Bibliographic networks analysis

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Introduction to bibliographic network analysis

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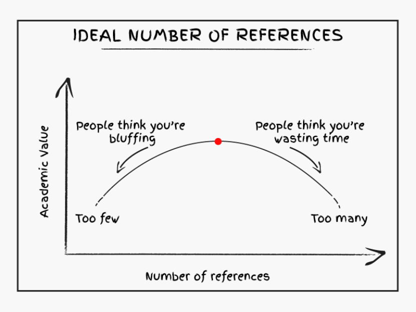
Outline



J-Gate

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Current version of slides (October 2, 2023 at 12 : 05): slides PDF
https://github.com/bavla/biblio/

Motivation

Bibliographic databases such as WoS (Web of Science), Scopus, Google Scholar, etc. contain a lot of interesting information.

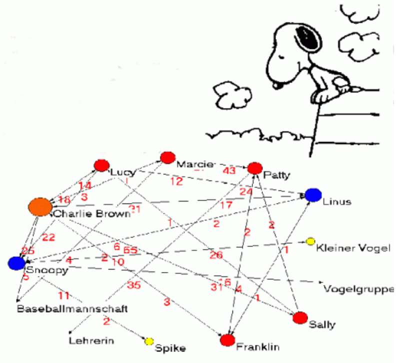
Usually, they are used for searching for works, evaluation of researchers or groups or institutions or journals, etc.

We can get more – higher-order bibliographic services.

- Student preparing a thesis. Which works to read?
- Journal editor. Select a reviewer for a given paper.
- Wrote a paper. To which journal to submit it?
- Preparing a project. Whom to invite to collaborate?
- etc.

Bibliographic network analysis provides methods to support such services.

Networks



Alexandra Schuler/ Marion Laging-Glaser: Analyse von Snoopy Comics

A *network* is based on two sets – a set of *nodes* (vertices), that represent the selected *units*, and a set of *links* (lines), that represent *ties* between units. They determine a *graph*. A link can be *directed* – an *arc*, or *undirected* – an *edge*. Additional data about nodes or links may be known – their *properties* (attributes). For example: name/label, type, age, value, ...

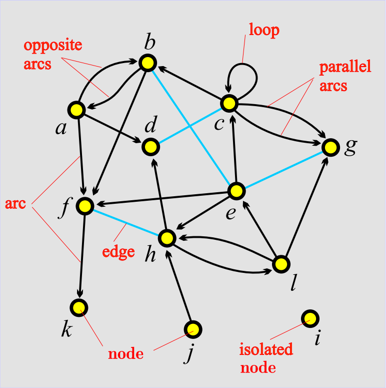
Network = Graph + Data

Network

A *network* $\mathcal{N} = (\mathcal{V}, \mathcal{L}, \mathcal{P}, \mathcal{W})$ consists of:

- a *graph* $\mathcal{G} = (\mathcal{V}, \mathcal{L})$, where $\mathcal{V}$ is the set of nodes, $\mathcal{A}$ is the set of arcs, $\mathcal{E}$ is the set of edges, and $\mathcal{L} = \mathcal{E} \cup \mathcal{A}$ is the set of links. $n = |\mathcal{V}|$, $m = |\mathcal{L}|$
- $\mathcal{P}$ *node value functions* / properties: $p : \mathcal{V} \to A$
- $\mathcal{W}$ *link value functions* / weights: $w : \mathcal{L} \to B$

Graph



unit, actor – node, vertex
tie, line – link, edge, arc

arc = directed link, (a, d)
a is the *initial* node,
d is the *terminal* node.

edge = undirected link, $(c : d)$
c and d are *end* nodes.

Types of networks

In a *two-mode* network $\mathcal{N} = ((\mathcal{V}_1, \mathcal{V}_2), \mathcal{L}, \mathcal{P}, \mathcal{W})$ its set of nodes is split to two subsets. Each link has its end-nodes in both sets.

In a *multi-relational* network $\mathcal{N} = (\mathcal{V}, (\mathcal{L}_i, i \in I), \mathcal{P}, \mathcal{W})$ the set of its links is partitioned into several mutally disjoint subsets – relations. (Subject Verb Object).

In a *temporal* network $\mathcal{N} = (\mathcal{V}, \mathcal{L}, \mathcal{T}, \mathcal{P}, \mathcal{W})$ the time $\mathcal{T}$ is added. To each node and to each link its *activity* set is assigned. Also properties and weights can change through time – temporal quantities.

In a *linked* or *multimodal* network $\mathcal{N} = ((\mathcal{V}_1, \ldots, \mathcal{V}_j), (\mathcal{L}_1, \ldots, \mathcal{L}_k), \mathcal{P}, \mathcal{W})$ the set of nodes $\mathcal{V}$ is partitioned into subsets (*modes*) $\mathcal{V}_i$, $\mathcal{L}_s \subseteq \mathcal{V}_p \times \mathcal{V}_q$, and properties and weights are usually partial functions.

A *collection* of networks consists of some networks with common subsets of nodes.

Types of networks can be combined – for example: a temporal two-mode multi-relational network.

Record from Web of Science

```
PT J
AU Dipple, H
   Evans, B
TI The Leicestershire Huntington’s disease support group: a social network
   analysis
SO HEALTH & SOCIAL CARE IN THE COMMUNITY
LA English
DT Article
C1 Rehabil Serv, Troon Way Business Ctr, Leicester LE4 9HA, Leics, England.
RP Dipple, H, Rehabil Serv, Troon Way Business Ctr, Sandringham
   Suite,Humberstone Lane, Leicester LE4 9HA, Leics, England.
CR BORGATTI SP, 1992, UCINET 4 VERSION 1 0
   FOLSTEIN S, 1989, HUNTINGTONS DIS DISO
   SCOTT J, 1991, SOCIAL NETWORK ANAL
NR 3
TC 3
PU BLACKWELL SCIENCE LTD
PI OXFORD
PA P O BOX 88, OSNEY MEAD, OXFORD OX2 ONE, OXON, ENGLAND
SN 0966-0410
J9 HEALTH SOC CARE COMMUNITY
JI Health Soc. Care Community
PD JUL
PY 1998
VL 6
IS 4
BP 286
EP 289
PG 4
SC Public, Environmental & Occupational Health; Social Work
GA 105UP
UT ISI:000075092200008
ER
```

WoS2Pajek

Networks from bibliographies

For data from the Web of Science (Knowledge) we can obtain the corresponding networks using the program `WoS2Pajek`:

- citation network **Ci**: works $\times$ works;
- authorship network **WA**: works $\times$ authors, for works without complete description only the first author is known;
- keywords network **WK**: works $\times$ keywords, only for works with complete description;
- journals network **WJ**: works $\times$ journals;
- partition *year* of works by the publication year;
- partition *CD* of works – complete description (1) / ISI name only (0);

Similar programs exist also for other bibliographic sources/formats: Scopus, BibTEX, Zentralblatt Math, Google Scholar, DBLP, IMDB, etc.

Example networks

SN5: WoS, January 2008, ("social network*" AND SO=(Social networks)) + most frequently cited works + around 100 SNA researchers. $|W| = 193376$, $|C| = 7950$, $|A| = 75930$, $|J| = 14651$, $|K| = 29267$.

ZBMath: Data from the Zentralblatt MATH data base for years 1990–2010. $|W| = 1339201$, $|A| = 557104$, $|J| = 3158$, $|K| = 143513$, $|M| = 12390$. paper.

PEERE: WoS, March 2016, using the queries `"peer review*"` and `refereeing` + manually prepared descriptions of frequently cited only works. `WoS2Pajek` produced networks with sets of the following sizes: works $|W| = 721547$, authors $|A| = 295849$, journals $|J| = 39988$, keywords $|K| = 36279$ and $m = 869821$ arcs. 22981 records were collected. paper

SNA18: WoS, January 2018, $|W| = 1297133/70792$, $|A| = 395971/93011$, $|K| = 32409/32409$, $|J| = 69146/8943$. paper

Statistics

Global/overall properties.

Extreme (minimal/maximal values) units.

Distributions of values.

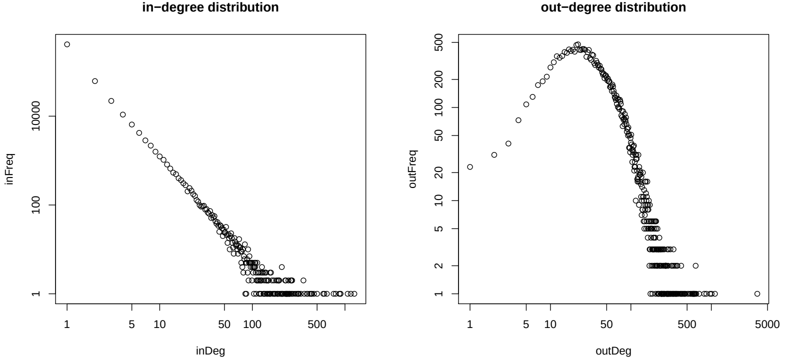
degree of node v, $\deg(v)$ = number of links with v as an endnode;
indegree of node v, $\text{indeg}(v)$ = number of links with v as a terminal node (endnode is both initial and terminal);
outdegree of node v, $\text{outdeg}(v)$ = number of links with v as an initial node.
weighted degree of node v, $\text{wdeg}(v)$ = sum of the weights of links with v as an endnode;
source node $v \Leftrightarrow \text{indeg}(v) = 0$
sink node $v \Leftrightarrow \text{outdeg}(v) = 0$

PEERE – most cited works: indegree in **Ci**

n	freq	first author	title
1	173	Cohen, J	Statistical Power Analysis for the Behavioral Sciences. Routledge,1988
2	164	Peters, DP	Peer-review practices of psychological journals - the fate of . . . Behav Brain Sci, 1982
3	151	Egger, M	Bias in meta-analysis detected by a simple, graphical test. Brit Med J, 1997
4	150	Stroup, DF	Meta-analysis of observational studies in epidemiology - A proposal for reporting. JAMA, 2000
5	135	Dersimonian, R	Metaanalysis in clinical-trials. Control Clin Trials, 1986
6	130	Zuckerma.H	Patterns of evaluation in science - institutionalisation, structure . . . Minerva, 1971
7	130	Higgins, JPT	Cochrane Handbook for Systematic Reviews of Interventions. Cochrane, 2011
8	126	Moher, D	Preferred Reporting Items for Systematic Reviews and Meta-Analyses. Plos Med, 2009
9	125	Higgins, JPT	Measuring inconsistency in meta-analyses. Brit Med J, 2003
10	121	Cicchetti, DV	The reliability of peer-review for manuscript and grant submissions - . . . Behav Brain Sci, 1991
11	119	Hirsch, JE	An index to quantify an individual's scientific research output. P Natl Acad Sci Usa, 2005
12	114	Mahoney, M	Publication prejudices: An experimental study of confirmatory bias . . . Cognitive T& R, 1977
13	114	van Rooyen, S	Effect of open peer review on quality of reviews and on reviewers' . . . Brit Med J, 1999
14	114	Easterbrook, PJ	Publication bias in clinical research. Lancet, 1991
15	110	Landis, JR	Measurement Of Observer Agreement For Categorical Data. Biometrics, 1977
16	109	Godlee, F	Effect on the quality of peer review of blinding reviewers and asking them to sign . . . JAMA, 1998
17	108	Horrobin, DF	The philosophical basis of peer-review and the suppression of innovation. JAMA, 1990
18	107	Moher, D	Preferred Reporting Items for Systematic Reviews and Meta-Analyses. Ann Intern Med, 2009
19	107	Jadad, AR	Assessing the quality of reports of randomized clinical trials. Control Clin Trials, 1996
20	105	Mcnutt, RA	The effects of blinding on the quality of peer-review - a randomized trial. JAMA, 1990
21	104	Cole, S	Chance and consensus in peer-review. Science, 1981
22	103	Moher, D	Improving the quality of reports of meta-analyses of randomised controlled trials. Lancet, 1999
23	98	Justice, AC	Does masking author identity improve peer review quality? JAMA, 1998
24	97	Lock, S	A Difficult Balance: Editorial Peer Review in Medicine. Nuffield Trust, 1985
25	95	van Rooyen, S	Effect of blinding and unmasking on the quality of peer review - A randomized trial. JAMA, 1998
26	92	Black, N	What makes a good reviewer and a good review for a general medical journal? JAMA, 1998
27	91	Scherer, RW	Full publication of results initially presented in abstracts - a metaanalysis. JAMA, 1994
28	90	Higgins, JPT	Quantifying heterogeneity in a meta-analysis. Stat Med, 2002
29	90	Smith, R	Peer review: a flawed process at the heart of science and journals. J Roy Soc Med, 2006
30	87	Goodman, SN	Manuscript quality before and after peer-review and editing at . . . . Ann Intern Med, 1994
31	87	Chubin, D	Peerless Science: Peer Review and U.S. Science Policy. SUNY Press, 1990

Distributions

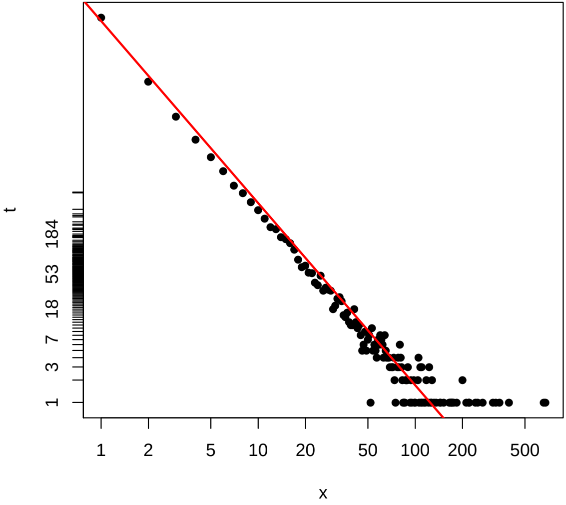
indegree and outdegree in citation network



The indegree distribution is "scale-free"-like. The parameters can be determined using the package of Clauset, Shalizi and Newman. See also Stumpf, et al.: Critical Truths About Power Laws.

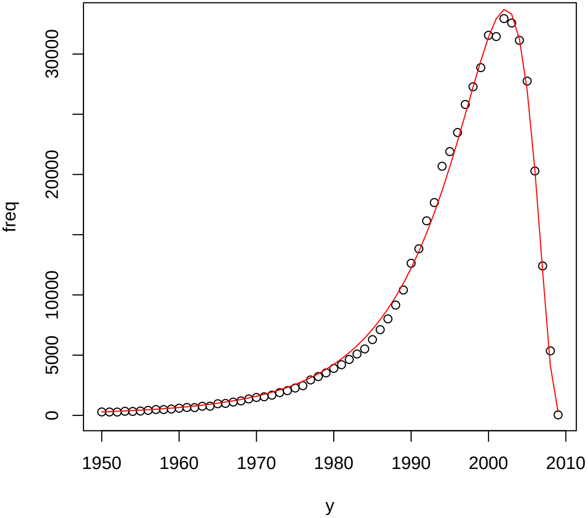
Distributions

SN5 citation network input degrees – scale-free fit

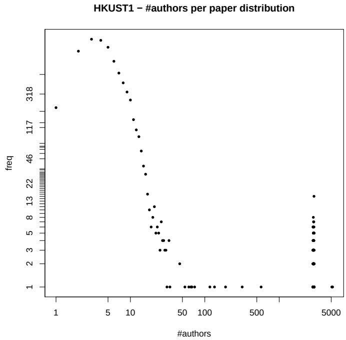


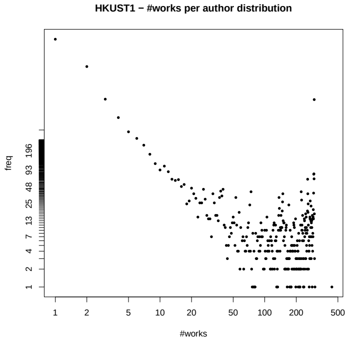
Distributions

year partition lognormal distribution fit



Distributions



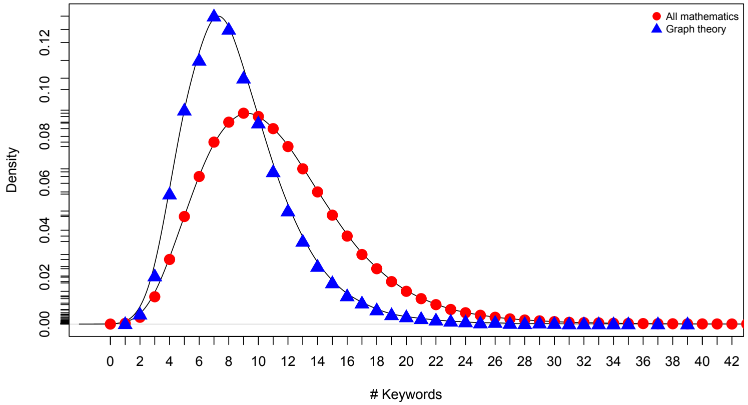


The Hong Kong University of Science and Technology (HKUST) 2017–2019

5215 co-authors: The ATLAS collaboration, & The CMS collaboration (2019). Combinations of single-top-quark production cross-section measurements and $|f\ LV\ Vtb|$ determinations at $\sqrt{s} = 7$ and 8 TeV with the ATLAS and CMS experiments. Journal of High Energy Physics, 2019(5), Article 88. https://doi.org/10.1007/JHEP05(2019)088 / Springer

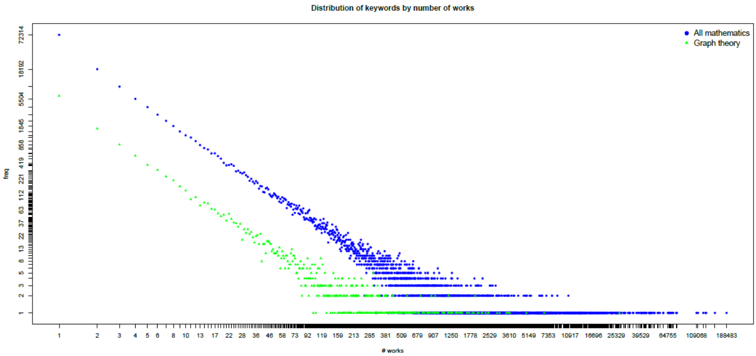
Distributions

number of keywords in **ZBMath**



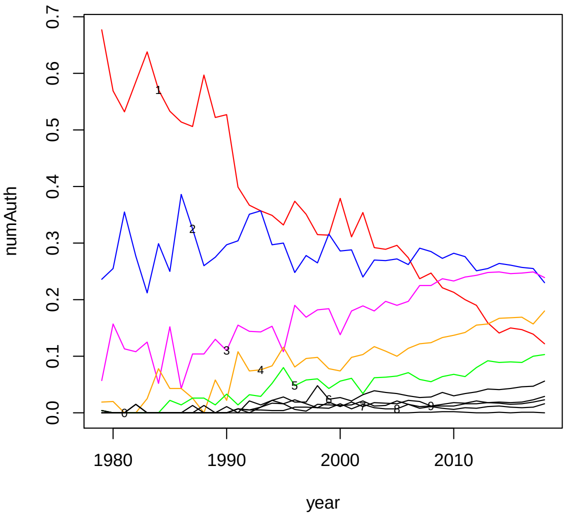
Distributions

keywords by the number of works using a keyword in their description



Temporal distribution

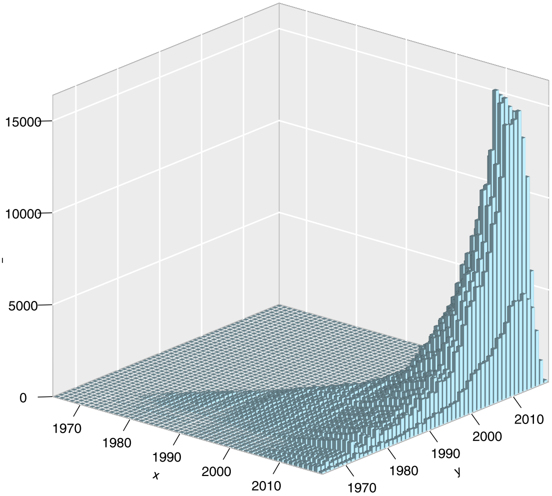
Number of authors SNA 2018



SocNet

Citations between years

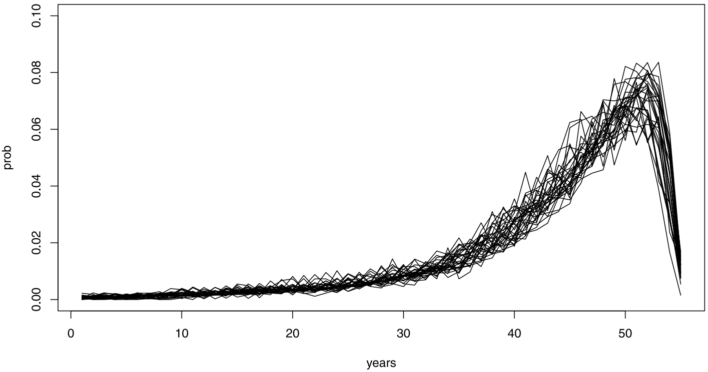
SNA 2018



SocNet

Citations per year

SNA 2018; normalized curves



SocNet

Citation networks

In a given set of works/nodes W (articles, books, reports, etc.) we introduce a *citing relation* $\mathbf{Ci} \subseteq W \times W$

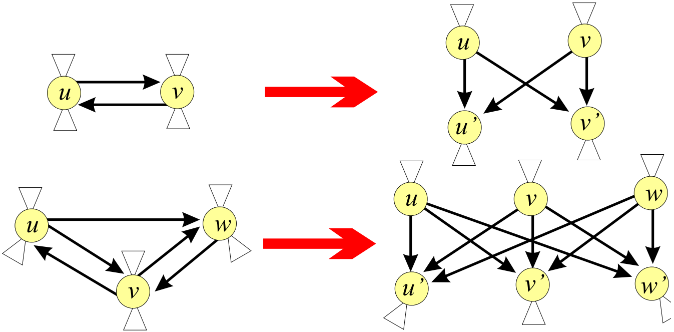
$$u \, \mathbf{Ci} \, v \equiv u \text{ cites } v$$

which determines a *citation network* $\mathcal{N} = (W, \mathbf{Ci})$.

A citing relation is usually *irreflexive* (no loops) and (almost) *acyclic*. We shall assume that it has these two properties.

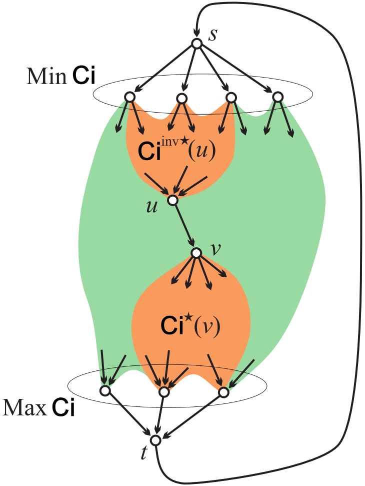
Since in real-life citation networks, the strong components are small (usually 2 or 3 nodes) we can transform such a network into an acyclic network by shrinking strong components and deleting loops.

A better way is the preprint transformation.



Transforming a citation network into an acyclic network using the preprint transformation.

Standardized citation network



We assume that the citation relation **Ci** is acyclic. It is useful to transform a citation network to its *standardized* form by adding a common *source* node $s \notin W$ and a common *sink* node $t \notin W$. The source s is linked by an arc to all minimal elements of **Ci**; and all maximal elements of **Ci** are linked to the sink t. We add also the 'feedback' arc (t, s).

Search path count method

Hummon and Doreian

The *search path count* (SPC) method is based on counters $n(u, v)$ that count the number of different paths from s to t through the arc (u, v).

The values of counters $n(u, v)$ form a flow in the citation network – the *Kirchoff's vertex law* holds: For every node u in a standardized citation network *incoming flow* = *outgoing flow*:

$$\sum_{v:v\,\mathbf{Ci}\,u} n(v, u) = \sum_{v:u\,\mathbf{Ci}\,v} n(u, v)$$

The weight $n(t, s)$ equals to the total flow through network and provides a natural normalization of weights

$$w(u, v) = \frac{n(u, v)}{n(t, s)} \quad \Rightarrow \quad 0 \leq w(u, v) \leq 1$$

and if C is a minimal arc-cut-set $\sum_{(u,v)\in C} w(u, v) = 1$.

The value $w(u, v)$ is equal to the probability that a random s-t path passes through the arc (u, v).

Cuts

The standard approach to find interesting groups inside a network is based on properties/weights – they can be *measured* or *computed* from network structure (for example Kleinberg's hubs and authorities).

The *node cut* of a network $\mathcal{N} = (\mathcal{V}, \mathcal{L}, p)$, $p : \mathcal{V} \to \mathbb{R}$, at selected level t is a subnetwork $\mathcal{N}(t) = (\mathcal{V}', \mathcal{L}(\mathcal{V}'), p)$, determined by the set

$$\mathcal{V}' = \{v \in \mathcal{V} : p(v) \geq t\}$$

and $\mathcal{L}(\mathcal{V}')$ is the set of links from $\mathcal{L}$ that have both endnodes in $\mathcal{V}'$.

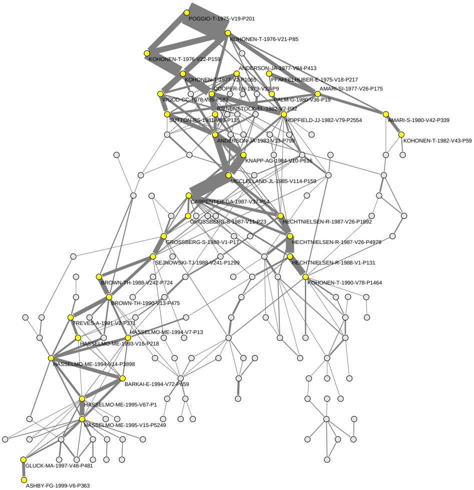
The *link cut* of a network $\mathcal{N} = (\mathcal{V}, \mathcal{L}, w)$, $w : \mathcal{L} \to \mathbb{R}$, at selected level t is a subnetwork $\mathcal{N}(t) = (\mathcal{V}(\mathcal{L}'), \mathcal{L}', w)$, determined by the set

$$\mathcal{L}' = \{e \in \mathcal{L} : w(e) \geq t\}$$

and $\mathcal{V}(\mathcal{L}')$ is the set of all endnodes of the links from $\mathcal{L}'$.

Citation weights

Link cut for SPC in SOM



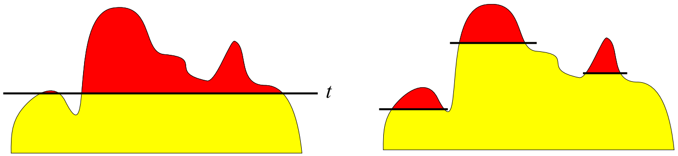
Main subnetwork (arc cut at level 0.007) of the SOM (selforganizing maps) citation network (4470 nodes, 12731 arcs).

For visualization of acyclic networks in Pajek use the macro `layers`.

See paper.

Islands

If we represent a given or computed value of nodes / links as a height of nodes / links and we immerse the network into a water up to selected level we get *islands*. Varying the level we get different islands.



We developed very efficient algorithms to determine the islands hierarchy and to list all the islands of selected sizes.
See details.

. . . Islands

Islands are very general and efficient approach to determine the 'important' subnetworks in a given network.
We have to express the goals of our analysis with a related property of the nodes or weight of the links. Using this property we determine the islands of an appropriate size (in the interval k to K).

In large networks we can get many islands which we have to inspect individually and interpret their content.
An important property of the islands is that they identify locally important subnetworks on different levels. Therefore they detect also emerging groups.

The set of nodes $\mathcal{C} \subseteq \mathcal{V}$ is a *local node peak*, if it is a regular node island and all of its nodes have the same value. Node island with a single local node peak is called a *simple node island*. In similar way we define simple link island.

. . . Islands

A set of nodes $C \subseteq \mathcal{V}$ is a *regular node island* in a network $\mathcal{N} = (\mathcal{V}, \mathcal{L}, p)$, $p : \mathcal{V} \to \mathbb{R}$ iff it induces a connected subgraph and the nodes from the island are 'higher' than the neighboring nodes

$$\max_{u \in N(C)} p(u) < \min_{v \in c} p(v)$$

A set of nodes $C \subseteq \mathcal{V}$ is a *regular link island* in a network $\mathcal{N} = (\mathcal{V}, \mathcal{L}, w)$, $w : \mathcal{L} \to \mathbb{R}$ iff it induces a connected subgraph and the links inside the island are 'stronger related' among them than with the neighboring nodes – in $\mathcal{N}$ there exists a spanning tree $\mathcal{T}$ over C such that

$$\max_{(u,v) \in \mathcal{L}, u \notin C, v \in C} w(u, v) < \min_{(u,v) \in \mathcal{T}} w(u, v)$$

A *simple island* is an island with only one peak.

US patents

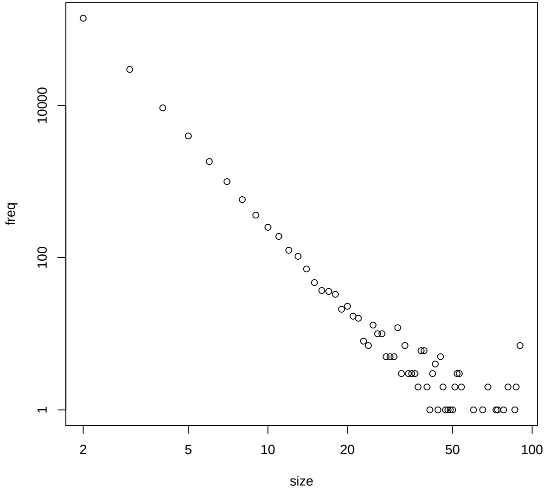
US patents network (Nber, US Patents) has 3774768 nodes and16522438 arcs (1 loop). Without the loop it is acyclic. The weight of an arc is the proportion of paths through the arc from some initial node to some terminal node. We determined al (2,90)-link islands. The corresponding subnetwork has 470137 nodes, 307472 arcs and different k: C_2 =187610, C_5 =8859, C_{30} =101, C_{50} =30, ... islands. Rolex

[1]	0	139793	29670	9288	3966	1827	997	578	362	250
[11]	190	125	104	71	47	37	36	33	21	23
[21]	17	16	8	7	13	10	10	5	5	5
[31]	12	3	7	3	3	3	2	6	6	2
[41]	1	3	4	1	5	2	1	1	1	1
[51]	2	3	3	2	0	0	0	0	0	1
[61]	0	0	0	0	1	0	0	2	0	0
[71]	0	0	1	1	0	0	0	1	0	0
[81]	2	0	0	0	0	1	2	0	0	7

The *Main path* starts in a link with the largest SPC weight and expands in both directions following the adjacent link with the largest SPC weight.

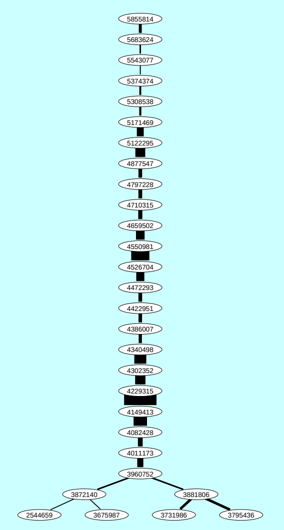
The *CPM path* is determined using the Critical Path Method from Operations Research (the sum of SPC weights along a path is maximal).

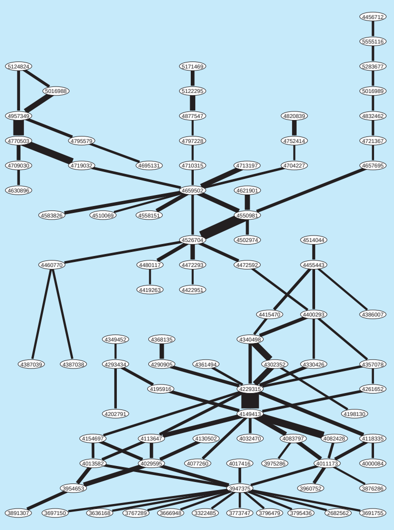
Distribution of island size



Main path and main island in US Patents

Nber, US Patents; $n = 3774768$, $m = 16522438$





Main island – Liquid crystal display

Table 1: Patents on the liquid-crystal display

patent	date	author(s) and title
2544659	Mar 13, 1951	Dreyer. Dichroic light-polarizing sheet and the like and the formation and use thereof
2682562	Jun 29, 1954	Wender, et al. Reduction of aromatic carbinols
3322485	May 30, 1967	Williams. Electro-optical elements utilazing an organic nematic compound
3636168	Jan 18, 1972	Josephson. Preparation of polynuclear aromatic compounds
3666948	May 30, 1972	Mechlowitz, et al. Liquid crystal termal imaging system having an undisturbed image on a disturbed background
3675987	Jul 11, 1972	Rafuse. Liquid crystal compositions and devices
3691755	Sep 19, 1972	Girard. Clock with digital display
3697150	Oct 10, 1972	Wysochi. Electro-optic systems in which an electrophoretic-like or dipolar material is dispersed throughout a liquid crystal to reduce the turn-off time
3731986	May 8, 1973	Fergason. Display devices utilizing liquid crystal light modulation
3767289	Oct 23, 1973	Aviram, et al. Class of stable trans-stilbene compounds, some displaying nematic mesophases at or near room temperature and others in a range up to 100°C
3773747	Nov 20, 1973	Steinstrasser. Substituted azoxy benzene compounds
3795436	Mar 5, 1974	Boller, et al. Nematogenic material which exhibit the Kerr effect at isotropic temperatures
3796479	Mar 12, 1974	Helfrich, et al. Electro-optical light-modulation cell utilizing a nematogenic material which exhibits the Kerr effect at isotropic temperatures
3872140	Mar 18, 1975	Klanderman, et al. Liquid crystalline compositions and method
3876286	Apr 8, 1975	Deutscher, et al. Use of nematic liquid crystalline substances
3881806	May 6, 1975	Suzuki. Electro-optical display device
3891307	Jun 24, 1975	Tsukamoto, et al. Phase control of the voltages applied to opposite electrodes for a cholesteric to nematic phase transition display
3947375	Mar 30, 1976	Gray, et al. Liquid crystal materials and devices
3954653	May 4, 1976	Yamazaki. Liquid crystal composition having high dielectric anisotropy and display device incorporating same
3960752	Jun 1, 1976	Klanderman, et al. Liquid crystal compositions
3975286	Aug 17, 1976	Oh. Low voltage actuated field effect liquid crystals compositions and method of synthesis
4000084	Dec 28, 1976	Hsieh, et al. Liquid crystal mixtures for electro-optical display devices
4011173	Mar 8, 1977	Steinstrasser. Modified nematic mixtures with positive dielectric anisotropy
4013582	Mar 22, 1977	Gavrilovic. Liquid crystal compounds and electro-optic devices incorporating them
4017416	Apr 12, 1977	Inukai, et al. P-cyanophenyl 4-alkyl-4'-biphenylcarboxylate, method for preparing same and liquid crystal compositions using same
4029595	Jun 14, 1977	Ross, et al. Novel liquid crystal compounds and electro-optic devices incorporating them
4032470	Jun 28, 1977	Bloom, et al. Electro-optic device
4077260	Mar 7, 1978	Gray, et al. Optically active cyano-biphenyl compounds and liquid crystal materials containing them
4082428	Apr 4, 1978	Hsu. Liquid crystal composition and method

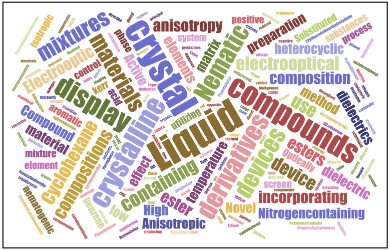
Table 2: Patents on the liquid-crystal display

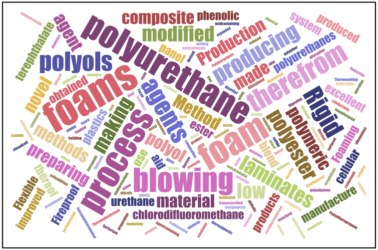
patent	date	author(s) and title
4083797	Apr 11, 1978	Oh. Nematic liquid crystal compositions
4113647	Sep 12, 1978	Coates, et al. Liquid crystalline materials
4118335	Oct 3, 1978	Krause, et al. Liquid crystalline materials of reduced viscosity
4130502	Dec 19, 1978	Eidenschink, et al. Liquid crystalline cyclohexane derivatives
4149413	Apr 17, 1979	Gray, et al. Optically active liquid crystal mixtures and liquid crystal devices containing them
4154697	May 15, 1979	Eidenschink, et al. Liquid crystalline hexahydroterphenyl derivatives
4195916	Apr 1, 1980	Coates, et al. Liquid crystal compounds
4198130	Apr 15, 1980	Boller, et al. Liquid crystal mixtures
4202791	May 13, 1980	Sato, et al. Nematic liquid crystalline materials
4229315	Oct 21, 1980	Krause, et al. Liquid crystalline cyclohexane derivatives
4261652	Apr 14, 1981	Gray, et al. Liquid crystal compounds and materials and devices containing them
4290905	Sep 22, 1981	Kanbe. Ester compound
4293434	Oct 6, 1981	Deutscher, et al. Liquid crystal compounds
4302352	Nov 24, 1981	Eidenschink, et al. Fluorophenylcyclohexanes, the preparation thereof and their use as components of liquid crystal dielectrics
4330426	May 18, 1982	Eidenschink, et al. Cyclohexylbiphenyls, their preparation and use in dielectrics and electrooptical display elements
4340498	Jul 20, 1982	Sugimori. Halogenated ester derivatives
4349452	Sep 14, 1982	Osman, et al. Cyclohexylcyclohexanoates
4357078	Nov 2, 1982	Carr, et al. Liquid crystal compounds containing an alicyclic ring and exhibiting a low dielectric anisotropy and liquid crystal materials and devices incorporating such compounds
4361494	Nov 30, 1982	Osman, et al. Anisotropic cyclohexyl cyclohexylmethyl ethers
4368135	Jan 11, 1983	Osman. Anisotropic compounds with negative or positive DC-anisotropy and low optical anisotropy
4386007	May 31, 1983	Krause, et al. Liquid crystalline naphthalene derivatives
4387038	Jun 7, 1983	Fukui, et al. 4-(Trans-4'-alkylcyclohexyl) benzoic acid 4'"-cyano-4"-biphenylyl esters
4387039	Jun 7, 1983	Sugimori, et al. Trans-4-(trans-4'-alkylcyclohexyl)-cyclohexane carboxylic acid 4'"-cyanobiphenyl ester
4400293	Aug 23, 1983	Romer, et al. Liquid crystalline cyclohexylphenyl derivatives
4415470	Nov 15, 1983	Eidenschink, et al. Liquid crystalline fluorine-containing cyclohexylbiphenyls and dielectrics and electro-optical display elements based thereon
4419263	Dec 6, 1983	Praefcke, et al. Liquid crystalline cyclohexylcarbonitrile derivatives
4422951	Dec 27, 1983	Sugimori, et al. Liquid crystal benzene derivatives
4455443	Jun 19, 1984	Takatsu, et al. Nematic halogen Compound
4456712	Jun 26, 1984	Christie, et al. Bismaleimide triazine composition
4460770	Jul 17, 1984	Petrzilka, et al. Liquid crystal mixture
4472293	Sep 18, 1984	Sugimori, et al. High temperature liquid crystal substances of four rings and liquid crystal compositions containing the same
4472592	Sep 18, 1984	Takatsu, et al. Nematic liquid crystalline compounds
4480117	Oct 30, 1984	Takatsu, et al. Nematic liquid crystalline compounds
4502974	Mar 5, 1985	Sugimori, et al. High temperature liquid-crystalline ester compounds
4510069	Apr 9, 1985	Eidenschink, et al. Cyclohexane derivatives

Table 3: Patents on the liquid-crystal display

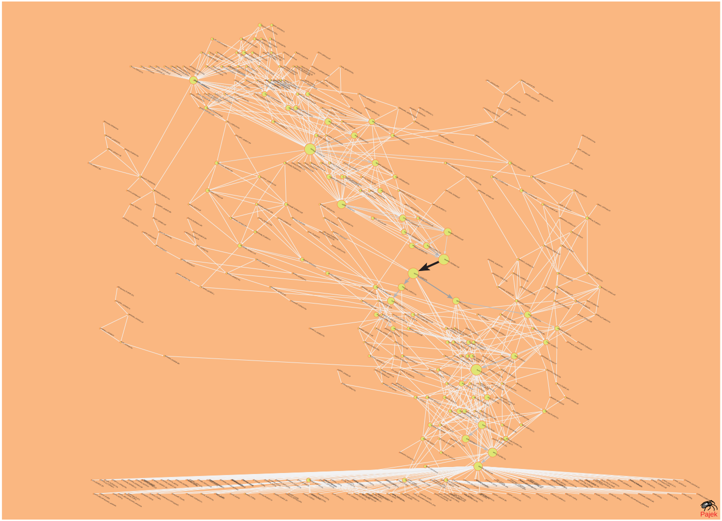
patent	date	author(s) and title
4514044	Apr 30, 1985	Gunjima, et al. 1-(Trans-4-alkylcyclohexyl)-2-(trans-4'-(p-substituted phenyl) cyclohexyl)ethane and liquid crystal mixture
4526704	Jul 2, 1985	Petrzilka, et al. Multiring liquid crystal esters
4550981	Nov 5, 1985	Petrzilka, et al. Liquid crystalline esters and mixtures
4558151	Dec 10, 1985	Takatsu, et al. Nematic liquid crystalline compounds
4583826	Apr 22, 1986	Petrzilka, et al. Phenylethanes
4621901	Nov 11, 1986	Petrzilka, et al. Novel liquid crystal mixtures
4630896	Dec 23, 1986	Petrzilka, et al. Benzonitriles
4657695	Apr 14, 1987	Saito, et al. Substituted pyridazines
4659502	Apr 21, 1987	Fearon, et al. Ethane derivatives
4695131	Sep 22, 1987	Balkwill, et al. Disubstituted ethanes and their use in liquid crystal materials and devices
4704227	Nov 3, 1987	Krause, et al. Liquid crystal compounds
4709030	Nov 24, 1987	Petrzilka, et al. Novel liquid crystal mixtures
4710315	Dec 1, 1987	Schad, et al. Anisotropic compounds and liquid crystal mixtures therewith
4713197	Dec 15, 1987	Eidenschink, et al. Nitrogen-containing heterocyclic compounds
4719032	Jan 12, 1988	Wachtler, et al. Cyclohexane derivatives
4721367	Jan 26, 1988	Yoshinaga, et al. Liquid crystal device
4752414	Jun 21, 1988	Eidenschink, et al. Nitrogen-containing heterocyclic compounds
4770503	Sep 13, 1988	Buchecker, et al. Liquid crystalline compounds
4795579	Jan 3, 1989	Vauchier, et al. 2,2'-difluoro-4-alkoxy-4'-hydroxydiphenyls and their derivatives, their production process and their use in liquid crystal display devices
4797228	Jan 10, 1989	Goto, et al. Cyclohexane derivative and liquid crystal composition containing same
4820839	Apr 11, 1989	Krause, et al. Nitrogen-containing heterocyclic esters
4832462	May 23, 1989	Clark, et al. Liquid crystal devices
4877547	Oct 31, 1989	Weber, et al. Liquid crystal display element
4957349	Sep 18, 1990	Clerc, et al. Active matrix screen for the color display of television pictures, control system and process for producing said screen
5016988	May 21, 1991	Iimura. Liquid crystal display device with a birefringent compensator
5016989	May 21, 1991	Okada. Liquid crystal element with improved contrast and brightness
5122295	Jun 16, 1992	Weber, et al. Matrix liquid crystal display
5124824	Jun 23, 1992	Kozaki, et al. Liquid crystal display device comprising a retardation compensation layer having a maximum principal refractive index in the thickness direction
5171469	Dec 15, 1992	Hittich, et al. Liquid-crystal matrix display
5283677	Feb 1, 1994	Sagawa, et al. Liquid crystal display with ground regions between terminal groups
5308538	May 3, 1994	Weber, et al. Supertwist liquid-crystal display
5374374	Dec 20, 1994	Weber, et al. Supertwist liquid-crystal display
5543077	Aug 6, 1996	Rieger, et al. Nematic liquid-crystal composition
5555116	Sep 10, 1996	Ishikawa, et al. Liquid crystal display having adjacent electrode terminals set equal in length
5683624	Nov 4, 1997	Sekiguchi, et al. Liquid crystal composition
5855814	Jan 5, 1999	Matsui, et al. Liquid crystal compositions and liquid crystal display elements

Word clouds for LCD island and foam island

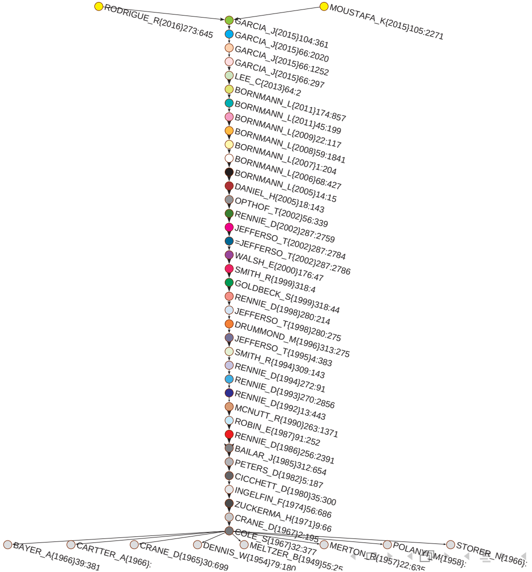




Main SPC island in SN5



PEERE – Main path



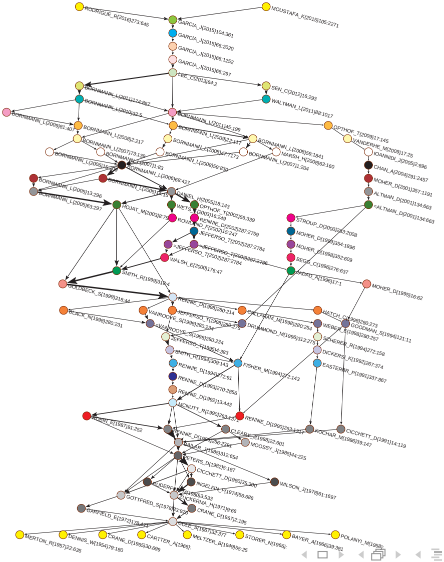
PEERE – List of publications on main path

year	first author	title	journal
1949	Meltzer BN	The productivity of social scientists	AmJSociol
1954	Dennis W	Bibliographies of eminent scientists	ScientificM
1957	Merton RK	Priorities in scientific discovery - a chapter in the sociology of sci...	AmSociolRev
1958	Polanyi M	Personal Knowledge: Towards a Post-Critical Philosophy	UPChicago
1965	Crane D	Scientists at major and minor universities	AmSociolRev
1966	Bayer AE	Some correlates of citation measure of productivity in science	SociolEduc
1966	Storer NW	The Social System of Science	HRW
1966	Cartter A	An Assessment of Quality in Graduate Education	ACE
1967	Crane D	Gatekeepers of science - some factors affecting selection...	AmSociol
1967	Cole S	Scientific output and recognition - study in operation of reward...	AmSociolRev
1971	Zuckerman H	Patterns of evaluation in science - institutionalisation, struct...	Minerva
1974	Ingelfinger FJ	Peer review in biomedical publication	AmJMed
1980	Cicchetti DV	Reliability of reviews for the american-psychologist	AmPsychol
1982	Peters DP	Peer-review practices of psychological journals - the fate...	BehavBrainSci
1985	Bailar JC	Journal peer-review - the need for a research agenda	NewEnglJMed
1986	Rennie D	Guarding the guardians - a conference on editorial peer-review	Jama
1987	Robin ED	Peer-review in medical journals	Chest
1990	Mcnutt RA	The effects of blinding on the quality of peer-review	Jama
1992	Rennie D	Suspended judgment - editorial peer-review - let us put it on trial	ControlClinTrials
1993	Rennie D	More peering into editorial peer-review	Jama
1994	Rennie D	The 2nd international-congress on peer-review in biomedical...	Jama
1994	Smith R	Promoting research into peer-review	BritMedJ
1995	Jefferson T	Are guidelines for peer-reviewing economic evaluations necessary	HealthEcon
1996	Drummond M	Guidelines for authors and peer reviewers of economic submis...	BritMedJ
1998	Jefferson T	Evaluating the BMJ guidelines for economic submissions	Jama
1998	Rennie D	Peer review in Prague	Jama

PEERE – . . . List of works on main path

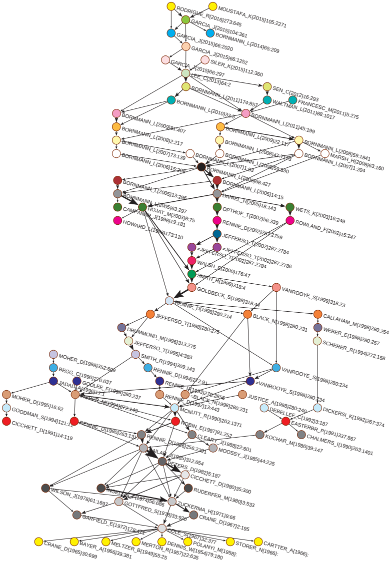
year	first author	title	journal
1999	Smith R	Opening up BMJ peer review - A beginning that should lead to...	BritMedJ
1999	Goldbeck-W. S	Evidence on peer review - scientific quality control or smokescreen?	BritMedJ
2000	Walsh E	Open peer review: a randomised controlled trial	BritJPsychiat
2002	Jefferson T	Effects of editorial peer review - A systematic review	Jama
2002	Rennie D	Fourth International Congress on Peer Review in Biomedical Pub...	Jama
2002	Opthof T	The significance of the peer review process against . . . bias	CardiovascRes
2002	Jefferson T	Measuring the quality of editorial peer review	Jama
2005	Bornmann L	Committee peer review at an international research foundation	ResEvaluat
2005	Daniel HD	Publications as a measure of scientific advancement and of...	LearnPubl
2006	Bornmann L	Selecting scientific excellence through committee peer review	Scientometrics
2007	Bornmann L	Convergent validation of peer review decisions using the h index	JInformetr
2008	Bornmann L	Selecting manuscripts for a high-impact journal through peer review	JAmSocInfSciTe
2009	Bornmann L	The luck of the referee draw: the effect of exchanging reviews	LearnPubl
2011	Bornmann L	Scientific Peer Review	AnnuRevInform
2011	Bornmann L	A multilevel modelling approach to investigating the predictive...	JRStatSocASta
2013	Lee CJ	Bias in peer review	JAmSocInfSciTe
2015	Garcia JA	The Principal-Agent Problem in Peer Review	JAssocInfSciTec
2015	Garcia JA	Adverse selection of reviewers	JAssocInfSciTec
2015	Garcia JA	Bias and effort in peer review	JAssocInfSciTec
2015	Garcia JA	The author-editor game	Scientometrics
2015	Moustafa K	Don't infer anything from unavailable data	Scientometrics
2016	Rodriguez-S. R	Evolutionary games between authors and their editors	ApplMathComp

PEERE – Main paths for 100 largest weights



PEERE – SPC – Link island1

$w_{max} = 0.297$



This island is very similar to the main paths for 100 largest weights and includes main path.

Matrix representation of a network

A simple (no parallel links) two-mode network $\mathcal{N}_A = ((I, K), L_A, a)$ can be represented by a matrix $\mathbf{A} = [A[i,k]]_{I \times K}$ where $A[i,k] = a(i,k)$ iff $(i,k) \in L_A$ and $\square$ otherwise.

We extend the codomain $\mathbb{R}$ of the weight $a : L_A \to \mathbb{R}$ with a *structural zero* $\square$ such that

$$\square + x = x \qquad \text{and} \qquad \square \cdot x = \square$$

In the case $a : L_A \to \mathbb{R}^+$ we can set $\square = 0$.

Multiplication of networks

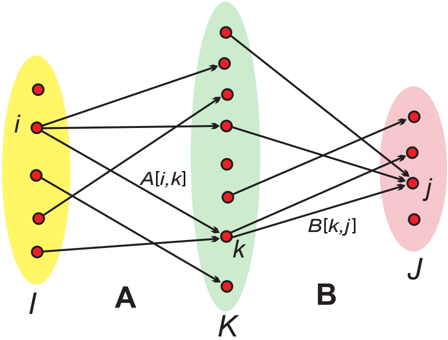
The product $\mathbf{C} = \mathbf{A} \cdot \mathbf{B}$ of two compatible matrices $\mathbf{A}_{I \times K}$ and $\mathbf{B}_{K \times J}$ is defined in the standard way

$$C[i,j] = \sum_{k \in K} A[i,k] \cdot B[k,j]$$

(semirings !!!)

The product of two compatible networks $\mathcal{N}_A = ((I,K), L_A, a)$ and $\mathcal{N}_B = ((K,J), L_B, b)$ is the network $\mathcal{N}_C = ((I,J), L_C, c)$ where $L_C = \{(i,j) : c[i,j] \neq \square\}$ and the weight c is determined by the matrix $\mathbf{C}$, $c(i,j) = C[i,j]$.

Multiplication of networks



If all weights in networks $\mathcal{N}_A$ and $\mathcal{N}_B$ are equal to 1, the value of $C[i,j]$ of $\mathbf{C} = \mathbf{A} \cdot \mathbf{B}$ counts the number of ways we can go from the node $i \in I$ to the node $j \in J$ passing through K, $C[i,j] = |N_A(i) \cap N_B^-(j)|$.

$$C[i,j] = \sum_{k \in N_A(i) \cap N_B^-(j)} A[i,k] \cdot B[k,j]$$

Multiplication of networks

The standard matrix multiplication has the complexity $O(|\mathcal{I}| \cdot |\mathcal{K}| \cdot |\mathcal{J}|)$ – it is too slow to be used for large networks. For sparse large networks, we can multiply much faster considering only nonzero elements.

for k **in** $\mathcal{K}$ **do**
  for (i, j) **in** $N_A^-(k) \times N_B(k)$ **do**
    if $\exists c_{i,j}$ **then** $c_{i,j} := c_{i,j} + a_{i,k} \cdot b_{k,j}$
    else new $c_{i,j} := a_{i,k} \cdot b_{k,j}$

In general, the multiplication of large sparse networks is a 'dangerous' operation since the result can 'explode' – it is not sparse.

Multiplication of networks

From the network multiplication algorithm we see that each intermediate node $k \in \mathcal{K}$ adds to a product network a complete two-mode subgraph $K_{N_A^-(k),N_B(k)}$ (or, in the case $\mathcal{I} = \mathcal{J}$, a complete subgraph $K_{N(k)}$). If both degrees $\deg_A(k) = |N_A^-(k)|$ and $\deg_B(k) = |N_B(k)|$ are large then already the computation of this complete subgraph has a quadratic (time and space) complexity – the result 'explodes'.

If at least one of the sparse networks $\mathcal{N}_A$ and $\mathcal{N}_B$ has small maximal degree on $\mathcal{K}$ then also the resulting product network $\mathcal{N}_C$ is sparse.

If for the sparse networks $\mathcal{N}_A$ and $\mathcal{N}_B$ there are in $\mathcal{K}$ only few nodes with large degree and no one among them with large degree in both networks then also the resulting product network $\mathcal{N}_C$ is sparse.

Outer product decomposition

For vectors $x = [x_1, x_2, \ldots, x_n]$ and $y = [y_1, y_2, \ldots, y_m]$ their *outer product* $x \circ y$ is defined as a matrix

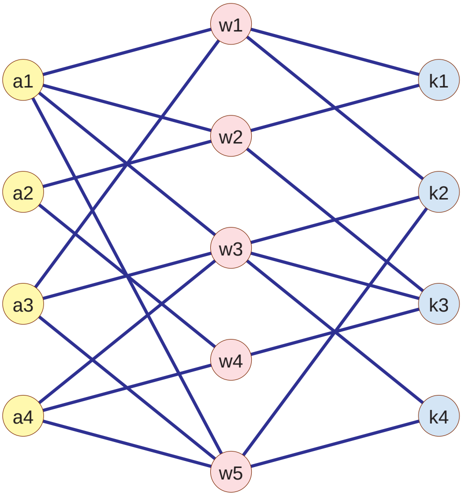
$$x \circ y = [x_i \cdot y_j]_{n \times m}$$

then we can express the product **C** of two compatible matrices **A** and **B** as the *outer product decomposition*

$$\mathbf{C} = \mathbf{A} \cdot \mathbf{B} = \sum_k \mathbf{H}_k \quad \text{where} \quad \mathbf{H}_k = \mathbf{A}[\cdot, k] \circ \mathbf{B}[k, \cdot],$$

$\mathbf{A}[., k]$ is the k-th column of matrix **A**, and $\mathbf{B}[k, .]$ is the k-th row of matrix **B**.

$WA^T \cdot WK$



Example

$$\mathbf{H} = \mathbf{AW} \cdot \mathbf{WK}, \quad \mathbf{WA} = \begin{array}{c c} & \begin{array}{cccc} a_1 & a_2 & a_3 & a_4 \end{array} \\ \begin{array}{c} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \end{array} & \begin{bmatrix} 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 1 \end{bmatrix} \end{array}, \quad \mathbf{WK} = \begin{array}{c c} & \begin{array}{cccc} k_1 & k_2 & k_3 & k_4 \end{array} \\ \begin{array}{c} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \end{array} & \begin{bmatrix} 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \end{bmatrix} \end{array}$$

$$\begin{array}{c c} \mathbf{H} & \begin{array}{cccc} k_1 & k_2 & k_3 & k_4 \end{array} \\ \begin{array}{c} a_1 \\ a_2 \\ a_3 \\ a_4 \end{array} & \begin{bmatrix} 2 & 3 & 2 & 2 \\ 1 & 0 & 2 & 0 \\ 1 & 3 & 1 & 2 \\ 0 & 2 & 2 & 2 \end{bmatrix} \end{array} = \begin{array}{c c} \mathbf{H}_1 & \begin{array}{cccc} k_1 & k_2 & k_3 & k_4 \end{array} \\ \begin{array}{c} a_1 \\ a_2 \\ a_3 \\ a_4 \end{array} & \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \end{array} + \begin{array}{c c} \mathbf{H}_2 & \begin{array}{cccc} k_1 & k_2 & k_3 & k_4 \end{array} \\ \begin{array}{c} a_1 \\ a_2 \\ a_3 \\ a_4 \end{array} & \begin{bmatrix} 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \end{array} +$$

$$\begin{array}{c c} \mathbf{H}_3 & \begin{array}{cccc} k_1 & k_2 & k_3 & k_4 \end{array} \\ \begin{array}{c} a_1 \\ a_2 \\ a_3 \\ a_4 \end{array} & \begin{bmatrix} 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 \end{bmatrix} \end{array} + \begin{array}{c c} \mathbf{H}_4 & \begin{array}{cccc} k_1 & k_2 & k_3 & k_4 \end{array} \\ \begin{array}{c} a_1 \\ a_2 \\ a_3 \\ a_4 \end{array} & \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \end{array} + \begin{array}{c c} \mathbf{H}_5 & \begin{array}{cccc} k_1 & k_2 & k_3 & k_4 \end{array} \\ \begin{array}{c} a_1 \\ a_2 \\ a_3 \\ a_4 \end{array} & \begin{bmatrix} 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{bmatrix} \end{array}$$

Derived networks

WA – works $\times$ authors – authorship network
WK – works $\times$ keywords
Ci – works $\times$ works – citation network
JD – journal $\times$ discipline

$\mathbf{AK} = \mathbf{WA}^T * \mathbf{WK}$ – authors $\times$ keywords
$\mathbf{Co} = \mathbf{WA}^T * \mathbf{WA}$ – coauthorship
$\mathbf{ACi} = \mathbf{WA}^T * \mathbf{Ci} * \mathbf{WA}$ – citations between authors
$\mathbf{DCi} = \mathbf{JD}^T * \mathbf{WJ}^T * \mathbf{Ci} * \mathbf{WJ} * \mathbf{JD}$ – citations between disciplines

Interpretation!!!

Projections

A standard approach to the analysis of a two-mode network $\mathcal{N}$ is to transform it into the corresponding one-mode networks determined by:

row projection to U: $\text{row}(\mathbf{A}) = \mathbf{A} \cdot \mathbf{A}^T$, or
column projection to V: $\text{col}(\mathbf{A}) = \mathbf{A}^T \cdot \mathbf{A}$

and analyze the obtained weighted network.

$$\text{col}(\mathbf{A}) = \mathbf{A}^T \cdot \mathbf{A} = \mathbf{A}^T \cdot (\mathbf{A}^T)^T = \text{row}(\mathbf{A}^{\mathbf{T}}), \quad \text{row}(\mathbf{A}) = \text{col}(\mathbf{A}^{\mathbf{T}})$$

Binary projections

In the following, we will consider a two-mode network $\mathcal{N} = ((W, A), L, wa)$ described with the corresponding binary matrix **WA**. To support our intuition, we can interpret it as an authorship network linking a work $w \in W$ to its authors from A.

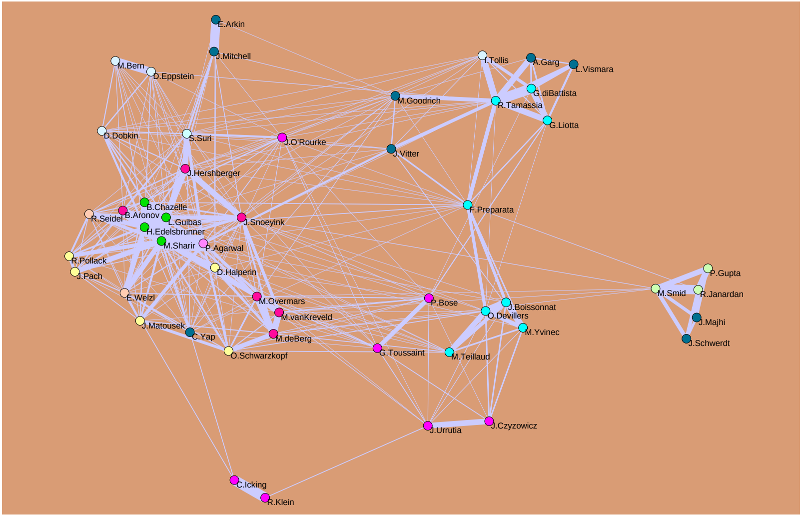
Its column projection $\mathbf{Co} = col(\mathbf{WA}) = \mathbf{WA}^T \cdot \mathbf{WA}$ has entries

$Co[a, b] = |N(a) \cap N(b)| = Co[b, a] = \#$ of works that authors a and b coauthored

Co is a *co-appearance* / coauthorship matrix.

$Co[a, a] = |N(a)| = \text{indeg}_{WA}(a) = \#$ of works (co)authored by the author a.

p_S-core at level 46 in Computational Geometry co-authorship network



… nodes

A real-life network $\mathcal{N}$ can contain nodes $w \in W$ of degree 0 (works with no author) and 1 (single author works). Works with no author do not contribute to the matrix **Co**. Single author works contribute only to the author's diagonal entry in the matrix **Co**.

We denote $W_{[d]} = \{w \in W : \deg(w) \geq d\}$ and
$\mathcal{N}_{[d]} = ((W_{[d]}, A), L(W_{[d]}), wa/W_{[d]})$.

Using the entries of the matrix **Co** we can express the *Salton's cosine similarity* between nodes a_i and a_j as

$$S(i,j) = cos[a_i, a_j] = \frac{Co[a_i, a_j]}{\sqrt{Co[a_i, a_i] \cdot Co[a_j, a_j]}}$$

Properties of Salton's cosine similarity

The Salton's cosine has the following properties

1. $S(i, j) \in [-1, 1]$
2. $S(i, j) = S(j, i)$
3. $S(i, i) = 1$
4. $wa_{ki} \in \mathbb{R}_0^+ \Rightarrow S(i, j) \in [0, 1]$
5. $S(\alpha i, \beta j) = S(i, j), \quad \alpha, \beta > 0$
6. $S(\alpha i, i) = 1, \quad \alpha > 0$

Total weight

The *total weight* of links in the network $\mathcal{N} = (V, L, w)$, $w : L \to \mathbb{R}$

$$T(\mathcal{N}) = \sum_{(u,v) \in L} w(u, v)$$

On the basis of outer product decomposition, we have

$$T(\mathbf{C}) = T(\sum_k \mathbf{H}_k) = \sum_k T(\mathbf{H}_k)$$

$$T(\mathbf{H}_k) = (\sum_i A[i, k]) \cdot (\sum_j B[k, j]) = \text{windeg}_A(k) \cdot \text{woutdeg}_B(k)$$

Therefore for **Co** we have $\mathbf{H}_w = \mathbf{K}_{N(w)}$ and

$$T(\mathbf{Co}) = \sum_{w \in W} \text{outdeg}_{WA}(w)^2$$

Structure of projection

In words

- a projection network is a sum of complete subgraphs;
- the contribution of a node w from the other set W to the total is $\mathrm{outdeg}(w)^2$.

This means that the nodes with a large degree in W are over-represented in the projection.

To make a contribution of each active node $k \in W_{[1]}$ equal to 1 we normalize matrices $\mathbf{A}$ and $\mathbf{B}$ such that for the normalized matrices $n(\mathbf{A})$ and $n(\mathbf{B})$ we have

$$\mathrm{windeg}_{n(A)}(k) = 1 \qquad \text{and} \qquad \mathrm{woutdeg}_{n(B)}(k) = 1$$

– *fractional approach*.

. . . fractional approach

We define the *normalized* matrices

$$n(\mathbf{WA}) = \mathrm{diag}(\frac{1}{\deg_{WA}})\mathbf{WA}, \quad n(\mathbf{WK}) = \mathrm{diag}(\frac{1}{\deg_{WK}})\mathbf{WK}$$

Then the *normalized product* matrix is

$$\mathbf{AKn} = n(\mathbf{WA})^T \cdot n(\mathbf{WK})$$

Denoting $\mathbf{F}_w = \frac{1}{\deg_{WA}(w)\deg_{WK}(w)}\mathbf{H}_w$ the outer product decomposition gets form

$$\mathbf{AKn} = \sum_w \mathbf{F}_w$$

Example

normalized matrices

$$\mathrm{diag}\left(\frac{1}{\deg_{WA}}\right) = \begin{array}{c c} & \begin{array}{ccccc} w_1 & w_2 & w_3 & w_4 & w_5 \end{array} \\ \begin{array}{c} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \end{array} & \begin{bmatrix} 1/2 & 0 & 0 & 0 & 0 \\ 0 & 1/2 & 0 & 0 & 0 \\ 0 & 0 & 1/3 & 0 & 0 \\ 0 & 0 & 0 & 1/2 & 0 \\ 0 & 0 & 0 & 0 & 1/3 \end{bmatrix} \end{array}$$

$$\mathrm{diag}\left(\frac{1}{\deg_{WK}}\right) = \begin{array}{c c} & \begin{array}{ccccc} w_1 & w_2 & w_3 & w_4 & w_5 \end{array} \\ \begin{array}{c} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \end{array} & \begin{bmatrix} 1/2 & 0 & 0 & 0 & 0 \\ 0 & 1/2 & 0 & 0 & 0 \\ 0 & 0 & 1/3 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1/2 \end{bmatrix} \end{array}$$

$$n(\mathbf{WA}) = \begin{array}{c c} & \begin{array}{cccc} a_1 & a_2 & a_3 & a_4 \end{array} \\ \begin{array}{c} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \end{array} & \begin{bmatrix} 1/2 & 0 & 1/2 & 0 \\ 1/2 & 1/2 & 0 & 0 \\ 1/3 & 0 & 1/3 & 1/3 \\ 0 & 1/2 & 0 & 1/2 \\ 1/3 & 0 & 1/3 & 1/3 \end{bmatrix} \end{array}, \quad n(\mathbf{WK}) = \begin{array}{c c} & \begin{array}{cccc} k_1 & k_2 & k_3 & k_4 \end{array} \\ \begin{array}{c} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \end{array} & \begin{bmatrix} 1/2 & 1/2 & 0 & 0 \\ 1/2 & 0 & 1/2 & 0 \\ 0 & 1/3 & 1/3 & 1/3 \\ 0 & 0 & 1 & 0 \\ 0 & 1/2 & 0 & 1/2 \end{bmatrix} \end{array}$$

...example

normalized matrices

$$\mathbf{F}_1 = \begin{array}{c} \\ a_1 \\ a_2 \\ a_3 \\ a_4 \end{array} \begin{array}{c} \begin{array}{cccc} k_1 & k_2 & k_3 & k_4 \end{array} \\ \begin{bmatrix} 1/4 & 1/4 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1/4 & 1/4 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \end{array} \qquad \mathbf{F}_5 = \begin{array}{c} \\ a_1 \\ a_2 \\ a_3 \\ a_4 \end{array} \begin{array}{c} \begin{array}{cccc} k_1 & k_2 & k_3 & k_4 \end{array} \\ \begin{bmatrix} 0 & 1/6 & 0 & 1/6 \\ 0 & 0 & 0 & 0 \\ 0 & 1/6 & 0 & 1/6 \\ 0 & 1/6 & 0 & 1/6 \end{bmatrix} \end{array}$$

$$\mathbf{AKn} = \mathbf{F} = \begin{array}{c} \\ a_1 \\ a_2 \\ a_3 \\ a_4 \end{array} \begin{array}{c} \begin{array}{cccc} k_1 & k_2 & k_3 & k_4 \end{array} \\ \begin{bmatrix} 0.50000 & 0.52778 & 0.36111 & 0.27778 \\ 0.25000 & 0.00000 & 0.75000 & 0.00000 \\ 0.25000 & 0.52778 & 0.11111 & 0.27778 \\ 0.00000 & 0.27778 & 0.61111 & 0.27778 \end{bmatrix} \end{array}$$

Fractional approach

The normalized 2-mode network $n(\mathbf{WA})$ has weights

$$n(WA)[w,a] = \frac{WA[w,a]}{\max(1, \mathrm{outdeg}_{WA}(w))}$$

$$\sum_{a \in A} n(WA)[w,a] = 1, \quad w \in W_{[1]}$$

Normalized projection $\mathbf{Cn} = n(\mathbf{WA})^T \cdot n(\mathbf{WA})$
Network: opposite arcs replaced by an edge with double weight.

$$T(\mathbf{Cn}) = |W_{[1]}|$$

Each work (with a least one author) has a value 1 that is distributed over the links of the projection.

. . . fractional approach
Collaborativness

Note: instead of the matrix $n(\mathbf{WA})$ we could use a matrix of authors' contributions $\mathbf{N} = [N[w,a]]$ such that $\sum_{a\in A} N[w,a] = 1$. Unfortunately, it is very difficult to get such data.

In the network $n(\mathbf{WA})$,

- $\text{indeg}_{n(WA)}(a) = \#$ of works (co-)authored by the author a
- $\text{windeg}_{n(WA)}(a) =$ fractional contribution of the author a to his/her works

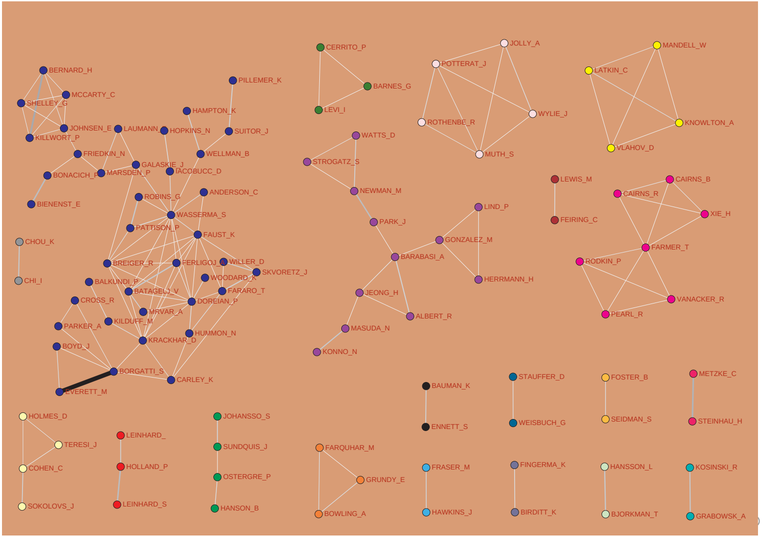
Self-sufficiency: $S(a) = \dfrac{\text{windeg}_{n(WA)}(a)}{\text{indeg}_{WA}(a)}$

Collaborativness: $K(a) = 1 - S(a)$

. . . fractional approach
SNA18 collaborativness

#	Author	Total # works	Total contri-bution	Collabora tivness, %	#	Author	Total # works	Total contri-bution	Collabora tivness, %
1	**LATKIN_C**	130	32.99	**75**	31	**EVERETT_M**	44	22.58	49
2	**VALENTE_T**	97	34.96	**64**	32	MORRIS_M	43	17.22	**60**
3	**DUNBAR_R**	91	40.02	**56**	33	**CONTRACT_N**	43	14.15	**67**
4	*NEWMAN_M*	81	**50.02**	38	34	**WHITE_H**	42	27.28	35
5	CHRISTAK_N	74	22.89	**69**	35	**SKVORETZ_J**	42	20.07	**52**
6	**DOREIAN_P**	72	**46.19**	36	36	*PENTLAND_A*	41	14.12	**66**
7	**CARLEY_K**	72	28.11	**61**	37	**MOODY_J**	40	17.7	**56**
8	**BURT_R**	71	**55.73**	22	38	SMITH_A	40	14.2	**65**
9	**BORGATTI_S**	71	29.72	**58**	39	**MARSDEN_P**	39	30.17	23
10	**SNIJDERS_T**	67	29.63	**56**	40	BERKMAN_L	39	14.3	**63**
11	*BARABASI_A*	67	27.61	**59**	41	**SMITH_M**	39	13.29	**66**
12	FOWLER_J	65	20.14	**69**	42	**KRACKHAR_D**	38	18.24	**52**
13	*KAZIENKO_P*	64	21.97	**66**	43	JACKSON_M	38	17.78	**53**
14	**ROBINS_G**	64	19.67	**69**	44	**THELWALL_M**	37	18.41	**50**
15	**WELLMAN_B**	63	36.43	42	45	**FRIEDKIN_N**	36	28.17	22
16	FALOUTSO_C	60	17.86	**70**	46	SINGH_A	36	14.5	**60**
17	RAHMAN_M	59	19.18	**67**	47	**WASSERMA_S**	35	15.64	**55**
18	**PATTISON_P**	58	18.94	**67**	48	**BRANDES_U**	35	14.39	**59**
19	**JOHNSON_J**	54	21.19	**61**	49	GONZALEZ_A	35	14.13	**60**
20	**MARTINEZ_M**	53	21.9	**59**	50	KLEINBER_J	34	15.05	**56**
21	*GONZALEZ_M*	52	17.76	**66**	51	FARINE_D	34	14.04	**59**
22	RODRIGUE_J	52	15.9	**69**	52	**BATAGELJ_V**	33	14.64	**56**
23	SCHNEIDE_J	52	13.89	**73**	53	**BREIGER_R**	31	19.73	36
24	**LEYDESDO_L**	51	33.28	35	54	WILLIAMS_A	31	14.5	**53**
25	**LITWIN_H**	50	32.42	35	55	**SCOTT_J**	28	17.54	37
26	RICE_E	48	13.09	**73**	56	*MASUDA_N*	28	14.26	49
27	**BONACICH_P**	46	34	26	57	**FREEMAN_L**	27	20.03	26
28	RODRIGUE_M	46	13.21	**71**	58	*WATTS_D*	27	13.67	49
29	NGUYEN_H	46	12.76	72	59	**LAZEGA_E**	26	14.17	46
30	CROFT_D	46	11.6	**75**	60	**FAUST_K**	25	13.5	46

p_S-core at level 0.75 in **Cn**(SN5)



Newman's normalization – strict coauthorship

Mark Newman proposed an alternative normalization that considers only coauthorship between different authors – single-author works and self-coauthorship are excluded.

The *Newman's normalized* 2-mode network $n'(\mathbf{WA})$ has weights

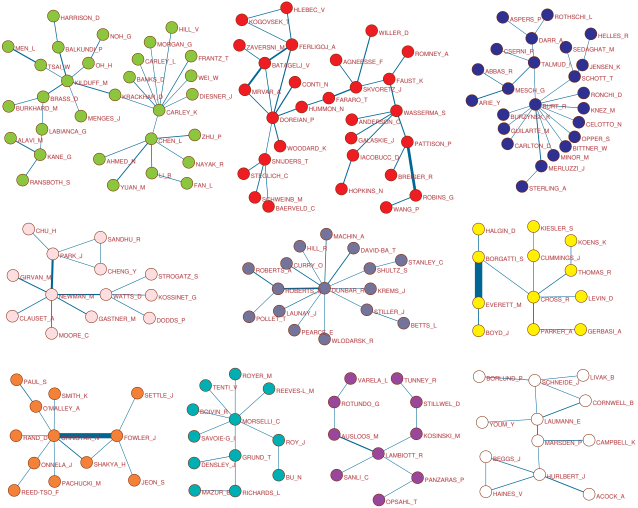
$$n'(WA)[w,a] = \begin{cases} \dfrac{WA[w,a]}{\deg(w)-1} & w \in W_{[2]} \\ 0 & \text{otherwise} \end{cases}$$

Strict projection $\quad \mathbf{Ct} = D_0(n(\mathbf{WA})^T \cdot n'(\mathbf{WA}))$.
$D_0(\mathbf{M})$ sets the diagonal of the square matrix $\mathbf{M}$ to 0.
Network: opposite arcs replaced by an edge with double weight.

$$T(\mathbf{Ct}) = |W_{[2]}|$$

Example: SNA18[18] /selected strict islands 10-30

$|W| = 70792$, $|A| = 93011$



Normalizations

In networks obtained from large two-mode networks, there are often huge differences in weights. Therefore it is not interesting to compare the nodes according to the raw data – the nodes with large weights will prevail. First, we have to *normalize* the network to make the weights comparable.

There exist several ways how to do this. Assume that the network is described with a square matrix $\mathbf{C}_{V \times V}$.

Balassa or activity normalization:

$$A[u, v] = \frac{C[u, v] \cdot T(C)}{\text{woutdeg}(u) \cdot \text{windeg}(v)}$$

If $A[u, v] > 1$ the measured weight is larger than expected.

$$c_B[u, v] = \log_2 A[u, v] \quad \text{for } A[u, v] > 0$$

. . . Normalizations

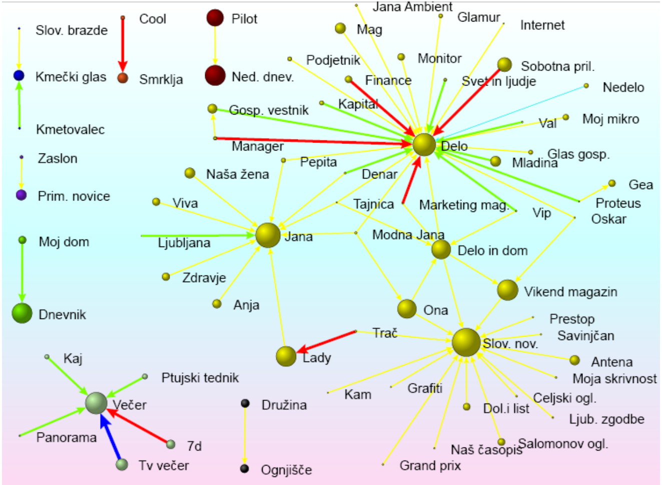
$$c_{\min}[u,v] = \frac{C[u,v]}{\min(C[u,u], C[v,v])} \qquad c_{\max}[u,v] = \frac{C[u,v]}{\max(C[u,u], C[v,v])}$$

$$c_{\mathrm{minDir}}[u,v] = \begin{cases} \dfrac{C[u,v]}{C[u,u]} & C[u,u] \leq C[v,v] \\ 0 & \textit{otherwise} \end{cases}$$

$$c_{\mathrm{maxDir}}[u,v] = \begin{cases} \dfrac{C[u,v]}{C[v,v]} & C[u,u] \leq C[v,v] \\ 0 & \textit{otherwise} \end{cases}$$

After a selected normalization the important parts of the network are obtained by link-cuts or islands approaches.

minDir of Slovenian journals 2000



Over 100000 people were asked in the years 1999 and 2000 about the journals they read. They mentioned 124 different journals. (source Cati)

Keywords and journals for selected groups of authors

To uncover the research topic and disciplinary identities of a selected group of authors we constructed networks of authors and keywords $\mathbf{AKn} = n(\mathbf{WA})^T * n(\mathbf{WK})$ and authors and journals $\mathbf{AJn} = n(\mathbf{WA})^T * n(\mathbf{WJ})$. Both networks are normalized. In the network **AKn**, the weight $AKn[a,k]$ is equal to the fractional use (in publishing) of author a of keyword k. In the network **AJn**, the weight $AJn[a,j]$ is equal to the fractional use of author a of journal j. For a given keyword k and journal j, it can be extended to a group of authors $C \subseteq A$

$$\mathbf{AKn}[C,k] = \sum_{a \in C} AKn[a,k] \qquad \text{and} \qquad \mathbf{AJn}[C,j] = \sum_{a \in C} AJn[a,j]$$

SNA18[18] /keywords for 3 selected islands

	Wasserman et al.		Dunbar et al.		Newman et al.	
Rank	Value	Keyword	Value	Keyword	Value	Keyword
1	30.02	*network*	3.80	*social*	11.27	*network*
2	20.11	*social*	3.60	*network*	5.05	*social*
3	8.62	*model*	2.97	**size**	4.13	**complex**
4	7.36	*analysis*	1.41	**human**	3.80	**world**
5	6.01	*graph*	1.31	**evolution**	3.54	**small**
6	5.50	*structure*	1.17	**brain**	2.68	*graph*
7	3.19	*datum*	1.13	**group**	2.51	*structure*
8	3.03	*structural*	0.90	**primate**	2.43	**web**
9	3.00	**correction**	0.84	**support**	2.31	**internet**
10	2.96	exchange	0.79	perspective	2.24	*model*
11	2.80	**equivalence**	0.75	**constraint**	1.96	community
12	2.68	**random**	0.69	**neocortex**	1.82	degree
13	2.54	*theory*	0.69	relationship	1.46	**random**
14	2.53	**power**	0.61	**communication**	1.39	**dynamics**
15	2.51	**markov**	0.60	**hypothesis**	1.28	*analysis*
16	2.41	**evolution**	0.57	**evolutionary**	1.16	*base*
17	2.28	group	0.55	**behavior**	1.10	sequence
18	2.25	**statistical**	0.52	**cooperation**	1.03	**percolation**
19	2.19	*method*	0.51	**cognitive**	0.93	**collaboration**
20	2.18	**dynamics**	0.49	difference	0.92	**online**
21	1.88	**generalized**	0.47	**kinship**	0.90	centrality
22	1.82	journal	0.44	**altruism**	0.74	**science**
23	1.80	**regression**	0.43	**bond**	0.70	**cluster**
24	1.78	**exponential**	0.40	organization	0.69	**scientific**
25	1.78	**blockmodel**	0.40	**emotional**	0.67	*algorithm*
26	1.76	**logit**	0.38	female	0.67	access
27	1.73	**balance**	0.38	closeness	0.66	**spread**
28	1.73	**p**	0.36	*analysis*	0.65	control
29	1.68	*measure*	0.36	individual	0.64	solution
30	1.66	*algorithm*	0.35	**baboon**	0.64	**scale**
31	1.66	**cluster**	0.35	**internet**	0.62	*datum*
32	1.64	*approach*	0.35	**dynamics**	0.60	user
33	1.62	actor	0.34	*structure*	0.60	*theory*
34	1.59	**logistic**	0.34	personal	0.59	distribution
35	1.55	relation	0.33	volume	0.56	**food**
36	1.54	introduction	0.33	world	0.56	pattern
37	1.54	**bias**	0.32	**community**	0.56	use
38	1.51	**dynamic**	0.32	**friendship**	0.55	service
39	1.45	**blockmodeling**	0.31	*theory*	0.53	relationship
40	1.44	friendship	0.30	society	0.52	**disease**

SNA18[18] /journals for 3 selected islands

Wasserman et al.			Dunbar et al.		Newman et al.	
Rank	Value	Journal	Value	Journal	Value	Journal
1	122.60	Soc Networks	4.67	Hum Nature-Int Bios	35.02	Phys Rev E
2	25.18	J Math Sociol	4.17	Evol Hum Behav	8.62	P Natl Acad Sci
3	10.75	Psychometrika	3.33	Philos T R Soc B	5.25	Nature
4	8.08	J Math Psychol	2.95	Soc Networks	4.75	Phys Rev Lett
5	7.33	Sociol Method Res	2.75	Anim Behav	3.00	Soc Networks
6	7.10	J Classif	2.57	P Roy Soc B-Biol Sci	2.92	Science
7	7.08	Qual Quant	2.33	Biol Lett-Uk	2.83	Lect Notes Comput Sc
8	5.04	Sociol Methodol	2.25	J Theor Biol	2.75	Eur Phys J B
9	4.00	J Am Stat Assoc	2.20	Roy Soc Open Sci	2.50	Am J Sociol
10	4.00	Contemp Sociol	2.00	Pers Indiv Differ	2.00	J Stat Mech-Theory
11	3.90	Am Sociol Rev	2.00	Trends Cogn Sci	1.97	Plos One
12	3.59	Lect Notes Comput Sc	2.00	Behaviour	1.67	Siam Rev
13	3.58	Am J Sociol	1.70	Sci Rep-Uk	1.33	Reliab Eng Syst Sa
14	3.53	Scientometrics	1.67	Comput Hum Behav	1.33	Secur Commun Netw
15	3.40	Soc Forces	1.62	Plos One	1.25	Nat Commun
16	3.38	Sociol Method	1.58	Hum Nature	1.12	J Comput Sci-Neth
17	3.17	Brit J Math Stat Psy	1.57	Adapt Hum Behav Phys	1.08	Scientometrics
18	3.00	J Am Soc Inform Sci	1.53	P Natl Acad Sci	1.03	J Supercomput
19	2.98	Annu Rev Sociol	1.50	Brit J Psychol	1.00	Inform Process Ma
20	2.75	Soc Psychol Quart	1.25	Soc Cogn Affect Neur	1.00	Comm Com Inf Sc
21	2.50	Inform Process Manag	1.00	Int J Dev Disabil	1.00	Symmetry-Basel
22	2.19	Plos One	1.00	Group Dyn-Theor Res	1.00	Electron Libr
23	2.17	Netw Sci	1.00	Curr Dir Psychol Sci	1.00	Contemp Phys
24	2.00	Poetics	1.00	Brit J Dev Psychol	1.00	Comput Phys Commun
25	2.00	Sociol Rev	1.00	Soc Dev	1.00	J Consum Res
26	2.00	Soc Sci Res	1.00	J Community Appl Soc	1.00	J Stat Phys
27	2.00	Comput Stat Data An	1.00	Folia Primatol	1.00	Harvard Bus Rev
28	1.92	Methods Ser	1.00	Hist Hum Sci	1.00	Annu Rev Sociol
29	1.92	Organ Sci	1.00	Underst Complex Syst	1.00	Jpn J Polit Sci
30	1.75	Sociol Perspect	1.00	Orig Hum Behav	1.00	Phys Lett A

Citations among authors from the network clustering literature [13]

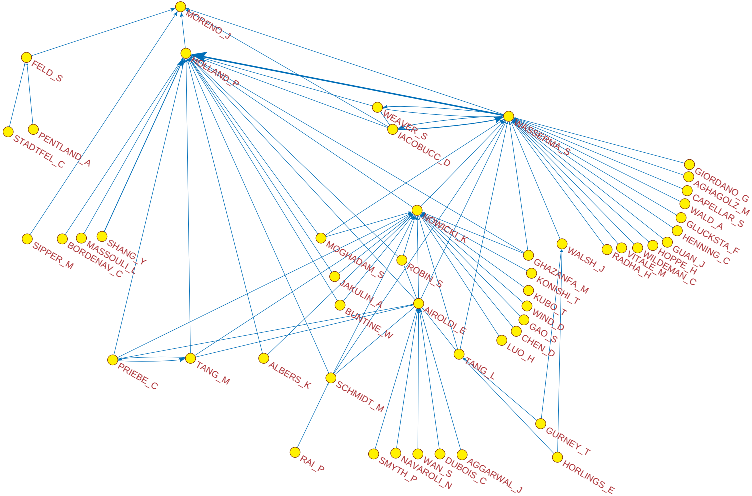
We consider the bibliometric data on the network clustering literature from the book [13]. We analyze the normalized network of citations among authors

$$\mathbf{nAcite} = n(\mathbf{WA})^T \cdot n(\mathbf{Cite}) \cdot n(\mathbf{WA})$$

The weight $\mathbf{nAcite}[u, v]$ is equal to the fractional share of works co-authored by u that are citing a work co-authored by v.

We removed loops (self-citations). We identified clusters such that the corresponding induced subnetworks are connected and contain a single center.

The **nAcite** weights are similarities, $s \in [\infty, 0]$. To convert them to dissimilarities d we selected $d = 1 - s/s_{\max} \in [0, 1]$ with $s_{\max} = 2.52$. On the obtained network, we applied, in Pajek, the hierarchical clustering with relational constraints procedure with the Maximum/Leader strategy and determined the partition of units into clusters of size at most 50. There are 257 such clusters.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AGHAGOLZ_M
CAPELLAR_S
WALD_A
GLUCKSTA_F
HENNING_C
NOWICKI_K
SIPPER_M
BORDENAV_C
MASSOULI_L
SHANG_Y
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ROBIN_S
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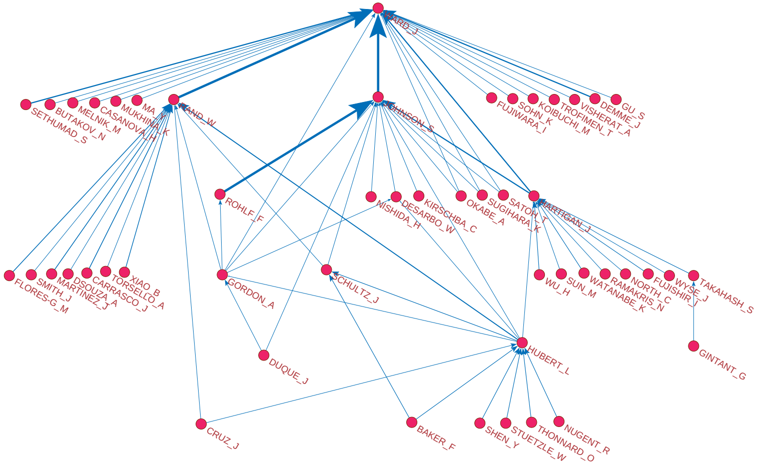

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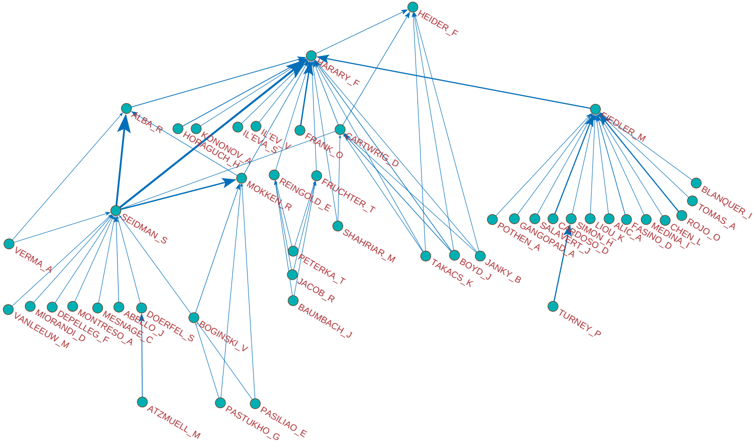
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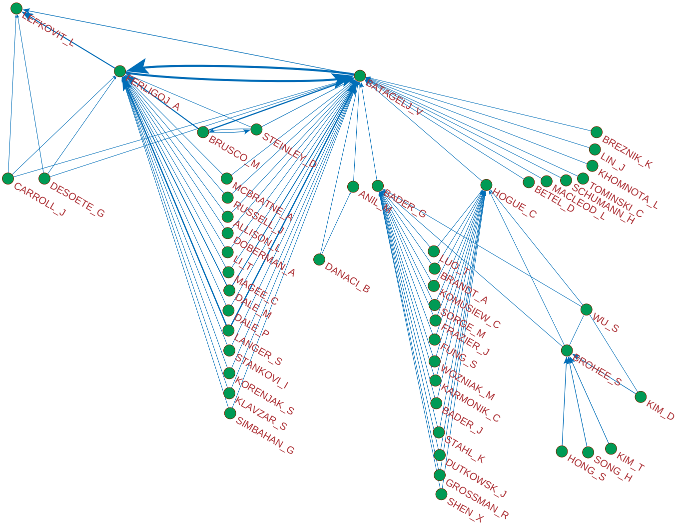

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BRUSCO_M
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ALLISON_L
DOBERMAN_A
LI_T
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FRAZIER_J
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WOZNIAK_M
KARMONIK_C
BADER_J
STAHL_K
DUTKOWSK_J
GROSSMAN_R
SHEN_X
BREZNIK_K
LIN_J
KHOMNOTA_L
TOMINSKI_C
SCHUMANN_H
MACLEOD_L
BETEL_D
WU_S
BROHEE_S
KIM_D
KIM_T
SONG_H
HONG_S

Linking through a network

Let a network $\mathbf{S}$ links works to works. The derived network $\mathbf{WA}^T \cdot \mathbf{S} \cdot \mathbf{WA}$ links authors to authors *through* $\mathbf{S}$. Again, the normalization question has to be addressed. Among different options let us consider the derived networks defined as:

$$\mathbf{C} = \mathbf{WAn}^T \cdot \mathbf{S} \cdot \mathbf{WAn}$$

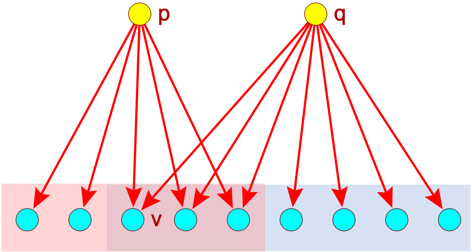
It is easy to verify that:

- if $\mathbf{S}$ is symmetric, $\mathbf{S}^T = \mathbf{S}$, then also $\mathbf{C}$ is symmetric, $\mathbf{C}^T = \mathbf{C}$;
- if $W_{[1]} = W$, the total of weights of $\mathbf{S}$ is redistributed in $\mathbf{C}$:

$$T(\mathbf{C}) = \sum_{e \in L(\mathbf{C})} c(e) = \sum_{e \in L(\mathbf{S})} s(e) = T(\mathbf{S})$$

Bibliographic Coupling

Bibliographic coupling occurs when two works each cite a third work in their bibliographies, see figure. The idea was introduced by Kessler (1963) and has been used extensively since then. See figure where two citing works, p and q, are shown. Work p cites five works and q cites seven works. The key idea is that there are three works cited by both p and q. This suggests some content communality for the three works cited by both p and q. Having more works citing pairs of prior works increases the likelihood of them sharing content.



Bibliographic Coupling

We assume that the citation relation means
$p\ \mathbf{Ci}\ q \equiv$ work p cites work q. Then the *bibliographic coupling* network **biCo** can be determined as

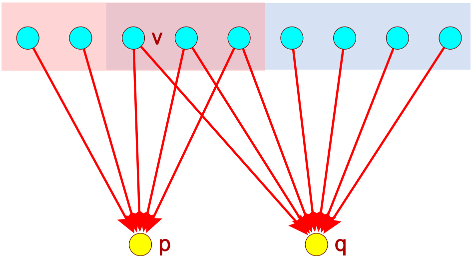
$$\mathbf{biCo} = \mathbf{Ci} * \mathbf{Ci}^T$$

The weight $bico_{pq}$ is equal to the number of works cited by both works p and q; $bico_{pq} = |\mathbf{Ci}(p) \cap \mathbf{Ci}(q)|$. Bibliographic coupling weights are symmetric: $bico_{pq} = bico_{qp}$:

$$\mathbf{biCo}^T = (\mathbf{Ci} \cdot \mathbf{Ci}^T)^T = \mathbf{Ci} \cdot \mathbf{Ci}^T = \mathbf{biCo}$$

Co-citation

Co-citation is a concept with strong parallels with bibliographic coupling (Small and Marshakova 1973). The focus is on the extent to which works are co-cited by later works. The basic intuition is that the more earlier works are cited, the higher the likelihood that they have common content.



Bibliographic Coupling

The *co-citation* network **coCi** can be determined as

$$\mathbf{coCi} = \mathbf{Ci}^T \cdot \mathbf{Ci}.$$

The weight $coci_{pq}$ is equal to the number of works citing both works p and q. The network **coCi** is symmetric $coci_{pq} = coci_{qp}$:

$$\mathbf{coCi}^T = (\mathbf{Ci}^T \cdot \mathbf{Ci})^T = \mathbf{Ci}^T \cdot \mathbf{Ci} = \mathbf{coCi}$$

An important property of co-citation is that $\mathbf{coCi}(\mathbf{Ci}) = \mathbf{biCo}(\mathbf{Ci}^T)$:

$$\mathbf{biCo}(\mathbf{Ci}^T) = \mathbf{Ci}^T \cdot (\mathbf{Ci}^T)^T = \mathbf{Ci}^T \cdot \mathbf{Ci} = \mathbf{coCi}(\mathbf{Ci})$$

Therefore the constructions proposed for bibliographic coupling can be applied also for co-citation.

Normalization

What about normalizations? Searching for the most coupled works we have again problems with works with many citations, especially with review papers. To neutralize their impact we can introduce normalized measures. The fractional approach works fine for normalized co-citation

$$\mathbf{CoCit} = \mathbf{Cin}^T \cdot \mathbf{Cin}$$

where $\mathbf{Cin} = \mathbf{D} \cdot \mathbf{Ci}$ and $\mathbf{D} = \text{diag}(\frac{1}{\max(1, \text{outdeg}(p))})$. $\mathbf{D}^T = \mathbf{D}$. In the normalized network every work has value 1 and it is equally distributed to all cited works.

Normalization of Bibliographic Coupling

The fractional approach can not bi directly applied to bibliographic coupling – to get the outer product decomposition work we would need to normalize **Ci** by columns – a cited work has value 1 which is distributed equally to the citing works – the most cited works give the least. This is against our intuition. To construct a reasonable measure we can proceed as follows. Let us first look at

$$\mathbf{biC} = \mathbf{Cin} \cdot \mathbf{Ci}^T$$

we have

$$\mathbf{biC} = (\mathbf{D} \cdot \mathbf{Ci}) \cdot \mathbf{Ci}^T = \mathbf{D} \cdot \mathbf{biCo}$$

$$\mathbf{biC}^T = (\mathbf{D} \cdot \mathbf{biCo})^T = \mathbf{biCo}^T \cdot \mathbf{D}^T = \mathbf{biCo} \cdot \mathbf{D}$$

Normalization of Bibliographic Coupling

For $\mathbf{Ci}(p) \neq \emptyset$ and $\mathbf{Ci}(q) \neq \emptyset$ it holds

$$\mathbf{biC}_{pq} = \frac{|\mathbf{Ci}(p) \cap \mathbf{Ci}(q)|}{|\mathbf{Ci}(p)|} \quad \text{and} \quad \mathbf{biC}_{qp} = \frac{|\mathbf{Ci}(p) \cap \mathbf{Ci}(q)|}{|\mathbf{Ci}(q)|} = \mathbf{biC}^T_{pq}$$

and $\mathbf{biC}_{pq} \in [0, 1]$. $\mathbf{biC}_{pq}$ is the proportion of its references that the work p shares with the work q. The network **biC** is not symmetric.

We have different options to construct normalized symmetric measures such as

$$\mathbf{biCoa}_{pq} = \frac{1}{2}(\mathbf{biC}_{pq} + \mathbf{biC}_{qp}) \quad \text{Average}$$

$$\mathbf{biCom}_{pq} = \min(\mathbf{biC}_{pq}, \mathbf{biC}_{qp}) \quad \text{Minimum}$$

$$\mathbf{biCoM}_{pq} = \max(\mathbf{biC}_{pq}, \mathbf{biC}_{qp}) \quad \text{Maximum}$$

Normalization of Bibliographic Coupling

or, may be more interesting

$$\mathbf{biCog}_{pq} = \sqrt{\mathbf{biC}_{pq} \cdot \mathbf{biC}_{qp}} = \frac{|\mathbf{Ci}(p) \cap \mathbf{Ci}(q)|}{\sqrt{|\mathbf{Ci}(p)| \cdot |\mathbf{Ci}(q)|}}$$ Geometric mean Salton cosinus

$$\mathbf{biCoh}_{pq} = 2 \cdot (\mathbf{biC}_{pq}^{-1} + \mathbf{biC}_{qp}^{-1})^{-1} = \frac{2|\mathbf{Ci}(p) \cap \mathbf{Ci}(q)|}{|\mathbf{Ci}(p)| + |\mathbf{Ci}(q)|}$$ Harmonic mean

$$\mathbf{biCoj}_{pq} = (\mathbf{biC}_{pq}^{-1} + \mathbf{biC}_{qp}^{-1} - 1)^{-1} = \frac{|\mathbf{Ci}(p) \cap \mathbf{Ci}(q)|}{|\mathbf{Ci}(p) \cup \mathbf{Ci}(q)|}$$ Jaccard index

All these measures are similarities.

It is easy to verify that $biCoX_{pq} \in [0, 1]$ and: $biCoX_{pq} = 1$ iff the works p and q are referencing the same works, $\mathbf{Ci}(p) = \mathbf{Ci}(q)$.

Normalization of Bibliographic Coupling

From $m \leq H \leq G \leq A \leq M$ and $J \leq m$, $(\frac{|P \cap Q|}{|P \cup Q|} \leq \min(\frac{|P \cap Q|}{|P|}, \frac{|P \cap Q|}{|Q|}))$ we get

$$\mathbf{biCoj}_{pq} \leq \mathbf{biCom}_{pq} \leq \mathbf{biCoh}_{pq} \leq \mathbf{biCog}_{pq} \leq \mathbf{biCoa}_{pq} \leq \mathbf{biCoM}_{pq}$$

The equalities hold iff $\mathbf{Ci}(p) = \mathbf{Ci}(q)$.

To get a dissimilarity we can use transformations $dis = 1 - sim$ or $dis = \frac{1}{sim} - 1$ or $dis = -\log sim$. For example

$$\mathbf{biCod}_{pq} = 1 - \mathbf{biCoj}_{pq} = \frac{|\mathbf{Ci}(p) \oplus \mathbf{Ci}(q)|}{|\mathbf{Ci}(p) \cup \mathbf{Ci}(q)|} \quad \text{Jaccard distance}$$

where $\oplus$ denotes the symmetric difference of sets.

Bibliographic Coupling, Co-citation and Linking through a network

Bibliographic coupling and co-citation networks are linking works to works. To get linking between authors, journals or keywords considering citation similarity we can apply the construction from *Linking through a network* to the normalized co-citation or bibliographic coupling network.

Temporal bibliographic networks

The presented concepts can be extended to temporal bibliographic networks. For details see [8, 16].

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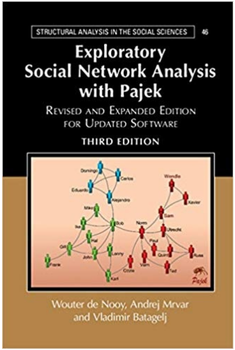
Books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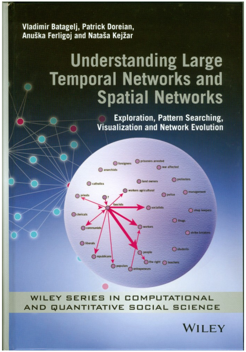
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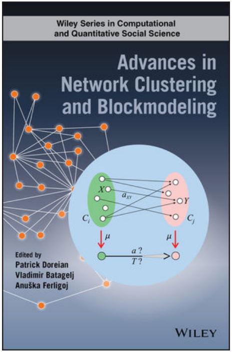
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