comparison of methods for clustering scientific publications based on citations

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IBMI seminar

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

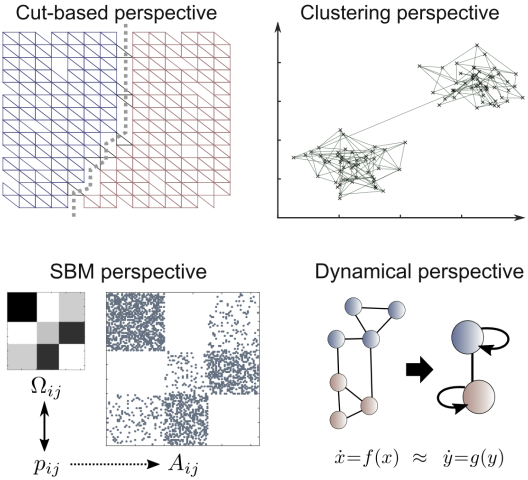
Scientometrics — journals Journal of Informetrics, Scientometrics and JASIST

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



Cut-based perspective

Clustering perspective

SBM perspective

Dynamical perspective

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

clustering methods

methods

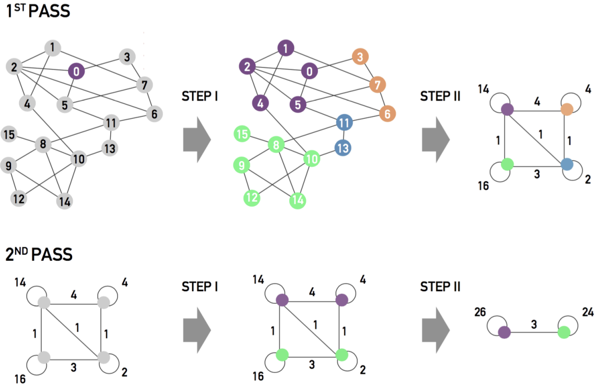
30 basic/derived graph partitioning/community detection methods

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

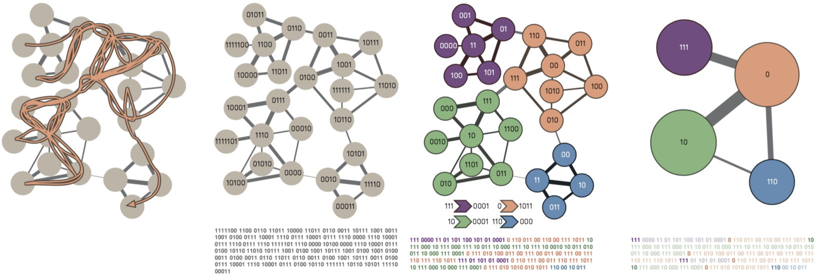
S|L — small|large clusters

methods Louvain



Blondel, Guillaume, Lambiotte & Lefebvre (2008) *J. Stat. Mech.*, P10008.

methods Infomap



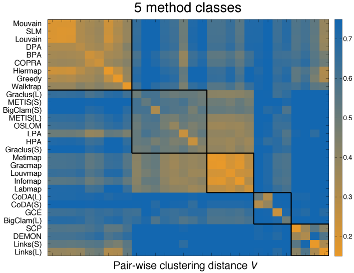
Rosvall & Bergstrom (2008) *P. Natl. Acad. Sci. USA* **105**(4), 1118–1123.

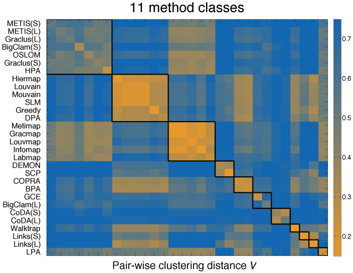
clustering distances

clusterings

distances between clusterings by considered methods

10/15 selected representative methods


5 method classes


11 method classes

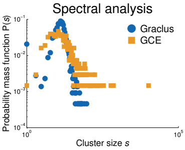
distance — normalized variation of information of clusterings

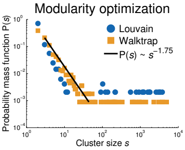
clustering distributions

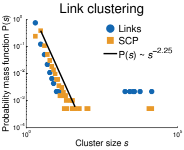
sizes

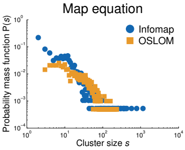
size distributions of clusterings by representative methods

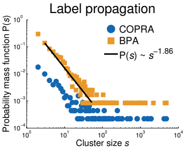
from homogeneous to inhomogeneous distributions


Spectral analysis


Modularity optimization


Link clustering


Map equation

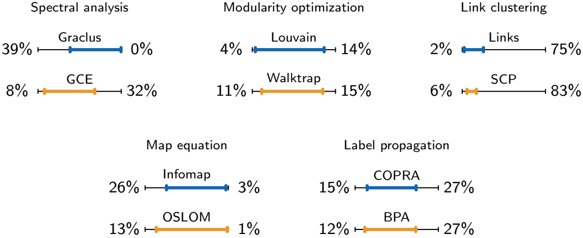

Label propagation

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

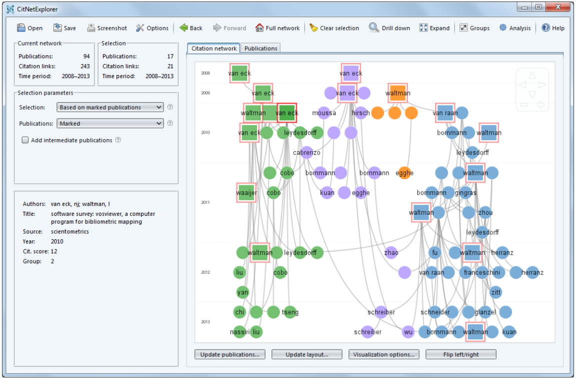
coverage — % links covered by clusters

clustering tool

assessment tool

CitNetExplorer for analyzing citation networks

freely available at www.citnetexplorer.nl



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 ambigous/heterogeneous clusters

clustering assessment

expert assessment

largest scientometrics clusters by Metimap and Infomap methods

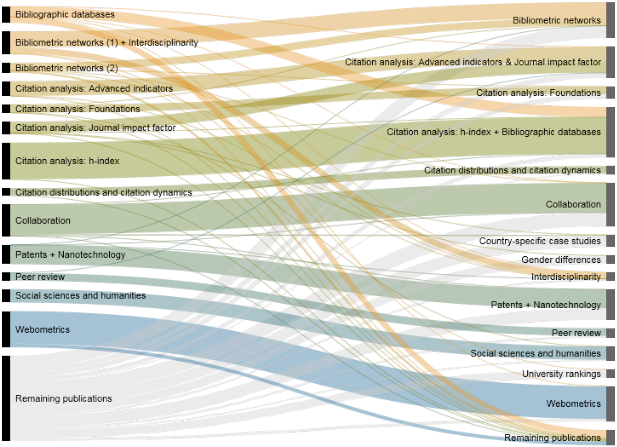
identified research topics of clusters covering ≈ 75% publications

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



clustering WoS

clustering metrics for WoS by fastest methods

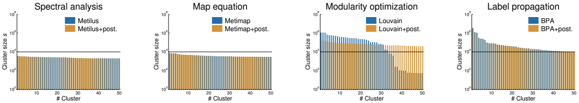
method	size	orders	degree	coverage	Flake	complexity
Metilus	50.0	2.3	5.9	27%	69%	30 min
Metimap	33.2	3.6	10.3	47%	45%	94 min
Louvain	334.4	5.7	18.5	84%	5%	52 min
BPA	105.4	6.2	18.5	84%	7%	66 min

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

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