Social Network Analysis
The evolution of the field

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1 Introduction

Social Network Analysis (SNA) has moved from a fragmented direction represented by the works of individual scientific groups unrelated to each other, to a discipline whose representatives by 1990 have formed an "invisible college" and achieved the status of what Kuhn had labeled a "normal science" (Freeman, 2004; Hummon and Carley, 1993). Starting from that time, the field has grown significantly, which can be seen by the number of scientific publications (Otte and Rousseau, 2002) in different scientific fields, including Natural Sciences, which lead to the so called "physicists‘ invasion" into SNA (Batagelj et al., 2014) and resulted with the development of Network Science discipline. This calls into a question whether the field remains unified and which scientific groups (by disciplines, thematic agenda, etc.) it is currently formed of. Thus, the aim of the current study is to trace the evolution of the field of Social Network Analysis using bibliographic approach.

The phenomenon of scientific collaboration and communication by means of bibliometric tools has been extensively studied and reviewed over the last decades. The studies were devoted to the descriptions of scientific fields in different scientific traditions, such as co-authorship trends in Sociology in the USA (Moody, 2004; Hunter and Leahy, 2008), the USA and France (Pontille, 2003), Slovenia (Mali et al. 2010), Russia (Sokolov et al., 2010); Scientometrics and Informetrics (Hou et al., 2008), Library and Information science in Argentina (Chinchilla-Rodríguez et al., 2012), Economics in Poland (Lopaciuk-Gonczaryk, 2016); citation trends in some disciplines represented by thematic journals (Carley et al., 1993) and thematic sets of literature (Hummon and Doreian, 1989; Batagelj et al., 2017).

Different patterns of collaboration and their change over time were studied based on the analysis of co-authorship networks from different subjects, such as Biology, Physics and Mathematics (Newman 2001; Newman 2004) , Mathematics and Neuro-science (Barabasi et al., 2002), or even all research disciplines in one country (Kronegger et al., 2012; Ferligoj et al., 2015; Cugmas et al., 2016). Scientific networks on multinational level (Glänzel and Schubert, 2004) and international collaboration in science (Wagner and Leydesdorff, 2005) were studied.

The development of the field of our interest, Social Network Analysis, was reflected in several studies focused both on its historiographical description (Freeman, 2004), as well as structures of citation

(Hummon and Carley, 1993 Batagelj et al., 2014) and co-authorship (Leidesdorff et al., 2008; Otte, Rousseau, 2002). Attention was also given to citation structures of works written on some topics in SNA - centrality-productivity (Hummon et al., 1990; Batagelj et al., 2014, pp. 117-139), clustering and classification (Kejzar et al., 2010; Batagelj), blockmodeling (Batagelj).

Following Hummon and Carley (1993), we formulate the research purpose of the current study as to determine "whether the research in social networks hangs together, whether there are major divisional splits, either institutional or paradigmatic, and whether the members of the specialty attend to each other's work" (Hummon and Carley, 1993). We believe that the study of scientific community of Russian network researchers is not only important from epistemological point of view, but also can help to identify main active clusters and groups of knowledge exchange and have a possibility to facilitate the development of the field in the future.

2 Social network analysis: review of the previous studies

The issues of collaboration and citation in the field of Social Network analysis was studied by the means of historiographical and bibliometric studies. Using the first approach, patterning the links among the people who were involved in the development of the field — its social network — and pointing out the main events and in the field, Freeman (2004) presented "the history of social network analysis written from a social network perspective". As Freeman shows, the period started from 1940 till the late 1960‘s can be associated with the emergence of a large number of "schools", not aware of each other but potentially competing, which caused a fragmentation of the field in the 1970‘s. The special survey conducted by Freeman showed that there was no common agreement about the intellectual antecedents among the "founding fathers" of the discipline. It was only with some special efforts started in 1970‘s that caused the institutionalization of the field, among which Freeman points out "bridging" positions of some scholars travelling around different institutions, production of computer programs standardizing analysis of social network data, conferences and regular meetings that brought separate groups together (including those connected by early kind of internet), organization of INSNA association and creation of special journal "Social Networks", educational programs at the universities.

The early example of studying the SNA discipline by bibliometric tools is done by Hummon and Carley (1993). Analyzing citations within the first 12 volumes of journal "Social Network" and important articles that were cited by its authors and brief historical review, authors came to the conclusion that by the 1990‘s the members of SNA community have met the requirements for being an invisible college – a core active group of scientists "in the know" (INSNA members), having shared paradigm (understanding of the society as a network), defining important problems, promoting common methods of analysis, and establishing criteria of accomplishment and advance, working in core substantive areas in which ideas developed incrementally. They also had primary professional outlet (Social Networks Journal) and regular face-to-face interaction (through the conferences). Moreover, they also found that the main paths through the citation network were few in number, densely connected, extensive in the number of articles linked together, and continuous, that's why they made a conclusion that the SNA not only acceded the status of discipline, but also that the type of science engaged in within social networks field was what Kuhn had labeled "normal science".

The institutionalization of the SNA reflected in the intensification of the works within the field. Studying Social Network analysis in Information sciences based on data obtained from Sociological Abstracts base in period 1974-1999, Otte and Rousseau (2002), demonstrated that the yearly number of articles related to SNA was constantly growing, starting from 1980‘s. According to Freeman (2004), these data shows that the study of social networks is rapidly becoming one of the major areas of social science research (Freeman, 2004).

The most important works and central players, influencing others, were studied by the means of co-authorship networks analysis (Leidesdorff et al., 2008; Otte, Rousseau, 2002) and analysis of citations structures (Hummon, Carley, 1993; Batagelj et al., 2014). (What was found) Some studies focused on some subfields of SNA, such as centrality (Batagelj et al., 2014, pp. 117-139), clustering and classification (Kejzar et al., 2010; Batagelj – new), blockmodeling (Batagelj) (What was found)

Even though the Initial involvement into the field of Social Network Analysis was interdisciplinary (Hummon, Carley, 1993) and the field did not develop only within Sociology (Otte, Rousseau, 2002), recently it passed through some major changes. In their study of citation analysis of the literature on Social Network Analysis Batagelj et al. (2014, pp. 160-172) demonstrated that at the beginning (1970‘s) this direction was developing in the fields of Social Sciences, but starting from 2000‘s key works on this topic moves to the sphere of Physics and Neurosciences. The same trend is seen in the analysis of literature on centrality - one of the metrics in SNA (Batagelj et al., 2014, pp. 117-139).

3 Data

3.1 Data collection and cleaning

The resource for the data collection is Web of Science (WoS), Clarivate Analytics's multidisciplinary databases of bibliographic information. The data set is composed of two parts. First part SN5 data collected in 2008 [Batagelj et al., 2014], contains all the records found by query `"social network*"`, as well as all articles from the`Social Networks Journal`, till 2007. Another part was collected in June 2018 using same search scheme. Additionally, in 2018, all the articles from the networks-related journals were included - such as `Network Science`, `Computational Social Networks`, `Applied Network Science`, `Social Network Analysis and Mining`, `Online Social Networks and Media`, `Journal of Complex Networks`, `Journal of Social Structure`, and `Connections`. Figure 1 shows an example of records that are extracted from WoS. We had to linit the search to the Web of Science Core Collection because for other data bases in WoS special CR fields, which contain citation information, can not be exported.

The nodes, which are described only in WoS CR fields as references, do not have a full description in the colleced data set, and are called *terminal* nodes. As such nodes can be higly cited and in this sense important, we additionally collected the full descriptions for those which had the largest values of citing by others (indegree value between 1506 and 150), using WoS. If a description of a node was not available in WoS we constructed a corresponding description without CR data, searching for the work in Google Scholar (and then using RIS biblographic format and converting it to WoS with special R program). We also included manual descriptions of important works without the CR field from data set BM.WoS on the topic of blockmodeling [Batagelj, Chapter 2?]. We should note that such additional influental papers, usually published earlier, could be overlooked by our research queries because it could happen that they do not use the now established terminology. Finally, our data set included 70,795 records with complete descripton (there were 15 duplicates).

3.2 Original networks construction

Using WoS2Pajek 1.5 (Batagelj, 2007), we transformed our data into a collection of networks: the citation network $Cite$ on works (from the field CR), the authorship network WA on works $\times$ authors (from the field AU), the journalship network WJ on works $\times$ journals (from the field CR or J9),and the

```
PT J
AU JOHNSTON, RD
   BARTON, GW
AF JOHNSTON, RD
   BARTON, GW
TI STRUCTURAL EQUIVALENCE AND MODEL-REDUCTION
SO INTERNATIONAL JOURNAL OF CONTROL
LA English
DT Article
RP JOHNSTON, RD (reprint author), UNIV SYDNEY,DEPT CHEM ENGN,SYDNEY,NSW 2006,AUSTRALIA.
CR JOHNSTON RD, 1984, INT J CONTROL, V40, P257, DOI 10.1080/00207178408933271
   JOHNSTON RD, 1984, UNPUB COMPUT CHEM EN
   MORARI M, 1980, AICHE J, V26, P232, DOI 10.1002/aic.690260206
   Morari M., 1977, THESIS U MINNESOTA
NR 4
TC 6
Z9 6
U1 0
U2 0
PU TAYLOR & FRANCIS LTD
PI LONDON
PA ONE GUNDPOWDER SQUARE, LONDON, ENGLAND EC4A 3DE
SN 0020-7179
J9 INT J CONTROL
JI Int. J. Control
PY 1985
VL 41
IS 6
BP 1477
EP 1491
DI 10.1080/00207178508961210
PG 15
WC Automation & Control Systems
SC Automation & Control Systems
GA AQJ42
UT WOS:A1985AQJ4200007
ER
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Figure 1: WoS record

keywordship network WK on works $\times$ keywords (from the field ID or DE or TI). An important property of all these networks is that they share the same node set as the first one – i.e. the set of works (papers, reports, books, etc.) - wich means that they are *linked* and can be easily multiplied with each other, creating other networks.

Works that appears in descriptions can be of two types: those which has full descriptions (called hits), and those, which wer eonly cited (listed in the CR fields, but not presented among the hits). These data was stored in a partition DC, where DC[w] = 1 if a work w has a WoS description, and DC[w] = 0 otherwise. Partition year contains the work‘s publication year from the fields PY or CR. Also the vector NP was obtained, where NP[w] = number of pages in each work w. WoS2Pajek also builds a CSV file titles with main data about works with DC = 1 (name, WoS line, author, title, journal, year), which can be used to list results.

The usual *ISI name* of a work (its description in the field CR) has the following structure: `AU + ', ' + PY + ', ' + SO[:20] + ', V' + VL+ ', P' + BP` (surname, first letters of name, year of publication, abbreviation of the journal, its volume and number of starting page), which results in such descriptions as `LEFKOVITCH LP, 1985, THEOR APPL GENET, V70, P585` (all the elements are in upper case). As in WoS the same work can have different ISI names, the program WoS2Pajek supports also *short names* (similar to the names used in HISTCITE output), which has the following format: `LastNm[:8] + '_' + FirstNm[0] + '(' + PY+ ')' + VL + ':' + BP`. For example, for the mentioned work the ISI name is `LEFKOVIT_L(1985)70:585`. From the last names with prefixes `VAN`, `DE`, ... the space is deleted, and unusual names start with characters $\star$ or `$`.

However, some problems associated with names recognition still can occur in the data base. It

Table 1: Reduced networks

	# nodes (sum)	# nodes 1	# nodes 2	# arcs
WKn	1,329,542	1,297,133	32,409	1,167,670
WKr	103,201	70,792	32,409	1,167,666
WJn	1,367,558	1,297,133	70,425	1,301,276
WJr	80,011	70,792	9,219	74,933
WAn	1693105	1,297,133	395,972	1,442,242
WAr	163,804	70,792	93,012	215,901
CiteN	1,297,133			2,753,767
CiteR	70,792			398,199

can turn out, that the same works can be named by different names. For example, in our case, the names `BOYD_D(2007)13` and `BOYD_D(2008)13:210` were describing the same work of Danah Boyd, originally published in 2007, but in many cases referenced as being published in 2008.

Two possibilities to correct the data are: (1) to make corrections in the local copy of original data (WoS file); and (2) to make the equivalence partition of nodes and shrink the set of works accordingly in all obtained networks. We used the second option (Batagelj, Chapter 2). For the works with largest counts we prepared lists of possible equivalents and manually determined equivalence classes. With a program in R we produced a Pajek's partition $EQ.clu$ file used for shrinking the set of works. Using the partition $p = worksEQ$,in Pajek we shrunk the Citation network $cite$, WA, WJ, and WK. The partitions $year$, DC and the vector NP were also shrunk.

After these iterations, we finally constructed the data set used in this paper. From 70,792 hits (works with full description, DC=1) we produced networks with sets of the following sizes: works —W— = 1,297,133, authors —A— = 395,972, journals —J— = 70,425, key words —K— = 32,409. We removed multiple linkes and loops from the networks and obtaind cleaned networks **CiteN**, **WAn**, **WJn**, and **WKn**. In the following section, we present some The statistical properties of the obtained networks are presented in the section 4.

3.3 Redused networks construction

As it was shown above, for the works which are cited only (DC=0) information is provided in a restricted way: we have only information about the first author, and we have no information on the keywords (as there is no titles in the descriptions). That is why, for further analysis we also constructed networks, which contain only works with complete description (DC¿0). All the lines in the obtained networks were set to 1. The sizes of the obtained **reduced networks** are shown in the Table 1. In obtaind reduced networks **CiteR**, **WAr**, **WJr**, and **WKr** the amount of sets is the following:works —W— = 70,792, authors —A— = 93,012, journals —J— = 9,219, key words —K— = 32,409 (remained the same).

3.4 Boundary problem in Citation network

The original network **CiteN** had 1,297,133 nodes and 2,753,767 arcs. Considering the indegree distribution in this network we got the following counts for the lowest number of recieved citations: 0 (41,954), 1 (933,315), 2 (154,895), 3 (58,141), and 4 (29, 885), which alltogether combine 94% of citations. Thus, most of the works were terminal (DC=0) or were referenced only once (indegree = 1). Therefore, we

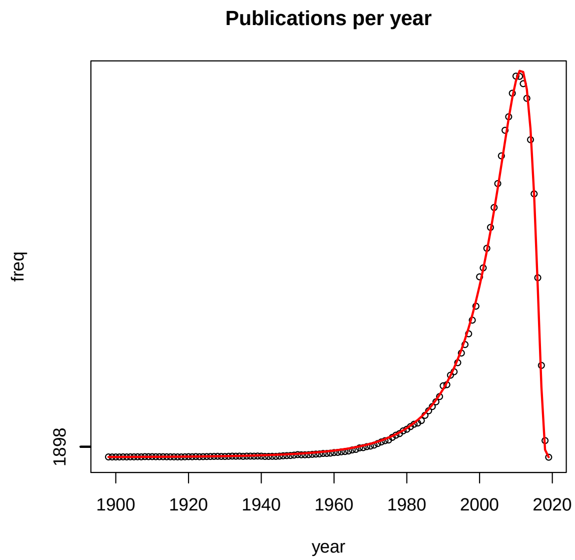

Figure 2: Citation network: Distribution of works by years

decided to remove all the 'cited only' nodes with indegree smaller then 3 (DC = 0 and indeg¡3) - the boundary problem (Batagelj et al. 2014). We also removed all the nodes starting with string `[ANON`. Finally, we got a subnetwork **CiteB** with 222,086 nodes and 1 ,521,434 arcs.

3.5 Derieved networks

Using obtained networks - original **CiteN**, **WAn**, **WJn**, and **WKn**, reduced **CiteR**, **WAr**, **WJr**, and **WKr**, and bounded **CiteB** we constructed other networks for the further analysis. These networks can be of two types. First type are one-mode networks made by the multiplication of two two-mode networks: network of co-occurence of key words **KK** (out of WK net), networks of coauthorship **Co**, **Cn**, and **Ct'** (out of WA net), network of authors and keywods **AK** (out of WA and WK). Another type of networks are those which are produced by the multiplication of three networks: network of citations among authors (made out of Citation net and WA net) **AACite**, network of citations among journals **JJCite**, co-citation network **ACoj'**. The normalization was also used in production of these networks. The description on each derieved network construction is presented in the corresponding sections.

4 Statistics on original networks

4.1 Distributions on CiteN

In the Figure 2, the distribution of all works (hits + cited only) by year is shown. It is ineteresting to note that this distribution fits very well the log normal distribution (Batagelj et al. 2014, pp. 119–121):

$$c \cdot \text{dlnorm}(2019 - year, a, b), where$$

$a = 2.543$, $b = 0.7206$, $c = 1.27810^6$

In the Figure 3, the indegree distribution in citation network - cumulative and usual - logarithmic scale (?) is shown. This distribution fits well the the *power law* $f = c \cdot n^{-\alpha}$, where fitted $\alpha = 2.3007$,

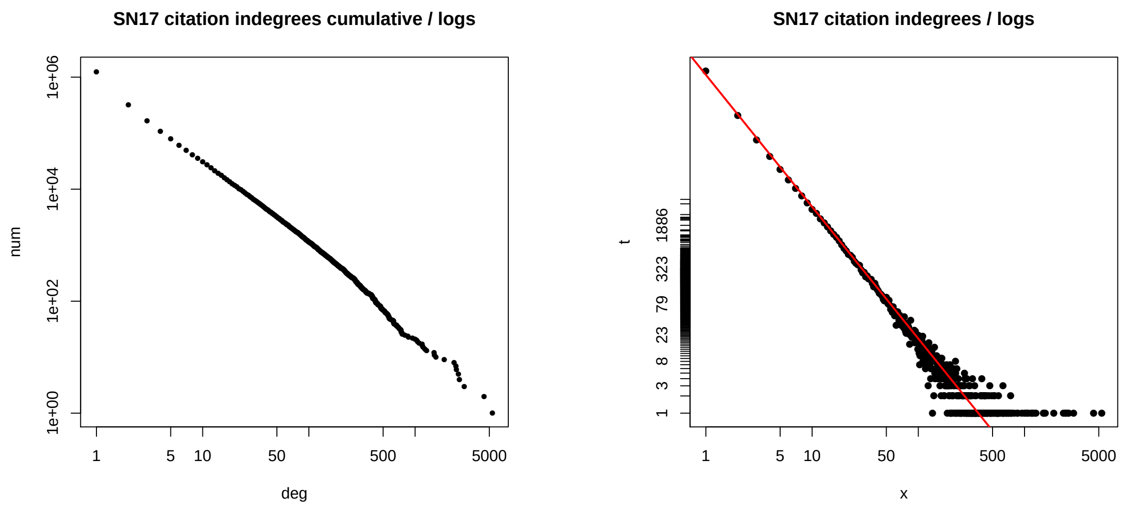

Figure 3: Citation network: Indegree distribution

$c = 749338$, which means that the small number of works attracts a large number of citations, and the large number of works attarcts only small number of citations. Works with the largest indegrees are the most cited papers.

Table 2 shows 60 the most $cited$ works (indegree in **CiteN**). It can be seen that half of these works (28 works) are published earlier, before 2000. It is also seen that some of these works (15) are books. The top ranked work is the well-known book of Wasserman and Faust published in 1994, and the second ranked work is also a classical article of Granovetter on the “strenght of weak ties” concept. The other books of “social” networks scientists cited more then 500 times (number in parentheses) are: Burt RS, Structural Holes: The Social Structure of Competition, 1992 (2333); Putnam RD, Bowling alone: America’s declining social capital, 2000 (1510); Scott J, Social Network Analysis: A Handbook, 2000 (1192); Everett MG, $UcinetforWindows : Softwareforsocialnetworkanalysis$, 2002 (1171); Coleman J, Foundations of Social Theory, 1990 (1093); Borgatti SP, $UcinetforWindows : SoftwareforSocialNetworkAnalysis$, 2002 (999); Hanneman RA, Introduction to social network methods, 2005 (854); Lin N, Social capital. A theory of social structure and action, 2001 (800); Rogers EM, Diffusion of innovations, 2003 (628); Putnam RD, Making democracy work: Civic institutions in modern Italy, 1993 (613); Zachary WW, An information flow model for conflict and fission in small groups, 1977 (583); Burt, RS Brokerage and closure: An introduction to social capital, 2005 (565); Rogers EM, Diffusion of Innovation. 4th, 1995 (555); Fischer CS, To dwell among friends: Personal networks in town and city, 1982 (539). Other artciles of “social” network scientists listed in the table (topics in parentheses) belong to McPherson (homophily), Freeman and Bonachich (centrality, betweenness), Burt (structural holes), Coleman, Portes, Adler (social capital), Granovetter, Uzzi (embeddedness), Milgram (small world), Borgatti.

Interestingly, the list also includes a lot of names of phisicists working with network approach: highly ranked articles of Watts DJ - Collective dynamics of ’small-world’ networks, appeared in NATURE in 1998 (2906), as well as Barabasi AL- Emergence of scaling in random networks, appeared in SCIENCE in 1999 (2614). Other works are of Newman, Albert, Girvan, Fortunato, Blondel, Clauset on large and complex networks, community detection and clustering. A famous work of Erdos “On random graphs”, published in 1959, is also in the list.

Table 2: Citation net: The most cited works - indegree

i	freq	id	i	freq	id
1	5348	WASSERMA_S(1994):	31	734	NEWMAN_M(2001)98:404
2	4471	GRANOVET_M(1973)78:1360	32	719	NEWMAN_M(2010):
3	2906	WATTS_D(1998)393:440	33	701	PORTES_A(1998)24:1
4	2614	BARABASI_A(1999)286:509	34	687	BLEI_D(2003)3:993
5	2561	FREEMAN_L(1979)1:215	35	670	BURT_R(2004)110:349
6	2447	BOYD_D(2007)13:210	36	654	HANSEN_M(1999)44:82
7	2429	MCPHERSO_M(2001)27:415	37	639	PALLA_G(2005)435:814
8	2330	BURT_R(1992):	38	634	CLAUSET_A(2004)70:066111
9	1886	COLEMAN_J(1988)94:95	39	629	BONACICH_P(1987)92:1170
10	1572	NEWMAN_M(2003)45:167	40	628	ERDOS_P(1959)6:290
11	1520	GIRVAN_M(2002)99:7821	41	628	UZZI_B(1997)42:35
12	1510	PUTNAM_R(2000):	42	628	ROGERS_E(2003):
13	1285	ALBERT_R(2002)74:47	43	613	PUTNAM_R(1993):
14	1240	GRANOVET_M(1985)91:481	44	593	BERKMAN_L(1979)109:186
15	1192	SCOTT_J(2000):	45	583	ZACHARY_W(1977)33:452
16	1171	EVERETT_M(2002):	46	572	BORGATTI_S(2009)323:892
17	1166	NEWMAN_M(2004)69:026113	47	569	NEWMAN_M(2001)64:025102
18	1093	COLEMAN_J(1990):	48	565	BURT_R(2005):
19	1058	STEINFIE_C(2007)12:1143	49	561	ADLER_P(2002)27:17
20	1034	FORTUNAT_S(2010)486:75	50	559	CHRISTAK_N(2008)358:2249
21	999	BORGATTI_S(2002):	51	555	ROGERS_E(1995):
22	945	CHRISTAK_N(2007)357:370	52	554	MILGRAM_S(1967)1:61
23	867	FREEMAN_L(1977)40:35	53	553	BARON_R(1986)51:1173
24	854	HANNEMAN_R(2005):	54	550	GRANOVET_M(1978)83:1420
25	800	LIN_N(2001):	55	539	FISCHER_C(1982):
26	757	KAPLAN_A(2010)53:59	56	537	BRIN_S(1998)30:107
27	756	BLONDEL_V(2008):P10008	57	524	MARSDEN_P(1990)16:435
28	742	NAHAPIET_J(1998)23:242	58	523	KEMP_D(2003):137
29	740	FORNELL_C(1981)18:39	59	523	KLEINBER_J(1999)46:604
30	740	NEWMAN_M(2006)103:8577	60	517	BOCCALET_S(2006)424:175

There are also some representatives of the other spheres - in such expecte topics as social network sites and social media (including highly rated artile of Boyd “Social network sites: Definition, history, and scholarship”, published in 2007 and having 2447 citations); medicine (including famous works of Christakis NA on spread of obesity and smoking), and management.

Table 3 shows 20 the most *citing* works (works with the largest outdegree in **CiteN**). These works are books, books introductory chapters, and review articles. Most of these works belong to the field of social sciences and cover different topics, including education, human relationships, archeology, migration, internet studies, and social media. The topic of social network analysis is not presented separately in this type of works. However, it is presented in the works published in journals in physics and computer science from the list (Bocaletti on complex networks, Costa on complex networks, Castellano on social physics of social dynamics, Brandes on methodological foundations of network analysis), as well as works representing the field of animal social networks.

Table 3: Citation net: The most citing work – outdegree

i	freq	id	i	freq	id
1	1572	CHAPMAN_C(2016):1	11	731	TSATSOU_P(2014):1
2	1406	HRUSCHKA_D(2010)5:1	12	654	GOODALE_E(2017):IX
3	1293	COWARD_F(2015):1	13	649	PEPPER_G(2017)40:S0140525X1700190X
4	1254	FITZGERA_P(2008):1	14	632	STROM_R(2012):1
5	1207	DAVIES_N(2015):V	15	613	SCHACHNE_G(2015)23:49
6	1055	MARSH_C(2009):1	16	597	COSTA_L(2011)60:329
7	942	YUS_F(2011)213:1	17	593	BRANDES_U(2005)3418:1
8	929	BOCCALET_S(2006)424:175	18	586	ROBERTS_J(2014):1
9	799	REEVES_M(2017):1	19	557	GUNTER_B(2016):1
10	768	GROSS_J(2007):1	20	547	CASTELLA_C(2009)81:591

Table 4: WA net: Authors with the largest number of papers – indegree

Rank	Value	Id	Rank	Value	Id
1	1169	WANG_Y	21	552	KIM_H
2	883	ZHANG_Y	22	550	CHEN_J
3	868	CHEN_Y	23	536	LIU_X
4	847	LI_Y	24	533	WANG_L
5	838	WANG_X	25	509	LI_H
6	819	ZHANG_J	26	490	KIM_Y
7	788	WANG_J	27	485	ZHANG_Z
8	786	LIU_Y	28	474	WANG_Z
9	766	LEE_J	29	471	WANG_S
10	765	LEE_S	30	471	CHEN_X
11	749	LI_J	31	471	**NEWMAN_M**
12	708	LI_X	32	462	CHEN_L
13	696	CHEN_C	33	461	ZHANG_L
14	690	KIM_J	34	450	YANG_Y
15	620	WANG_H	35	450	ZHANG_H
16	611	ZHANG_X	36	432	WU_J
17	611	LIU_J	37	431	LEE_H
18	570	CHEN_H	38	420	LI_Z
19	557	KIM_S	39	420	WANG_W
20	554	WANG_C	40	417	LI_L

4.2 Distributions on WAn

Table 4 shows authors with the largest number of papers, which is shown by the indegree distribution of the **WAn** network. It can be seen that almost all of these names, except Newman, belong to Chinese authors. However, this is the result of the well-known ”three Zhang, four Li” effect: as the number of original surnames in China is relatively small, there is a high chance that different authors, having the same surname and first letter of the name, shrink together, creating “generalized” authors. Such problem could be overcame if we had a special ID for each scientists.

Looking at the outdegree of **WAn** network, we can get an information on the number of authors in works. This distribution is presented in the Table 5. It can be seen that the majority of works (95.5%) has only one author (however, the majority of this group are works that are cited only, which contain information only on the first author). Other 4% of all the works have from 2 to 5 authors. In some

Table 5: WA net: Number of authors in works – outdegree

outdeg	Freq	Freq%	outdeg	Freq	Freq%
1	1239496	95.5566	21	4	0.0003
2	18637	1.4368	22	3	0.0002
3	16661	1.2844	23	4	0.0003
4	10617	0.8185	24	2	0.0002
5	5759	0.4440	25	1	0.0001
6	2802	0.2160	26	2	0.0002
7	1322	0.1019	27	5	0.0004
8	686	0.0529	28	2	0.0002
9	384	0.0296	29	1	0.0001
10	247	0.0190	31	3	0.0002
11	155	0.0119	36	1	0.0001
12	90	0.0069	41	1	0.0001
13	70	0.0054	42	1	0.0001
14	54	0.0042	43	1	0.0001
15	32	0.0025	48	1	0.0001
16	12	0.0009	53	1	0.0001
17	14	0.0011	126	1	0.0001
18	9	0.0007			
19	6	0.0005			
20	2	0.0002			
SUM				1297133	100

works, hovever, the amount of authors is pretty high. On the (Table 6) we present the works which have more then 25 authors. The most "extreme" case is the work "Sharing and community curation of mass spectrometry data with Global Natural Products Social Molecular Networking", published in $NatureBiotechnology$ in 2016, which has 126 authors. Almost all the works from this list belong to the fields of Natural science - medical, health, epidemiological, and behavioral studies. For these fields, the inclusion of all the authors inplementing a research project to the paper is quite a frequent situation. However, the third rated article - "Discussion on the paper by Handcock, Raftery and Tantrum", - published in $RoyalStatisticalSociety.Journal.SeriesA$: $StatisticsinSociety$ collect 48 "social" networks scientists.

Table 6: WA net: Works with the largest number of authors

Value	First author	Title	Journal	Year
126	Wang, MX	Sharing and community curation of mass spectrometry data with Global Natural Products Social Molecular Networking	NAT BIOTECHNOL	2016
53	Vashisht, R	Crowd Sourcing a New Paradigm for Interactome Driven Drug Target Identification in Mycobacterium tuberculosis	PLOS ONE	2012
48	Snijders, TAB	Discussion on the paper by Handcock, Raftery and Tantrum	J ROY STATIST SOC SER A STAT	2007
43	Gustavsson, A	Cost of disorders of the brain in Europe 2010	EUR NEUROPSYCHOPHARM	2011
42	DOLL, LS	Homosexually and nonhomosexually identified men who have sex with men - a behavioral-comparison	J SEX RES	1992

Table 6: WA net: Works with the largest number of authors

Value	First author	Title	Journal	Year
41	Magliano, L	Family psychoeducational interventions for schizophrenia in routine settings: impact on patients' clinical status and social functioning and on relatives' burden and resources	EPIDEMIOL PSICHIATR SOC	2006
36	Auradkar, A	Data Infrastructure at LinkedIn	PROC INT CONF DATA	2012
31	Durkee, T	Prevalence of pathological internet use among adolescents in Europe: demographic and social factors	ADDICTION	2012
31	Kaur, K	Fluoroquinolone-related neuropsychiatric and mitochondrial toxicity: a collaborative investigation by scientists and members of a social network	J COMMUNITY SUPPORT	2016
31	Hermanussen, M	Adolescent Growth: Genes, hormones and the Peer Group. Proceedings of the 20th Aschauer Soiree, held at Gkicksburg castle, Germany, 15th to 17th November 2013	PEDIATR ENDOCR REV P	2014
29	Corazza, O	Promoting innovation and excellence to face the rapid diffusion of Novel Psychoactive Substances in the EU: the outcomes of the ReDNet project	HUM PSYCHOPHARM CLIN	2013
28	Magliano, L	"I have got something positive out of this situation": psychological benefits of caregiving in relatives of young people with muscular dystrophy	J NEUROL	2014
28	Console, L	WantEat: interacting with social networks of smart objects for sharing cultural heritage and supporting sustainability	FRONT ARTIF INTEL AP	2012
27	Sikora, M	Ancient genomes show social and reproductive behavior of early Upper Paleolithic foragers	SCIENCE	2017
27	Magliano, L	Burden, professional support, and social network in families of children and young adults with muscular dystrophies	MUSCLE NERVE	2015
27	Lopez-Fernandez, O	Self-reported dependence on mobile phones in young adults: A European cross-cultural empirical survey	J BEHAV ADDICT	2017
27	Gine-Garriga, M	The SITLESS project: exercise referral schemes enhanced by self-management strategies to battle sedentary behaviour in older adults: study protocol for a randomised controlled trial	TRIALS	2017
27	Maher, BS	The AVPR1A Gene and Substance Use Disorders: Association, Replication, and Functional Evidence	BIOL PSYCHIAT	2011
26	SEMPLE, SJ	Identification of psychobiological stressors among hiv-positive women	WOMEN HEALTH	1993
26	Wang, X	Reliability and validity of the international dementia alliance schedule for the assessment and staging of care in China	BMC PSYCHIATRY	2017
25	Banos, O	An Innovative Platform for Person-Centric Health and Wellness Support	LECT N BIOINFORMAT	2015

Table 7: WJ net:The most used journals – indegree

Rank	Value	Id	Rank	Value	Id
1	7080	LECT NOTES COMPUT SC	31	1258	RES POLICYAM J PSYCHIAT
2	3859	SOC SCI MED	32	1221	J BUS RES
3	3408	J PERS SOC PSYCHOL	33	1217	**MANAGE SCI**
4	2719	COMPUT HUM BEHAV	34	1185	**ACAD MANAGE REV**
5	2631	SCIENCE	35	1182	**J CONSULT CLIN PSYCH**
6	2602	AM J PUBLIC HEALTH	36	1151	**ORGAN SCI**
7	2599	P NATL ACAD SCI USA	37	1150	ADDICTION
8	2208	NATURE	38	1143	**STRATEGIC MANAGE J**
9	2058	**AM SOCIOL REV**	39	1087	**J GERONTOL B-PSYCHOL**
10	1945	PHYSICA A	40	1075	PEDIATRICS
11	1815	ANIM BEHAV	41	1055	AM J EPIDEMIOL
12	1778	JAMA-J AM MED ASSOC	42	1050	COMPUT EDUC
13	1763	LANCET	43	1022	DEV PSYCHO
14	1759	**SCIENTOMETRICS**	44	1022	**PSYCHOL BULL**
15	1734	**AM J SOCIOL**	45	1007	J ADOLESCENT HEALTH
16	1703	**ACAD MANAGE J**	46	997	**J MARKETING**
17	1632	LECT NOTES ARTIF INT	47	996	ARCH GEN PSYCHIAT
18	1573	**J APPL PSYCHOL**	48	994	AIDS BEHAV
19	1551	**SOC NETWORKS**	49	972	PERS INDIV DIFFER
20	1509	**AM ECON REV**	50	949	PERS SOC PSYCHOL B
21	1433	**J MARRIAGE FAM**	51	947	J BUS ETHICS
22	1400	BRIT MED J	52	939	**J MARKETING RES**
23	1399	CHILD DEV	53	925	INFORM SCIENCES
24	1373	EXPERT SYST APPL	54	916	**HARVARD BUS REV**
25	1365	NEW ENGL J MED	55	915	IEEE T KNOWL DATA EN
26	1363	COMMUN ACM	56	901	DRUG ALCOHOL DEPEN
27	1355	RES POLICY	57	900	WORLD DEV
28	1279	GERONTOLOGIST	58	899	AM J PREV MED
29	1275	BRIT J PSYCHIAT	59	895	ADDICT BEHAV
30	1271	**SOC FORCES**	60	893	**J CONSUM RES**

4.3 Distributions on WJn

Table 7 shows the most used journals, which have the maximum values of indegree distribution of the **WJn** network. In general, there are quite a lot of journals from the social sciences in the list, which are marked in boldface. The dominant journal is $LectureNotesinComputerScience$, which has more then 7,000 citations, followed by *Social Science & Medicine* and *Journal of Personality and Social Psychology* with more then 3,000 citations. Other journals that have more then 2,000 citations are multidisciplinary journals *Science, Proceedings of the National Academy of Sciences of the USA, Nature*, as well as such disciplinary journals as *Computers in Human Behavior, American Journal of Public Health, and American Sociological Review*.These journals are followed by other top-ranked journals in different disciplines having more than 1,500 citations, such as (descending number of citations) *Physica A, Animal Behaviour, Journal of the American Medical Association, Lancet, Scientometrics, American Journal of Sociology, Academy of Management Journal, Lecture Notes in Artificial Intelligence, Journal of Applied Psychology, American Economic Review*. The top-ranked social science journal Social Networks is in 19-th place. The remaining journals cover many disciplines such as medicine, psychiatry, gerontology, epidemiology, psychology, management, marketing, computer and information science.

As an idea: we can make a distributioN of WJ_IndegreeN

4.4 Distributions on WKn

For some works, the keywords are presented in the description in the special fields `DE` (Author Keywords) and `ID` (Keywords Plus). However, for some articles this information is not provided, thats is why they are constructed by **WoS2Pajek** from the titles of works. All composite keywords were split into single words, and lemmatization was used to deal with the "word-equivalence problem".

The majority of works in **WKn** (95%) do not have any keywords - these are the works which do not have a complete description (DC=0). The amount of keywords for other 70,792 works varies from 1 to 84. Idea: loolk at moda, or average?

The most frequent keywords are presented in the Table 8. We have 'social' and 'network' as the highest rated words, followed (with a large margin) by 'analysis', which is trivial. Some frequently used words - model, community, graph, structure, relationship, tie (marked in boldface) - are connected to network analysis, while others - datum, base, information, research, theory, algorithm, approach, pattern, effect - to the scientific research in general. There are also words that belongs to some exact topics - online, networking, facebook, internet, site, web; health, behavior; support; communication; influence; innovation; trust - which are being studied in network analysis. We should note that keywords can have different meanings in different contexts; however, their identification in differnt subgroups (of authors or works) can bring us better understading of the topic structure of the field.

5 Topic structure of the field

We already presented the most common keywords in the Table 8. In this section we present the results of keywords co-occurence in different articles.

5.1 Network KKn production

To construct the one-mode network **KKn**, we applied the Newman normalization to the **reduced WKr net**: the weight of each arc [w, k] was divided by the sum of weights of all arcs having the same initial node as this arc (outdegree of a node) subtracting the initial node (article), equal to 1. Then the normalized network was transposed and multiplied with normalized network. In the obtained network, the loops were deleted and bidirected arcts were transformed to edges (with summation of the line weights). The obtained network KKn consists of 32,409 nodes and 2,799,530 edges.

```
KKn = t(n(WK))*n(WK), where n(W,K)[w,k] = WK[w,k]/ (outdeg(w)-1)
```

5.2 Networks of key words co-occurence

However, exploratory analysis showed that in the obtained network, the most frequentlty words *social*, *network*, and *analysis* were connecting most of the other keywords, that's why we deleted these 3 nodes from the obtained network. Using Islands approach, we tried to obtain subnetwork with the size minimum 2 and maximum 75 nodes. We got a large number of islands - 342, - where the majority of islands (301) represent just pairs of keywords. The main island includes 75 nodes; there are also some islands of smaller sizes. All these islands are shown below.

Large part of Main island are the keywords on the topic of networking sites and social media (such as *networking, media, online, site, facebook, internet, technology, we 2.0*). Other central nodes are *information* associated with networking topic, words *diffusion* and *privacy*, as well as *base* and *datum* (which also have links to many other keywords, including *big*, and *mining*). Other two central keywords

Table 8: WK net: The most used keywords – indegree

Rank	Value	Id	Rank	Value	Id
1	51333	**social**	31	3485	**structure**
2	46191	**network**	32	3479	life
3	11751	**analysis**	33	3444	risk
4	10219	**model**	34	3358	research
5	8104	**community**	35	3143	learn
6	8090	use	36	3116	influence
7	7596	base	37	3054	student
8	7439	information	38	3054	impact
9	7061	health	39	3049	perspective
10	7023	behavior	40	3042	complex
11	6745	online	41	3024	theory
12	6087	networking	42	2859	organization
13	5833	media	43	2828	**relationship**
14	5404	support	44	2802	algorithm
15	5101	communication	45	2776	education
16	5013	study	46	2714	group
17	4759	datum	47	2704	mobile
18	4376	management	48	2698	**tie**
19	4372	internet	49	2695	adult
20	4164	knowledge	50	2633	approach
21	4126	user	51	2608	care
22	4023	facebook	52	2551	adolescent
23	3984	technology	53	2479	role
24	3907	site	54	2472	state
25	3888	web	55	2467	innovation
26	3855	self	56	2434	pattern
27	3784	**graph**	57	2385	effect
28	3676	performance	58	2339	people
29	3534	service	59	2333	trust
30	3512	dynamics	60	2332	family

are *model* and *graph*, which are connected to each other and other nodes, such as *dynamics, complex, spread, influence* (for the first one) and *random, theory, centrality - betweenness, large - scale - free, cluster* (for the second). These central nodes are also connected to the words *community* and *algorithm*, which have links to *detection* and *structure*. Other topics appeared in this subnetwork are associated with *health* and *education*.

Other islands represented at the Figure XX identify some topics being studied in network analysis (*strength, weak, tie; corporate - interlock - directorate; triadic - closure; small - world*, or some broade topics under study (*organ - donor - donation; persecutory - delusion - paranoia; trade - international - migration*), as well as some stable phrases (*special, issue, introduction*).

6 Citation network

We restricted the original citation network **CiteN** to its 'boundary' - **CiteB** with 222,086 nodes and 1,521,434 arcs. A citation network is usually (almost) acyclic; however, it can include some small cyclic parts, which can be obtained as strong components of the network (with the minimum size 2). At first we searched for nontrivial strong components.To get an acyclic network we applied the *preprint transformation* to CiteB. The preprint transformation function replaces each work u from a strong component by pair of nodes - published work u and its preprint version u'. A published work could cite only preprints. Each strong component was replaced by a corresponding complete bipartite graph on pairs (Batagelj et al. 2014). The resulting network **CiteT** had 222,189 nodes and 1,521,658 arcs. The increase in the number of works is due to some of them appearing twice with one name starting with an = sign indicating the "preprint" version of a paper.

Then we computed the **SPC weights** on **CiteT** network arcs. The total flow is [xx]. We identified main paths (CPM main path and Key-route paths) in this network, and then used an *Link islands approach* () to find the most connected components of this network. For the same network, we also computed the **probabilistic flow**, and used the *Vertex islands approach* to get its components. The obtained results are presented in the following section.

6.1 Strong components

The citation network CiteB has 41 nontrivial strong components of different size, which are presented in the Figure 4). The reciprocal (cycle) links are marked with the bluse colour, while directed pink lines also show the connections of these nodes with others. In the majority of the cases, mutual referencing between the works is a characteristic of papers published in the same issue of the journal. For example, the first large cycle combined of 12 works published in a special issue named "Social Networks: new perspectives" in the journal 'Behavioral Ecology and Sociobiology (Volume 63, Issue 7, May 2009). Another example are the works `BATAGELJ_V(1992)14:63` and `BATAGELJ_V(1992)14:121`, and `FAUST_K(1992)14:5` and `ANDERSON_C(1992)14:137` in the special Issue on Blockmodels in the journal 'Social networks' (Volume 14, Issues 1–2, March–June 1992).

Other cases are: `TUMMINEL_M(2011):P01019` and `TUMMINEL_M(2011)6:0017994`, `WILSON_A(2015)69:1` and `WILSON_A(2015)26:1577`, `PARSEGOV_S(2015):3475` and `PARSEGOV_S(2017)62:2270` (same author); `VEENSTRA_R(2013)23:399` and `DAHL_V(2014)24:399` (same journal); `ALMAHMOU_E(2015)33:` and `MOK_K(2017)35:463`, `XIA_W(2016)3:46` and `PROSKURN_A(2016)61:1524` (different authors and journals).

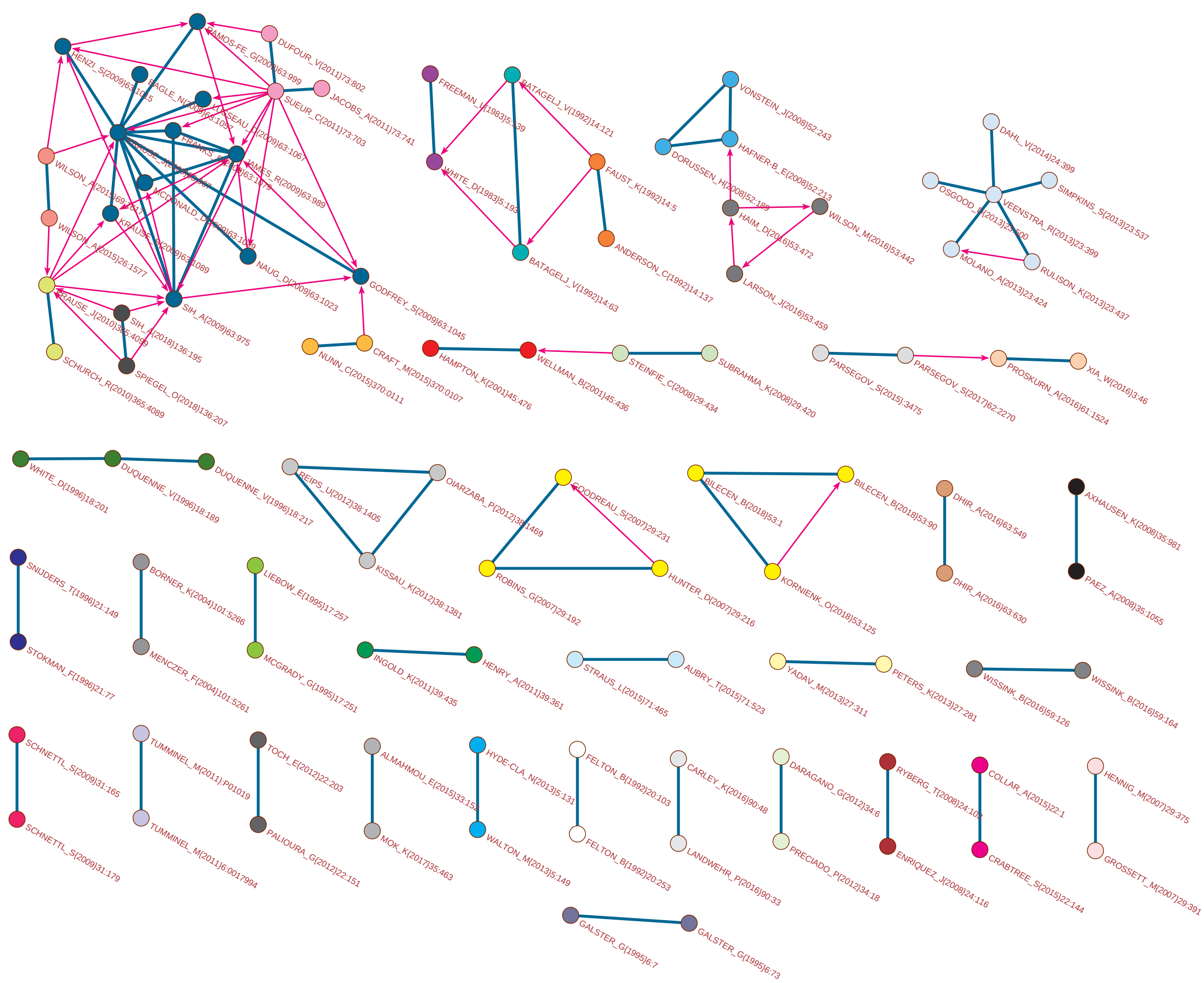

Figure 4: Strong components from SPC network

6.2 CPM main path and Key Routes

Figure 5 shows the CPM main path through the social network analysis literature (which is the same to the one obtained with Main path procedure), which includes 59 nodes. We devided this CPM main to three parts, according to the disciplinary of the works that are presented. The first group composed of the works published in 1944 – 1996, present the works of 'social' network scientists. These works appeared in such journals as 'Social networks', 'Administrative Science Quarterly','Annual Review of Sociology', 'American Sociological Review', 'Social Forces ', 'Sociological Methods & Research', 'Journal of Mathematical Psychology', 'Psychological Review', 'The Journal of Psychology ', recalling the history of social network analysis formation. 6 of 20 works in this group belong to R. Burt.

However, since 1999 the initiative in this discipline goes to the physicists, whose works appears in such journals as 'Physical Review E', 'Journal of Statistical Physics', 'Reviews of Modern Physics', 'European Physical Journal B', 'Physics Reports', 'Nature', and 'SIAM Review'. 9 of 14 works in this part of network belong to M. Newman.

The third part of the main path, which contains works from 2008 to 2018, is devoted to completely another topic – animal social networks. The works apper at such journals as 'Animal Behaviour', 'American Journal of Primatology', 'Primates','Journal of Evolutionary Biology', 'Journal of Animal Ecology', 'Journal of Evolutionary Biology', 'Trends in Ecology & Evolution', and others. The most active author in this group is D. Farine, who has 6 out of 25 works.

While the "invasion of physics" into the social network analysis was already shown by other studies (), the appearance of the third group in the main path is quite surprising, because previously it was shown that the trend goes from physics to neuroscience ().

The procedure of key-route paths () produces a more nuanced image of most important paths in the social network analysis literature, as it implies some deviations from the structure of the network, identified with the CPM path method. Figure 6 shows the obtained Key-route paths, which contain 127 nodes. Basically, we can see the division into three previously mentioned groups.

The first period (1944–1999) includes 50 works of the 'Network science' discipline. It starts with two works of Heider on his theory of social perception and cognitive organization of 1944 and 1946, which form the basis for the work of Cartwright of 1956 on structural balance. Then , with some marin, two works of Holland on structural models follows, published in 1970-1971. Next comes a classical paper of Granovetter on strength of weak ties (1973), which is a basis for the works of Breiger on clustering relational data and White on blockmodels, followed by the one by Alba on the measure based on social proximity in networks, and Boorman on role structures in multiple networks, published in 1975-76. Then there are 6 works of Burt on the 'main' path on the topics of positions in multiple networks (stratifiction and prestige), structural equivalence and networks subgoups, published from 1977 to 1981, which also have connections to the works of Holland on social structure, Breiger, Lauman, and Wellman on communities structures, Breiger on social roles, and Faust on structural and general equivalences, published at about the same time period. Summing up, this group of works is dealing with network and community strcutures, positions, structural equivalence, and blockmodels.

These works are followed by the works on measurement and different network metrics - Romney and Bernard (1982) on recalled data for networks constructin, and Stephenson on centrality (1989). The last work is also connected to the works of Mizruchi on measures of influence, Bonacich on power and centrality measures, and Burt, Mariolis, Mizruchi on interlock networks. This is followed by the work of Freeman on the measure of centrality, which was published in 1991, and it is very strongly connected to the work of Valente on social network thresholds in the diffusion of innovations (1996). Another strong

Figure 5: Main path by fragments – sociology, physics, biology

connection of Valente goes to the previous work of Michaelson (1993) on thedevelopment of a scientific speciality as diffusion through social relations.

The work of Valente is the one bridging the first group of 'social' network scientists with the group of physicists, which includes 28 works from the 'Network science' discipline and form the **second period (1999–2008)**. It is cited by Newman in the work on the small-world network model, appeared in 1999. This work is followed by others on the same topic (small-world networks), written by Moore, Newman, as well as by the work of Callaway on random graphs (2000). Then both directions meet at the work of Strogatz on complex networks, and then this topic continues, including clustering and preferential attachment in growing networks and spread of epidemic disease on networks (Newman, 2001, 2002). Sincel 2003 to 2006, the topic went to the direction of community structures identification in large networks.

We should note, however, that there is also a 'epidemiological turn' in the observed network, which starts from the works of Stephens and Freeman, followed by Milardo, Neaigus, and Rothenberg in the works on the deseases transmission (1992-98), and Potterat in the infections transmission (1999). These works are cited by Ferguson (desease transmission), and then the route comes back to the main path - the Newman's on the structure and function of complex networks (2003).

Since that time, the topics of the obtained Key-routes network changes significantly. The work of Newman on community structares is strongly connected to the work of Lusseau (2009) on animal social networks, which starts the **third period (2008–2018)**, which includes 49 works of the behavioural ecologists. This work is followed by many others, at the same topic - Krause, James (2009) with general works on animal social network analysis, and Ramos-Fernandez, Kasper, Voell, Lehmann, Brent, Sueur (2009-2011), working with social networks of Nonhuman Primates (monkeys, baboons). These works are followed by the one of Croft (2011), which represent a practical guide on hypothesis testing in animal social networks. This work is cited by the works presented the research on mixed-species groups (Farine), killer whales (Foster), sharks (Mourier), dolphins (Cantor), published in 2012, and birds (Silk), and starlings (Boogert), published in 2014. There are also some more works on and methodological issues of Hobson ('An analytical framework for quantifying and testing patterns of temporal dynamics in social networks'), Castels (' Social networks created with different techniques are not comparable'), and Pinter-Wollman ('The dynamics of animal social networks: analytical, conceptual, and theoretical advances'), published in 2013-2014. These works are followed by four works of Farine, published in 2015, on both methodological issues on constructing, conducting and interpreting animal social network analysis, and study of the wild birds territory acquisition. We should also note that there are some works connected to the 'main' path, which represents the social personality and phenotypic types (Wilson, Alpin, Farine), published in 2013-14.

The upper part of the network contains works published in the last years, 2016-18. It presents studies on desease transmission (Adelman, Sah, Silk, Dougherty), and the studies of animal paths tracking (Leu, Spiegel). Also it contains works on theoretical issues ('Current directions in animal social networks' by Croft, 'Social traits, social networks and evolutionary biology' by Fisher) and implementation of different models of network analysis to animal behaviour research: exponential random graph models and statistical network models (Silk), the potential of stochastic actor-oriented models (Fisher), dynamic vs. static social network analysis (Farine).

The full information on the papers (label of the work, first author, title, journal where it was published, year of publication) included into the Main path and Key-route paths is presented on the Table 10. They are also relevant for our analysis on the islands, presented in the following subsections. In this table, the second column (code) describes in which analysis the work appeared (1- Key-routes, 2- Main Path (CPM), 3- Island 5, 4 - Island 4, 5 - Node Island, 6 - Probilistic Flow Island).

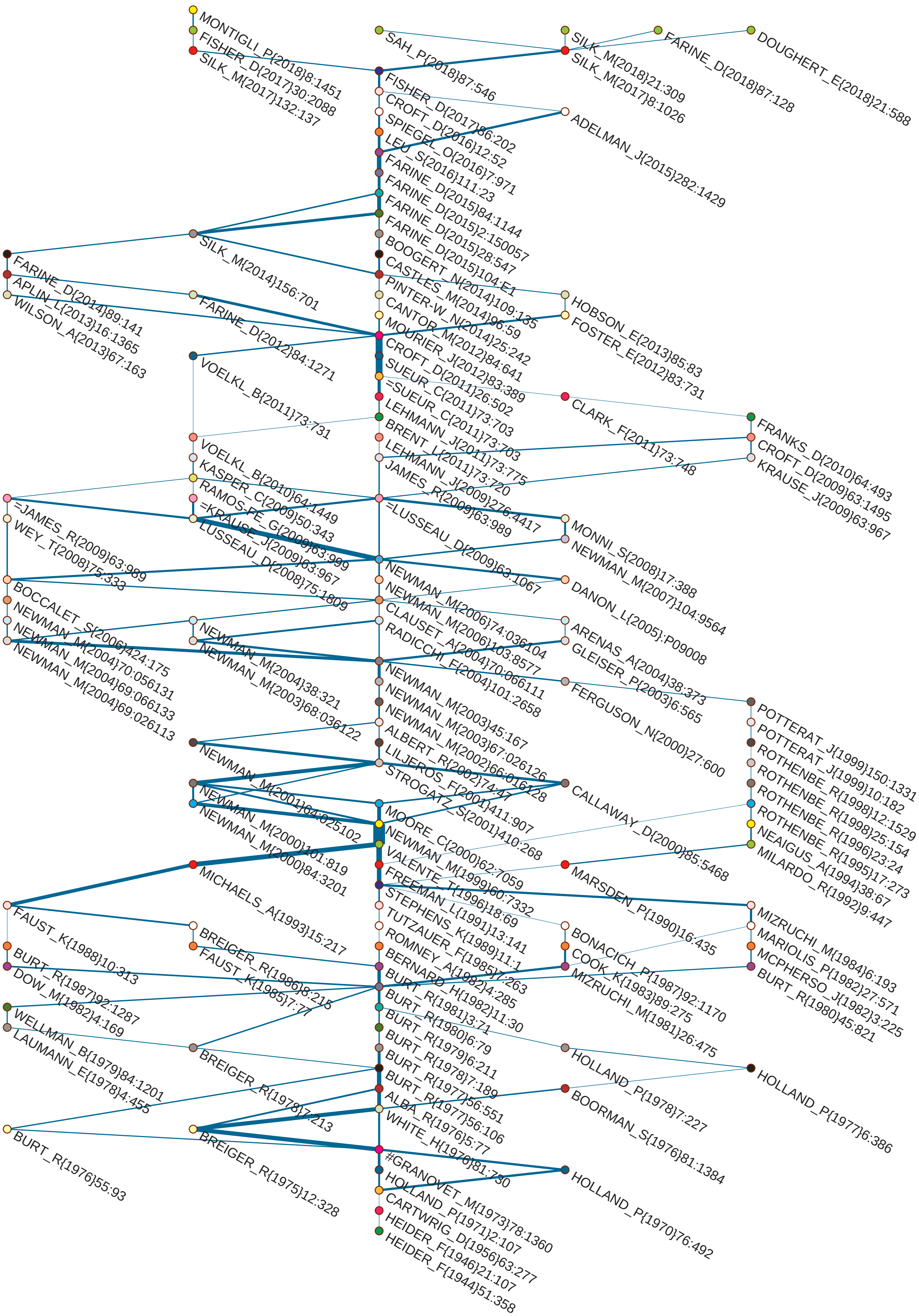

Figure 6: Key Routes

6.3 Link Islands

Using Islands approach, we searched for SPC link islands (on line weights) with the number of nodes between 20 and 200, and found 5 islands of 138, 65, 13, 12, and 11 nodes. The obtained largest Islands 4 of 138 is presented on the Figure 7. It structure reminds the structure if the Key-route paths - there are 89 overlapping nodes in two networks. The majority of the works presented in this island (from bottom to the work of Valente, published in 1996) belong to the 'social' network scientists, whose works were alreday discussed upper. In comparison to the Key-routes, this network includes more evident group of works on blockmodeling - by Faust, Doreian, and Batagelj, published in 1992-1997. In the 'physicists'' part (from Newman, 1999 to Newman, 2006 on the 'main' route) the topic of evolving networks is also presented (Bianconi, Yook, 2001, Jeong, 2003). The third, behavioural ecologists' part is pretty short and finishes by the works on animal social networks published in 2010.

However, this group is fully presented in another Island 5 containing 65 nodes and presented on the Figure 7. It has 39 overlapping nodes with the Key-routes. 'New' works presented in the island also belong to the topics on animal social networks described above. Howver, there are some more works devoted to the methodological issues of network analysis itself - reconstructing animal social networks from independent small-group observations Perreault, 2010), temporal dynamics and network analysis (Blonder, 2012), mining of animal social systems (Krause, 2013), animal social network inference and permutations for ecologists in R (Farine, 2013), estimating uncertainty and reliability of social network data using Bayesian inference (Farine, 2015). It is ineteresting, that this group form a separate subnetwork, even though it is connected to the upper part of Island 4 by topic. It may mean that the works included into this subnetwork are more connected to each other, while social animal network works in the Island 4 are more stongly connected to the works of phisicists.

Three other obtained islands are presented on the Figure 9. For the purpose of better visibility of the picture, the weights were maximized by 100. The left Island 2 consitst of 12 work in the field of social networks in educations, imcluding issues of leadership, teachers and students communication and collaboration. Another very coherent group is presented in the same figure on the bottom left. These are 11 works in neuropsychiatrie written bu Ausrian authors. The left upper island presenets 13 works of physicists with the strongest links between the work of Bocaletti published in 2014 on the structure and dynamics of multilayer networks and others on the topics of complex, multilayer, dynamic, and temporal networks, as well as spreading processes in these networks.

6.4 Probabilistic flow

We computed the Probabilistic flow on weighted network, and determined node islands (on vertex weights) with the number of nodes between 10 and 200 and got one island with the size of 200 of nodes.

Table 9 present the list of the most important works, which have the highest indegree values of Probabilistic flow network. For the purposes of visibility, the values were maximized by 1,000,000. 39 works from this list overlap with the table, obtained from the highest indegree values of network CiteN. First 30 works in the list, except `BLEI_D(2003)3:993` on latent dirichlet allocation, `ALBERT_R(1999)401:130` on world-wide web, and `O'REILLY_T(2005)` on web 2.0 are met in the both lists. Other works appeared in this island, which are not in the list of the most cited works, are works of physicists (Strogatz, Watts, Albert), computer scientists (Brin), mathematics (Bollobas), scientometrics (Page, Redner), and social scientists (Katz, Mitchell, Glaser).

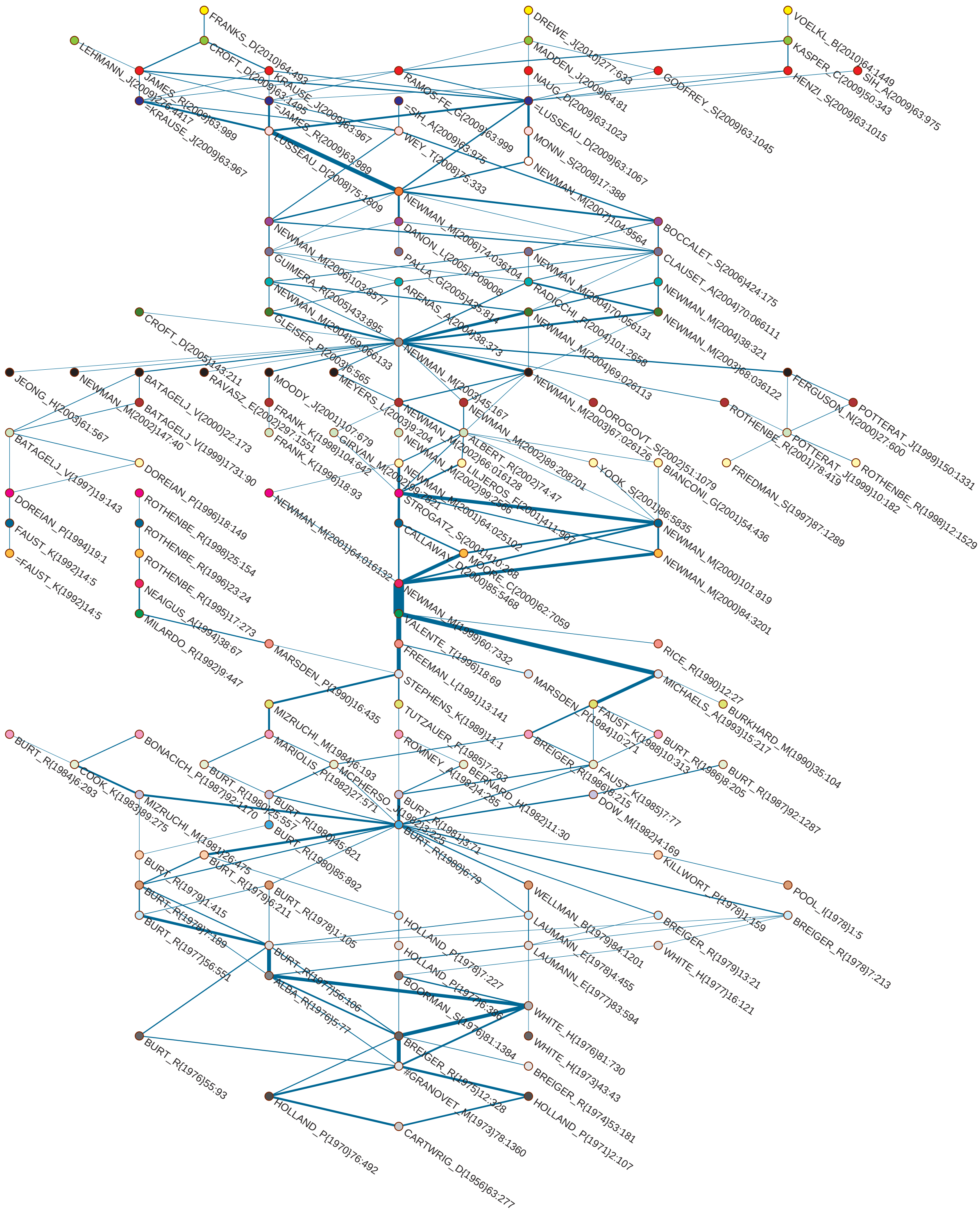

Figure 7: Island 4, from SPC network

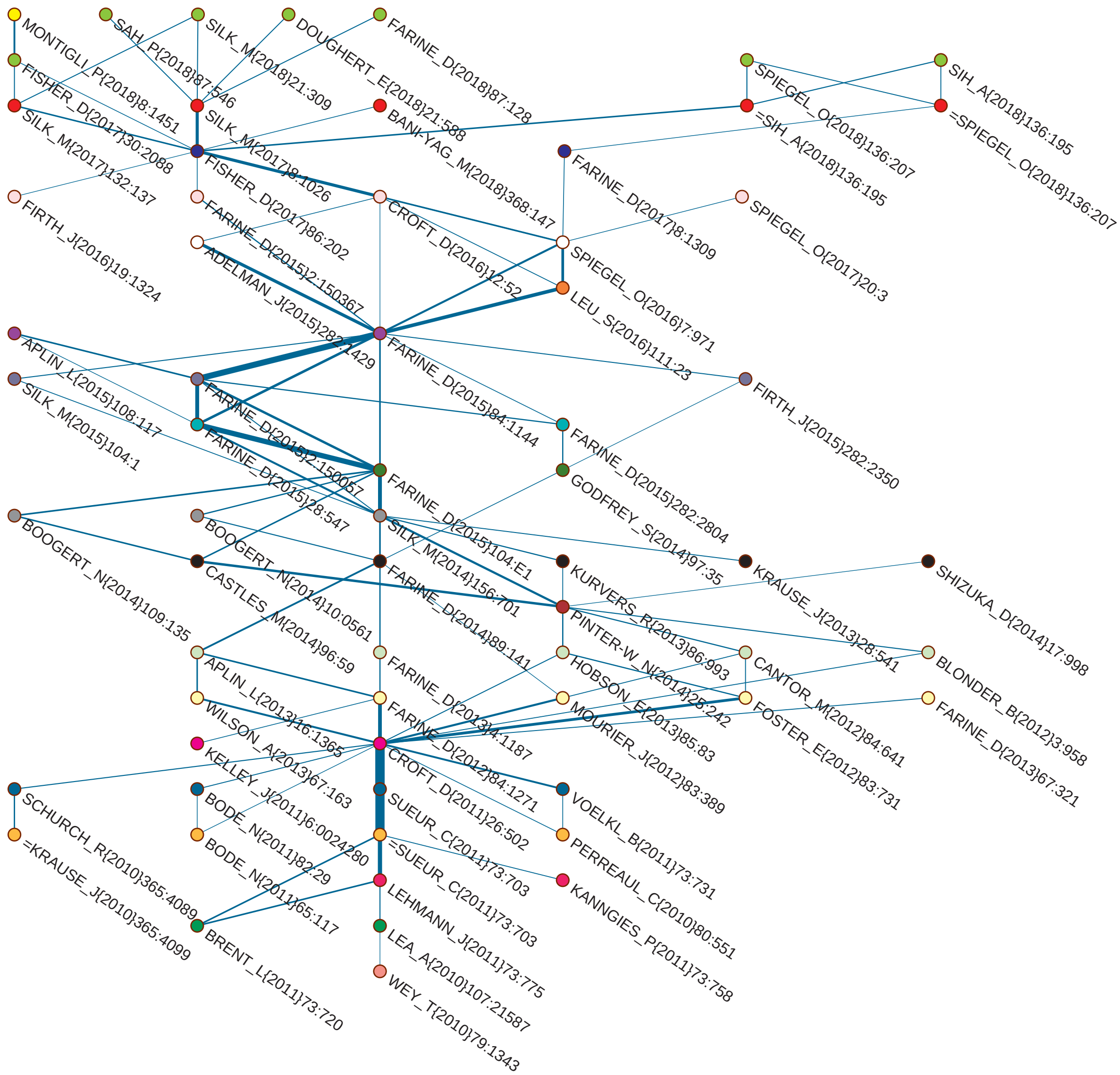

Figure 8: Island 5, from SPC network

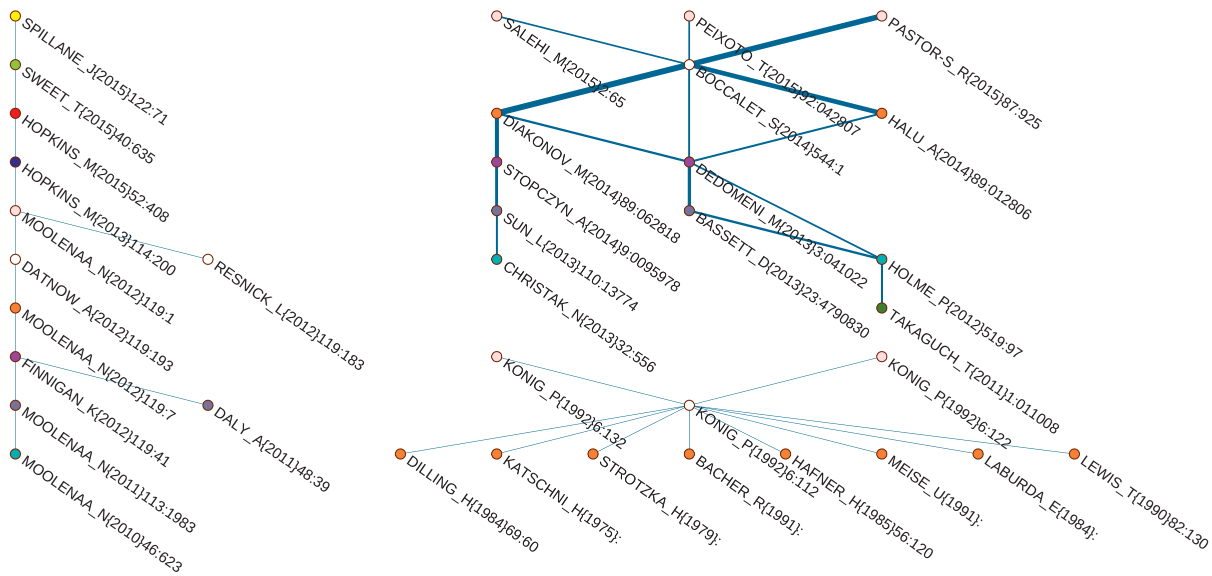

Figure 9: Islands 1-3, from SPC network

Table 9: Most important works from Probabilistic Flow network

Rank	Value	Id	Rank	Value	Id
1	4691	WASSERMA_S(1994):	31	545	BLONDEL_V(2008):P10008
2	2941	WATTS_D(1998)393:440	32	527	KATZ_L(1953)18:39
3	2676	GRANOVET_M(1973)78:1360	33	526	NEWMAN_M(2010):
4	2445	BOYD_D(2007)13:210	34	520	STROGATZ_S(2001)410:268
5	2241	BARABASI_A(1999)286:509	35	517	PALLA_G(2005)435:814
6	1926	FREEMAN_L(1979)1:215	36	499	CLAUSET_A(2004)70:066111
7	1396	GIRVAN_M(2002)99:7821	37	497	ERDOS_P(1960)5:17
8	1299	NEWMAN_M(2003)45:167	38	488	ROGERS_E(2003):
9	1227	MCPHERSO_M(2001)27:415	39	485	NEWMAN_M(2006)103:8577
10	1158	ALBERT_R(2002)74:47	40	481	COLEMAN_J(1990):
11	1105	SCOTT_J(2000):	41	478	BRIN_S(1998)30:107
12	1098	BURT_R(1992):	42	477	AMARAL_L(2000)97:11149
13	1045	MILGRAM_S(1967)1:61	43	475	ERDOS_P(1959)6:290
14	1013	NEWMAN_M(2004)69:026113	44	465	WATTS_D(1999):
15	928	KAPLAN_A(2010)53:59	45	462	LAVE_J(1991):
16	878	FREEMAN_L(1977)40:35	46	460	KLEINBER_J(1999)46:604
17	852	PUTNAM_R(2000):	47	449	SCOTT_J(1991):
18	847	COLEMAN_J(1988)94:95	48	446	BOLLOBAS_B(1985):
19	835	BLEI_D(2003)3:993	49	442	PAGE_L(1999):
20	742	GRANOVET_M(1985)91:481	50	440	NEWMAN_M(2001)64:025102
21	731	CHRISTAK_N(2007)357:370	51	436	NEWMAN_M(2004)69:066133
22	727	EVERETT_M(2002):	52	431	REDNER_S(1998)4:131
23	726	NEWMAN_M(2001)98:404	53	429	CHRISTAK_N(2008)358:2249
24	719	ALBERT_R(1999)401:130	54	424	ADOMAVIC_G(2005)17:734
25	701	O'REILLY_T(2005):	55	424	KEMP_D(2003):137
26	669	BORGATTI_S(2002):	56	423	DOMINGOS_P(2001):57
27	667	FORTUNAT_S(2010)486:75	57	423	MITCHELL_J(1969):
28	633	HANNEMAN_R(2005):	58	415	ALBERT_R(2000)406:378
29	569	STEINFIE_C(2007)12:1143	59	415	GLASER_B(1967):
30	549	ZACHARY_W(1977)33:452	60	410	ROGERS_E(1995):

Table 10: Cite net: Overlapping of components:
(1- Key Routes, 2- Main Path (CPM), 3- Island5, 4 - Island 4, Node Island, 5 - Prob Flow Island)

year	code	author	title	journal
1934	6	Moreno, JL	Who Shall Survive: A New Approach to the Problem of Human Interrelations	*****
1941	6	Davis, A	Deep South: A Social Anthropological Study of Caste and Class	*****
1944	1,2	Heider, F	Social perception and phenomenal causality	PSYCHOL REV
1946	1,2	Heider, F	Attitudes and cognitive organization	J PSYCHOL
1948	6	Bavelas, A	A mathematical model for group structure	HUM ORGAN
1950	6	Homans, GC	The human group	*****
1951	6	Leavitt, HJ	Some effects of certain communication patterns on group performance	J ABNORM SOC PSYCH
1953	6	Katz, L	A new status index derived from sociometric analysis	PSYCHOMETRIKA
1954	6	Barnes, JA	Class and committees in a norwegian island parish	HUM RELAT
1955	6	Katz, E	Personal influence	*****
1956	1,2,4,5,6	Cartwright, D	Structural balance - a generalization of heider theory	PSYCHOL REV
1957	6	Bott, E	Family and social network: roles	*****
1958	6	Heider, F	The psychology of interpersonal relations	*****
1959	6	Goffman, E	The presentation of self in everyday life	*****
1959	6	Erdos, P	On random graphs I	*****
1960	6	Erdos, P	On the evolution of random graphs	PUBL MAT INST HUNG ACAD SCI
1962	6	Rogers, EM	Diffusion of innovations	*****
1965	6	Price, DJD	Networks of scientific papers	SCIENCE
1965	6	Harary, F	Structural models: an introduction to the theory of directed graphs	*****
1965	6	Hubbell, CH	”An input-output approach to clique identification	SOCIOMETRY
1966	6	Sabidussi, G	the centrality of a graph	*****
1966	6	Coleman, JS	Equality of educational opportunity	*****
1967	6	Glaser, BG	The discovery of grounded theory: strategies for qualitative theory	*****
1967	6	Milgram, S	The small world problem	PSYCHOL TODAY
1967	6	Milgram, S	The small world problem	*****
1969	6	Travers, J	An experimental study of the small world problem	*****
1969	6	Kauffman, S	Metabolic stability and epigenesis in randomly constructed genetic nets	THEORET BIOL
1969	6	Mitchell, JC	Social networks in urban situations: analyses of personal relationships in central african towns	*****

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year	code	author	title	journal
1970	1,2,4,5	Holland, PW	Method for detecting structure in sociometric data	AMER J SOCIOL
1970	5	White, HC	Search parameters for small world problem	SOC FORCES
1970	6	Kernighan, BW	An efficient heuristic procedure for partitioning graphs	*****
1971	1,4,5	Holland, PW	Transitivity in structural models of small groups	COMP GROUP STUD
1971	6	Lorrain, F	Structural equivalence of individuals in social networks	*****
1972	6	Bonacich, P	Factoring and weighting approaches to status scores and clique identification	J MATH SOCIOL
1973	1,2,4,5,6	Granovet,MS	Strength of weak ties	AMER J SOCIOL
1973	4	White, HC	Everyday life in stochastic networks	SOCIOL INQ
1973	5	Holland, PW	Structural implications of measurement error in sociometry	J MATH SOCIOL
1973	6	Laumann, EO	Bonds of pluralism: the form and substance of urban social networks	*****
1974	4,5	Breiger, RL	Duality of persons and groups	SOC FORCES
1974	6	Granovetter, M.S.	Getting a job: a study of contacts and careers	*****
1975	1,2,4,5	Breiger, RL	Algorithm for clustering relational data with applications to social network analysis and comparison with multidimensional-scaling	J MATH PSYCHOL
1975	6	Fishbein, M	Intention and behavior: an introduction to theory and research	*****
1976	1,2,4,5,6	White, HC	Social-structure from multiple networks 1 Blockmodels of roles and positions	AMER J SOCIOL
1976	1,2,4,5	Alba, RD	Intersection of social circles - new measure of social proximity in networks	SOCIOL METHOD RES
1976	1,4,5	Burt, RS	Positions in networks	SOC FORCES
1976	1,4,5	Boorman, SA	Social-structure from multiple networks 2 Role structures	AMER J SOCIOL
1977	1,2,4,5	Burt, RS	Positions in multiple network systems 1 General conception of stratification and prestige in a system of actors cast as a social topology	SOC FORCES
1977	1,2,4,5	Burt, RS	Positions in multiple network systems 2 Stratification and prestige among elite decision-makers in community of altneustadt	SOC FORCES
1977	1,4,5	Holland, PW	Social-structure as a network process	Z SOZ
1977	4,5	Laumann, EO	Community-elite influence structures - extension of a network approach	AMER J SOCIOL
1977	4,5	White, HC	Probabilities of homomorphic mappings from multiple graphs	J MATH PSYCHOL

Table 10: Cite net: Overlapping of components:
(1- Key Routes, 2- Main Path (CPM), 3- Island5, 4 - Island 4, Node Island, 5 - Prob Flow Island)

year	code	author	title	journal
1977	6	Freeman, LC	Set of measures of centrality based on betweenness	SOCIOMETRY
1977	6	Zachary, WW	An information flow model for conflict and fission in small groups	*****
1978	1,2,4,5	Burt, RS	Cohesion versus structural equivalence as a basis for network subgroups	SOCIOL METHOD RES
1978	1,4,5	Holland, PW	Omnibus test for social-structure using triads	SOCIOL METHOD RES
1978	1,4,5	Laumann, EO	Community structure as interorganizational linkages	ANNU REV SOCIOL
1978	1,4,5	Breiger, RL	Joint role structure of 2 communities elites	SOCIOL METHOD RES
1978	4,5,6	Pool, ID	Contacts and influence	SOC NETWORKS
1978	4,5	Killworth, PD	Reversal small-world experiment	SOC NETWORKS
1978	4,5	Burt, RS	Stratification and prestige among elite experts in methodological and mathematical sociology circa 1975	SOC NETWORKS
1978	6	Granovetter, M	Threshold models of collective behavior	AM J SOCIOL
1979	1,2,4,5	Burt, RS	Relational equilibrium in a social topology	J MATH SOCIOL
1979	1,4,5	Wellman, B	Community question - intimate networks of east yorkers	AMER J SOCIOL
1979	4,5	Breiger, RL	Toward an operational theory of community elite structures	QUAL QUANT
1979	4,5	Burt, RS	Structural theory of interlocking corporate directorates	SOC NETWORKS
1979	6	Freeman, LC	Centrality in social networks conceptual clarification	SOC NETWORKS
1979	6	Berkman, LF	Social networks, host-resistance, and mortality - 9-year follow-up-study of alameda county residents	AMER J EPIDEMIOL
1979	6	Garey, MR	Computers and intractability: a guide to the theory of np-completeness	*****
1980	1,2,4,5	Burt, RS	Models of network structure	ANNU REV SOCIOL
1980	1,2,4,5	Burt, RS	Testing a structural theory of corporate cooptation - interorganizational directorate ties as a strategy for avoiding market constraints on profits	AMER SOCIOL REV
1980	4,5	Burt, RS	Cooptive corporate actor networks - a reconsideration of interlocking directorates involving american manufacturing	ADMIN SCI QUART
1980	4,5	Burt, RS	Autonomy in a social topology	AMER J SOCIOL

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(1- Key Routes, 2- Main Path (CPM), 3- Island5, 4 - Island 4, Node Island, 5 - Prob Flow Island)

year	code	author	title	journal
1981	1,4,5	Mizruchi, MS	Influence in corporate networks - an examination of 4 measures	ADMIN SCI QUART
1981	1,4,5	Burt, RS	A note on inferences regarding network subgroups	SOC NETWORKS
1981	6	Holland, PW	An exponential family of probability-distributions for directed-graphs	J AMER STATIST ASSN
1981	6	Feld, SL	The focused organization of social ties	AM J SOCIOL
1982	1,2,4,5	Mcpherson, JM	Hypernetwork sampling - duality and differentiation among voluntary organizations	SOC NETWORKS
1982	1,2,4,5	Mariolis, P	Centrality in corporate interlock networks - reliability and stability	ADMIN SCI QUART
1982	1,4,5	Bernard, HR	Informant accuracy in social-network data 5 An experimental attempt to predict actual communication from recall data	SOC SCI RES
1982	1,4,5	Romney, AK	Predicting the structure of a communications network from recalled data	SOC NETWORKS
1982	1,4,5	Dow, MM	Network auto-correlation - a simulation study of a foundational problem in regression and survey-research	SOC NETWORKS
1982	6	Fischer, CS	To dwell among friends: personal networks in town and city	*****
1982	6	Burt, RS	Toward a structural theory of action: network models of social structure, perception and action	*****
1983	1,4,5	Cook, KS	The distribution of power in exchange networks - theory and experimental results	AM J SOCIOL
1983	6	Granovetter, M	”The strength of weak ties: a network theory revisited	SOCIOL THEORY
1983	6	Salton, G	introduction to modern information retrieval	*****
1984	1,2,4,5	Mizruchi, MS	Interlock groups, cliques, or interest-groups - comment	SOC NETWORKS
1984	4,5	Burt, RS	Network items and the general social survey	SOC NETWORKS
1984	4,5	Marsden, PV	Mathematical ideas in social structural-analysis	J MATH SOCIOL
1984	6	Lazarus, R	Stress, appraisal, and coping	*****
1984	6	Axelrod, R	The evolution of cooperation	*****
1984	6	Kuramoto, Y	Chemical oscillations, waves, and turbulence	*****
1985	1,4,5	Faust, K	Does structure find structure - a critique of burt use of distance as a measure of structural equivalence	SOC NETWORKS
1985	1,4,5	Tutzauer, F	Toward a theory of disintegration in communication-networks	SOC NETWORKS
1985	6	Cohen, S	Stress, social support, and the buffering hypothesis	PSYCHOL BULL

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(1- Key Routes, 2- Main Path (CPM), 3- Island5, 4 - Island 4, Node Island, 5 - Prob Flow Island)

year	code	author	title	journal
1985	6	Granovetter, M	Economic-action and social-structure - the problem of embeddedness	AMER J SOCIOL
1985	6	Bollobas, B	Random graphs	*****
1986	1,4,5	Breiger, RL	Cumulated social roles - the duality of persons and their algebras	SOC NETWORKS
1986	4,5	Burt, RS	A cautionary note	SOC NETWORKS
1986	6	Bourdieu P	The forms of capital	*****
1986	6	Baron, RM	The moderator mediator variable distinction in social psychological-research - conceptual, strategic, and statistical considerations	J PERSONAL SOC PSYCHOL
1986	6	Bandura, A	Social foundations of thought and action: a social cognitive theory	*****
1987	1,4,5,6	Bonacich, P	Power and centrality - a family of measures	AMER J SOCIOL
1987	1,4,5	Burt, RS	Social contagion and innovation - cohesion versus structural equivalence	AMER J SOCIOL
1988	1,4,5	Faust, K	Comparison of methods for positional analysis - structural and general equivalences	SOC NETWORKS
1988	6	House, JS	Social relationships and health	SCIENCE
1988	6	Coleman, JS	Social capital in the creation of human capital	AM JOUR SOC
1988	6	Wellman, B	Social structures: a network approach	******
1989	1,2,4,5	Stephenson, K	Rethinking centrality - methods and examples	SOC NETWORKS
1989	6	Kamada, T	An algorithm for drawing general undirected graphs	INFORM PROCESS LETT
1989	6	Davis, FD	Perceived usefulness, perceived ease of use, and user acceptance of information technology	MIS QUART
1989	6	Kochen, M	The small world	*****
1990	1,4,5,6	Marsden, PV	Network data and measurement	ANNU REV SOCIOL
1990	4	Burkhardt, ME	Changing patterns or patterns of change - the effects of a change in technology on social network structure and power	ADMIN SCI QUART
1990	4	Rice, RE	Individual and network influences on the adoption and perceived outcomes of electronic messaging	SOC NETWORKS
1990	6	Coleman,J.	Foundations of social theory	*****
1990	6	Guare, J	Six degrees of separation: a play	*****
1990	6	Deerwester, S	Indexing by latent semantic analysis	J AM SOC INF SCI TEC
1991	1,2,4,5	Freeman, LC	Centrality in valued graphs - a measure of betweenness based on network flow	SOC NETWORKS
1991	6	Ajzen, I	The theory of planned behavior	ORGAN BEHAV HUM DEC
1991	6	Scott, J	Social network analysis: a handbook	*****

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(1- Key Routes, 2- Main Path (CPM), 3- Island5, 4 - Island 4, Node Island, 5 - Prob Flow Island)

year	code	author	title	journal
1991	6	Lave, J	Situated learning: legitimate peripheral participation	*****
1991	6	Fruchterman, TMJ	Graph drawing by force-directed placement	SOFTWARE PRACT EXPER
1992	1,4,5	Milardo, RM	Comparative methods for delineating social networks	J SOC PERSON RELAT
1992	4,5	Faust, K	Blockmodels - interpretation and evaluation	SOC NETWORKS
1992	4,5	Faust, K	Blockmodels - interpretation and evaluation	SOC NETWORKS
1992	5	Batagelj, V	Direct and indirect methods for structural equivalence	SOC NETWORKS
1992	5	Batagelj, V	An optimizational approach to regular equivalence	SOC NETWORKS
1992	5	Batagelj, V	Direct and indirect methods for structural equivalence	SOC NETWORKS
1992	5	Batagelj, V	An optimizational approach to regular equivalence	SOC NETWORKS
1992	6	Burt, RS	Structural holes: the social structure of competition	*****
1992	6	Nowak, MA	Evolutionary games and spatial chaos	NATURE
1993	1,4,5	Michaelson, AG	The development of a scientific specialty as diffusion through social-relations - the case of role analysis	SOC NETWORKS
1993	6	Putnam, RD	Making democracy work: civic institutions in modern italy	*****
1993	6	Padgett, JF	Robust action and the rise of the medici, 1400-1434	AMER J SOCIOL
1993	6	Manski, CF	Identification of endogenous social effects - the reflection problem	REV ECON STUD
1993	6	Ahuja, RK	Network flows: theory, algorithms, and applications	*****
1994	1,4,5	Neaigus, A	The relevance of drug injectors social and risk networks for understanding and preventing hiv-infection	SOC SCI MED
1994	4,5	Doreian, P	Partitioning networks based on generalized concepts of equivalence	J MATH SOCIOL
1994	6	Wasserman, S	Social network analysis: methods and applications	*****
1995	1,4,5	Rothenberg, RB	Choosing a centrality measure - epidemiologic correlates in the colorado-springs study of social networks	SOC NETWORKS
1995	6	Molloy, M	A critical-point for random graphs with a given degree sequence	RANDOM STRUCT ALGOR

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(1- Key Routes, 2- Main Path (CPM), 3- Island5, 4 - Island 4, Node Island, 5 - Prob Flow Island)

year	code	author	title	journal
1995	6	Rogers, EM	Diffusion of Innovation. 4th	*****
1995	6	Granovetter, M.S.	Getting a Job: A Study of Contacts and Careers	*****
1995	6	Nonaka, I	The knowledge creation company: how Japanese companies create the dynamics of innovation	*****
1995	6	Putnam, RD	Bowling Alone: America's Declining Social Capital. An Interview with Robert Putnam	J DEMOCR
1996	1,2,4,5	Valente, TW	Social network thresholds in the diffusion of innovations	SOC NETWORKS
1996	1,4,5	Rothenberg, R	The relevance of social network concepts to sexually transmitted disease control	SEX TRANSM DIS
1996	4,5	Doreian, P	A partitioning approach to structural balance	SOC NETWORKS
1996	4	Frank, KA	Mapping interactions within and between cohesive subgroups	SOC NETWORKS
1996	6	Wasserman, S	Logit models and logistic regressions for social networks .1. An introduction to Markov graphs and p	PSYCHOMETRIKA
1996	6	Kretzschmar, M	Measures of concurrency in networks and the spread of infectious disease	MATH BIOSCI
1997	4,5	Friedman, SR	Sociometric risk networks and risk for HIV infection	AMER J PUBLIC HEALTH
1997	4,5	Batagelj, V	Notes on blockmodeling	SOC NETWORKS
1997	6	Uzzi, B	Social structure and competition in interfirm networks: The paradox of embeddedness	ADMIN SCI QUART
1998	1,4,5	Rothenberg, RB	Social network dynamics and HIV transmission	AIDS
1998	1,4	Rothenberg, RB	Using social network and ethnographic tools to evaluate syphilis transmission	SEX TRANSM DIS
1998	4,5	Frank, KA	Linking action to social structure within a system: Social capital within and between subgroups	AMER J SOCIOL
1998	6	Watts, DJ	Collective dynamics of 'small-world' networks	NATURE
1998	6	Portes, A	Social Capital: Its origins and applications in modern sociology	ANNU REV SOCIOL
1998	6	Nahapiet, J	Social capital, intellectual capital, and the organizational advantage	ACAD MANAGE REV
1998	6	Redner, S	How popular is your paper? An empirical study of the citation distribution	*****
1998	6	Wenger, E	Communities ofpractice: Learning, meaning, and identity	*****
1998	6	Page, L	The pagerank citation ranking: Bringing order to the web.	*****
1998	6	Brin, S	The anatomy of a large-scale hypertextual Web search engine	COMPUT NETWORKS ISDN
1998	6	Huberman, B	Strong regularities in world wide web surfing .	Science

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year	code	author	title	journal
1999	1,2,4,5	Newman, MEJ	Scaling and percolation in the small-world network model	PHYS REV E
1999	1,4,5	Potterat, JJ	Chlamydia transmission: Concurrency, reproduction number, and the epidemic trajectory	AMER J EPIDEMIOL
1999	1,4,5	Potterat, JJ	Network structural dynamics acid infectious disease propagation	INT J STD AIDS
1999	4,5	Batagelj, V	Partitioning approach to visualization of large graphs	LECT NOTE COMPUT SCI
1999	6	Barabasi, AL	Emergence of scaling in random networks	SCIENCE
1999	6	Hansen, MT	The search-transfer problem: The role of weak ties in sharing knowledge across organization subunits	ADMIN SCI QUART
1999	6	Faloutsos, M	On power-law relationships of the internet topology	*****
1999	6	Watts, DJ	Small Worlds: The Dynamics of Networks Between Order and Randomness	*****
1999	6	Barabasi, AL	Mean-field theory for scale-free random networks	PHYSICA A
1999	6	Albert, R	Internet - Diameter of the World-Wide Web	NATURE
1999	6	Banavar, JR	Size and form in efficient transportation networks. Nature,	Nature
1999	6	Kleinberg, JM	Authoritative sources in a hyperlinked environment	J ACM
1999	6	Haberman, B	Internet: growth dynamics of the world-wide web	Nature
1999	6	Lawrence, S	Accessibility of information on the Web.	Nature
1999	6	Barthélémy, M	Small-world networks: Evidence for a crossover picture	PHYS REV LETT
2000	1,2,4,5	Newman, MEJ	Models of the small world	J STATIST PHYS
2000	1,2,4,5	Moore, C	Exact solution of site and bond percolation on small-world networks	PHYS REV E
2000	1,4,5	Callaway, DS	Network robustness and fragility: Percolation on random graphs	PHYS REV LETT
2000	1,4,5	Newman, MEJ	Mean-field solution of the small-world network model	PHYS REV LETT
2000	1,4,5	Ferguson, NM	More realistic models of sexually transmitted disease transmission dynamics - Sexual partnership networks, pair models, and moment closure	SEX TRANSM DIS
2000	4,5	Batagelj, V	Some analyses of Erdos collaboration graph	SOC NETWORKS
2000	6	Putnam RD	Bowling alone: America's declining social capital	*****
2000	6	Jeong, H	The large-scale organization of metabolic networks	NATURE

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(1- Key Routes, 2- Main Path (CPM), 3- Island5, 4 - Island 4, Node Island, 5 - Prob Flow Island)

year	code	author	title	journal
2000	6	Berkman, LF	From social integration to health: Durkheim in the new millennium	SOC SCI MED
2000	6	Albert, R	Error and attack tolerance of complex networks	NATURE
2000	6	Amaral, LAN	Classes of small-world networks	PROC NAT ACAD SCI USA
2000	6	Broder, A	Graph structure in the Web	COMPUT NETW
2000	6	Scott, J	Social Network Analysis: A Handbook	*****
2000	6	Shi, JB	Normalized cuts and image segmentation	IEEE T PATTERN ANAL
2001	1,2,4,5,6	Newman, MEJ	Clustering and preferential attachment in growing networks	PHYS REV E
2001	1,2,4,5,6	Strogatz, SH	Exploring complex networks	NATURE
2001	1,4,5	Liljeros, F	The web of human sexual contacts	NATURE
2001	4,5,6	Newman, MEJ	Scientific collaboration networks. II. Shortest paths, weighted networks, and centrality	PHYS REV E
2001	4,5	Moody, J	Race, school integration, and friendship segregation in America	AMER J SOCIOL
2001	4,5	Rothenberg, R	The risk environment for HIV transmission: Results from the Atlanta and Flagstaff network studies	J URBAN HEALTH
2001	4	Yook, SH	Weighted evolving networks	PHYS REV LETT
2001	4	Bianconi, G	Competition and multiscaling in evolving networks	EUROPHYS LETT
2001	6	Mcpherson, M	Birds of a feather: Homophily in social networks	ANNU REV SOCIOL
2001	6	Newman, MEJ	The structure of scientific collaboration networks	PROC NAT ACAD SCI USA
2001	6	Lin, N	Social capital. A theory of social structure and action.	*****
2001	6	Brandes, U	A faster algorithm for betweenness centrality	J MATH SOCIOL
2001	6	Domingos, P	Mining the network value of customers	*****
2001	6	Goldenberg, J	Talk of the network: A complex systems look at the underlying process of word-of-mouth	MARK LETT
2001	6	Pastor-satorras, R	Epidemic spreading in scale-free networks	PHYS REV LETT
2002	1,2,4,5,6	Albert, R	Statistical mechanics of complex networks	REV MOD PHYS
2002	1,2,4,5,6	Newman, MEJ	Spread of epidemic disease on networks	PHYS REV E
2002	4,5,6	Girvan, M	Community structure in social and biological networks	PROC NAT ACAD SCI USA
2002	4,5,6	Newman, MEJ	Assortative mixing in networks	PHYS REV LETT
2002	4,5	Dorogovtsev, SN	Evolution of networks	ADV PHYS
2002	4,5	Newman, MEJ	Random graph models of social networks	PROC NAT ACAD SCI USA

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year	code	author	title	journal
2002	4	Ravasz, E	Hierarchical organization of modularity in metabolic networks	SCIENCE
2002	4	Newman, MEJ	The structure and function of networks	COMPUT PHYS COMMUN
2002	6	Watts, DJ	Identity and search in social networks	SCIENCE
2002	6	Barabasi, AL	Linked: The New Science Of Networks	*****
2002	6	Barabasi, AL	Evolution of the social network of scientific collaborations	PHYSICA A
2002	6	Adler, PS	Social capital: Prospects for a new concept	ACAD MANAGE REV
2002	6	Otte, E	Social network analysis: a powerful strategy, also for the information sciences	J INFORM SCI
2002	6	Richardson, M	Mining knowledge-sharing sites for viral marketing	*****
2003	1,2,4,5,6	Newman, MEJ	The structure and function of complex networks	SIAM REV
2003	1,2,4,5,6	Newman, MEJ	Mixing patterns in networks	PHYS REV E
2003	1,4,5	Newman, MEJ	Why social networks are different from other types of networks	PHYS REV E
2003	1,4,5	Gleiser, PM	Community structure in jazz	ADV COMPLEX SYST
2003	4,5	Meyers, LA	Applying network theory to epidemics: Control measures for Mycoplasma pneumoniae outbreaks	EMERG INFECT DIS
2003	4	Jeong, H	Measuring preferential attachment in evolving networks	EUROPHYS LETT
2003	5,6	Guimera, R	Self-similar community structure in a network of human interactions	PHYS REV E
2003	6	Rogers, EM	Diffusion of innovations	*****
2003	6	Borgatti, SP	The network paradigm in organizational research: A review and typology	J MANAGE
2003	6	Dorogovtsev, SN	Evolution of Networks: From Biological Nets to the Internet and WWW	*****
2003	6	Watts, DJ	Six Degrees: The Science of a Connected Age	*****
2003	6	Blei, DM	Latent Dirichlet allocation	J MACH LEARN RES
2003	6	Adamic, LA	Friends and neighbors on the Web	SOC NETWORKS
2003	6	Lusseau, D	The bottlenose dolphin community of Doubtful Sound features a large proportion of long-lasting associations - Can geographic isolation explain this unique trait?	BEHAV ECOL SOCIOBIOL
2003	6	Venkatesh, V	User acceptance of information technology: Toward a unified view	MIS QUART

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(1- Key Routes, 2- Main Path (CPM), 3- Island5, 4 - Island 4, Node Island, 5 - Prob Flow Island)

year	code	author	title	journal
2003	6	Kempe, D	"Maximizing the spread of influence through a social network	ACM SIGKDD CONF
2003	6	Kempe, D	Maximizing the spread of influence through a social network	ACM SIGKDD CONF
2004	1,2,4,5,6	Newman, MEJ	Finding and evaluating community structure in networks	PHYS REV E
2004	1,2,4,5,6	Newman, MEJ	Detecting community structure in networks	EUR PHYS J B
2004	1,2,4,5,6	Clauset, A	Finding community structure in very large networks	PHYS REV E
2004	1,4,5,6	Radicchi, F	Defining and identifying communities in networks	P NATL ACAD SCI USA
2004	1,4,5,6	Newman, MEJ	Fast algorithm for detecting community structure in networks	PHYS REV E
2004	1,4,5	Arenas, A	Community analysis in social networks	EUR PHYS J B
2004	1,4,5	Newman, MEJ	Analysis of weighted networks	PHYS REV E
2004	6	Cross, RL	The hidden power of social networks: Understanding how work really gets done in organizations	*****
2004	6	Freeman, LC	The development of social network analysis. A Study in the Sociology of Science	*****
2004	6	Eubank, S	Modelling disease outbreaks in realistic urban social networks	NATURE
2004	6	Burt, RS	Structural holes and good ideas	AMER J SOCIOL
2005	1,4,5	Danon, L	Comparing community structure identification	J STAT MECH-THEORY E
2005	4,5,6	Guimera, R	Functional cartography of complex metabolic networks	NATURE
2005	4,5,6	Palla, G	Uncovering the overlapping community structure of complex networks in nature and society	NATURE
2005	4	Croft, DP	Assortative interactions and social networks in fish	OECOLOGIA
2005	6	Burt, RS	Brokerage and closure: An introduction to social capital	*****
2005	6	Adomavicius, G	Toward the next generation of recommender systems: A survey of the state-of-the-art and possible extensions	*****
2005	6	Carrington, P	Models and Methods in Social Network Analysis	*****
2005	6	Borgatti, SP	Centrality and network flow	SOC NETWORKS
2005	6	Gross, R	Information revelation and privacy in online social networks	*****
2006	1,2,4,5,6	Boccaletti, S	Complex networks: Structure and dynamics	PHYS REP-REV SECT PHYS LETT

Table 10: Cite net: Overlapping of components:
(1- Key Routes, 2- Main Path (CPM), 3- Island5, 4 - Island 4, Node Island, 5 - Prob Flow Island)

year	code	author	title	journal
2006	1,2,4,5,6	Newman, MEJ	Finding community structure in networks using the eigenvectors of matrices	PHYS REV E
2006	1,4,5,6	Newman, MEJ	Modularity and community structure in networks	PROC NAT ACAD SCI USA
2006	6	Kossinets, G	Empirical analysis of an evolving social network	SCIENCE
2006	6	Newman, M	The Structure and Dynamics of Networks	*****
2006	6	Eagle, N	Reality mining: sensing complex social systems	PERS UBIQUIT COMPUT
2007	1,4,5	Newman, MEJ	Mixture models and exploratory analysis in networks	PROC NAT ACAD SCI USA
2007	5	Krause, J	Social network theory in the behavioural sciences: potential applications	BEHAV ECOL SOCIOBIOL
2007	6	Onnela, JP	Structure and tie strengths in mobile communication networks	PROC NAT ACAD SCI USA
2007	6	Palla, G	Quantifying social group evolution	NATURE
2007	6	Christakis, NA	The spread of obesity in a large social network over 32 years	N ENGL J MED
2007	6	Mazer, JP	I'll see you on Facebook: The effects of computer-mediated teacher self-disclosure on student motivation, affective learning, and classroom climate	*****
2007	6	Liben-nowell, D	The link-prediction problem for social networks	J AM SOC INF SCI TECHNOL
2007	6	Robins, G	An introduction to exponential random graph (p*) models for social networks	SOC NETWORKS
2007	6	Fortunato, S	Resolution limit in community detection	PROC NAT ACAD SCI USA
2007	6	Boyd, DM	Social network sites: Definition, history, and scholarship	J COMPUT-MEDIAT COMM
2007	6	Raghavan, UN	Near linear time algorithm to detect community structures in large-scale networks	PHYS REV E
2007	6	Mislove, A	Measurement and Analysis of Online Social Networks	*****
2007	6	Leskovec, J	Cost-effective Outbreak Detection in Networks	*****
2007	6	Josang, A	A survey of trust and reputation systems for online service provision	DECIS SUPPORT SYST
2007	6	Steinfield c	, The benefits of Facebook "friends:" Social capital and college students' use of online social network sites.	J COMPUT-MEDIAT COMM
2007	6	Dwyer, C	Trust and privacy concern within social networking sites: A comparison of Facebook and MySpace.	AMCIS 2007 proceedings

Table 10: Cite net: Overlapping of components:
(1- Key Routes, 2- Main Path (CPM), 3- Island5, 4 - Island 4, Node Island, 5 - Prob Flow Island)

year	code	author	title	journal
2007	6	Lenhart, A	Teens, Privacy & Online Social Networks: How Teens Manage Their Online Identities and Personal Information in the Age of MySpace	*****
2007	6	Ellison, NB	The benefits of Facebook “friends:” Social capital and college students’ use of online social network sites	J COMPUT-MEDIAT COMM
2008	1,2,4,5	Lusseau, D	Incorporating uncertainty into the study of animal social networks	ANIM BEHAV
2008	1,4,5	Wey, T	Social network analysis of animal behaviour: a promising tool for the study of sociality	ANIM BEHAV
2008	1,4,5	Monni, S	Vertex clustering in random graphs via reversihle jump Markov chain Monte Carlo	J COMPUT GRAPH STAT
2008	6	Blondel, VD	Fast unfolding of communities in large networks	J STAT MECH-THEORY E
2008	6	Smith, KP	Social networks and health	ANNU REV SOCIOL
2008	6	Gonzalez, MC	Understanding individual human mobility patterns	NATURE
2008	6	Christakis, NA	The collective dynamics of smoking in a large social network	NEW ENGL J MED
2008	6	Fowler, JH	Dynamic spread of happiness in a large social network: longitudinal analysis over 20 years in the Framingham Heart Study	BRIT MED J
2009	1,2,4,5	Kasper, C	A social network analysis of primate groups	PRIMATES
2009	1,2,4,5	Ramos-Fernandez, G	Association networks in spider monkeys (Ateles geoffroyi)	BEHAV ECOL SOCIOBIOL
2009	1,2,4,5	Lusseau, D	The emergence of unshared consensus decisions in bottlenose dolphins	BEHAV ECOL SOCIOBIOL
2009	1,4,5	Croft, DP	Behavioural trait assortment in a social network: patterns and implications	BEHAV ECOL SOCIOBIOL
2009	1,4,5	James, R	Potential banana skins in animal social network analysis	BEHAV ECOL SOCIOBIOL
2009	1,4,5	Krause, J	Animal social networks: an introduction	BEHAV ECOL SOCIOBIOL
2009	1,4,5	James, R	Potential banana skins in animal social network analysis	BEHAV ECOL SOCIOBIOL
2009	1,4,5	Krause, J	Animal social networks: an introduction	BEHAV ECOL SOCIOBIOL
2009	1,4	Lehmann, J	Network cohesion, group size and neocortex size in female-bonded Old World primates	P ROY SOC B-BIOL SCI

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(1- Key Routes, 2- Main Path (CPM), 3- Island5, 4 - Island 4, Node Island, 5 - Prob Flow Island)

year	code	author	title	journal
2009	4,5	Godfrey, SS	Network structure and parasite transmission in a group living lizard, the gidgee skink, Egernia stokesii	BEHAV ECOL SOCIOBIOL
2009	4,5	Sih, A	Social network theory: new insights and issues for behavioral ecologists	BEHAV ECOL SOCIOBIOL
2009	4,5	Naug, D	Structure and resilience of the social network in an insect colony as a function of colony size	BEHAV ECOL SOCIOBIOL
2009	4,5	Madden, JR	The social network structure of a wild meerkat population: 2. Intragroup interactions	BEHAV ECOL SOCIOBIOL
2009	4,5	Henzi, SP	Cyclicity in the structure of female baboon social networks	BEHAV ECOL SOCIOBIOL
2009	4,5	Sih, A	Social network theory: new insights and issues for behavioral ecologists	BEHAV ECOL SOCIOBIOL
2009	5	Mcdonald, DB	Young-boy networks without kin clusters in a lek-mating manakin	BEHAV ECOL SOCIOBIOL
2009	6	Pempek, TA	College students' social networking experiences on Facebook	J APPL DEV PSYCHOL
2009	6	Borgatti, SP	Network Analysis in the Social Sciences	SCIENCE
2009	6	Chen, W	Efficient Influence Maximization in Social Networks	*****
2009	6	Clauset, A	Power-Law Distributions in Empirical Data	SIAM REV
2009	6	Eagle, N	Inferring friendship network structure by using mobile phone data	P NATL ACAD SCI USA
2010	1,2,4,5	Voelkl, B	Simulation of information propagation in real-life primate networks: longevity, fecundity, fidelity	BEHAV ECOL SOCIOBIOL
2010	1,4,5	Franks, DW	Sampling animal association networks with the gambit of the group	BEHAV ECOL SOCIOBIOL
2010	4,5	Drewe, JA	Who infects whom? Social networks and tuberculosis transmission in wild meerkats	P ROY SOC B-BIOL SCI
2010	3,5	Lea, AJ	Heritable victimization and the benefits of agonistic relationships	P NATL ACAD SCI USA
2010	3,5	Wey, TW	Social cohesion in yellow-bellied marmots is established through age and kin structuring	ANIM BEHAV
2010	3,5	Schurch, R	The building-up of social relationships: behavioural types, social networks and cooperative breeding in a cichlid	PHILOS T R SOC B
2010	3,5	Perreault, C	A note on reconstructing animal social networks from independent small-group observations	ANIM BEHAV
2010	3,5	Krause, J	Personality in the context of social networks	PHILOS T R SOC B
2010	6	Fortunato, S	Community detection in graphs	PHYS REP

Table 10: Cite net: Overlapping of components:
(1- Key Routes, 2- Main Path (CPM), 3- Island5, 4 - Island 4, Node Island, 5 - Prob Flow Island)

year	code	author	title	journal
2010	6	Kaplan, AM	Users of the world, unite! The challenges and opportunities of Social Media	BUS HORIZONS
2010	6	Centola, D	The Spread of Behavior in an Online Social Network Experiment	SCIENCE
2010	6	Roblyer, MD	Findings on Facebook in higher education: A comparison of college faculty and student uses and perceptions of social networking sites	INTERNET HIGH EDUC
2011	1,2,3,5	Croft, DP	Hypothesis testing in animal social networks	TRENDS ECOL EVOL
2011	1,2,3,5	Brent, LJN	Social Network Analysis in the Study of Nonhuman Primates: A Historical Perspective	AM J PRIMATOL
2011	1,2,3,5	Sueur, C	How Can Social Network Analysis Improve the Study of Primate Behavior?	AM J PRIMATOL
2011	1,2,3,5	Lehmann, J	Baboon (Papio anubis) Social Complexity-A Network Approach	AM J PRIMATOL
2011	1,2,3,5	Sueur, C	How Can Social Network Analysis Improve the Study of Primate Behavior?	AM J PRIMATOL
2011	1,3,5	Voelkl, B	Network Measures for Dyadic Interactions: Stability and Reliability	AM J PRIMATOL
2011	1	Clark, FE	Space to Choose: Network Analysis of Social Preferences in a Captive Chimpanzee Community, and Implications for Management	AM J PRIMATOL
2011	3,5	Bode, NWF	Social networks and models for collective motion in animals	BEHAV ECOL SOCIOBIOL
2011	3,5	Kanngiesser, P	Grooming Network Cohesion and the Role of Individuals in a Captive Chimpanzee Group	AM J PRIMATOL
2011	3,5	Bode, NWF	The impact of social networks on animal collective motion	ANIM BEHAV
2011	6	Kietzmann, JH	Social media? Get serious! Understanding the functional building blocks of social media	BUS HORIZONS
2011	3	Kelley, JL	Predation Risk Shapes Social Networks in Fission-Fusion Populations	PLOS ONE
2012	1,2,3,5	Farine, DR	Social network analysis of mixed-species flocks: exploring the structure and evolution of interspecific social behaviour	ANIM BEHAV
2012	1,3,5	Mourier, J	Evidence of social communities in a spatially structured network of a free-ranging shark species	ANIM BEHAV
2012	1,3,5	Cantor, M	Disentangling social networks from spatiotemporal dynamics: the temporal structure of a dolphin society	ANIM BEHAV

Table 10: Cite net: Overlapping of components:
(1- Key Routes, 2- Main Path (CPM), 3- Island5, 4 - Island 4, Node Island, 5 - Prob Flow Island)

year	code	author	title	journal
2012	1,3,5	Foster, EA	Social network correlates of food availability in an endangered population of killer whales, Orcinus orca	ANIM BEHAV
2012	3,5	Blonder, B	Temporal dynamics and network analysis	METHODS ECOL EVOL
2013	1,2,3,5	Aplin, LM	Individual personalities predict social behaviour in wild networks of great tits (Parus major)	ECOL LETT
2013	1,3,5	Wilson, ADM	Network position: a key component in the characterization of social personality types	BEHAV ECOL SOCIOBIOL
2013	1,3,5	Hobson, EA	An analytical framework for quantifying and testing patterns of temporal dynamics in social networks	ANIM BEHAV
2013	3,5	Farine, DR	Animal social network inference and permutations for ecologists in R using asnipe	METHODS ECOL EVOL
2013	3,5	Krause, J	Reality mining of animal social systems	TRENDS ECOL EVOL
2013	3,5	Kurvers, RHJM	Contrasting context dependence of familiarity and kinship in animal social networks	ANIM BEHAV
2013	3,5	Farine, DR	Social organisation of thornbill-dominated mixed-species flocks using social network analysis	BEHAV ECOL SOCIOBIOL
2014	1,2,3,5	Farine, DR	Measuring phenotypic assortment in animal social networks: weighted associations are more robust than binary edges	ANIM BEHAV
2014	1,2,3,5	Silk, MJ	The importance of fission-fusion social group dynamics in birds	IBIS
2014	1,3,5	Pinter-Wollman, N	The dynamics of animal social networks: analytical, conceptual, and theoretical advances	BEHAV ECOL
2014	1,3,5	Castles, M	Social networks created with different techniques are not comparable	ANIM BEHAV
2014	1,3,5	Boogert, NJ	Perching but not foraging networks predict the spread of novel foraging skills in starlings	BEHAV PROCESS
2014	3,5	Boogert, NJ	Developmental stress predicts social network position	BIOL LETTERS
2014	3,5	Godfrey, SS	A contact-based social network of lizards is defined by low genetic relatedness among strongly connected individuals	ANIM BEHAV
2014	3	Shizuka, D	Across-year social stability shapes network structure in wintering migrant sparrows	ECOL LETT
2015	1,2,3,5	Farine, DR	Constructing, conducting and interpreting animal social network analysis	J ANIM ECOL
2015	1,2,3,5	Farine, DR	Selection for territory acquisition is modulated by social network structure in a wild songbird	J EVOLUTION BIOL

Table 10: Cite net: Overlapping of components:
(1- Key Routes, 2- Main Path (CPM), 3- Island5, 4 - Island 4, Node Island, 5 - Prob Flow Island)

year	code	author	title	journal
2015	1,2,3,5	Farine, DR	The role of social and ecological processes in structuring animal populations: a case study from automated tracking of wild birds	ROY SOC OPEN SCI
2015	1,2,3,5	Farine, DR	Proximity as a proxy for interactions: issues of scale in social network analysis	ANIM BEHAV
2015	1,3,5	Adelman, JS	Feeder use predicts both acquisition and transmission of a contagious pathogen in a North American songbird	P ROY SOC B-BIOL SCI
2015	3,5	Silk, MJ	The consequences of unidentifiable individuals for the analysis of an animal social network	ANIM BEHAV
2015	3,5	Aplin, LM	Consistent individual differences in the social phenotypes of wild great tits, Parus major	ANIM BEHAV
2015	3,5	Farine, DR	Estimating uncertainty and reliability of social network data using Bayesian inference	ROY SOC OPEN SCI
2015	3,5	Firth, JA	Experimental manipulation of avian social structure reveals segregation is carried over across contexts	P ROY SOC B-BIOL SCI
2015	3,5	Farine, DR	Interspecific social networks promote information transmission in wild songbirds	P ROY SOC B-BIOL SCI
2016	1,2,3,5	Spiegel, O	Socially interacting or indifferent neighbours? Randomization of movement paths to tease apart social preference and spatial constraints	METHODS ECOL EVOL
2016	1,2,3,5	Croft, DP	Current directions in animal social networks	CURR OPIN BEHAV SCI
2016	1,2,3,5	Leu, ST	Environment modulates population social structure: experimental evidence from replicated social networks of wild lizards	ANIM BEHAV
2016	3,5	Firth, JA	Social carry-over effects underpin trans-seasonally linked structure in a wild bird population	ECOL LETT
2016	5	Jacoby, DMP	Emerging Network-Based Tools in Movement Ecology	TRENDS ECOL EVOL
2017	1,2,3,5	Fisher, DN	Analysing animal social network dynamics: the potential of stochastic actor-oriented models	J ANIM ECOL
2017	1,2,3,5	Silk, MJ	Understanding animal social structure: exponential random graph models in animal behaviour research	ANIM BEHAV
2017	1,2,3,5	Fisher, DN	Social traits, social networks and evolutionary biology	J EVOLUTION BIOL
2017	1,3,5	Silk, MJ	The application of statistical network models in disease research	METHODS ECOL EVOL
2017	3,5	Farine, DR	A guide to null models for animal social network analysis	METHODS ECOL EVOL

Table 10: Cite net: Overlapping of components:
(1- Key Routes, 2- Main Path (CPM), 3- Island5, 4 - Island 4, Node Island, 5 - Prob Flow Island)

year	code	author	title	journal
2017	5	Formica, V	Consistency of animal social networks after disturbance	BEHAV ECOL
2017	5	Mourier, J	Does detection range matter for inferring social networks in a benthic shark using acoustic telemetry?	ROY SOC OPEN SCI
2017	3	Spiegel, O	What's your move? Movement as a link between personality and spatial dynamics in animal populations	ECOL LETT
2018	1,2,3,5	Montiglio, PO	Social structure modulates the evolutionary consequences of social plasticity: A social network perspective on interacting phenotypes	ECOL EVOL
2018	1,3,5	Dougherty, ER	Going through the motions: incorporating movement analyses into disease research	ECOL LETT
2018	1,3,5	Silk, MJ	Contact networks structured by sex underpin sex-specific epidemiology of infection	ECOL LETT
2018	1,3,5	Farine, DR	When to choose dynamic vs. static social network analysis	J ANIM ECOL
2018	1,3,5	Sah, P	Disease implications of animal social network structure: A synthesis across social systems	J ANIM ECOL
2018	3,5	Spiegel, O	Where should we meet? Mapping social network interactions of sleepy lizards shows sex-dependent social network structure	ANIM BEHAV
2018	3,5	Sih, A	Integrating social networks, animal personalities, movement ecology and parasites: a framework with examples from a lizard	ANIM BEHAV
2018	3,5	Spiegel, O	Where should we meet? Mapping social network interactions of sleepy lizards shows sex-dependent social network structure	ANIM BEHAV
2018	3,5	Sih, A	Integrating social networks, animal personalities, movement ecology and parasites: a framework with examples from a lizard	ANIM BEHAV
2018	5	Blaszczyk, MB	Consistency in social network position over changing environments in a seasonally breeding primate	BEHAV ECOL SOCIOBIOL
2018	3	Bani-Yaghoub, M	A methodology to quantify the long-term changes in social networks of competing species	ECOL MODEL

7 Authors Collaboration

In the following part, we present the patterns of collaboration between authors working in the field of netwirks analysis. This results are based on the analysis of the reduced network **WAr**. In general, there are different ways to create one-mode networks of collaboration between authors (AA) out of two-mode networks of works and authors (WA). These ways were presented and used in the previous works [works of Vlado]. Multiplying the original WAr network to transposed WAr network, and using different types of normalizations, we created three collaboration networks **Co**, **Cn**, and **Ct'**. The results are presented below.

7.1 Networks creation

The standard and the easiest way to obtain the collaboration network from the WA network was to make a **first collaboration network Co** [Batagelj, Cerinšek 2013] by the multiplication of a transposed WA network (to AW) and initial one:

```
Co = t(WA) * WA = AW * WA = AA
```

In derived network **Co**, the weight of the edges between the nodes is equal to total number of works author i and j wrote together. The degree of each author (node) is equal to the number of works he or she co-authored. The loops are equal to the total number of works that each author have (which is also equal to the indegree values of the WA network).

It was proved, however, that the proposed approach has some limitations, such as the overrating of the contribution of works with many authors. That's why the textbffractional approach (Batagelj, ...) was proposed which deals with the authors contribution in collaboration networks and propose different types of normalization.

Thus, in the **second collaboration network Cn** the contribution of authors to their own works and works written with co-authors is considered. The normalization which is used create network n(WA) where the weight of each arc is divided by the sum of weights of all arcs having the same initial node as this arc (outdegree of a node) (for example, if the work has 3 authors, each weight is equal to 1/3). The network is constructed by the transposition of the WA network (to AW) and multiplying it with the (normalized) n(WA) network.

```
Cn = t(WA) * n(WA) = AW * n(WA), where n(WA)[w,a] = WA[w,a] / outdeg(w)
```

In the derived network Cn, the weight of the edges between the nodes (authors) is equal to the contribution of author i to works, that he or she wrote together with author j (which can not be symmetric). The total contribution for a given work by all its authors is equal to the number of its authors. The total contribution for an author is equal to the number of works that he or she co-authored (indegree). The diagonal (loops) of the matrix is equal to the total contribution of author to his or her own works. Based on it, Batagelj and Cerinšek () proposed **self-sufficiency index** as the proportion of author's contribution to his/her works and the total number of works he/she co-authored, and the **collaborativness index**, which is complementary to it (is equal to 1 minus self-sufficiency).

Using another type of normalization - Newman normalization, who interpret the weight as a proportion of time spent for the collaboration with each co-author [Batagelj, slides], - the **fourth co-authorship network Ct'** can be constructed, considering the total contribution of "strict collaboration" of authors i and j to works. In this case, for the initial WA network the weight of each arc is divided by the sum of weights of all arcs having the same initial node as this arc (outdegree of a node) subtracting the initial article (which is 1):

```
Ct' = t(n(WA)) * n'(WA), where n'(WA)[w,a] = WA[w,a] / (outdeg(w)-1)
```

7.2 Collaboration between authors

As it was already shown in the section 4.1. (Table 4 the authors having the largest number of papers have (except Newman) Chinese names. In this sense, it is not productive to look at the 'most writing' authors. However, from the **Co** network we still get an important information about collaboration between groups of authors. The Figure (XX) shows the groups of authors, who have 20 and more works written together. As it can be seen, all of them are only pairs.

However, it is interesting to compare the values of the number of works that author has (in general, written by himself or herself or in collaboration) with the values of author's contribution to these works and index of collaborativeness with others. Because of the 'Chinese problem' mentioned above we had to exclude the names of the Chinese authors from the output presented on the Table 11. The names are ordered by authors' fractional total contribution to the field.

The first rated author in sence of largest productivity is social scientist R. Burt, followed by phisician M. Newman. They are followed by P. Doreian, H. Park, and R. Dunbar. Other authors with large total contribution values are B. Wellamn, T. Valente, S. Park, P. Bonachich, L. Leidersdorf, C. Latkin, H. Litwin, and P. Marsden. There are a lot of authors representing social science in the table. The authors with the highest index of collaborativeness are marked in boldface.

Using Link islands approach, we extracted all the islands with the size between 5 and 50 nodes from the network **Ct'**. We got a large number of islands - 2,195 - with 14,227 nodes. Four largest island have, respectively, 35, 23, 21, and 19 nodes; other 70 islands have between 12 and 18 nodes. More then half of islands - 58% - are composed of 5 nodes.

The structures of the largest islands of size from 12 to 35 nodes is presented on the Figure (xx) (1,037 nodes). These subnetworks have different structures. Part of these structures are not very interesting: they are star-like networks, which represent one author collaborating with many others, or (almost) complete clusters (cliques), where all authors collaborate with (mostly) everyone else. However, some islands can be intesting to inspect - those large islands, which have more interesting structures.

Another way to get interesting cases to inspect is to find the islands which have the strongest ties between the nodes. For this, we removed all the lines lower then certain trashold from the **Ct' net** and got the network of 32 nodes. Then we used and Island approach and got simple line weight islands of size [2,50] out of the same metwork (number of islands = 14,222). Then we manualy searched for the islands to which these 32 nodes belong, and extracted them. We also found the islands for T. Snijders (should we add someone else?).These islands are presented below. Some of the authors having the strongest ties with each other goes from the field of social sciences (Everett and Boragatti, Pattison and Robins), some - from physics (Barabasi, Albert, Posfai), some - from both of the fields (Christakis and Fowler).

To better know what these authors are working at, we made an analysis of key words in coauthorship islands, which is presented in the following section.

8 Key words in coauthorship islands

In this section we look at the key words for some of the islands inspected in the previous section.

8.1 Network creation

To construct the network of authors and keywords **AK**, we used normalized **reduced** networkds **WAr** and **WKr**.The first network was transpose and then multiplied with the second in the following way:

```
nAWr x nWKr = AK
```

Table 11: Collaborativeness

#	Author	Total contri-bution	Total # works	Collabora tiveness	#	Author	Total contri-bution	Total # works	Collabora tiveness
1	BURT_R	55,73	71	0,22	31	**PATTISON_P**	18,94	58	0,67
2	NEWMAN_M	50,02	81	0,38	32	THELWALL_M	18,41	37	0,5
3	DOREIAN_P	46,19	72	0,36	33	KRACKHAR_D	18,24	38	0,52
4	**PARK_H**	41,94	113	0,63	34	FALOUTSO_C	17,86	60	0,7
5	DUNBAR_R	40,02	91	0,56	35	JACKSON_M	17,78	38	0,53
6	WELLMAN_B	36,43	63	0,42	36	**GONZALEZ_M**	17,76	52	0,66
7	**VALENTE_T**	34,96	97	0,64	37	MOODY_J	17,7	40	0,56
8	**PARK_S**	34,59	109	0,68	38	SCOTT_J	17,54	28	0,37
9	BONACICH_P	34	46	0,26	39	MORRIS_M	17,22	43	0,6
10	LEYDESDO_L	33,28	51	0,35	40	**RODRIGUE_J**	15,9	52	0,69
11	LATKIN_C	32,99	130	0,75	41	WASSERMA_S	15,64	35	0,55
12	LITWIN_H	32,42	50	0,35	42	KLEINBER_J	15,05	34	0,56
13	MARSDEN_P	30,17	39	0,23	43	BATAGELJ_V	14,64	33	0,56
14	BORGATTI_S	29,72	71	0,58	44	WILLIAMS_A	14,5	31	0,53
15	SNIJDERS_T	29,63	67	0,56	45	**SINGH_A**	14,5	36	0,60
16	FRIEDKIN_N	28,17	36	0,22	46	BRANDES_U	14,39	35	0,59
17	CARLEY_K	28,11	72	0,61	47	**BERKMAN_L**	14,3	39	0,63
18	BARABASI_A	27,61	67	0,59	48	MASUDA_N	14,26	28	0,49
19	WHITE_H	27,28	42	0,35	49	**SMITH_A**	14,2	40	0,65
20	**CHRISTAK_N**	22,89	74	0,69	50	LAZEGA_E	14,17	26	0,46
21	EVERETT_M	22,58	44	0,49	51	**CONTRACT_N**	14,15	43	0,67
22	**KAZIENKO_P**	21,97	64	0,66	52	**GONZALEZ_A**	14,13	35	0,60
23	MARTINEZ_M	21,9	53	0,59	53	**PENTLAND_A**	14,12	41	0,66
24	**JOHNSON_J**	21,19	54	0,61	54	FARINE_D	14,04	34	0,59
25	**FOWLER_J**	20,14	65	0,69	55	SCHNEIDE_J	13,89	52	0,73
26	SKVORETZ_J	20,07	42	0,52	56	WATTS_D	13,67	27	0,49
27	FREEMAN_L	20,03	27	0,26	57	FAUST_K	13,5	25	0,46
28	BREIGER_R	19,73	31	0,36	58	**SMITH_M**	13,29	39	0,66
29	**ROBINS_G**	19,67	64	0,69	59	**RODRIGUE_M**	13,21	46	0,71
30	**RAHMAN_M**	19,18	59	0,67	60	**RICE_E**	13,09	48	0,73

8.2 Key words in largest islands and islands with largest weights between the nodes

Using this two-mode network we can inspect all the keywords which are associated with each author. However, what is interesting is to look at the keywords for certain islands.

Again, we start with the largest islands 1-3, which have, respectively, 35, 23, and 21 nodes. These islands are associated with large number of keywords. However, we can extract some 'special' wirds in each group. In Island 1 these are the keywords *uganda, south,saharan, epidemiology,africa, rural, agricultural,development, tuberculosis, molecular, mycobacterium, transmission, genotype, hiv, drug*, in Island 2 - *support, risk, woman, abuse, health, environment, self, drug, hiv, echange, behavior, injection, transition, population, city, integration*, in Island 3 - *radiation, radioactivity, environment, measurement, cancer, clinical, medicine, family, community*.

Then we also looked at some certain islands with the largest values of weights between the nodes, which were identified before. For the group of authors with Barabasi in the center the keywords are *network, model, time, social, scale, dynamics, community, web*. The group of Fowler, Christakis, and Shakya have keywords *group, population, association, mobilization, facebook, ownership, child, weight, national, and state*. The island of Borgatti, Everett, and Halgin is associated with the keywords *world, disease, model, structural, network, structure, role, social, exchange, graph*. Other group of social network analysts Robins and Pattison have the words *complex, difference, wireless, group, population, association, ground, chain, perceive, similarity*. The group of Snijders have the keywords *similarity, peer, model, network, family, orient, use, actor, social, behavior* which of course represent their work in stochastic actor-oriented models.

The group with large weight of lines between Grabowska and Kosinski have the keywords *network, time, model, community, social, scale, dynamics, web, world, behavior*. The large group of Litwin in the center connected to Stoekel and Shiovitz have the keywords *social, older, network, health, support, life, people, adult, israel, family*. The island of Chinese authors wih strong ties between Wang and Ma have the keywords *network, social, ranking, community, link, world, framework, model, evolution, attack*.

9 Citation among authors

After analysing Cite network and WA network and looking at citations between works and collaborations between authors separately, we can also look at the derieved **CiteA network**, which shows citations among authors.

9.1 Network creation

To get information about citations among authors we computed the **derived CiteA network** as a product of multiplication of the networks **WAr net** and **CiteR net**.In this network, the value of element CiteA[u;v] is equal to the number of citations from works coauthored by u to works coauthored by v.

```
CiteA=t(WAr) * CiteR * WAr
```

We also produced the normalized version of this network, **CiteAn**, where the value of element CiteAn[u;v] is equal to the number of fractional contribution of citations from works coauthored by u to works coauthored by v.

```
CiteA=t(WAr) * nCiteR * WAr
```

9.2 Citations

After the exploratory analysis of the obtined networks, we had to exclude the top-cited work of Wasserman and Faus (`[WASSERMA_S(1994):]` from the data set as a lot of nodes were connected to it.

Then we used Islands approach to get islands of the size [5, 200] from the **CiteA**. However, the combination of nodes with large number of citations (to Wasserman, Granovetter, Boyd, Newman) with the 'Chinese cloud', which was already identified above, blured the results. This why the normalized network **CiteAn** was used for identification of islands. We got 195 islands of size between 5 and 200.

The Main island of CiteAn network consits of 200 nodes. In this network, cutations separates between M. Granovetter and D. Boyd, each of them have their own 'cloud' of other authors. They are also connected through several authors citing both of them. However, most of these authors are againg from the 'Chinese group'.

Figure XX presents other 21 islands consists of minimum 10 nodes (in sum, 268 nodes). Most of these islands are star-like islands, meaning that the author in the center actively cites a set of other authors. There are also two more 'clique-like' islands, identifying groups of connected authors who cites each other. However, there are several more interesting structures 1, 2, 3), which shows several groups of authors connected to each other.

10 Co-citation among authors. Bibliographic Coupling

10.1 Network creation

Jaccard - ?

11 Citation among journals

In this section, we present the results on the citations between journals featuring works in the area of network analysis.

11.1 Network JJf creation

To get information about citations among journals we computed the **derived JJf network**, which takes into account citations from papers published in journal *i* to papers published in journal *j*, which appeared in the works included into the **WJr net**. We used a **CiteR net** to get information on citations between works. As journals of different sizes were included into the data set, using the *fractional approach* this network was normalized. Then the networks were multyplied in the following way. Thus, the weights in the obtained network take into account *fractional* contribution of citations from papers published in journal *i* to papers published in journal *j*.

```
JJf = t(WJr) * n(CiteR) * WJr
```

11.2 Citations

Looking at the loops of this network, we got the list of journals with highest self-citation (Table 12). The highest value belongs to the *Social Networks* journal, which is one of the main journals in the field of social network analysis. Second highest ranked is the *Computers in Human Behavior* - a journal in the field of computer interactions and cyberpsychology. Other quite highly ranked journals are *Physica*

Table 12: Journals with the highest self-citation

#	Value	Journal
1	1083,68	SOC NETWORKS
2	533,84	COMPUT HUM BEHAV
3	212,1	LECT NOTES COMPUT SC
4	163,32	PHYSICA A
5	135,71	J COMPUT-MEDIAT COMM
6	111,53	SOC SCI MED
7	110,49	AM J SOCIOL
8	84,33	SCIENTOMETRICS
9	68,29	CYBERPSYCH BEH SOC
10	55,33	NEW MEDIA SOCI
11	54,94	J MED INTERNET RES
12	54,48	EXPERT SYST APPL
13	51,01	ANIM BEHAV

A-Statistical Mechanics And Its Applications, Journal of Computer-Mediated Communication, Social Science & Medicine, and American Journal of Sociology. However, we note that the differences between values of first and last mentioned journals are quite significant.

We also generated Islands of size between 2 and 5, and got 115 islands, with the largest island containing 50 nodes. The islands 1-11 (with maximum 3 nodes) are presented on the Figure XX. In the main island, there are three groups of journals: two large groups of journals in Social Sciences and Computer Science, as well as one smaller group of journals in Physics. Citations among journals have clear acyclic (hierarchical) organization.

In the Social Sciences group, the most citing journal is *Social Networks*, which is strongly connected to the *Amercian Journal of Sociology*, as well as have connections with many other sociological journals (*Structural Analysis in Social Sciences, American Sociological Review, Social Forces, Journal of Mathematical Sociology, Social Network Analysis*, which are, in turn, also have connections to the American Journal of Sociology. This journal is also cited by a large number of other journals from differnt fields of social sciences: sociology, family studies, social work, psychology, behavioral science, communication, migration studies, business, management, organization studies, urban and rural studies.

In the Computer Science group of journals, the most citing position is taken by *Computers in Human Behavior* journal, which is largerly citing *Journal of Computer-Mediated Communication*, as well as to *CyberPsychology & Behavior, Cyberpsychology, Behavior, and Social Networking*, which are are also connected to it, and the *American Journal of Sociology*. *Journal of Computer-Mediated Communication* is also cited by other journals from computer science, education technology.

Both top cited journals have shared journals which cite both of them. The are *Information, Communication & Society, Communications in Computer and Information Science, Lecture Notes in Artificial Intelligence, New Media & Society*. The journal with the largest citations of both of these jornals is *Lecture Notes in Computer Science*, which is also citing other journals, such as *Social Networks, Structural Analysis in Social Science, and Nature*.

The Physics group has is presented by the journals *Physica A-Statistical Mechanics And Its Applications, Physical Review E*, and also include some interdisciplinary journals *Plos One*, *Science*, and *Nature*. There are links from *Physica A* and *Plos One* to the *American Journal of Sociology*.

Table 13: Pairs of journals

#	Value	Journals	#	Value	Journals
1	17,38	SEX TRANSM DIS – AIDS	21	4	IEEE INT SYMP INFO – IEEE T INFORM THEORY
2	14,17	PREV VET MED – TRANSBOUND EMERG DIS	22	4	HEALTH RISK SOC – RISK ANAL
3	10,47	ACTA PSYCHIAT SCAND – BRIT J PSYCHIAT	23	4	QUAL RES SPORT EXERC – SPORT MANAG REV
4	10,27	IEEE T PARALL DISTR – IEEE INFOCOM SER	24	4	UROL ONCOL-SEMIN ORI – BJU INT
5	8,1	IEEE T VEH TECHNOL – IEEE T MOBILE COMPUT	25	4	PSYCHIAT DANUB – QJM-INT J MED
6	6,77	J CONSTR ENG M – J CONSTR ENG M ASCE	26	4	COMMUNITY DENT ORAL – J AM DENT ASSOC
7	5,68	SOC COGN AFFECT NEUR – NEUROIMAGE	27	4	Z ETHNOL – J SOC HIST
8	5	APHASIOLOGY – ADULT EDUC QUART	28	4	J AM SOC HYPERTENS – NAT BIOTECHNOL
9	4,67	J INTELL DISABIL RES – J APPL RES INTELLECT	29	4	MATERN CHILD HLTH J – J NERV MENT DIS
10	4,67	APPL ENERG – ENERG BUILDINGS	30	4	TRANSPL P – AM J TRANSPLANT
11	4,67	J ISL COAST ARCHAEOL – ANTIQUITY	31	4	J AFFECT DISORDERS – DEATH STUD
12	4,67	INFORM SOC-ESTUD – PERSPECT CIENC INF	32	4	J NEW APPROACHES EDU – ESTUD SOBRE MENSAJ P
13	4,5	J ACAD LIBR – REF USER SERV Q	33	4	J ADDICT NURS – CLIN PSYCHOL REV
14	4,18	CIENC SAUDE COLETIVA – CAD SAUDE PUBLICA	34	4	INT J CARDIOL – WIRES DATA MIN KNOWL
15	4	ETHN DIS – HEART LUNG	35	4	MCN-AM J MATERN-CHIL – AM J NURS
16	4	EPIDEMIOL PREV – HUM VACC IMMUNOTHER	36	4	INT J PEDIATR-MASSHA – BEHAV MED
17	4	OPTIM LETT – ARTIF LIFE	37	4	HEALTH EXPECT – CAN J CARDIOL
18	4	ACTAS UROL ESP – AESTHET SURG J	38	4	ARCTIC ANTHROPOL – ARCTIC
19	4	J RETAIL CONSUM SERV – AUSTRALAS MARK J	39	4	REV BRAS ENFERM – REV LAT-AM ENFERM
20	4	J MARITAL FAM THER – J CONSTR PSYCHOL	40	3,36	J CHILD PSYCHOL PSYC – J AUTISM DEV DISORD

Other groups of journals citing each other are the ones on the topics of substance abuse and addiction; archeology, anthropology and antiquity, behavioral ecology and animal behavior; geriatric psychiatry; psychology and deviation; child psychology and psychiatry; medicine; family medicine, sexual and reproductive health; speech-language; computer graphics.

Other islands 12-115 contains only 2 nodes - they are pairs of journals. Journals with the largest weights of lines are presented on the Table 13. The links are directed: first written journal cites second one. These journals cover the wide range of disciplines, including health studies, epidemiology, medicine, surgery, veterinary disciplines, biotechnology, psychiatry, family studies, neuroscience, education, sport, archeology, ethnology, anthropology, history, engineering, mobile computing, information science.

12 Conclusions

Basic statistics of derived networks allow us to get the most important works, authors, journals, keywords.

Citation network analysis reveals its main structure - gropus of works which are connected with each other. Obtained components are interlinked.

Deeper analysis of other derived networks, including those which can be constructed out of different initial ones (e.g., WA and WK), will show other patterns of Social Network Analysis field development.

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