applications *bibliometrics*

introduction to *network analysis* (*ina*)

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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

citation *networks*

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

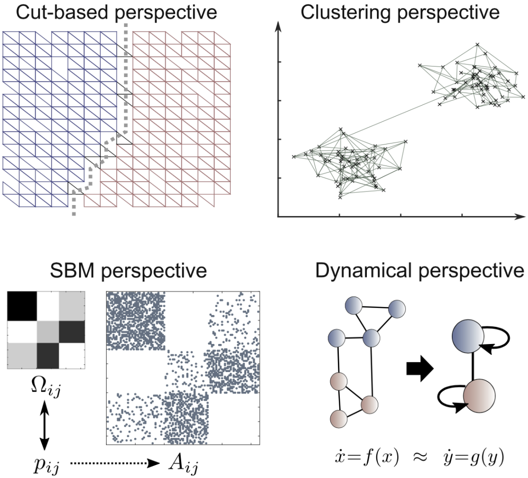
Scientometrics — journals *Journal of Informetrics*, *Scientometrics* and *JASIST*

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*



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

clustering *methods*

methods

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

class	method	description
Spectral analysis	Graclus(S|L)	*k*-means clustering iteration
	METIS(S|L)	multi-level *k*-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*

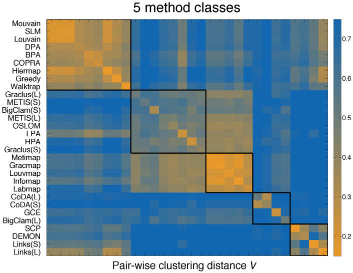
S|*L* — *small*|*large* clusters

clustering *distances*

clusterings

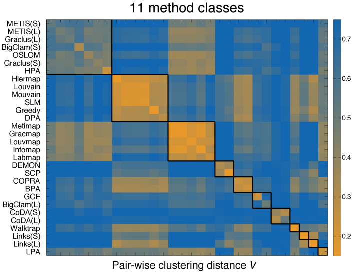
distances between clusterings by *considered* methods

10/15 *selected representative* methods



5 method classes

Pair-wise clustering distance V



11 method classes

Pair-wise clustering distance V

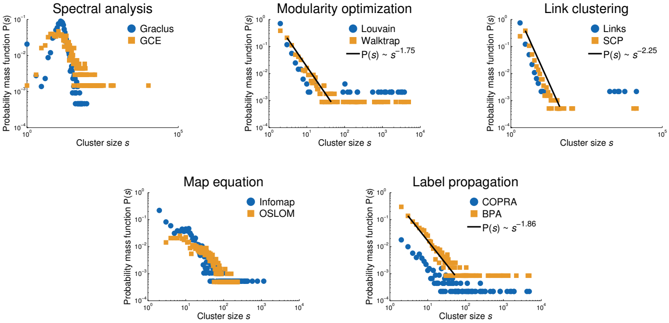
distance — normalized *variation of information* of clusterings

clustering *distributions*

sizes

size distributions of clusterings by *representative* methods

from homogeneous to inhomogeneous distributions

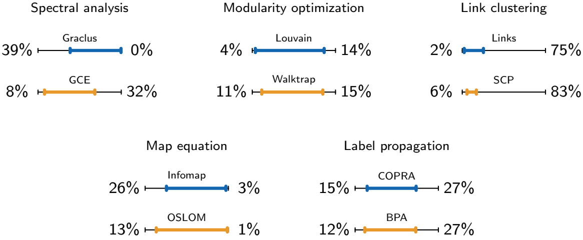


clustering *degeneracy*

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*

clustering *bibmetrics*

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

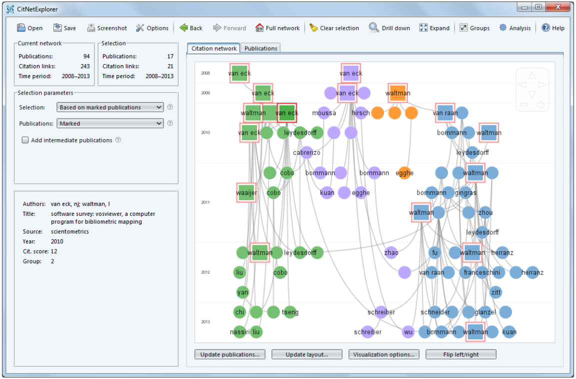
coverage — % links *covered by clusters*

clustering *tool*

assessment tool

CitNetExplorer for analyzing *citation networks*

freely available at *www.citnetexplorer.nl*



CitNetExplorer

Current network

Publications: 94
Citation links: 243
Time period: 2008–2013

Selection

Publications: 17
Citation links: 21
Time period: 2008–2013

Selection parameters

Selection: Based on marked publications
Publications: Marked
□ Add intermediate publications

Authors: van eck, nj; waltman, l
Title: software survey: vosviewer, a computer program for bibliometric mapping
Source: scientometrics
Year: 2010
Cit. score: 12
Group: 2

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*

clustering *assessment*

expert assessment

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

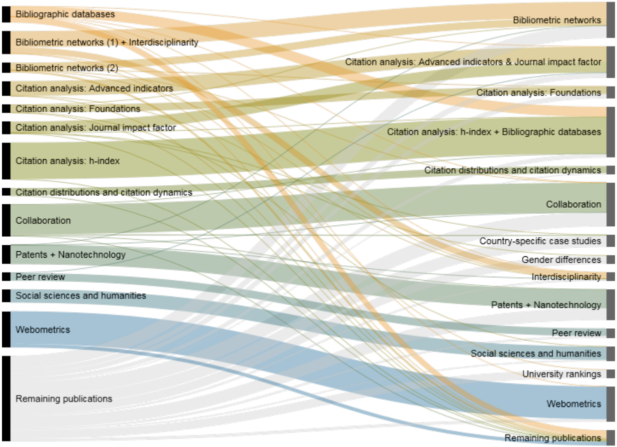
identified *research topics* of clusters covering ≈ *75% publications*

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



Bibliographic databases
Bibliometric networks (1) + Interdisciplinarity
Bibliometric networks (2)
Citation analysis: Advanced indicators
Citation analysis: Foundations
Citation analysis: Journal impact factor
Citation analysis: h-index
Citation distributions and citation dynamics
Collaboration
Patents + Nanotechnology
Peer review
Social sciences and humanities
Webometrics
Remaining publications
Bibliometric networks
Citation analysis: Advanced indicators & Journal impact factor
Citation analysis: Foundations
Citation analysis: h-index + Bibliographic databases
Citation distributions and citation dynamics
Collaboration
Country-specific case studies
Gender differences
Interdisciplinarity
Patents + Nanotechnology
Peer review
Social sciences and humanities
University rankings
Webometrics
Remaining publications

clustering *WoS*

clustering *metrics for WoS* by *fastest* methods

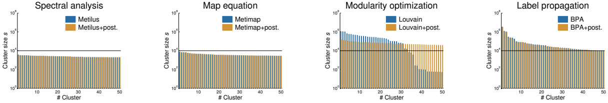
method	size	orders	degree	coverage	Flake	complexity
Metilus	50.0	2.3	5.9	27%	69%	30 min
Metimap	33.2	3.6	10.3	47%	45%	94 min
Louvain	334.4	5.7	18.5	84%	5%	52 min
BPA	105.4	6.2	18.5	84%	7%	66 min

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 $> 10^4$ *nodes* *repartitioned* by same method



study *summary*

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.