

Localization of hubs in complex networks with overlapping modular structure

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Localization of hubs in complex networks with overlapping modular structure

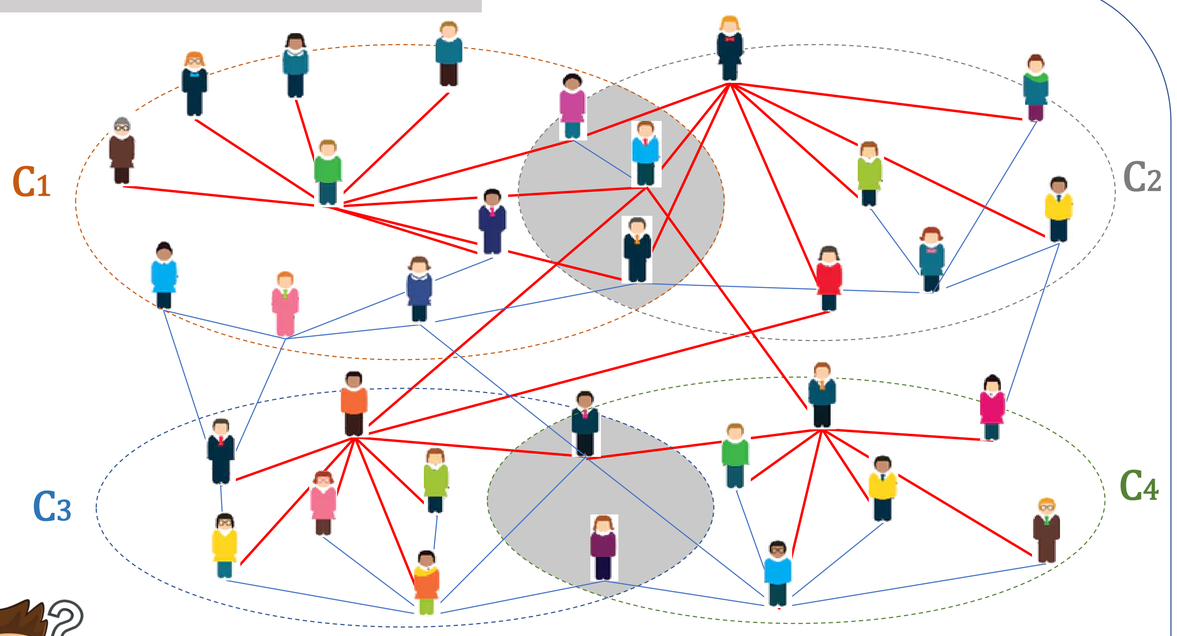
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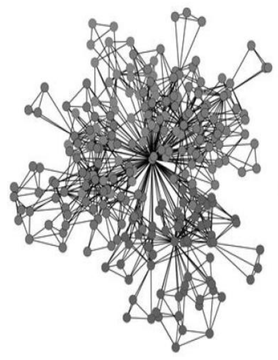
Problematic



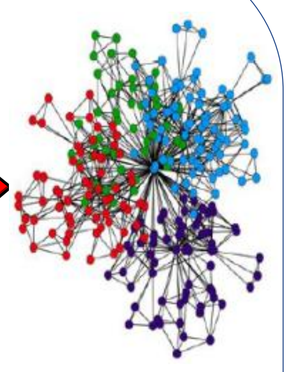


Overlapping nodes ? **Hubs**

Methodology



Community detection



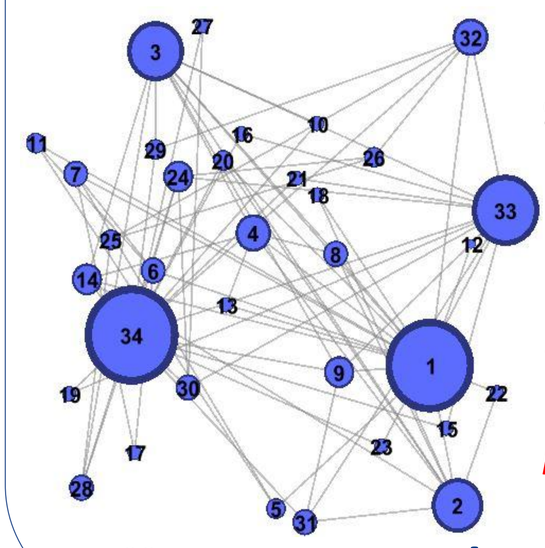
Evaluation measures

Proportion of hubs
Rank-biased overlap
Correlation
Degree distribution

Ego-network of overlapping nodes & List of Hubs

Empirical Networks

Small Network



Social network

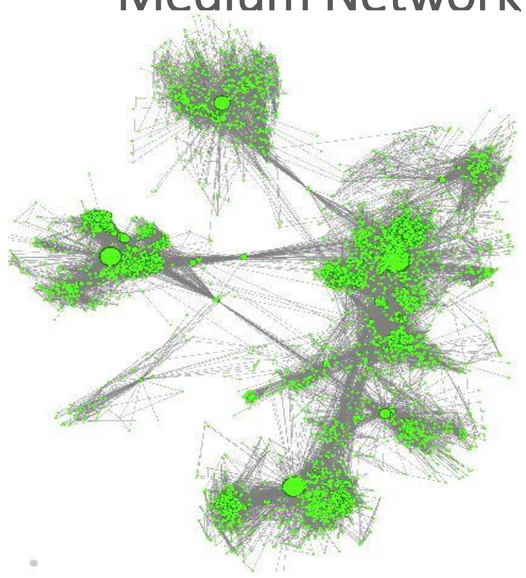
N 34
E 78

Relatively high density

Non Assortative

Karate network

Medium Network



Social network

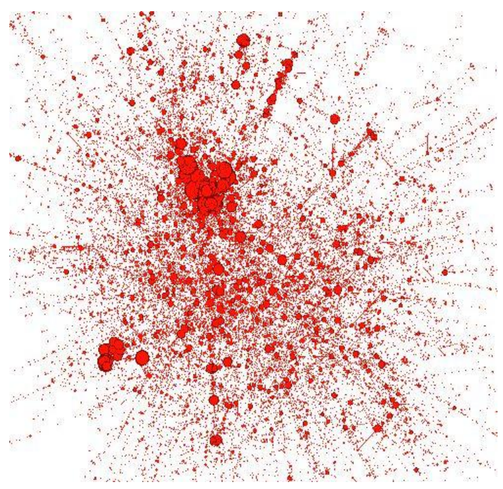
N 4039
E 88234

Small density

Assortative

Ego-Facebook network

Large Network



Collaboration network

N 23133
E 93497

Very small density

Assortative

Condense Matter network

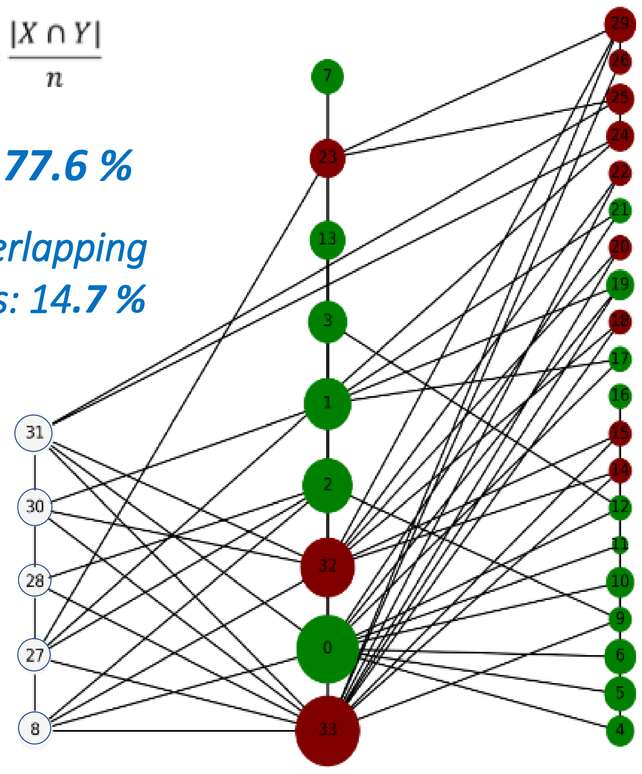
Results

Proportion of hubs

$$p = \frac{|X \cap Y|}{n}$$

p = 77.6 %

P. overlapping nodes: 14.7 %



Overlapping nodes — Hubs

Network	P. overlapping nodes (%)	Proportion of hubs (%)
ego-Facebook	3.1	59.25
ca-CondMat	2.1	79.57

Rank-biased overlap

$$RBO(X,Y) = \sum_d w_d A_d$$

$$A_d = \frac{|X_{1:d} \cap Y_{1:d}|}{d}$$

$$w_d = (1-p) * p^{d-1}$$

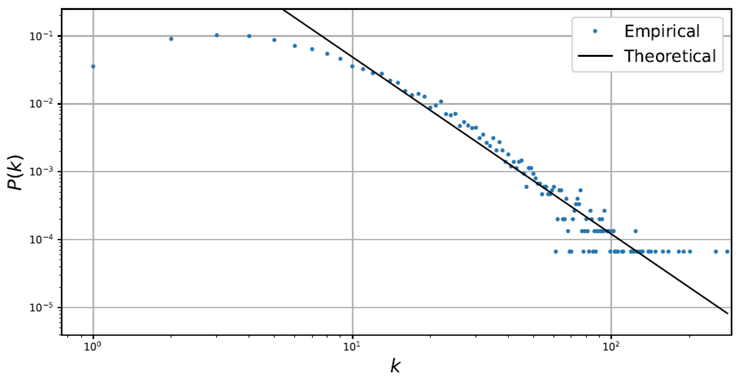
Network	RBO		
	p=0.5	p=0.8	p=0.98
Karate club	0.998	0.952	0.844
Ego-facebook	0.998	0.952	0.844
ca-CondMat	1	0.999	0.999

Correlation

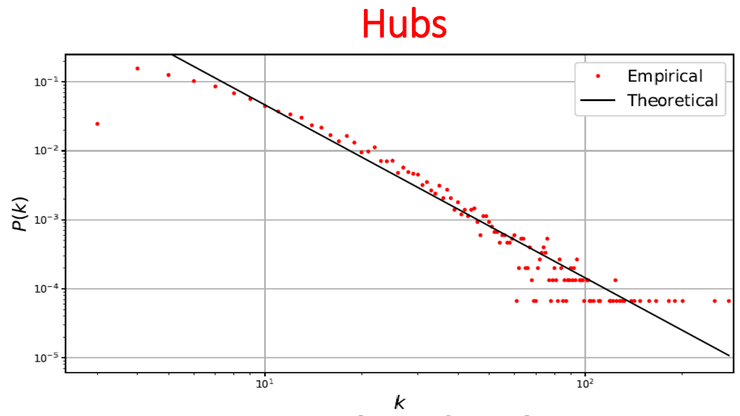
Network	Pearson Correlation	Spearman Correlation
Karate club	0.991	0.98
ego-Facebook	0.985	0.98
ca-CondMat	0.989	0.99

Degree distribution

Neighbors of the overlapping nodes



Hubs



Power law distribution

Ghalmane, Z., Cherifi, C., Cherifi, H., & El Hassouni, M. (2020). Exploring Hubs and Overlapping Nodes Interactions in Modular Complex Networks. *IEEE Access*, *8*, 79650-79683.