GNNs Getting ComFy: Community and Feature Similarity Guided Rewiring

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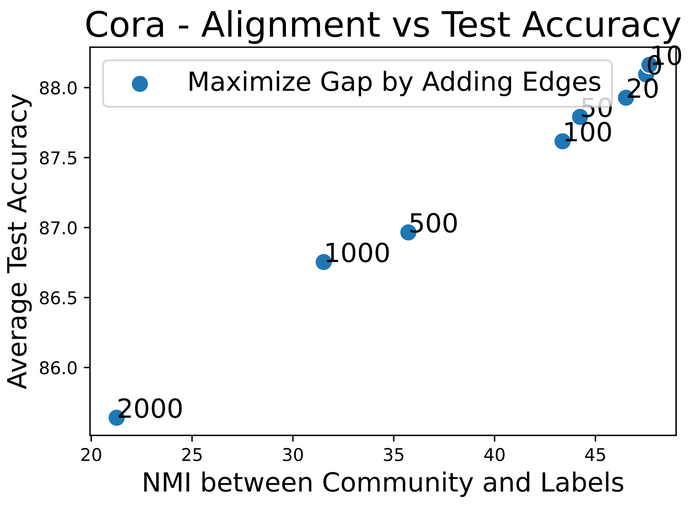
Background

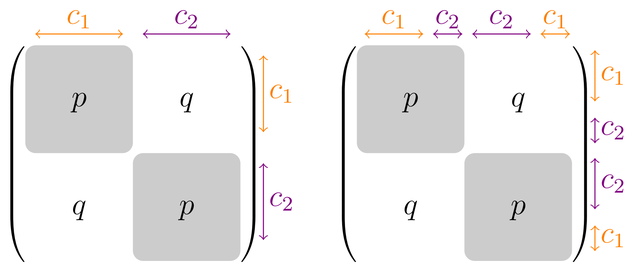
Information flow issues like *over-squashing* limit GNNs' performance. Rewiring the graph can mitigate them.

Insight: Maximizing the spectral gap can destroy community structure. This can be *harmful*, especially when node labels align well with communities.



Research questions

- When is spectral gap maximization or minimization beneficial?
- How does graph and task alignment influence GNN performance?
- Can graph (or communities) and task (or features) be leveraged together to rewire GNNs' input graphs?

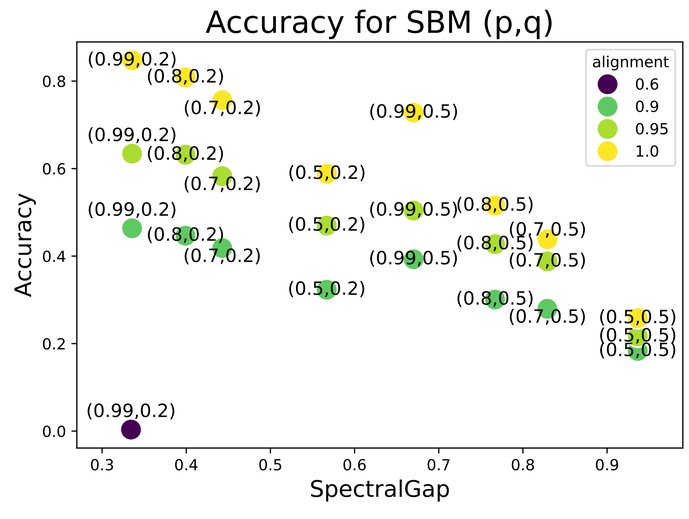


(a) $\psi = 1$. (b) $\psi = \frac{2}{3}$.

Adjacency matrices of (p, q)-SBMs for different alignments. In Fig. (a), the two blocks match classes c_1 and c_2. In Fig. (b), a third of the nodes in each block are of opposite class.

Theory on (p, q)-SBMs

1. Spectral gap $\lambda_1 \sim -(p-q)/(p+q)$. Maximizing it means $\downarrow p$ and $\uparrow q$, which destroys communities.
2. If task labels = community membership labels (high alignment), destroying them is harmful.
3. If the alignment changes, this is not necessarily the case. But spectral gap rewiring cannot tackle this.



Rewiring methods

- ComMa: Randomly draws edges to modify community strength.
- FeaSt: Prioritizes edges that maximize feature similarity.
- ComFy: Maximizes similarity proportionally to each community.

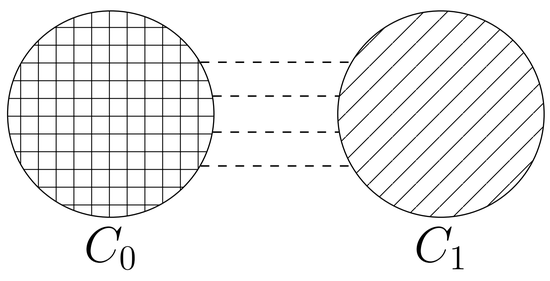
Experiments

Methods	Cora	Citeseer	Chameleon	Roman-Empire
GCN	86.12±0.36	77.83±0.35	39.33±0.59	70.30±0.73
GCN+ProxyAddMax	85.92±0.43	79.25±0.35	38.20±0.70	77.54±0.74
GCN+ProxyAddMin	84.10±0.39	78.77±0.40	39.33±0.55	79.18±0.06
GCN+ProxyDelMax	86.32±0.38	**81.84±0.38**	39.33±0.70	77.45±0.68
GCN+ProxyDelMin	85.92±0.37	79.01±0.34	39.89±0.59	79.09±0.05
GCN+FeaStAdd	87.73±0.39	78.54±0.34	43.26±0.62	**79.67±0.07**
GCN+FeaStDel	**90.74±0.39**	81.60±0.39	42.70±0.69	78.99±0.05
GCN+ComFyAdd	87.73±0.26	77.36±0.38	41.57±0.83	79.53±0.07
GCN+ComFyDel	88.13±0.27	78.07±0.35	**45.51±0.76**	79.17±0.07

Conclusions

We show that incorporating features into graph rewiring significantly boosts GNN performance. Moreover, spectral graph rewiring and other topology-based methods are insufficient because they fail to account for the alignment between the graph and the task.

2-cluster graph:



Sizes A, B, and C of the three edge areas:

$A := |C_0| \cdot |C_0|$ $B := |C_0| \cdot |C_1|$ $C := |C_1| \cdot |C_1|$

	ComMa(k)		FeaSt(k)		ComFy(k)	
	LowerComMa	HigherComMa	Add	Del	Add	Del
$C_0 \times C_0$	If Del, draw and delete $\lfloor \frac{A}{A+C} \cdot k \rfloor$ edges	If Add, draw and add $\lfloor \frac{A}{A+C} \cdot k \rfloor$ edges	Add top k of $\text{sim}(u,v)$ for $(u,v) \in \bar{\mathcal{E}}$	Delete bottom k of $\text{sim}(u,v)$ for $(u,v) \in \mathcal{E}$	FeaSt Add $\left(\lfloor \frac{A}{A+B+C} \cdot k \rfloor \right)$	FeaSt Del $\left(\lfloor \frac{A}{A+B+C} \cdot k \rfloor \right)$
$C_0 \times C_1$	If Add, draw and add k edges	If Del, draw and delete k edges			FeaSt Add $\left(\lfloor \frac{B}{A+B+C} \cdot k \rfloor \right)$	FeaSt Del $\left(\lfloor \frac{B}{A+B+C} \cdot k \rfloor \right)$
$C_1 \times C_1$	If Del, draw and delete $\lfloor \frac{C}{A+C} \cdot k \rfloor$ edges	If Add, draw and add $\lfloor \frac{C}{A+C} \cdot k \rfloor$ edges			FeaSt Add $\left(\lfloor \frac{C}{A+B+C} \cdot k \rfloor \right)$	FeaSt Del $\left(\lfloor \frac{C}{A+B+C} \cdot k \rfloor \right)$