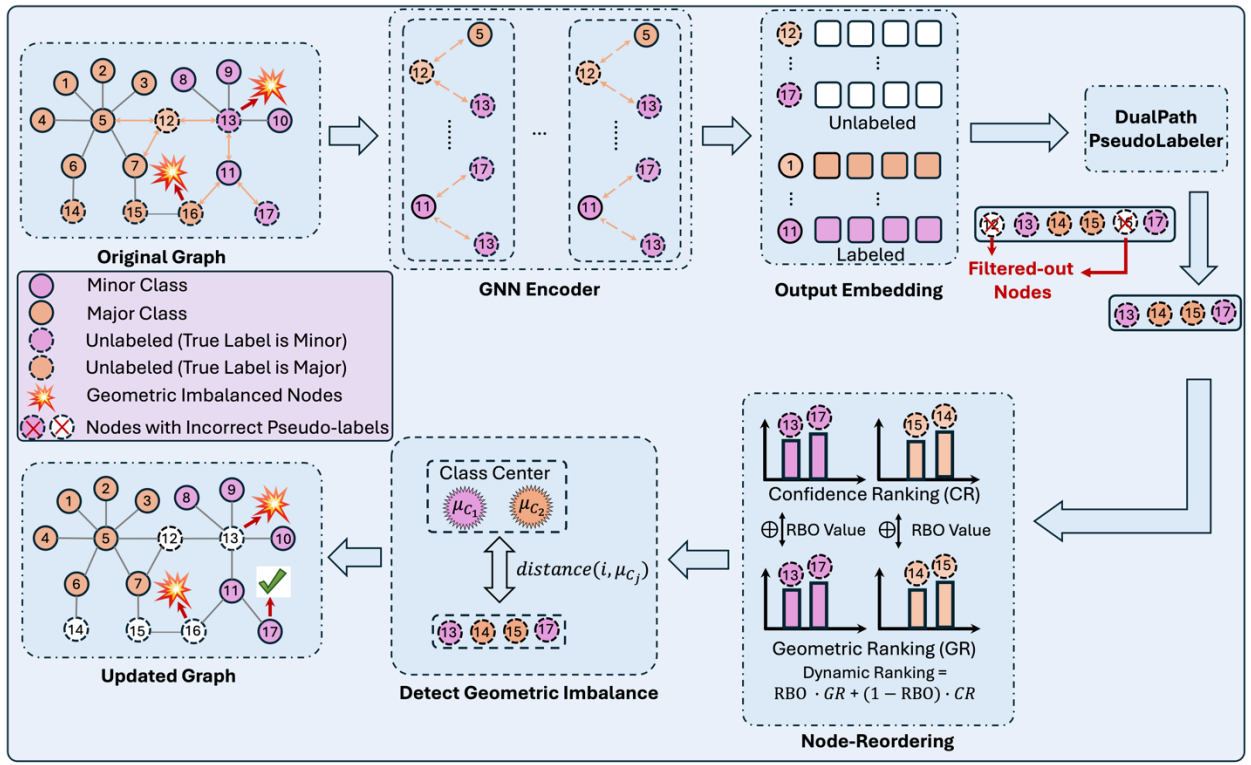


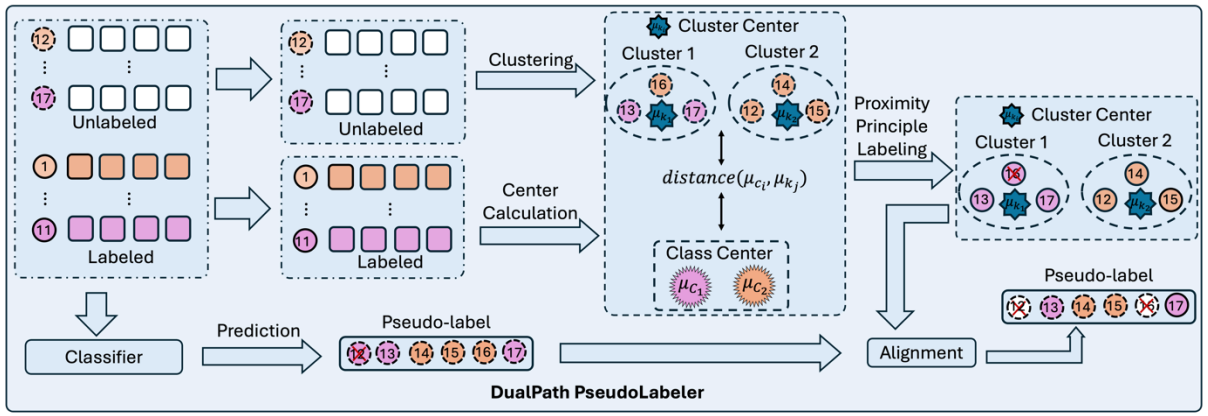
(b) MLP-Fintune

Geometric Imalance

The Experiment Results

UNREAL





Our UNREAL Framework

Results

	Dataset	Cora		CiteSeer		PubMed		Amazon-Computers	
	Imbalance Ratio ($\rho = 10$)	bAcc.	F1	bAcc.	F1	bAcc.	F1	bAcc.	F1
GCN	Vanilla	62.82 ± 1.43	61.67 ± 1.59	38.72 ± 1.88	28.74 ± 3.21	65.64 ± 1.72	56.97 ± 3.17	80.01 ± 0.71	71.56 ± 0.81
	Re-Weight	65.36 ± 1.15	64.97 ± 1.39	44.69 ± 1.78	38.61 ± 2.37	69.06 ± 1.84	64.08 ± 2.97	80.93 ± 1.30	73.99 ± 2.20
	PC Softmax	68.04 ± 0.82	67.84 ± 0.81	50.18 ± 0.55	46.14 ± 0.14	72.46 ± 0.80	70.27 ± 0.94	81.54 ± 0.76	73.30 ± 0.51
	GraphSMOTE	66.39 ± 0.56	65.49 ± 0.93	44.87 ± 1.12	39.20 ± 1.62	67.91 ± 0.64	62.68 ± 1.92	79.48 ± 0.47	72.63 ± 0.76
	BalancedSoftmax	69.98 ± 0.58	68.68 ± 0.55	55.52 ± 0.97	53.74 ± 1.42	73.73 ± 0.89	71.53 ± 1.06	81.46 ± 0.74	74.31 ± 0.51
	BalancedSoftmax (*w* TAM)	69.94 ± 0.45	69.54 ± 0.47	56.73 ± 0.71	56.15 ± 0.78	74.62 ± 0.97	72.25 ± 1.30	82.36 ± 0.67	72.94 ± 1.43
	Renode	67.03 ± 1.41	67.16 ± 1.67	43.47 ± 2.22	37.52 ± 3.10	71.40 ± 1.42	67.27 ± 2.96	81.89 ± 0.77	73.13 ± 1.60
	Renode (*w* TAM)	68.26 ± 1.84	68.11 ± 1.97	46.20 ± 1.17	39.96 ± 2.76	72.63 ± 2.03	68.28 ± 3.30	80.36 ± 1.19	72.51 ± 0.68
	GraphENS	70.89 ± 0.71	70.90 ± 0.81	56.57 ± 0.98	55.29 ± 1.33	72.13 ± 1.04	70.72 ± 1.07	82.40 ± 0.39	74.26 ± 1.05
	GraphENS (*w* TAM)	71.69 ± 0.36	72.14 ± 0.53	58.01 ± 0.68	56.32 ± 1.03	74.14 ± 1.42	72.42 ± 1.39	81.02 ± 0.99	70.78 ± 1.72
	GraphSR	70.85 ± 0.44	71.37 ± 0.63	59.28 ± 0.72	55.96 ±0.95	73.61 ± 1.25	71.88 ± 1.33	83.09 ± 0.29	72.03 ± 0.98
	BIM	72.19 ± 0.42	72.67 ± 0.48	58.54 ± 0.61	56.81 ± 0.98	74.62 ± 1.15	72.93 ± 1.21	82.34 ± 0.21	72.32 ± 0.32
	Ours	**78.33 ± 1.04**	**76.44 ± 1.06**	**65.63 ± 1.38**	**64.94 ± 1.38**	**75.35 ± 1.41**	**73.65 ± 1.43**	**85.08 ± 0.38**	**75.27 ± 0.23**
	Δ	**+6.14**	**+3.77**	**+6.35**	**+8.13**	**+0.73**	**+0.72**	**+1.99**	**+0.96**
GAT	Vanilla	62.33 ± 1.56	61.82 ± 1.84	38.84 ± 1.13	31.25 ± 1.64	64.60 ± 1.64	55.24 ± 2.80	79.04 ± 1.60	70.00 ± 2.50
	Re-Weight	66.87 ± 0.97	66.62 ± 1.13	45.47 ± 2.35	40.60 ± 2.98	68.10 ± 2.85	63.76 ± 3.54	80.38 ± 0.66	69.99 ± 0.76
	PC Softmax	66.69 ± 0.79	66.04 ± 1.10	50.78 ± 1.66	48.56 ± 2.08	72.88 ± 0.83	71.09 ± 0.89	79.43 ± 0.94	71.33 ± 0.86
	GraphSMOTE	66.71 ± 0.32	65.01 ± 1.21	45.68 ± 0.93	38.96 ± 0.97	67.43 ± 1.23	61.97 ± 2.54	79.38 ± 1.97	69.76 ± 2.31
	BalancedSoftmax	67.89 ± 0.36	67.96 ± 0.41	54.78 ± 1.25	51.83 ± 2.11	72.30 ± 1.20	69.30 ± 1.79	82.02 ± 1.19	72.94 ± 1.54
	BalancedSoftmax (*w* TAM)	69.16 ± 0.27	69.39 ± 0.37	56.30 ± 1.25	53.87 ± 1.14	73.50 ± 1.24	71.36 ± 1.99	75.54 ± 2.09	66.69 ± 1.44
	Renode	67.33 ± 0.79	68.08 ± 1.16	44.48 ± 2.06	37.93 ± 2.87	69.93 ± 2.10	65.27 ± 2.90	76.01 ± 1.08	66.72 ± 1.42
	Renode (*w* TAM)	67.50 ± 0.67	68.06 ± 0.96	45.12 ± 1.41	39.29 ± 1.79	70.66 ± 2.13	66.94 ± 3.54	74.30 ± 1.13	66.13 ± 1.75
	GraphENS	70.45 ± 1.25	69.87 ± 1.32	51.45 ± 1.28	47.98 ± 2.08	73.15 ± 1.24	71.90 ± 1.03	81.23 ± 0.74	71.23 ± 0.42
	GraphENS (*w* TAM)	70.15 ± 0.18	70.00 ± 0.40	56.15 ± 1.13	54.31 ± 1.68	73.45 ± 1.07	72.10 ± 0.36	81.07 ± 1.03	71.27 ± 1.98
	GraphSR	70.86 ± 0.22	70.61 ± 0.38	56.85 ± 1.09	55.02 ± 1.55	74.18 ± 1.01	72.65 ± 0.33	81.72 ± 1.00	71.91 ± 1.87
	BIM	71.53 ± 0.20	71.34 ± 0.36	57.54 ± 1.02	55.76 ± 1.48	73.91 ± 0.97	72.54 ± 0.35	82.48 ± 0.96	72.58 ± 1.81
	Ours	**78.91 ± 0.59**	**75.99 ± 0.47**	**64.10 ± 1.49**	**63.44 ± 1.47**	**74.68 ± 1.43**	**72.78 ± 0.89**	**85.62 ± 0.44**	**75.34 ± 0.99**
	Δ	**+7.38**	**+4.65**	**+6.56**	**+7.68**	**+0.50**	**+0.13**	**+3.14**	**+2.40**
SAGE	Vanilla	61.82 ± 0.97	60.97 ± 1.07	43.18 ± 0.52	36.66 ± 1.25	68.68 ± 1.51	64.16 ± 2.38	72.36 ± 2.39	64.32 ± 2.21
	Re-Weight	63.94 ± 1.07	63.82 ± 1.30	46.17 ± 1.32	40.13 ± 1.68	69.89 ± 1.60	65.71 ± 2.31	76.08 ± 1.14	65.76 ± 1.40
	PC Softmax	65.79 ± 0.70	66.04 ± 0.92	50.66 ± 0.99	47.48 ± 1.66	71.49 ± 0.94	70.23 ± 0.67	74.63 ± 3.01	66.44 ± 4.04
	GraphSMOTE	61.65 ± 0.34	60.97 ± 0.98	42.73 ± 2.87	35.18 ± 1.75	66.63 ± 0.65	61.97 ± 2.54	71.85 ± 0.98	68.92 ± 0.73
	BalancedSoftmax	67.43 ± 0.61	67.66 ± 0.69	51.74 ± 2.32	49.01 ± 3.16	71.36 ± 1.37	69.66 ± 1.81	73.67 ± 1.11	65.23 ± 2.44
	BalancedSoftmax (*w* TAM)	69.03 ± 0.92	69.03 ± 0.97	51.93 ± 2.19	48.67 ± 3.25	72.28 ± 1.47	71.02 ± 1.31	77.00 ± 2.93	70.85 ± 2.28
	Renode	66.84 ± 1.78	67.08 ± 1.75	48.65 ± 1.37	44.25 ± 2.20	71.37 ± 1.33	67.78 ± 1.38	77.37 ± 0.74	68.42 ± 1.81
	Renode (*w* TAM)	67.28 ± 1.11	67.15 ± 1.11	48.39 ± 1.76	43.56 ± 2.31	71.25 ± 1.07	68.69 ± 0.98	74.87 ± 2.25	66.87 ± 2.52
	GraphENS	68.74 ± 0.46	68.34 ± 0.33	53.51 ± 0.78	51.42 ± 1.19	70.97 ± 0.78	70.00 ± 1.22	82.57 ± 0.50	71.95 ± 0.51
	GraphENS (*w* TAM)	70.45 ± 0.74	70.40 ± 0.75	54.69 ± 1.12	53.56 ± 1.86	73.61 ± 1.35	72.50 ± 1.58	82.17 ± 0.93	72.46 ± 1.00
	GraphSR	69.24 ± 0.42	68.82 ± 0.36	53.98 ± 0.74	51.92 ± 1.10	71.43 ± 0.75	70.46 ± 1.15	82.97 ± 0.48	72.34 ± 0.55
	BIM	70.59 ± 0.71	70.55 ± 0.72	54.83 ± 1.08	53.71 ± 1.78	73.75 ± 1.30	72.66 ± 1.52	82.31 ± 0.91	**72.61 ± 0.98**
	Ours	**75.99 ± 0.98**	**73.63 ± 1.23**	**66.45 ± 0.39**	**65.83 ± 0.30**	**74.78 ± 1.30**	**72.80 ± 0.54**	**83.21 ± 1.50**	70.81 ± 1.70
	Δ	**+5.40**	**+3.08**	**+11.62**	**+12.12**	**+1.03**	**+0.14**	**+0.24**	**-1.65**

Experimental results on four benchmark datasets with an imbalance ratio of 10.

	Dataset	Cora		CiteSeer		PubMed		Amazon-Computers	
	Imbalance Ratio ($\rho = 20$)	bAcc.	F1	bAcc.	F1	bAcc.	F1	bAcc.	F1
GCN	Vanilla	53.20 ± 0.88	47.81 ± 1.23	35.32 ± 0.15	21.81 ± 0.12	61.13 ± 0.35	46.85 ± 0.76	72.34 ± 2.92	65.42 ± 3.00
	Re-Weight	57.51 ± 1.05	54.63 ± 1.08	36.99 ± 1.79	27.33 ± 2.32	66.52 ± 2.42	58.22 ± 3.65	72.45 ± 2.06	65.85 ± 1.46
	PC Softmax	61.74 ± 1.50	60.55 ± 1.97	42.53 ± 1.53	36.54 ± 1.13	68.26 ± 1.99	66.54 ± 1.87	73.84 ± 2.64	66.32 ± 2.97
	BalancedSoftmax	64.06 ± 0.74	62.88 ± 0.86	47.29 ± 1.29	44.08 ± 1.71	69.71 ± 1.74	68.31 ± 1.71	76.92 ± 2.01	69.86 ± 1.99
	BalancedSoftmax (*w* TAM)	64.75 ± 0.54	63.46 ± 0.72	48.52 ± 1.62	46.38 ± 1.79	69.95 ± 2.09	68.90 ± 1.86	77.09 ± 2.02	69.86 ± 1.76
	Renode	59.40 ± 1.00	56.88 ± 1.52	38.25 ± 1.60	27.61 ± 2.25	67.45 ± 3.34	60.40 ± 5.74	74.15 ± 1.72	67.27 ± 0.92
	Renode (*w* TAM)	59.88 ± 1.16	58.05 ± 1.66	41.11 ± 2.45	31.58 ± 2.62	68.53 ± 3.53	64.82 ± 4.32	73.46 ± 1.77	67.50 ± 1.18
	GraphENS	67.30 ± 1.45	66.82 ± 1.40	46.39 ± 3.48	42.38 ± 4.14	71.37 ± 1.77	69.37 ± 1.69	75.41 ± 1.75	69.32 ± 1.58
	GraphENS (*w* TAM)	66.94 ± 1.38	66.67 ± 1.42	48.80 ± 2.98	45.06 ± 4.16	71.92 ± 1.58	69.35 ± 1.88	75.78 ± 1.57	68.58 ± 1.78
	GraphSR	67.98 ± 1.42	67.53 ± 1.36	47.03 ± 3.40	43.06 ± 4.06	72.05 ± 1.72	70.01 ± 1.64	75.97 ± 1.70	69.96 ± 1.54
	BIM	67.94 ± 1.32	67.51 ± 1.26	46.98 ± 3.26	42.91 ± 3.95	72.05 ± 1.68	69.98 ± 1.52	76.04 ± 1.61	69.91 ± 1.44
	Ours	**77.02 ± 0.75**	**74.15 ± 0.87**	**55.81 ± 6.11**	**55.19 ± 6.23**	**73.06 ± 1.87**	**70.77 ± 1.96**	**85.69 ± 0.11**	**74.81 ± 0.68**
	Δ	**+9.04**	**+6.62**	**+7.01**	**+8.81**	**+1.01**	**+0.76**	**+8.60**	**+4.85**
GAT	Vanilla	51.51 ± 0.53	46.59 ± 0.61	34.74 ± 0.16	22.00 ± 0.15	60.22 ± 0.47	46.03 ± 0.70	68.09 ± 2.96	60.08 ± 2.76
	Re-Weight	58.68 ± 3.44	55.98 ± 3.97	36.78 ± 0.94	26.63 ± 1.61	63.47 ± 1.73	54.63 ± 3.25	71.44 ± 2.42	62.86 ± 1.94
	PC Softmax	59.62 ± 1.41	58.77 ± 1.95	43.38 ± 2.01	37.76 ± 2.12	70.81 ± 1.41	70.25 ± 1.30	71.16 ± 1.15	62.26 ± 0.87
	BalancedSoftmax	62.05 ± 1.62	61.14 ± 1.71	47.89 ± 1.25	44.84 ± 1.35	69.91 ± 1.68	67.43 ± 1.73	72.91 ± 1.93	62.79 ± 0.98
	BalancedSoftmax (*w* TAM)	63.30 ± 0.99	62.81 ± 1.18	49.34 ± 1.29	46.92 ± 1.39	71.17 ± 2.09	68.85 ± 2.90	65.59 ± 2.86	58.12 ± 1.22
	Renode	59.52 ± 2.28	57.16 ± 2.47	37.21 ± 2.01	27.09 ± 3.17	64.56 ± 1.65	55.87 ± 2.83	69.34 ± 2.35	59.02 ± 1.67
	Renode (*w* TAM)	61.32 ± 2.18	59.19 ± 2.64	39.85 ± 2.20	30.63 ± 2.63	66.28 ± 3.24	58.99 ± 3.04	65.81 ± 2.57	56.73 ± 1.62
	GraphENS	64.52 ± 2.05	62.52 ± 1.84	43.74 ± 3.81	37.47 ± 4.21	69.00 ± 2.67	65.54 ± 3.54	71.78 ± 2.30	61.83 ± 1.75
	GraphENS (*w* TAM)	65.78 ± 1.62	63.80 ± 1.79	44.81 ± 2.66	39.47 ± 3.54	70.33 ± 2.33	67.00 ± 3.25	73.55 ± 2.04	64.03 ± 1.32
	GraphSR	64.76 ± 2.01	62.75 ± 1.79	43.96 ± 3.70	37.73 ± 4.10	69.21 ± 2.61	65.76 ± 3.48	72.03 ± 2.25	62.04 ± 1.72
	BIM	64.72 ± 2.03	62.81 ± 1.88	43.91 ± 3.79	37.72 ± 4.18	69.21 ± 2.65	65.77 ± 3.52	72.01 ± 2.33	62.06 ± 1.76
	Ours	**79.10 ± 0.71**	**76.21 ± 0.58**	**55.11 ± 5.00**	**53.67 ± 5.51**	**72.54 ± 1.52**	**70.54 ± 1.91**	**83.19 ± 0.66**	**74.39 ± 0.89**
	Δ	**+13.22**	**+12.41**	**+6.75**	**+8.81**	**+1.37**	**+1.69**	**+9.64**	**+10.36**
SAGE	Vanilla	54.61 ± 1.21	50.95 ± 1.90	37.36 ± 1.03	27.49 ± 1.41	62.04 ± 1.34	54.18 ± 1.73	62.70 ± 2.87	55.39 ± 2.69
	Re-Weight	57.37 ± 0.61	55.30 ± 0.72	37.69 ± 1.20	27.92 ± 2.01	65.01 ± 2.69	58.34 ± 2.19	68.31 ± 2.06	60.45 ± 2.40
	PC Softmax	59.25 ± 0.74	58.55 ± 0.81	42.77 ± 1.82	40.08 ± 1.82	70.55 ± 1.19	67.60 ± 1.59	70.57 ± 2.86	62.73 ± 2.69
	BalancedSoftmax	61.93 ± 1.26	60.89 ± 1.36	43.64 ± 1.33	38.31 ± 1.13	69.89 ± 1.40	68.12 ± 0.78	68.45 ± 2.92	62.12 ± 3.10
	BalancedSoftmax (*w* TAM)	64.16 ± 0.94	63.63 ± 1.10	44.32 ± 2.36	40.17 ± 2.06	70.06 ± 1.46	69.54 ± 1.35	66.10 ± 2.37	59.22 ± 2.48
	Renode	58.48 ± 0.97	55.39 ± 0.94	40.65 ± 2.36	31.78 ± 3.24	66.50 ± 2.63	58.72 ± 4.16	68.36 ± 1.54	61.60 ± 2.00
	Renode (*w* TAM)	59.77 ± 2.20	57.98 ± 2.79	42.50 ± 0.93	35.11 ± 1.84	67.31 ± 2.73	60.63 ± 3.49	66.42 ± 2.32	58.62 ± 1.95
	GraphENS	63.54 ± 0.91	62.20 ± 0.87	44.89 ± 2.51	40.48 ± 2.94	71.37 ± 1.77	69.37 ± 1.69	75.47 ± 2.20	67.49 ± 1.65
	GraphENS (*w* TAM)	63.39 ± 1.36	61.66 ± 1.53	45.92 ± 1.96	41.97 ± 2.50	69.62 ± 2.57	66.85 ± 3.00	75.75 ± 2.30	68.86 ± 1.29
	GraphSR	63.75 ± 0.92	62.42 ± 0.89	45.06 ± 2.48	40.71 ± 2.91	71.59 ± 1.76	69.61 ± 1.67	75.71 ± 2.18	67.74 ± 1.66
	BIM	63.98 ± 0.93	62.68 ± 0.88	45.29 ± 2.50	40.93 ± 2.90	71.84 ± 1.78	69.86 ± 1.66	75.95 ± 2.21	67.97 ± 1.64
	Ours	**73.10 ± 1.60**	**69.92 ± 1.43**	**58.35 ± 4.58**	**57.51 ± 4.92**	**73.67 ± 0.58**	**71.15 ± 0.67**	**78.88 ± 2.16**	**69.00 ± 1.42**
	Δ	**+8.94**	**+5.69**	**+12.43**	**+15.54**	**+1.83**	**+1.29**	**+2.93**	**+0.14**

Experimental results on four benchmark datasets with an imbalance ratio of 20.

Results

Table 22: Experimental results of our method and other baselines on four class-imbalanced node classification benchmark datasets with $\rho = 50$. We report averaged balanced accuracy (bAcc.,%) and F1-score (%) with the standard errors over 5 repetitions on three representative GNN architectures.

	Dataset	Cora		CiteSeer		PubMed		Amazon-Computers	
	Imbalance Ratio ($\rho = 50$)	bAcc.	F1	bAcc.	F1	bAcc.	F1	bAcc.	F1
GCN	Vanilla	51.81 ± 0.62	43.98 ± 1.00	37.59 ± 0.17	23.54 ± 0.13	61.65 ± 0.34	47.95 ± 0.58	77.36 ± 3.41	69.68 ± 3.12
	Re-Weight	58.54 ± 2.39	54.13 ± 3.20	38.19 ± 1.28	27.43 ± 2.34	65.70 ± 1.59	56.35 ± 4.26	79.10 ± 2.44	71.40 ± 2.86
	PC Softmax	64.87 ± 2.23	62.01 ± 3.14	42.42 ± 2.19	38.83 ± 2.70	69.21 ± 0.59	69.40 ± 0.87	81.90 ± 1.63	74.34 ± 2.13
	BalancedSoftmax	65.94 ± 1.55	64.00 ± 2.05	47.62 ± 1.11	46.55 ± 1.46	70.40 ± 1.00	69.04 ± 0.66	82.97 ± 0.83	73.74 ± 1.27
	BalancedSoftmax (*w* TAM)	68.57 ± 1.58	67.25 ± 1.27	53.43 ± 2.42	51.74 ± 2.80	77.20 ± 1.45	74.86 ± 0.99	81.74 ± 2.30	73.85 ± 2.68
	Renode	62.22 ± 1.76	61.18 ± 2.24	41.23 ± 1.66	33.66 ± 2.69	68.67 ± 1.21	63.05 ± 1.47	81.71 ± 0.99	72.55 ± 1.61
	Renode (*w* TAM)	63.93 ± 1.96	61.64 ± 2.71	48.17 ± 1.58	41.07 ± 2.34	69.63 ± 2.55	64.30 ± 3.51	80.55 ± 1.75	72.33 ± 1.63
	GraphENS	63.47 ± 0.98	62.21 ± 1.65	48.17 ± 1.58	41.07 ± 2.34	69.63 ± 2.55	64.30 ± 3.51	81.63 ± 2.35	72.57 ± 2.33
	GraphENS (*w* TAM)	65.05 ± 1.11	62.11 ± 1.98	45.03 ± 1.34	42.65 ± 1.94	69.74 ± 0.78	70.82 ± 0.63	81.69 ± 2.22	72.09 ± 1.75
	GraphSR	64.12 ± 0.94	62.89 ± 1.58	48.84 ± 1.52	41.76 ± 2.26	70.31 ± 2.48	64.98 ± 3.40	82.28 ± 2.30	73.21 ± 2.28
	BIM	65.72 ± 1.07	62.80 ± 1.90	45.68 ± 1.29	43.33 ± 1.88	70.42 ± 0.74	71.46 ± 0.66	82.34 ± 2.17	72.76 ± 1.71
	Ours	**75.62 ± 2.02**	**72.59 ± 2.13**	**59.97 ± 4.59**	**58.66 ± 5.20**	**78.55 ± 0.84**	**75.91 ± 0.81**	**85.54 ± 0.26**	**75.76 ± 0.13**
	Δ	**+7.05**	**+5.34**	**+6.54**	**+6.92**	**+1.35**	**+1.06**	**+2.57**	**+1.91**
GAT	Vanilla	53.90 ± 0.63	45.53 ± 0.89	36.48 ± 0.08	23.68 ± 0.16	60.16 ± 0.47	46.99 ± 0.58	72.42 ± 2.17	64.41 ± 2.68
	Re-Weight	59.78 ± 1.92	56.69 ± 2.21	38.70 ± 2.23	29.38 ± 3.06	66.27 ± 0.68	57.34 ± 1.41	73.46 ± 3.07	67.00 ± 2.60
	PC Softmax	59.44 ± 2.62	58.06 ± 2.69	43.13 ± 1.56	37.04 ± 2.07	70.86 ± 0.44	70.96 ± 0.54	77.21 ± 2.90	69.17 ± 2.89
	BalancedSoftmax	64.71 ± 2.28	62.55 ± 2.61	51.89 ± 1.15	49.36 ± 1.52	70.94 ± 1.09	70.33 ± 0.99	77.49 ± 1.58	70.44 ± 2.33
	BalancedSoftmax (*w* TAM)	68.05 ± 1.03	66.07 ± 1.14	54.28 ± 0.79	52.77 ± 0.97	75.65 ± 1.11	74.02 ± 1.44	78.86 ± 1.53	70.71 ± 2.04
	Renode	63.81 ± 1.72	60.63 ± 2.26	41.60 ± 2.30	33.94 ± 4.60	70.35 ± 1.26	67.43 ± 0.01	72.39 ± 2.75	65.23 ± 3.35
	Renode (*w* TAM)	64.40 ± 1.83	63.48 ± 2.83	43.54 ± 1.54	35.80 ± 2.43	71.23 ± 2.04	66.61 ± 4.31	76.07 ± 2.70	68.43 ± 2.68
	GraphENS	64.52 ± 2.51	61.41 ± 3.15	45.23 ± 2.97	41.12 ± 4.23	69.66 ± 1.01	66.83 ± 0.94	78.36 ± 2.74	70.44 ± 2.51
	GraphENS (*w* TAM)	65.33 ± 2.67	65.34 ± 2.53	48.00 ± 1.46	48.14 ± 1.43	71.50 ± 1.26	72.58 ± 1.07	80.02 ± 2.32	72.38 ± 2.47
	GraphSR	65.17 ± 2.44	62.11 ± 3.08	45.89 ± 2.89	41.79 ± 4.10	70.31 ± 0.98	67.49 ± 0.91	79.05 ± 2.66	71.12 ± 2.46
	BIM	65.98 ± 2.60	66.03 ± 2.47	48.63 ± 1.42	48.87 ± 1.38	72.19 ± 1.22	73.28 ± 1.03	80.65 ± 2.27	73.03 ± 2.42
	Ours	**77.07 ± 0.83**	**73.44 ± 1.05**	**57.70 ± 4.35**	**56.81 ± 4.67**	**79.41 ± 0.29**	**77.38 ± 0.39**	**86.06 ± 0.45**	**77.55 ± 0.71**
	Δ	**+9.02**	**+7.37**	**+3.42**	**+4.04**	**+3.76**	**+3.36**	**+5.41**	**+4.52**
SAGE	Vanilla	53.02 ± 0.83	45.58 ± 1.30	38.81 ± 0.89	25.28 ± 0.51	61.41 ± 1.01	50.46 ± 2.47	56.53 ± 2.12	48.52 ± 2.75
	Re-Weight	58.03 ± 0.81	54.32 ± 0.99	38.49 ± 1.34	30.41 ± 1.82	62.41 ± 0.90	51.37 ± 2.62	70.36 ± 2.21	61.52 ± 2.73
	PC Softmax	62.33 ± 1.62	59.97 ± 1.98	41.79 ± 1.19	36.90 ± 0.84	69.58 ± 1.09	67.13 ± 0.95	73.53 ± 2.02	66.12 ± 3.19
	BalancedSoftmax	64.57 ± 0.77	62.22 ± 0.82	41.84 ± 1.72	40.09 ± 1.04	70.43 ± 0.38	68.99 ± 0.99	73.27 ± 2.30	68.30 ± 1.97
	BalancedSoftmax (*w* TAM)	65.97 ± 0.71	65.53 ± 0.88	52.89 ± 1.65	49.92 ± 1.83	71.11 ± 0.75	71.73 ± 0.79	73.12 ± 1.41	66.45 ± 1.04
	Renode	61.35 ± 1.86	58.88 ± 2.53	40.37 ± 2.33	32.57 ± 3.62	67.54 ± 3.05	59.77 ± 5.30	70.46 ± 3.45	62.30 ± 4.40
	Renode (*w* TAM)	62.79 ± 0.47	61.05 ± 0.82	43.04 ± 1.30	36.97 ± 1.92	71.79 ± 1.33	67.80 ± 2.45	74.55 ± 2.95	66.06 ± 2.16
	GraphENS	63.95 ± 0.96	62.63 ± 2.12	41.99 ± 1.54	37.44 ± 2.43	66.07 ± 1.12	61.63 ± 1.82	76.21 ± 2.84	68.10 ± 2.56
	GraphENS (*w* TAM)	65.98 ± 1.37	64.84 ± 1.13	49.54 ± 1.79	49.48 ± 1.70	73.24 ± 1.32	73.73 ± 1.14	80.75 ± 1.22	72.31 ± 0.95
	GraphSR	64.58 ± 0.91	63.32 ± 2.05	42.67 ± 1.49	38.13 ± 2.35	66.78 ± 1.08	62.31 ± 1.75	76.87 ± 2.78	68.74 ± 2.49
	BIM	65.60 ± 0.91	64.32 ± 2.06	43.70 ± 1.50	39.13 ± 2.35	67.84 ± 1.07	63.37 ± 1.76	77.92 ± 2.79	69.78 ± 2.49
	Ours	**76.04 ± 1.30**	**72.99 ± 1.25**	**58.70 ± 4.10**	**57.53 ± 4.59**	**75.27 ± 1.26**	**72.16 ± 1.50**	**82.03 ± 0.77**	**72.98 ± 0.52**
	Δ	**+10.06**	**+7.46**	**+5.81**	**+7.61**	**+2.03**	**-1.57**	**+1.28**	**+0.67**

Table 23: Experimental results of our method and other baselines on four class-imbalanced node classification benchmark datasets with $\rho = 100$. We report averaged balanced accuracy (bAcc.,%) and F1-score (%) with the standard errors over 5 repetitions on three representative GNN architectures.

	Dataset	Cora		CiteSeer		PubMed		Amazon-Computers	
	Imbalance Ratio ($\rho = 100$)	bAcc.	F1	bAcc.	F1	bAcc.	F1	bAcc.	F1
GCN	Vanilla	51.62 ± 0.20	43.91 ± 0.25	38.83 ± 0.26	24.71 ± 0.25	61.28 ± 0.12	47.55 ± 0.16	76.09 ± 3.79	69.32 ± 3.49
	Re-Weight	59.11 ± 1.06	54.04 ± 1.36	42.67 ± 2.06	33.17 ± 3.40	67.14 ± 2.71	55.24 ± 5.36	81.53 ± 2.20	71.45 ± 2.05
	PC Softmax	63.75 ± 1.02	61.19 ± 1.43	38.34 ± 0.71	33.65 ± 1.42	70.85 ± 0.44	70.26 ± 0.63	82.22 ± 1.99	72.38 ± 2.52
	BalancedSoftmax	63.03 ± 1.57	61.28 ± 1.77	48.49 ± 1.20	46.59 ± 1.34	70.77 ± 1.88	68.88 ± 1.74	83.33 ± 3.35	74.34 ± 2.74
	BalancedSoftmax (*w* TAM)	69.44 ± 0.59	67.10 ± 0.88	52.60 ± 0.69	51.21 ± 0.84	73.73 ± 1.10	73.72 ± 0.83	83.70 ± 2.17	75.39 ± 1.43
	Renode	60.76 ± 2.53	58.09 ± 3.00	43.41 ± 2.07	33.69 ± 2.76	67.63 ± 2.77	61.70 ± 4.84	82.13 ± 1.73	71.79 ± 1.85
	Renode (*w* TAM)	64.19 ± 1.46	60.90 ± 1.56	44.78 ± 1.51	35.90 ± 2.61	70.53 ± 0.75	64.35 ± 1.79	82.32 ± 2.19	73.09 ± 1.75
	GraphENS	63.00 ± 1.30	62.33 ± 1.67	45.99 ± 2.06	37.23 ± 3.40	68.65 ± 1.00	62.17 ± 1.60	83.37 ± 2.17	73.96 ± 1.98
	GraphENS (*w* TAM)	60.40 ± 4.42	57.77 ± 4.02	42.72 ± 2.54	39.40 ± 2.57	70.73 ± 1.96	72.50 ± 1.87	81.29 ± 1.52	71.66 ± 1.75
	GraphSR	64.64 ± 1.25	64.04 ± 1.62	47.66 ± 1.98	38.96 ± 3.28	70.29 ± 0.95	63.85 ± 1.52	83.02 ± 2.12	73.60 ± 1.90
	BIM	64.38 ± 1.26	63.69 ± 1.61	47.31 ± 2.00	38.61 ± 3.28	70.03 ± 0.96	63.51 ± 1.54	82.77 ± 2.10	73.24 ± 1.91
	Ours	**72.82 ± 3.55**	**69.12 ± 3.45**	**57.66 ± 1.96**	**56.50 ± 1.12**	**78.73 ± 0.88**	**76.03 ± 1.08**	**84.30 ± 0.30**	**76.06 ± 0.32**
	Δ	**+3.38**	**+2.02**	**+5.06**	**+5.29**	**+5.00**	**+2.31**	**+0.60**	**+0.67**
GAT	Vanilla	51.58 ± 0.32	43.37 ± 0.21	37.91 ± 0.28	23.49 ± 0.21	62.07 ± 0.17	47.39 ± 0.20	72.66 ± 2.97	64.87 ± 3.46
	Re-Weight	58.28 ± 1.88	54.47 ± 2.35	38.13 ± 1.55	29.60 ± 3.02	67.41 ± 2.69	58.06 ± 5.07	77.10 ± 3.26	68.35 ± 2.71
	PC Softmax	63.74 ± 2.01	59.76 ± 2.19	45.07 ± 1.13	39.21 ± 2.29	69.68 ± 1.29	69.44 ± 1.29	79.72 ± 1.52	70.78 ± 1.45
	BalancedSoftmax	63.19 ± 1.35	61.03 ± 1.46	46.03 ± 2.11	43.38 ± 2.24	71.45 ± 1.23	69.10 ± 1.20	79.15 ± 2.08	69.68 ± 2.13
	BalancedSoftmax (*w* TAM)	64.96 ± 3.23	62.91 ± 3.96	52.75 ± 1.29	50.69 ± 1.83	73.38 ± 0.77	72.45 ± 0.88	80.86 ± 2.52	72.93 ± 2.95
	Renode	60.04 ± 2.21	58.04 ± 2.66	42.40 ± 2.97	34.09 ± 0.04	68.54 ± 2.11	65.63 ± 3.15	75.34 ± 1.65	69.99 ± 1.60
	Renode (*w* TAM)	63.45 ± 1.41	61.51 ± 1.95	41.55 ± 1.39	36.13 ± 2.87	71.53 ± 2.35	68.11 ± 4.28	78.60 ± 1.90	70.35 ± 2.80
	GraphENS	63.93 ± 2.70	61.77 ± 3.38	44.43 ± 1.90	39.26 ± 2.55	68.50 ± 1.81	64.14 ± 3.28	81.63 ± 2.08	71.20 ± 2.75
	GraphENS (*w* TAM)	62.52 ± 0.95	61.65 ± 1.19	45.79 ± 1.31	44.80 ± 1.14	69.09 ± 1.11	70.64 ± 1.10	83.33 ± 0.83	72.81 ± 1.22
	GraphSR	64.89 ± 2.62	62.74 ± 3.30	45.39 ± 1.86	40.18 ± 2.48	69.47 ± 1.75	65.08 ± 3.21	82.52 ± 2.02	72.13 ± 2.69
	BIM	65.84 ± 2.55	63.72 ± 3.22	46.26 ± 1.82	41.10 ± 2.42	70.45 ± 1.70	66.00 ± 3.15	83.39 ± 1.97	73.04 ± 2.63
	Ours	**75.42 ± 0.91**	**71.50 ± 0.89**	**60.35 ± 1.87**	**59.63 ± 1.86**	**77.88 ± 1.31**	**74.98 ± 1.35**	**85.33 ± 0.19**	**75.83 ± 0.74**
	Δ	**+9.58**	**+7.78**	**+7.60**	**+8.94**	**+4.50**	**+2.53**	**+1.94**	**+2.79**
SAGE	Vanilla	52.65 ± 0.24	43.79 ± 0.47	36.63 ± 0.09	24.12 ± 0.09	62.29 ± 0.25	47.02 ± 0.38	55.94 ± 2.37	47.21 ± 2.73
	Re-Weight	59.42 ± 2.88	55.26 ± 4.40	36.24 ± 1.30	27.07 ± 2.88	63.33 ± 0.75	55.11 ± 1.62	70.76 ± 3.35	62.09 ± 3.30
	PC Softmax	64.01 ± 1.15	60.74 ± 1.68	44.74 ± 1.41	37.61 ± 1.69	72.62 ± 1.42	70.95 ± 1.70	75.96 ± 2.44	69.12 ± 2.90
	BalancedSoftmax	63.43 ± 2.12	62.30 ± 2.27	49.33 ± 1.12	44.58 ± 1.64	70.68 ± 0.92	69.15 ± 0.84	74.66 ± 0.86	66.28 ± 1.92
	BalancedSoftmax (*w* TAM)	66.58 ± 1.53	64.56 ± 2.49	53.33 ± 1.06	50.15 ± 1.45	72.59 ± 2.06	72.22 ± 2.08	78.01 ± 1.06	71.02 ± 1.08
	Renode	62.42 ± 0.90	60.08 ± 1.19	39.61 ± 2.66	30.13 ± 3.86	67.11 ± 1.12	61.09 ± 3.50	73.73 ± 2.26	64.47 ± 2.39
	Renode (*w* TAM)	62.06 ± 2.08	60.72 ± 3.32	42.08 ± 1.88	33.19 ± 3.45	69.95 ± 1.01	65.99 ± 2.28	74.81 ± 3.29	67.48 ± 3.32
	GraphENS	63.09 ± 0.97	61.20 ± 1.74	42.03 ± 1.88	36.71 ± 2.99	69.71 ± 1.87	63.47 ± 3.87	81.33 ± 1.66	72.83 ± 1.76
	GraphENS (*w* TAM)	65.95 ± 2.25	63.88 ± 1.78	51.03 ± 1.51	50.49 ± 1.88	73.58 ± 2.01	72.44 ± 1.77	81.72 ± 1.08	72.31 ± 1.98
	GraphSR	66.45 ± 2.10	64.42 ± 1.83	53.52 ± 1.47	53.01 ± 1.75	74.09 ± 2.12	72.97 ± 1.90	81.45 ± 0.87	72.65 ± 1.54
	BIM	67.75 ± 2.13	64.68 ± 1.95	53.83 ± 1.62	53.29 ± 1.80	74.38 ± 2.08	73.24 ± 1.85	82.01 ± 0.43	72.32 ± 1.01
	Ours	**73.47 ± 2.31**	**68.30 ± 2.11**	**59.77 ± 2.98**	**58.92 ± 3.07**	**77.11 ± 0.59**	**74.03 ± 0.81**	**82.92 ± 2.94**	**73.11 ± 2.57**
	Δ	**+5.72**	**+3.62**	**+6.04**	**+5.63**	**+2.73**	**+0.79**	**+0.91**	**+0.79**

Experimental results on four benchmark datasets with an imbalance ratio of 50.

Experimental results on four benchmark datasets with an imbalance ratio of 100.

Results

Table 16: Experimental results of our method and other baselines on Computers-Random. We report averaged balanced accuracy (bAcc.,%) and F1-score (%) with the standard errors over 5 repetitions on three representative GNN architectures.

Dataset (Computers-Random)	GCN		GAT		SAGE	
Imbalance Ratio ($\rho = 25.50$)	bAcc.	F1	bAcc.	F1	bAcc.	F1
Vanilla	78.43 ± 0.41	77.14 ± 0.39	71.35 ±1.18	69.60 ± 1.11	65.30 ± 1.07	64.77 ± 1.19
Re-Weight	80.49 ± 0.44	75.07 ± 0.58	71.95 ± 0.80	70.67 ± 0.51	66.50 ± 1.47	66.10 ± 1.46
PC Softmax	81.34 ± 0.55	75.17 ± 0.57	70.56 ± 1.46	67.26 ± 1.48	69.73 ± 0.53	67.03 ± 0.6
BalancedSoftmax	81.39 ± 0.25	74.54 ± 0.64	72.09 ± 0.31	68.38 ± 0.69	73.80 ± 1.06	69.74 ± 0.60
GraphSMOTE	80.50 ± 1.11	73.79 ± 0.14	71.98 ± 0.21	67.98 ± 0.31	72.69 ± 0.82	68.73 ± 1.01
Renode	81.64 ± 0.34	76.87 ± 0.32	72.80 ± 0.94	71.40 ± 0.97	70.94 ± 1.50	70.04 ± 1.16
GraphENS	82.66 ± 0.61	76.55 ± 0.17	75.25 ± 0.85	71.49 ± 0.54	77.64 ± 0.52	72.65 ± 0.53
BalancedSoftmax+TAM	81.64 ± 0.48	75.59 ± 0.83	74.00 ± 0.77	70.72 ± 0.50	73.77 ± 1.26	71.03 ± 0.69
Renode+TAM	80.50 ± 1.11	75.79 ± 0.14	71.98 ± 0.21	70.98 ± 0.31	72.69 ± 0.82	70.73 ± 1.01
GraphENS+TAM	82.83 ± 0.68	76.76 ± 0.39	75.81 ± 0.72	72.62 ± 0.57	**78.98 ± 0.60**	**73.59 ± 0.55**
GraphSR	83.82 ± 0.74	77.78 ± 0.42	76.79 ± 0.68	73.61 ± 0.63	77.63 ± 0.32	72.56 ± 0.51
BIM	84.03 ± 0.73	77.96 ± 0.45	77.01 ± 0.70	73.82 ± 0.60	77.76 ± 0.65	72.09 ± 0.37
Ours	**85.32 ± 0.22**	**80.43 ± 0.56**	**82.52 ± 0.35**	**78.90 ± 0.38**	75.81 ± 1.86	71.86 ± 1.86
Δ	**+1.29**	**+2.47**	**+5.51**	**+5.08**	**-3.17**	**-1.73**

Table 17: Experimental results of our method and other baselines on CS-Random. We report averaged balanced accuracy (bAcc.,%) and F1-score (%) with the standard errors over 5 repetitions on three representative GNN architectures.

Dataset (CS-Random)	GCN		GAT		SAGE	
Imbalance Ratio ($\rho = 41.00$)	bAcc.	F1	bAcc.	F1	bAcc.	F1
Vanilla	84.85 ± 0.16	87.12 ± 0.14	82.47 ±0.36	84.21 ± 0.31	83.76 ± 0.27	86.22 ± 0.19
Re-Weight	87.42 ± 0.17	88.70 ± 0.10	83.55 ± 0.39	84.73 ± 0.32	85.76 ± 0.24	87.32 ± 0.16
PC Softmax	88.36 ± 0.12	88.94 ± 0.04	85.22 ± 0.31	85.54 ± 0.33	87.18 ± 0.14	88.00 ± 0.19
GraphSMOTE	85.76 ± 1.73	87.31 ± 1.32	84.65 ± 1.32	85.63 ± 1.01	85.76 ± 1.98	87.34 ± 0.98
BalancedSoftmax	87.72 ± 0.07	88.67 ± 0.07	84.38 ± 0.20	84.53 ± 0.41	86.78 ± 0.10	88.05 ± 0.09
BalancedSoftmax (*w* TAM)	88.22 ± 0.11	89.22 ± 0.08	85.48 ± 0.24	85.77 ± 0.50	87.83 ± 0.13	88.77 ± 0.07
Renode	87.53 ± 0.11	88.91 ± 0.06	85.98 ± 0.19	86.97 ± 0.09	86.13 ± 0.10	87.89 ± 0.09
Renode (*w* TAM)	87.55 ± 0.06	89.03 ± 0.05	86.61 ± 0.30	87.42 ± 0.24	85.21 ± 0.33	87.01 ± 0.31
GraphENS	85.97 ± 0.29	86.68 ± 0.20	85.86 ± 0.19	86.51 ± 0.32	85.39 ± 0.26	86.41 ± 0.24
GraphENS (*w* TAM)	86.34 ± 0.12	87.36 ± 0.08	86.29 ± 0.20	87.28 ± 0.13	85.99 ± 0.13	87.25 ± 0.07
GraphSR	86.73 ± 0.22	85.91 ± 0.21	85.34 ± 0.13	86.56 ± 0.29	85.44 ± 0.27	86.46 ±0.23
BIM	86.89 ± 0.23	85.99 ± 0.21	85.63 ± 1.87	86.65 ± 0.35	85.65 ± 0.28	86.73 ± 0.22
Ours	**88.94 ± 0.09**	**89.87 ± 0.06**	**87.65 ± 0.12**	**87.65 ± 0.11**	**88.03 ± 0.21**	88.65 ± 0.07
Δ	**+ 0.58**	**+ 0.65**	**+ 1.04**	**+ 0.23**	**+ 0.20**	**- 0.12**

Experimental results on two naturally imbalanced datasets, Computers-Random and CS-Random.

Results

Table 26: Experimental results of our method and other baselines on Flickr. We report averaged balanced accuracy (bAcc.,%) and F1-score (%) with the standard errors over 5 repetitions on three representative GNN architectures.

Model	GCN		GAT		SAGE	
Imbalance Ratio ($\rho = 10.80$)	bAcc.	F1	bAcc.	F1	bAcc.	F1
Vanilla	24.62 ± 0.07	24.53 ± 0.11	25.87 ± 0.30	25.32 ± 0.44	25.29 ± 0.18	24.16 ± 0.27
Re-weight	28.31 ± 1.64	24.06 ± 1.16	**30.66 ± 0.76**	27.12 ± 0.34	27.39 ± 1.84	22.62 ± 1.04
PC Softmax	29.21 ± 2.16	25.81 ± 1.75	30.20 ± 0.46	27.24 ± 0.37	25.40 ± 2.49	21.08 ± 1.73
GraphSMOTE	OOM	OOM	OOM	OOM	OOM	OOM
BalancedSoftmax	27.61 ± 0.61	23.70 ± 0.77	26.01 ± 2.81	23.50 ± 3.07	28.24 ± 2.10	24.98 ± 1.59
BalancedSoftmax (*w* TAM)	27.06 ± 1.03	23.97 ± 0.60	28.24 ± 0.99	25.52 ± 0.89	29.79 ± 0.37	27.56 ± 0.25
Renode	OOM	OOM	OOM	OOM	OOM	OOM
Renode (*w* TAM)	OOM	OOM	OOM	OOM	OOM	OOM
GraphENS	OOM	OOM	OOM	OOM	OOM	OOM
GraphENS (*w* TAM)	OOM	OOM	OOM	OOM	OOM	OOM
GraphSR	27.63 ± 0.59	23.73 ± 0.81	26.03 ± 2.75	23.53 ± 3.15	28.26 ± 2.18	25.01 ± 1.62
BIM	27.87 ± 0.65	23.75 ± 0.73	26.15 ± 2.70	23.74 ± 3.10	28.34 ± 2.00	25.03 ± 1.66
Ours	**30.76 ± 0.27**	**30.60 ± 0.29**	29.45 ± 0.72	**28.21 ± 0.76**	**30.68 ± 0.63**	**31.01 ± 1.34**
Δ	**+1.55**	**+4.79**	**-1.21**	**+0.97**	**+0.89**	**+3.45**

Table 27: Experimental results of our method and other baselines on Ogbn-Arxiv. We report averaged balanced accuracy (bAcc.,%) and F1-score (%) with the standard errors over 5 repetitions on three representative GNN architectures.

Model	GCN		GAT		SAGE	
Imbalance Ratio ($\rho = 775.40$)	bAcc.	F1	bAcc.	F1	bAcc.	F1
Vanilla	50.21 ± 0.65	49.60 ± 0.14	51.21 ± 0.87	49.23 ± 0.33	50.76 ± 0.21	49.43 ± 0.29
Re-weight	50.24 ± 0.40	49.71 ± 0.12	51.12 ± 0.80	49.65 ± 0.25	50.81 ± 0.19	49.78 ± 0.22
PC Softmax	50.20 ± 0.58	49.64 ± 0.12	51.18 ± 0.77	49.16 ± 0.28	50.82 ± 0.19	49.65 ± 0.24
GS	OOM	OOM	OOM	OOM	OOM	OOM
BalancedSoftmax	50.34 ± 0.41	49.73 ± 0.13	51.35 ± 0.69	49.36 ± 0.22	50.89 ± 0.19	49.56 ± 0.18
BalancedSoftmax (*w* TAM)	50.34 ± 0.48	49.72 ± 0.10	51.36 ± 0.72	49.98 ± 0.26	50.94 ± 0.17	49.95 ± 0.22
ReNode	OOM	OOM	OOM	OOM	OOM	OOM
REnode (*w* TAM)	OOM	OOM	OOM	OOM	OOM	OOM
GraphENS	OOM	OOM	OOM	OOM	OOM	OOM
GraphENS (*w* TAM)	OOM	OOM	OOM	OOM	OOM	OOM
GraphSR	50.31 ± 0.24	49.70 ± 0.17	51.31 ± 0.41	49.33 ± 0.26	50.86 ± 0.30	49.53 ± 0.20
BIM	50.33 ± 0.42	49.71 ± 0.19	51.35 ± 0.60	49.36 ± 0.28	50.87 ± 0.18	49.56 ± 0.23
Ours	$51.21_{\pm 0.32}$	$50.65_{\pm 0.32}$	$51.84_{\pm 0.87}$	$51.28_{\pm 0.42}$	$51.34_{\pm 0.32}$	$51.36_{\pm 0.27}$
Δ	**+0.87**	**+0.92**	**+0.48**	**+1.30**	**+0.40**	**+0.41**

Experimental results on two large-scale, naturally imbalanced datasets, Flickr and Ogbn-arxiv.