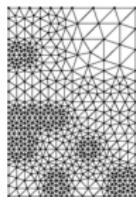


network *clustering*

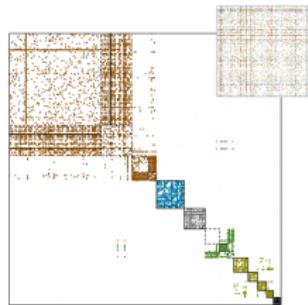
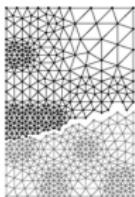
introduction to *network analysis in Python* (*NetPy*)

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19th Sep 2019

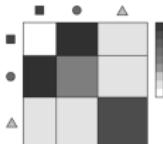
clustering *overview*



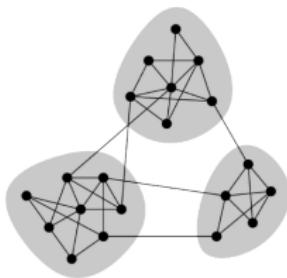
graph partitioning [KL70, Fie73]



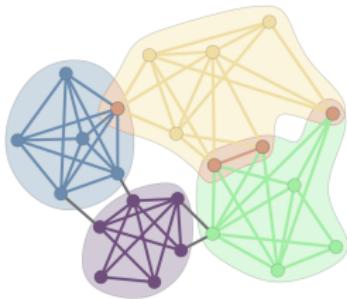
blockmodeling [LW71, WR83]



stochastic block models [Pei15]



communities [GN02]

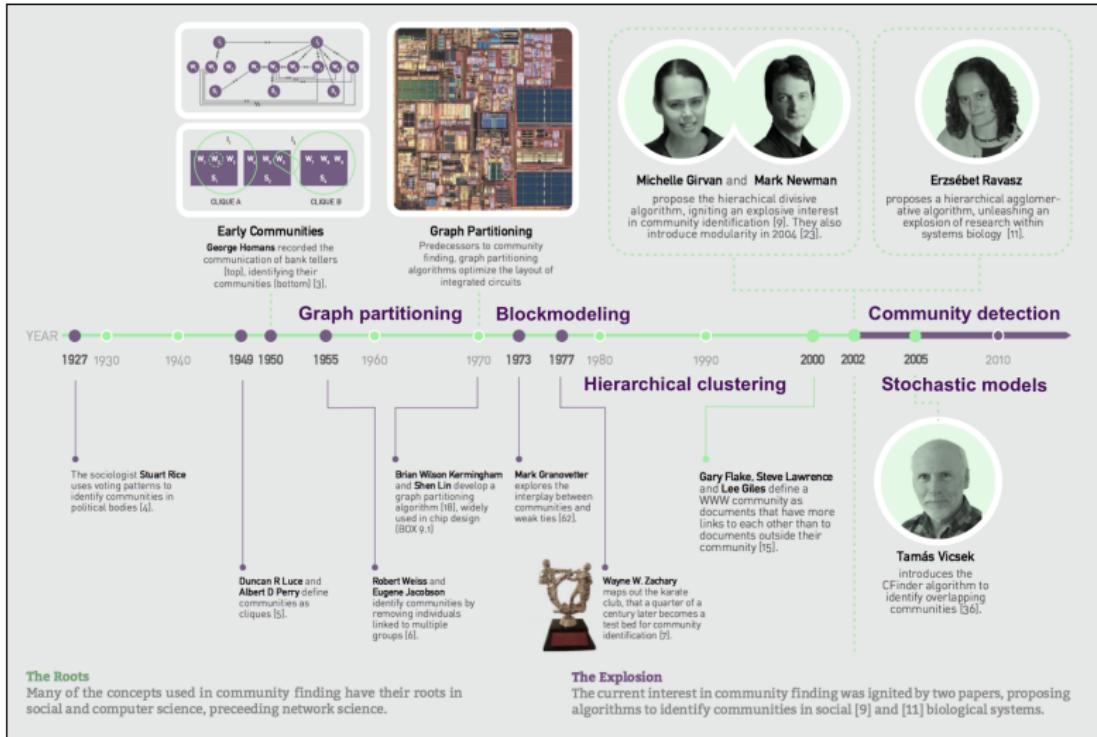


overlapping communities [PDFV05]



link communities [EL09, ABL10]

clustering *history*



community detection

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community *agglomerative*

— Ravasz *hierarchical clustering* [RSM⁺02]

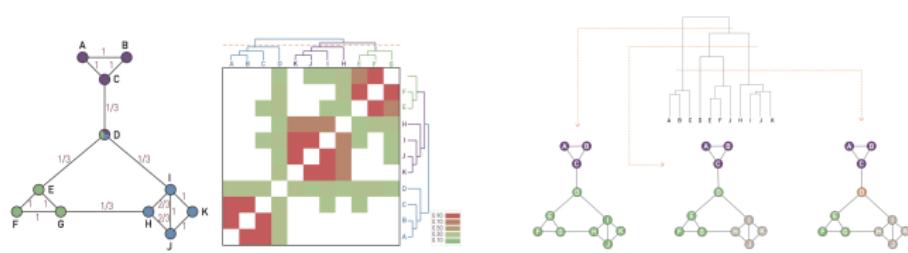
- define *node similarity* as *topological overlap*

$$s_{ij} = \frac{|\Gamma_i \cap \Gamma_j| + A_{ij}}{\min(k_i, k_j)}$$

- define *cluster similarity* as *average linkage*

$$S_{ij} = \frac{1}{n_i n_j} \sum_{xy} s_{xy} \delta_{c_x c_i} \delta_{c_y c_j}$$

1. bottom-up *agglomerative hierarchical clustering* $\mathcal{O}(n^2)$
2. cut *cluster dendrogram* at desired *clustering resolution*



community *divisive*

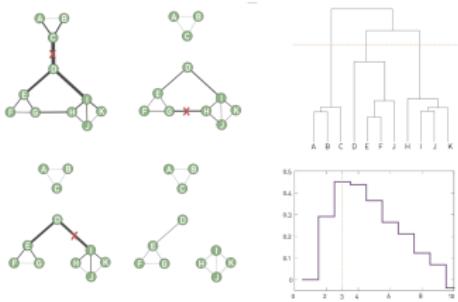
- Girvan-Newman *hierarchical clustering* [GN02]

- define *node dissimilarity* as *link betweenness*

$$\sigma_{ij} = \sum_{st \notin \{i,j\}} \frac{g_{st}^{ij}}{g_{st}}$$

1. top-down *divisive hierarchical clustering* $\mathcal{O}(nm^2)$
2. cut *cluster dendrogram* at *maximum modularity*

$$Q = \frac{1}{2m} \sum_{ij} (A_{ij} - \frac{k_i k_j}{2m}) \delta_{c_i c_j}$$



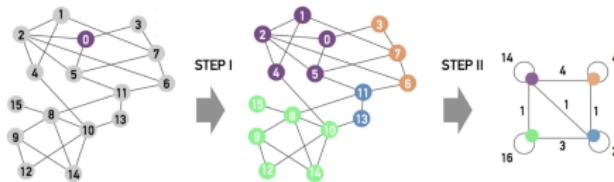
community *modularity*

— Louvain *modularity optimization* [BGLL08]

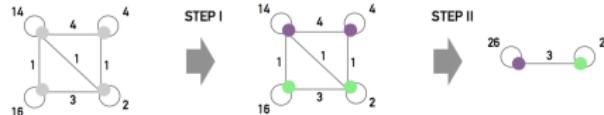
1. set *node community* by *modularity optimization* $\mathcal{O}(cm)$
2. *aggregate community nodes into supernodes* and repeat 1.
3. return *community structure maximizing modularity*

$$Q = \frac{1}{2m} \sum_{ij} (A_{ij} - \frac{k_i k_j}{2m}) \delta_{c_i c_j}$$

1ST PASS



2ND PASS



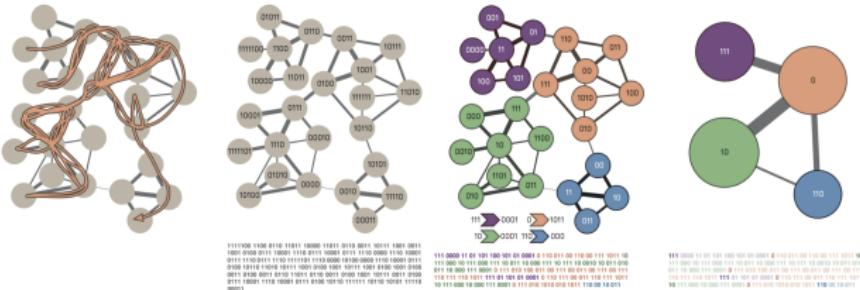
see `findcommunities` implementation

community *map equation*

— Infomap *map equation compression* [RB08]

1. set *node community* by *optimal coding* $\mathcal{O}(m \log m)$
2. *compress community nodes into supernodes* and repeat 1.
3. return *community structure maximizing map equation*

$$\mathcal{L} = \sum_i p_{i \rightsquigarrow} H(\tilde{\mathcal{C}}) + \sum_i p_{i \leftarrow} H(\mathcal{C}_i)$$



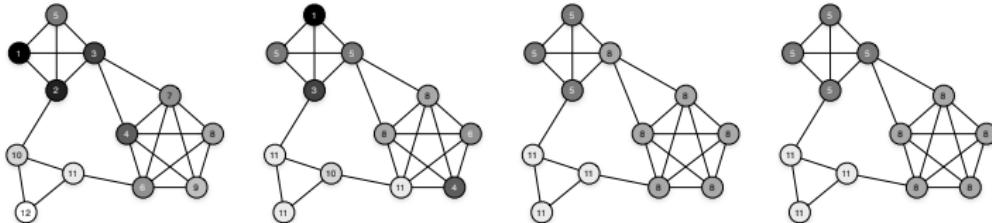
see [mapequation implementation](#)

community *propagation*

— Raghavan *label propagation* [RAK07, ŠB11]

1. set *node community* by *neighbors frequency* $\mathcal{O}(cm)$
2. *randomly shuffle nodes* and repeat 1. *until convergence*
3. return *community structure connected components*

$$\forall i : c_i = \arg \max_c \sum_j A_{ij} \delta_{c_j c}$$



see **balanced** implementation

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