

applications *bibliometrics*

introduction to *network analysis (ina)*

Lovro Šubelj
University of Ljubljana
spring 2023/24

study *overview*

problem

grouping publications into clusters based on *citation relations*

means

graph partitioning/community detection methods on *citation networks*

goals

clusters of *topically related* publications or *research areas*

wishes

experts should recognize cluster topics

- small differences in cluster sizes

- limited number of tiny clusters

- robustness to small perturbations

- reasonable computational complexity

data

in-house version of *Web of Science database* of CWTS

networks

citation networks represented as *simple undirected graphs*

field	period	# publications	# nodes	# links
Scientometrics	2009-2013	2,402	1,998	5,496
L&IS	1996-2013	43,741	32,628	131,989
Physics	2004-2013	1,314,458	1,233,542	9,838,008
WoS	2004-2013	11,780,132	11,063,916	122,148,955

Scientometrics — journals *Journal of Informetrics*, *Scientometrics* and *JASIST*

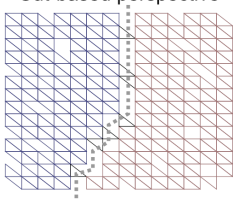
L&IS — *Information Science & Library Science* journal subject category

Physics — eight *Physics* journal subject categories and *Astronomy & Astrophysics*

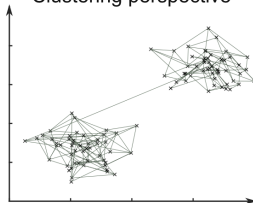
WoS — all journal subject categories in *Web of Science*

clustering *perspectives*

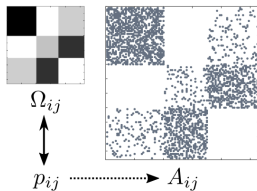
Cut-based perspective



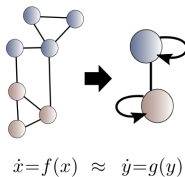
Clustering perspective



SBM perspective



Dynamical perspective



Schaub, Delvenne, Rosvall & Lambiotte (2017) *Appl. Netw. Sci.* 2, 4.

methods

30 *basic/derived graph partitioning/community detection* methods

class	method	description
Spectral analysis	Graclus(S L)	<i>k</i> -means clustering iteration
	METIS(S L)	multi-level <i>k</i> -way partitioning
Map equation	Infomap	information flows compression
	Hiermap	hierarchical flows compression
Modularity optimization	Louvain	greedy hierarchical optimization
	Mouvain	multi-level hierarchical optimization
	SLM	smart local moving optimization
Statistical methods	OSLOM	order statistics local optimization method
Label propagation	LPA	label propagation algorithm
	BPA	balanced propagation algorithm
	DPA	diffusion-propagation algorithm
	HPA	hierarchical propagation algorithm
	COPRA	community overlap propagation algorithm
Random walks	Walktrap	random walks hierarchical clustering
Link clustering	Links(S L)	link similarity hierarchical clustering
Graph models	BigClam(S L)	cluster affiliation matrix factorization
	CoDA(S L)	communities through directed affiliations
Ego-networks	DEMON	democratic estimate of modular organization
Cliques	SCP	sequential clique percolation
	GCE	greedy clique expansion
2-step methods	Metilus	METIS+Graclus
	Gracmap	Graclus+Infomap
	Metimap	METIS+Infomap
	Louvmap	Louvain+Infomap
	Labmap	LPA+Infomap

2-step — *second method* applied to clusters obtained by *first method*

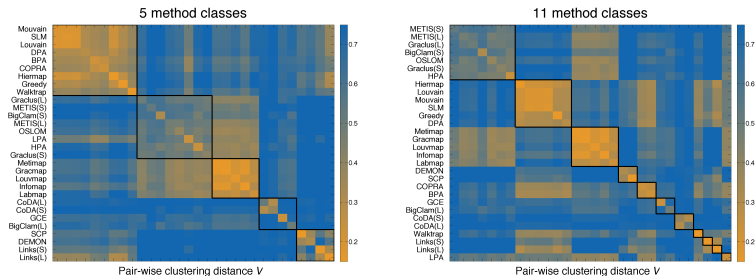
S|L — *small|large* clusters

clustering *distances*

clusterings

distances between clusterings by *considered* methods

10/15 *selected representative* methods

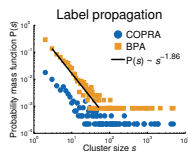
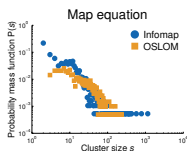
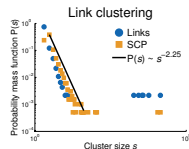
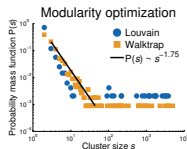
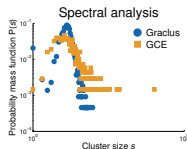


distance — normalized *variation of information* of clusterings

clustering *distributions*

sizes

size distributions of clusterings by *representative* methods
from *homogeneous* to *inhomogeneous* distributions

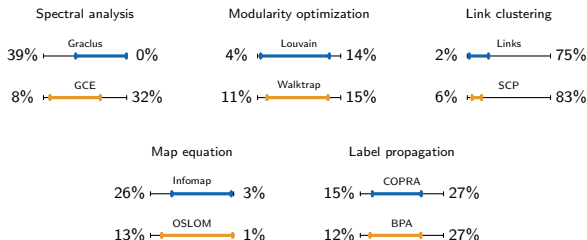


clustering *degeneracy*

ranges

degeneracy diagrams of clusterings by *representative* methods

narrowing effective ranges from left to right



left-hand side — % nodes in *tiny clusters* < 15 nodes

right-hand side — % nodes in *largest cluster*

clustering *metrics*

metrics

standard metrics of clusterings by *representative* methods

≈ 1500 *clusters* and *decreasing Flake score* from top/bottom

method	# clusters	degree	expansion	Flake	modularity
Graclus	2175	2.4	5.8	52%	0.29
OSLOM	1914	3.8	4.4	37%	0.45
Infomap	1871	5.0	3.2	19%	0.60
Louvain	488	6.8	1.2	3%	0.73
Walktrap	1127	6.5	1.6	7%	0.69
BPA	1002	7.0	1.0	3%	0.66
COPRA	3826	6.8	1.2	15%	0.65
Links	2933	6.4	1.8	20%	0.09
SCP	1969	4.9	3.2	37%	0.22
GCE	682	4.1	4.0	29%	0.43

degree — average node *intra-cluster* or *internal degree*

expansion — average node *inter-cluster* or *external degree*

Flake — % nodes with *larger external than internal degree*

bibmetrics

bibliometric metrics of clusterings by *representative* methods

orders $\gg 1$ and *increasing coverage* from top/bottom

method	size	orders	diameter	coverage	uncertainty
Graclus	15.0	1.1	3.4	29%	0.42
OSLOM	16.0	2.6	4.8	46%	0.36
Infomap	17.3	2.7	4.3	62%	0.13
Louvain	66.7	3.3	9.1	85%	0.19
Walktrap	29.0	3.4	7.8	80%	0.00
BPA	32.0	3.6	7.3	86%	0.21
COPRA	8.8	4.0	6.9	85%	0.22
Links	10.1	4.3	11.1	78%	0.05
SCP	16.6	4.2	23.1	61%	0.02
GCE	47.8	3.3	12.0	50%	0.24

orders — *orders of magnitude* spanned by *cluster sizes*

diameter — average within *cluster effective diameter*

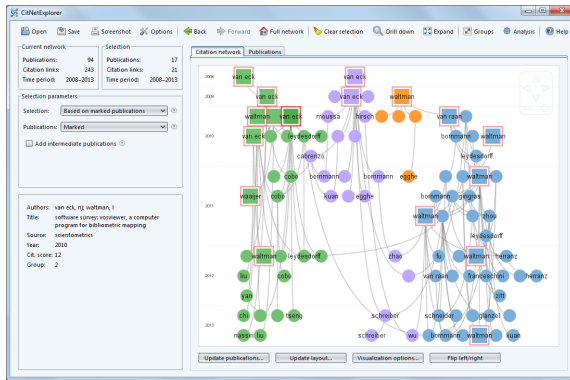
uncertainty — *variation of information* of clusterings

coverage — % links *covered by clusters*

assessment tool

CitNetExplorer for analyzing *citation networks*

freely available at www.citnetexplorer.nl



clustering *resolution*

clusterings for L&IS by *representative* methods
hands-on *expert assessment* for *scientometrics* using *CitNetExplorer*

low resolution

Walktrap and *BPA*

BPA returns *one cluster* covering *scientometrics*

high resolution

Graclus(S|L) and *METIS(S|L)*

Graclus returns *four clusters* covering *h-index*

topics resolution

OSLOM, *Louvain(10)*, *Metimap* and *Infomap*

OSLOM, Louvain(10) return *ambiguous/heterogeneous clusters*

expert assessment

largest *scientometrics clusters* by *Metimap* and *Infomap* methods

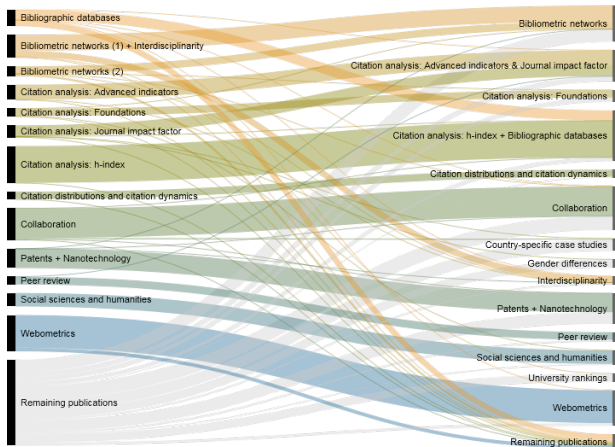
identified *research topics* of clusters covering $\approx 75\%$ *publications*

method	topic	size
Metimap	Citation analysis: h-index	262
	Webometrics	256
	Collaboration	224
	Bibliometric networks (1) + Interdisciplinarity	163
	Patents + Nanotechnology	137
	Bibliographic databases	115
	Citation analysis: Advanced indicators	107
	Social sciences and humanities	95
	Citation analysis: Journal impact factor	87
	Bibliometric networks (2)	69
	Citation analysis: Foundations	59
Infomap	Citation analysis: h-index + Bibliographic databases	358
	Collaboration	308
	Bibliometric networks	254
	Webometrics	250
	Citation analysis: Advanced indicators & Journal impact factor	220
	Patents + Nanotechnology	216
	Social sciences and humanities	104
	Country-specific case studies	87
	Citation analysis: Foundations	85
	Peer review	67
	Gender differences	59

clustering *comparison*

expert comparison

largest *scientometrics clusters* by *Metimap* and *Infomap* methods



clustering *metrics for WoS* by *fastest* methods

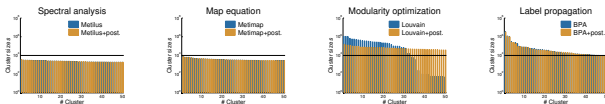
method	size	orders	degree	coverage	Flake	complexity
Metilus	50.0	2.3	5.9	27%	69%	30 min
Metimap	33.2	3.6	10.3	47%	45%	94 min
Louvain	334.4	5.7	18.5	84%	5%	52 min
BPA	105.4	6.2	18.5	84%	7%	66 min

post-processing

tiny clusters < 15 nodes merged by maximizing likelihood

method	size	orders	degree	coverage	Flake	complexity
Metilus+post.	51.5	2.2	5.9	27%	69%	34 min
Metimap+post.	58.9	3.6	10.3	47%	45%	99 min
Louvain+post.	320.9	4.9	15.2	69%	17%	79 min
BPA+post.	167.1	6.2	18.0	82%	9%	114 min

giant clusters > 10⁴ nodes repartitioned by same method



conclusions

methods return *substantially different clusterings*
no method performs satisfactory by all criteria
straightforward *post-processing performs poorly*
map equation methods provide *good trade-off*

limitations

limitations of expert assessment of clusterings
limited number of methods with default parameters
no directed, overlapping, multi-resolution, principled methods
no equivalence clusters or co-citation and bibliographic coupling

clustering *references*



A.-L. Barabási.

Network Science.

Cambridge University Press, Cambridge, 2016.



Wouter de Nooy, Andrej Mrvar, and Vladimir Batagelj.

Exploratory Social Network Analysis with Pajek: Expanded and Revised Second Edition.

Cambridge University Press, Cambridge, 2011.



David Easley and Jon Kleinberg.

Networks, Crowds, and Markets: Reasoning About a Highly Connected World.

Cambridge University Press, Cambridge, 2010.



Ernesto Estrada and Philip A. Knight.

A First Course in Network Theory.

Oxford University Press, 2015.



Mark E. J. Newman.

Networks.

Oxford University Press, Oxford, 2nd edition, 2018.



Michael T. Schaub, Jean-Charles Delvenne, Martin Rosvall, and Renaud Lambiotte.

The many facets of community detection in complex networks.

Appl. Netw. Sci., 2:4, 2017.



Lovro Šubelj, Nees Jan Van Eck, and Ludo Waltman.

Clustering scientific publications based on citation relations: A systematic comparison of different methods.

PLoS ONE, 11(4):e0154404, 2016.



Lovro Šubelj, Nees Jan Van Eck, and Ludo Waltman.

Comparison of methods for clustering citation networks.

In *Proceedings of the International Conference on Network Science X*, page 1, Wroclaw, Poland, 2016.

clustering *references*



Nees Jan Van Eck and Ludo Waltman.

CitNetExplorer: A new software tool for analyzing and visualizing citation networks.

J. Infometr., 8(4):802–823, 2014.