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Journals publishing social network analysis

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Abstract

This paper presents the analysis of journals publishing articles on social network analysis (SNA). The dataset consists of articles from the Web of Science database obtained by searching for "social network*", works intensively cited, written by the most prominent authors, and published in the main SNA journals up to July 2018. There were 8943 journals in 70,792 articles with complete descriptions. Using a two-mode network linking publications with journals and a one-mode network of citations between articles, we constructed and analysed the networks of citations and bibliographic coupling among journals. Based on the analysis of these networks, we identify the most prominent journals publishing SNA and reveal their relationships to each other. Special attention is given to the position of journal *Social Networks* among other journals in the field. We trace the development of some relationships through time and look at their distributions for selected journals. The results show that the field is growing, which can be seen by the annual rise of the number of journals publishing papers in SNA, and the average number of papers on SNA per journal (almost 3 in recent years). The journals which are currently present in the field belong to social and natural sciences. The social sciences group is represented mainly by journals from sociology and management. Other journals mainly come from the fields of physics, computer science, or are general scientific journals. While journals from social and computer sciences are connected with journals from the same fields, physics journals *Physica A* and *Physical Review E* have developed their own niche. SNA's main outlet *Social Networks* takes a very coherent and important position. It had explicit primacy up to the 2000s; in recent years its relative input has declined significantly due to the large number of papers published in other journals in the field.

Keywords Social network analysis · SNA · Bibliographic network · Temporal network · Journals · Citation · Bibliographic coupling · Development of scientific fields · Islands approach · Web of Science

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Introduction

Social network analysis (SNA) is a rapidly developing scientific field that has appeared and grown significantly over the past 50 years. Starting from highly fragmented individual scientific groups in the 1970s, by the beginning of the 1990s the representatives of SNA had formed a professional community, or“invisible college” (Freeman 2004), and due to the significant efforts of some individuals and institutions, the field achieved the status of a “normal science” (Hummon and Carley 1993) with its own journals, conferences, knowledge transfer centers and educational programs. This development was connected with specific measures which unified the field, such as the creation of *International Network for Social Network Analysis* by Barry Wellamn, its bulletin *Connections* in 1978, and the annual *Sunbelt* conference starting from 1981. One of the most crucial events was the establishment of the field's main journal, *Social Networks* in 1979. With Linton Freeman as the main editor, it very soon became the central source for the field (Hummon and Carley 1993). Since that time, SNA has grown significantly in terms of scientific publications, scholars using its methodology, and disciplines where it is applied (Borgatti and Foster 2003; Otte and Rousseau 2002; Batagelj and Maltseva 2020). From the 2000s, the methodology of SNA received considerable attention in the natural and computer sciences, and economics, which lead to the so-called “invasion of the physicists” (Bonacich 2004) to the field that until then was mainly represented by social scientists. Expanding of the scope of SNA application has also been associated with the development of the internet and online social networks in the 1990–2000s. The recent study of the SNA field's development (Maltseva and Batagelj 2019) showed that currently SNA is represented not only by scholars from the social sciences, physics, and computer science, but also many others, including neuroscience, medicine, and animal SNA in behavioral biology. This is inevitably reflected in the establishment of new journals aimed at the analysis of networks in different disciplines, such as *Social Network Analysis and Mining* (est. 2011), *Network Science* (est. 2013), *Journal on Complex Networks* (est. 2013), *Computational Social Networks* (est. 2014), *Applied Network Science* (est. 2016). With the overall interest in networks, SNA-related publications began to frequently occur in other journals—interdisciplinary scientific outlets, for example, *Science* and *Nature*, or monodisciplinary journals, for example, *Physical Review E*.

Scientific journals, playing social (coordination of communication and access to reputation) and intellectual (knowledge interchange and creation) roles, form scientific fields, serving as platforms with a shared social competence for a collective validation and the coordination of knowledge within particular scientific communities (Minguillo 2010), and provide a way to establish disciplinary or research field boundaries (Milojević and Leydesdorff 2013). The analysis of the journals where SNA research is published, which is the focus of the current study, can provide important insights on the whole field's development. In this paper, we address the following questions:—Which are the most prominent journals in the field of SNA and what was their role through time?—What are the relationships among them (citations, content sharing) and their dynamics?—What are the differences in self-citations of the prominent journals?—How did the position of the field's main journal *Social Networks* evolve? Answering these questions can allow us to identify the disciplines where SNA is developing the fastest.

The development of SNA has been reflected in a number of studies. In the context of the current article, it is worth mentioning the studies on citation and bibliographic coupling structures of the journals in the field of SNA, and the position of *Social Networks* in these structures (Leydesdorff 2007; Leydesdorff et al. 2008; Brandes and Pich 2011; Batagelj et al. 2014). Other studies were devoted to co-authorship structures of the SNA researchers (Otte and Rousseau 2002; Lietz 2009; Leydesdorff et al. 2008; Batagelj et al. 2014), citation structures and bibliographic coupling between works and authors (Hummon and Carley 1993; Chen 2005; Batagelj et al. 2014; Brandes and Pich 2011; Maltseva and Batagelj 2019), and SNA topics discussed in the field based on keyword co-occurrence networks (Leydesdorff et al. 2008; Maltseva and Batagelj 2020). These topics were also discussed in studies of different subdisciplines—sociology (Lazer et al. 2009), organizational research (Borgatti and Foster 2003; Varga and Nemeslaki 2012), information sciences (Otte and Rousseau 2002),—and subfields in SNA—literature on centrality–productivity (Hummon et al. 1990), clustering and classification (Kejžar et al. 2010), clustering and blockmodeling (Batagelj et al. 2020). Some studies analysed the network science literature—the citation networks of publications for the knowledge domain of complex networks in general (Shibata et al. 2007, 2008, 2009), or the "small world" literature (Garfield 2004). More historiographically oriented works written by Freeman (2004, 2011) should also be mentioned, as well as the work of Hidalgo (2016) addressing the main differences between the streams advanced by social and natural scientists.

Providing very important information, the studies on the main outlets of SNA are based on specific datasets, and cover only selected journals and subtopics in time periods which are no longer up-to-date. With the field's growth, the whole picture can be drawn only based on the results of the dataset collected by a comprehensive search, which would include the data from different areas of SNA. The current study is based on the analysis of articles, collected from the *Web of Science (WoS)* database (*Core Collection*) matching the query "social network*". The additional inclusion of the intensively cited papers, articles published in the flagship SNA journals indexed in WoS, and written by the most prominent authors makes the collected dataset and analyses more systematic. We study the structures of all journals from two different perspectives: their direct *citations* of each other (Garfield 1972), and *bibliographic coupling* (Kessler 1963), showing the similarities between journals according to the common literature referencing without requiring the presence of direct citations between them. Combination of the direct and indirect approaches to the connections allows us to make conclusions of how the structures coincide. The approach to bibliometric analysis that we use is based on the methodology already proposed in previous studies of different scientific fields and topics (Kejžar et al. 2010; Batagelj et al. 2014, 2017, 2020). This approach is extended by the analysis of the corresponding temporal networks (Batagelj and Praprotnik 2016; Batagelj and Maltseva 2020), previously applied to large bibliographic networks only partially.

Section 2 of this paper presents the literature review. Section 3 describes the dataset and some issues of the network construction from the original two-mode network connecting works with journals. Section 4 presents some statistical properties of the obtained networks, the lists of the most prominent journals having the largest number of works on SNA, and observes the importance of the selected journals through time. Sections 5 and 6 provide information on the relations between the most prominent journals based on the analysis of direct citations (and self-citations), and bibliographic coupling, where two journals are considered to be coupled if the works they reference overlap. In both cases, the networks are constructed using the information on citations between works. We used temporal versions of these networks to get an insight into the dynamics of the relationships between journals. We pay special attention to the position of *Social Networks* in the obtained structures. We finish with a discussion of the results and some concluding remarks.

Previous studies

Previous studies on journals publishing SNA topics are based on the analysis of journals' structures of citation or bibliographic coupling. While in some studies the datasets were based on the citing structures of *Social Networks*, due to the special role this journal has always played in the field, in other cases the data were based on the literature on some specific topic (e.g. clustering and blockmodeling), or the whole SNA field itself. The results are inevitably relative to the data and research questions of these studies.

In two studies, Leydesdorff (2007) and Leydesdorff et al. (2008) studied the disciplinary identity of *Social Networks* through its citation structures in the "being cited" and "citing" dimensions. The studies were based on the aggregated journal-to-journal citation data from the *Journal Citation Reports* of the *Science Citation Index*. The betweenness centrality was used as an indicator of the interdisciplinarity of a journal. According to the results of the 2007 study, in the "being cited" dimension, 54 journals cited the journal *Social Networks* more than once in 2004. *Social Networks* functioned as a bridge between (1) two social science clusters: sociology and organizational studies; (2) a computer science cluster including some statistics journals; and (3) a physics cluster related through the *Journal of Mathematical Sociology*. However, Leydesdorff et al. (2008) showed, that in 2006, 63 journals citing *Social Networks* formed only two clusters: one among journals in sociology (to which the journal itself belonged) and another among journals in organizational and management studies. The analysis of temporal data showed that during the period under study, *Social Networks* was a part of the cluster of sociological journals in most of the years. The temporal analysis of the *citing* dimension (2008) showed that *Social Networks* is embedded in a sociological set of journals even more firmly, and is connected with journals from psychology, organizational and management studies. These results allowed the authors to conclude that the journal "can be considered as a representative of sociology journals", or "a specialist journal with citation impacts outside sociology as a discipline", rather then an interdisciplinary journal (Leydesdorff et al. 2008).

Batagelj et al. (2020) used the dataset of publications in the area of graph and network clustering and blockmodeling (*WoS* descriptions of articles published before 2017) for the analysis of journal-to-journal citation networks. Even though they found a diversity in subject matter in the clusters obtained from the network, the largest island consisted of journals mainly from the physics-driven approach to SNA, which reflected the institutional dominance of the natural sciences, especially physics, in this topic. Only a small number of journals were from the social sciences, and they were connected to the physics literature through *Social Networks* linked to *Physical Review E*, which was seen as a transition point between the blockmodeling and community detection literature.

Using the dataset **SN5** of publications in the area of social networks in general (Batagelj 2005) presented by Batagelj et al. (2014) (*WoS*, descriptions of articles before 2007), Brandes and Pich (2011) produced the structures of bibliographic coupling among journals. The results showed that *Social Networks* has a similar citation pattern to *The American Journal of Sociology*, *American Sociological Review*, *The Annual Review of Sociology*, *Social Forces*, and some other journals in sociology, organizational studies and management. Based on that, the authors confirmed the conclusion of Hummon and Carley (1993) that *Social Networks* is the SNA field's own specialist journal; however, it is connected with journals from the social sciences.

The structures of bibliographic coupling were also produced for journals presented in the network clustering literature (Batagelj et al. 2020). The subnetworks with the largest link weights included journals from the physics-driven literature, the most prominent being *Physica A*, *Physical Review E* and *PLOS ONE*. Only two social science journals were present: from *Physica A* there was a link to *Social Networks*, which was in turn linked to the *The Journal of Mathematical Sociology*. In this kind of structure, *Social Networks* was again seen as a transition point between two types of literature; it had similar citation patterns both with physics and social sciences. Another journal on networks, *Social Network Analysis and Mining*, also appeared in the graph, connected to *Physica A* through the *Lecture Notes in Computer Science (LNCS)*. However, this journal is focused mainly on data mining in large networks and reflects a computer science orientation.

These results show that the SNA field is represented by journals with different disciplinary identities—social sciences (mainly sociology) and natural sciences (physics, computer science, medicine, etc.). As all of this research, to some extent, focuses on the position of *Social Networks*, we also address this issue and answer the question of whether the journal can be considered as the sole representative of the social science group (as was shown in some studies) or the one connected to the natural science group of journals (as was shown in other research).

Data

Data collection

The procedures of data collection, basic network construction and cleaning were presented in detail by Maltseva and Batagelj (2019). Here we reproduce some essential information. The dataset consists of articles from the WoS database (*Core Collection*). The initial search was made using the query "social network*", and thus some works related to the broader field of network analysis could have been overlooked. The search query for"network analysis" would be too broad, as it could include the works on computer networks, optimization problems for networks, etc. That is why we extended the results of the original query with a saturation search of papers which were intensively cited (having at least 150 citations). We also included works from the network-related journals indexed in WoS (*Social Networks*, *Network Science*, *Social Network Analysis and Mining*, and *Journal of Complex Networks*), and the works published by the most prominent authors (around 100 scholars). The obtained dataset covers not only the works of social scientists, but also influential papers published by physicists, biologists, information and computer scientists, etc. The dataset covers the works published up to July 2018.

Using **WoS2Pajek 1.5** (Batagelj 2017), we transformed our data into a collection of networks: a one-mode citation network **Cite** on works (from the field CR of the WoS file description (Wos 2020)) and two-mode networks—the authorship network **WA** on works × authors (from the field AU), the journal network **WJ** on works × journals (from the field CR or J9), and the keyword network **WK** on works × keywords (from the fields ID, DE or TI). Works can be of two types: with full descriptions (*hits*), and cited only (*terminal*, listed in the CR field). For the terminal works only partial information is provided: the name of the *first* author, journal, publication year, journal volume, and the number of the first page.

After data cleaning (see "Appendix"), from 70,792 hits we produced networks with sets of the following sizes: 1,297,133 works, 395,971 authors, 69,146 journals, 32,409 keywords. We removed multiple links and loops and obtained *basic* networks **CiteN**, **WAn**, **WJn**, and **WKn**. As terminal works do not contain information on references, it was not appropriate to use full networks for the analysis of connections between journals. That is why we constructed *reduced* networks on the works with complete descriptions **CiteR**, **WAr**, **WJr**, and **WKr**, which were used for further analysis, where the sizes of sets are as follows: 70,792 works, 93,011 authors, 8943 journals, 32,409 keywords.

Derived networks

Networks can be combined using matrix multiplication. A pair of two-mode networks is compatible for multiplication, if the second set of nodes in the first network is equal to the first set of nodes in the second network. The resulting networks are called *derived* networks. If all the weights in the two-mode networks are equal to 1, then the product of the weights will also be equal to 1 and therefore a [u, v] element of the product matrix counts the number of ways we can move from node u using the first network through the second set and afterwards using the second network to node v (Batagelj and Cerinšek 2013; Batagelj et al. 2014). In our case, this shared set is a set of works (papers, reports, books, etc.), which *links* bibliographic networks to each other.

By multiplying the network **WJ** with the network **Cite** we get the network of citations among journals $\mathbf{CiteJ} = \mathbf{WJ}^T * \mathbf{Cite} * \mathbf{WJ}$, where the weight of the edge between two journals $\mathbf{CiteJ}[i,j]$ is the number of times journal i cites journal j. Similarly, out of the same networks, we constructed the network of bibliographic coupling among journals **JCoj**, where the weight of the edge between two nodes (journals) shows the similarity of their referencing patterns. A detailed description of each derived network construction is presented in the following subsections.

The normalization of derived networks

Derived networks can have some deficiencies, such as the overrating of the contribution of bibliographic entities with many ties (publications with many authors, keywords or references, journals with many articles). To deal with such cases, the *fractional approach* (Gauffriau et al. 2007; Batagelj and Cerinšek 2013; Batagelj 2020b) was developed, which takes into account the contribution of bibliographic entities (works, authors, or journals) and normalizes their weights so that their joint contribution is equal to 1.

In this article, we normalized the network of citations between works **Cite**. In the original, basic network, the weight of each cited reference is equal to 1, and thus the outdegree of each node (work) is equal to the number of cited publications. This normalization creates network $n(\mathbf{Cite})$ where the weight of each arc (1) is divided by the sum of weights of all arcs having the same initial node (the outdegree of a node, or number of cited publications). Thus, the weight of *each* reference is relative to the total number of references (and we assume that each cited work contributed to the work equally), and the total weight of *all* citations from each paper p is equal to 1.

$$n(\mathbf{Cite})[p,q] = \frac{\mathbf{Cite}[p,q]}{\max(1, \text{outdeg}(p))}$$

A detailed descriptions of the usage of the normalized networks in other network creation is presented in the sections below.

Temporal networks

Applying the *temporal quantities* approach (Batagelj and Praprotnik 2016; Batagelj and Maltseva 2020) to networks **WJr** and **CiteR**, we constructed a set of temporal networks, using Python libraries Nets and TQ. They can be of two types—instantaneous (with values given per year) networks **WJins** and **CiteIns** or cumulative networks **WJcum** and **CiteCum**. These networks are stored in the `.json` format. Using the multiplication and normalization of temporal networks, different derived temporal networks can be constructed. The construction of these networks is presented in the corresponding sections.

Distributions of works and journals

Based on the distributions of works and journals in the two obtained networks—**WJn**, including the journals from the hits and those where the cited only works were published, and **WJr**, including the journals mentioned in hits,—we observe the main statistical properties of these networks, extract the lists of the most prominent journals with largest number of works, and trace the role (importance, or dominance) of some journals through time.

Network **WJn** consists of 69,146 journals. The distribution of the number of works per journal in this network has a scale-free form (Fig. 1). According to the indegree distribution of this network, 83% of journals are represented in the dataset with only one (58%), two (12%), three (6%), four (4%) or five (2.5%) works, as many works that occur in the reference lists of hits are from a variety of disciplines. Only 17% (11,976) of journals have 6 works or more on SNA. Network **WJr** consists of 8943 journals. The distribution of its temporal version **WJins** network (Fig. 2, left side) shows the number of journals per year with articles on SNA. There are several time points when the number was growing faster: at the beginning of the 1990s, around 2005, and most significantly in 2015. During this time, the range of journals publishing articles on SNA grew

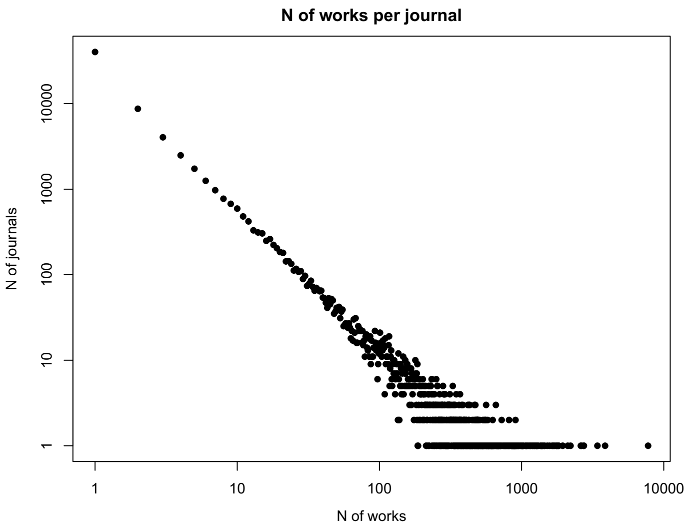

Fig. 1 WJn net: distribution of the number of works by journals

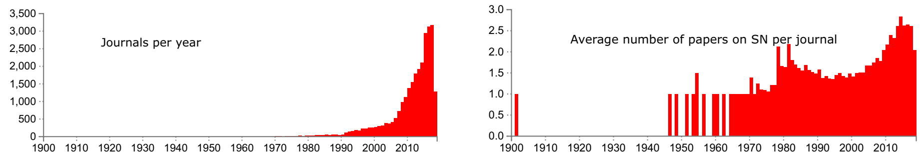

Fig. 2 WJins: distributions based on journals and works

significantly. We calculated the average number of papers on SNA per journal (Fig. 2, right side) as the proportion of the number of works and the number of journals per year. After an increase in the 1980s and until 2005 the average was around 1.5 papers, and then it started to grow steadily, up to almost three papers per journal in recent years.

Table 1 shows the journals which have the maximum indegree values (number of articles) for the networks **WJn** and **WJr**. For the two networks, different results are obtained. Network **WJn** (left side of Table 1), containing hits and cited only works, has many journals from the social sciences (marked in bold). However, the dominant journal is *LNCS*, which has 7,757 works, followed by *Social Science & Medicine* and *The Journal of Personality and Social Psychology* with more then 3000 works each. Other journals that have more then 2000 works are the multidisciplinary journals *Proceedings of the National Academy of Sciences of the USA (PNAS), Science, Nature*, and the monodisciplinary journals in computer science (*Computers in Human Behavior*), health studies (*The American Journal of Public Health*), and sociology (*American Sociological Review*). These journals are followed by other top-ranked journals in different disciplines having more than 1500 works published—in physics (*Physica A*), behavioral biology (*Animal Behaviour*), medical and health studies (*Journal of the American Medical Association, Lancet*), computer science (*Lecture Notes in Artificial Intelligence*), economics (*American Economic Review*), and social sciences (*American Journal of Sociology, Scientometrics, Academy of Management Journal, Journal of Applied Psychology*). The field's main outlet *Social Networks* is 18th, having 1642 works. The remaining journals cover many disciplines such as medicine, psychiatry, gerontology, psychology, management, marketing, computer and information science. Note that this list of journals includes many journals which are being cited in the SNA literature, but do not nesessary represent this field.

The situation changes significantly if we look at the journals with the largest number of works according to the **WJr** network indegree (right side of Table 1) obtained from the hits. In the first place is still the mega journal *LNCS* with 2009 works, which is followed by *Social Networks* with 1134 works. As the first journal is a set of publications and proceedings on computer science, this result means that *Social Networks* takes the central and coherent position in publishing the literature on SNA. Other top-rated journals are *Computers in Human Behavior, PLOS One, Lecture Notes in Artificial Intelligence, Physica A*, which have around 500 works published. In comparison to the first list, in the top-40 journals from the reduced network some journals appear (*PLOS One, Communications in Computer and Information Science, Social Network Analysis and Mining*), move down the list (*American Journal of Sociology*), or disappear (*Nature, Animal Behaviour*). Another observation is that in the list of the journals obtained from hits the number of journals from social sciences (marked in bold) is significantly lower than in the list obtained from all publications. This is due to the fact that the top journals from **WJn** network are cited intensively in the works found by the network-related

Table 1 WJn and WJr nets: the most used journals (indegree)

WJn—Journals used in all publications			WJr—Journals used in hits		
Rank	Value	Id	Rank	Value	Id
1	7757	LECT NOTES COMPUT SC	1	2009	LECT NOTES COMPUT SC
2	3866	SOC SCI MED	2	1134	***SOC NETWORKS***
3	3414	**J PERS SOC PSYCHOL**	3	806	COMPUT HUM BEHAV
4	2741	P NATL ACAD SCI USA	4	667	PLOS ONE
5	2734	COMPUT HUM BEHAV	5	531	LECT NOTES ARTIF INT
6	2631	SCIENCE	6	470	PHYSICA A
7	2609	AM J PUBLIC HEALTH	7	399	COMM COM INF SC
8	2208	NATURE	8	375	SOC SCI MED
9	2111	**AM SOCIOL REV**	9	319	**PROCD SOC BEHV**
10	1945	PHYSICA A	10	314	PHYS REV E
11	1825	ANIM BEHAV	11	283	PROCEDIA COMPUTER SCIENCE
12	1812	**AM J SOCIOL**	12	273	**SOC NETW ANAL MIN**
13	1780	JAMA-J AM MED ASSOC	13	238	ADV INTELL SYST
14	1763	LANCET	14	231	SCIENTOMETRICS
15	1759	SCIENTOMETRICS	15	225	CYBERPSYCHOL BEHAV
16	1703	**ACAD MANAGE J**	16	216	EDULEARN PROC
17	1668	LECT NOTES ARTIF INT	17	215	GERONTOLOGIST
18	1642	***SOC NETWORKS***	18	198	INTED PROC
19	1573	**J APPL PSYCHOL**	19	194	SCI REP-UK
20	1517	AM ECON REV	20	188	J MED INTERNET RES
21	1450	**J MARRIAGE FAM**	21	186	P NATL ACAD SCI USA
22	1441	EXPERT SYST APPL	22	180	EXPERT SYST APPL
23	1403	BRIT MED J	23	176	INFORM SCI
24	1399	CHILD DEV	24	170	BMC PUBLIC HEALTH
25	1379	**RES POLICY**	25	167	**NEW MEDIA SOC**
26	1372	COMMUN ACM	26	160	IEEE T KNOWL DATA EN
27	1365	NEW ENGL J MED	27	153	IEEE ACCESS
28	1311	PHYS REV E	28	145	AIDS BEHAV
29	1287	**SOC FORCES**	29	140	INFORM COMMUN SOC
30	1279	GERONTOLOGIST	30	139	STUD COMPUT INTELL
31	1278	**BRIT J PSYCHIAT**	31	136	IEEE ICC
32	1267	**AM J PSYCHIAT**	32	134	IEEE DATA MINING
33	1244	**STRATEGIC MANAGE J**	33	132	**AM J SOCIOL**
34	1225	**MANAGE SCI**	34	128	**J MATH SOCIOL**
35	1221	**J BUS RES**	35	120	IEEE INFOCOM SER
36	1189	**ACAD MANAGE REV**	36	120	**ORGAN SCI**
37	1188	**J CONSULT CLIN PSYCH**	37	119	PROC INT CONF DATA
38	1154	**ORGAN SCI**	38	118	KNOWL-BASED SYST
39	1150	ADDICTION	39	117	IFIP ADV INF COMM TE
40	1123	CYBERPSYCHOL BEHAV	40	114	IEEE GLOB COMM CONF

search query (hits), but do not necessarily publish a lot of articles on networks themselves. We suppose that the distribution from **WJr** network is a better representation of SNA.

To trace the role (importance) of the journals through time, we calculated the proportions of the number of works published in each journal in each year to the number of papers published in all journals per year. Let n_{jt} be the number of papers on SNA published in journal j in year t. We call a *share* of journal j in year t the quantity $s_{jt} = \frac{n_{jt}}{N_t}$ where $N_t = \sum_{j \in J} n_{jt}$. The share s_{jt} is equal to the probability that a paper on SNA published in year t was published in journal j. Because the values of the shares are in most cases small we multiplied them for visualization by 1000—they are expressed in promilles (‰). The input of a selected journal in each year can vary in the range from 0 to 1000‰. We extracted these proportions for journals which were identified as important in Table 1. For most of them, the values are low. We present the journals with larger values in Figs. 3 and 4.

Social Networks had the leading position in the 1980s, when its input to the field was in range of 200–400 ‰ (20–40%). However, then the input declines significantly, to the level lower than 100‰ in 1990, 50‰ in 2000, and 10‰ in 2010. In 2018, the input grew to 30‰ (the reason is the incomplete data for this year). The input of other journals specializing in SNA is low: for *Connections*, *Social Network Analysis and Mining*, *Network Science*, and *Journal of Complex Networks* it is less then 10‰ (1%). In the 1970s, the input of journals from the social sciences was important—*The American Journal of Sociology*, *The Journal of Mathematical Sociology*, *American Sociological review*, and *Social Forces* published SNA papers before *Social Networks* was established. In the 1970s, their inputs were 100‰ or more (note 400‰ for the *American Journal of Sociology* in 1973). These high inputs are due to the relatively low number of articles published in the early period.

LNCS, having the largest number of papers, has been active in publishing from 2000. As the number of papers has grown significantly since then, the input of *LNCS* is relatively low: maximum 70‰ in 2010. Other computer-oriented journals with a large number of works, *Computers in Human Behavior* and *Lecture Notes in Artificial*

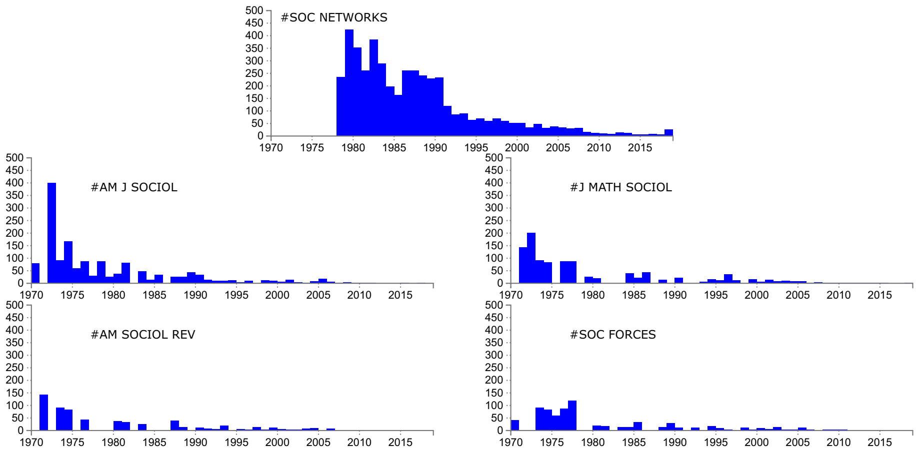

Fig. 3 Share of the selected social sciences journals through years: scale 0–500‰

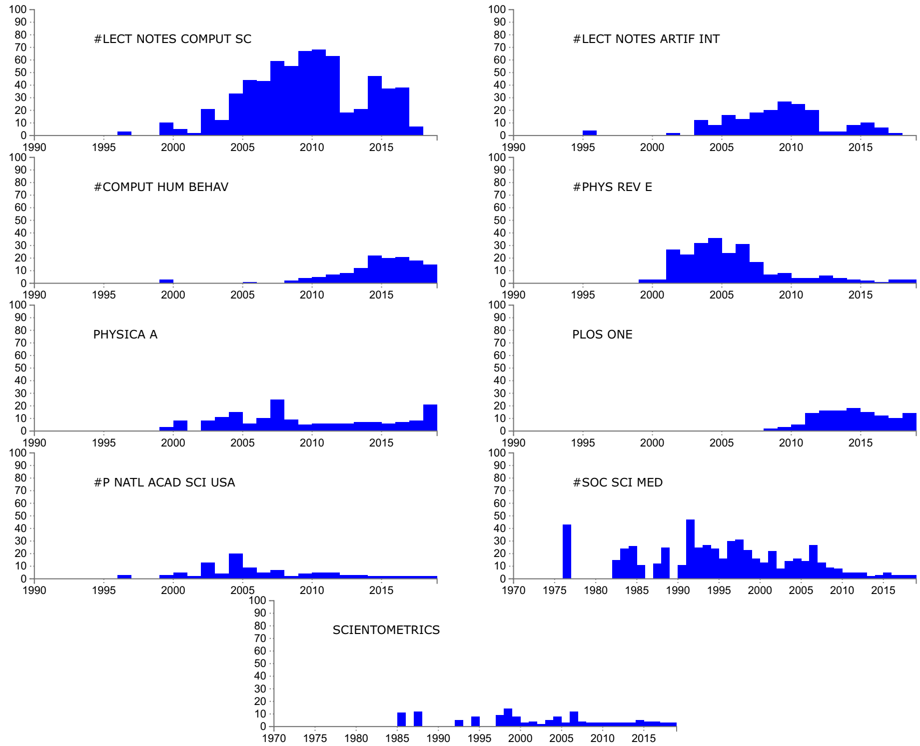

Fig. 4 Share of the selected journals through years: scale 0–100‰

Intelligence, have lower inputs of a maximum 20‰; there is a difference in the periods of their activity. The inputs of the physics journals *Physical Review E* and *Physica A* are also low. The first journal was more active in the 2000's, and for that time period its inputs are comparable with the inputs of *Social Networks*.

The traditional general scientific journals—*Science* and *Nature*—are not very actively involved in publishing works on SNA: the first published several works in the early years, before the 1970s, and in the 1980s, and both of them were active in 2000–2005, when their input was about 10‰. However, the journals *PNAS* and *PLOS One* have higher and more consistent inputs to the field. Another journal which has had a relatively high input to the field since the 1980s is *Social Science & Medicine*. The share of the journal *Scientometrics*, which can be of interest for the audience of this article, is also shown in Fig. 4. Its input to the field of SNA is rather moderate, maximum around 10‰, but quite consistent, starting from 1985 (the journal is established in 1978).

We considered also another normalization—a *dominance* $d_{jt} = \frac{n_{jt}}{M_t}$, where $M_t = \max_{j \in J} n_{jt}$. The value d_{jt} is the proportion of the number of works published in journal j in year t and the maximal number of papers M_t published in year t in any of the journals. The input of a selected journal in each year can vary from 0–100%. Figure 5 shows the distributions for some of the journals with high inputs. *Social Networks* had the leading position until 2005—the number of articles it published was as large as the maximum number of works published (in any journal) in that year. Since then, with the exception of 2012–2013, its input has declined significantly, and then, in recent years, has risen again (the reason is

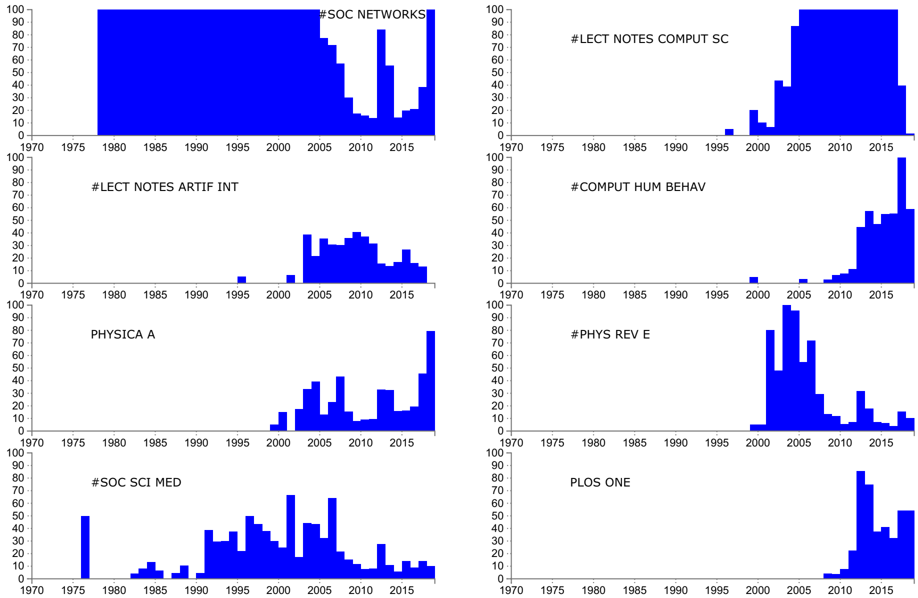

Fig. 5 Dominance of the journals: scale 0–100%

incomplete data for these years). Starting from 2005, the leading position of *Social Networks* was taken by *LNCS*. Other journals in computer sciences and physics, such as *Lecture Notes in Artificial Intelligence, Computers in Human Behavior, Physical Review E*, and *Physica A* also made a significant input. This measure was "corrupted" by the appearance of mega journals.

Networks of citations between journals

The analysis of the journal citation structures provides a way to look at the direct relations between the journals publishing SNA, extracting the subgroups of the most connected journals. The constructed networks also allow us to observe the patterns of self-citations of journals, and trace the dynamics of self-citations and citations between different journals through time.

Network creation

To get information about citations among journals, we computed the network $\mathbf{CiteJ} = \mathbf{WJ}^T * \mathbf{Cite} * \mathbf{WJ}$, which takes into account citations in papers published in journal i to papers published in journal j which appeared in the works included in the network **WJr**. We used the network **CiteR** to get the information on citations between works. In the network **CiteJ**, the value of the element $\mathbf{CiteJ}[i,j]$ is equal to the number of citations in journal i to journal j.

Using the *fractional approach* we normalized **CiteR** network (Sect. 3.3) and produced the network **CiteJn**:

$$\mathbf{CiteJn} = \mathbf{WJ}^T * n(\mathbf{Cite}) * \mathbf{WJ}$$

The value of the element **CiteJn**$[i, j]$ is equal to the fractional contribution of citations in papers published in journal i to papers published in journal j. For the network **WJ** no normalization is needed, $n(\mathbf{WJ}) = \mathbf{WJ}$, since each work corresponds to a single journal.

Based on temporal networks **WJins**, **WJcum**, and **CiteIns** (Sect. 3.4), we constructed two types of temporal networks of citations between journals **JCJ** and **JCJn**.

$$\mathbf{JCJ} = \mathbf{WJins}^T * \mathbf{CiteIns} * \mathbf{WJcum}$$
$$\mathbf{JCJn} = \mathbf{WJins}^T * n(\mathbf{CiteIns}) * \mathbf{WJcum}$$

The first network counts the number of citations between journals, and the second contains the fractional values per year.

Citations between journals

Self-citation

The loops of the **CiteJ** and **CiteJn** networks show the journals with the highest values of self-citations: absolute counts (Table 2) and fractional counts (Table 3, column "Value"). Even though some level of self-citation is typical for all journals, there are some journals that have higher levels.

The journals with the largest counts are *Social Networks* with more then 4400 self-citations, and *Computers in Human Behavior*—with more than 2000. *Physica A—Statistical Mechanics and its Applications*, *Physical Review E*, *LNCS*, *Cyberpsychology, Behavior, and Social Networking*, *PLOS One* and the more social science oriented *Social Science & Medicine* and *The American Journal of Sociology* also have relatively high values of self-citations. *Animal Behaviour*, not having a large count of self-citations (258), still occupies

Table 2 Journals with the highest self-citation counts

Rank	Value	Id
1	4443	SOC NETWORKS
2	2058	COMPUT HUM BEHAV
3	569	PHYSICA A
4	429	PHYS REV E
5	382	LECT NOTES COMPUT SC
6	339	CYBERPSYCHOL BEHAV
7	328	SOC SCI MED
8	315	AM J SOCIOL
9	303	PLOS ONE
10	258	ANIM BEHAV
11	246	SCIENTOMETRICS
12	232	J MED INTERNET RES
13	226	P NATL ACAD SCI USA
14	209	ORGAN SCI
15	194	BEHAV ECOL SOCIOBIOL

the 10th position in the list and makes the topic of animal social networks (Maltseva and Batagelj 2019) visible in the field.

The temporal distributions of the number of self-citations for the 11 journals with the largest link weights from Table 2 (including *Scientometrics*) are shown in Fig. 6 (note the different scales for *Social Networks* and *Computers in Human Behavior*). For different journals the patterns of self-citation vary: the total amount of self-citations is split among periods of different lengths. For example, compare the pictures produced for *The American Journal of Sociology*, established in 1895, having 315 self-citations and *PLOS One*, established in 2006, having 303 self-citations. Comparing the distributions for *Social Networks* and *Computers in Human Behavior*, we can also see that even though the first has twice the number of self-citations, the latter is much more intense in self-citation, as it has been in the field of SNA only since the 2010s. The counts are also sensitive to the number of papers published by journal.

In terms of the fractional values of self-citation, the set of journals is very similar to the one obtained above, however, in a slightly different order. The highest value again belongs to *Social Networks*. Other highly ranked journals are from computer science and

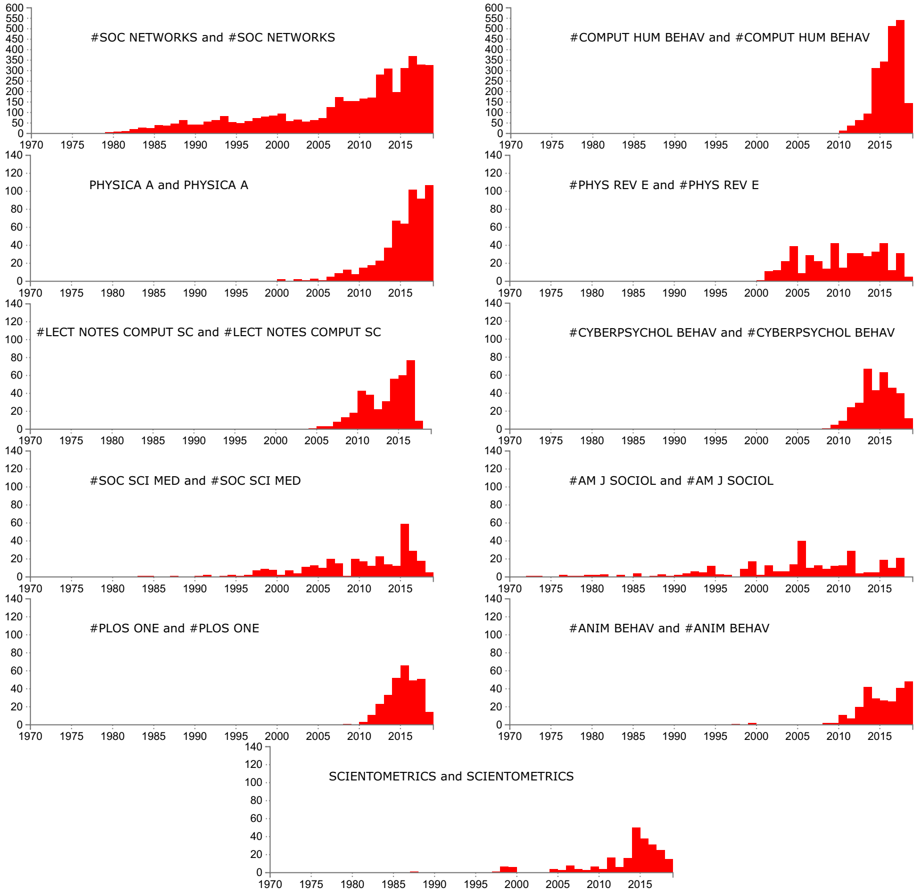

Fig. 6 JCJ network: self-citation of 11 top journals

cyberpsychology—*Computers in Human Behavior* and *LNCS*. The differences between values for the first three listed journals and the others are significant.

We computed the proportion of journal self-citations and their external citations in **CiteJn** network (Table 3, column "%"). Several journals (*Nature, The American Journal of Sociology, The American Journal of Epidemiology, The Journal of Medical Internet Research, Comunicar Journal*) have a high level of self-citation, around a quarter. *Social Networks* journal has even more (34%). A high level of self-citation may mean that the journal is seen as an important source of information for scientists involved in that particular field.

Journal-to-journal citation networks

We present the structures of citations between journals obtained from the networks **CiteJ** (based on counts) and **CiteJn** (based on fractional values). After removing loops from the network **CiteJ**, we used a link cut at the level 205 and extracted a subnetwork of 27 journals with the largest citation counts to each other (Fig. 7). The largest component of this network consists of two parts, with *Social Networks* in the center, citing journals from the social sciences, and also being cited by *The American Journal of Sociology* and *The Journal of Mathematical Sociology*. Another group of journals connected to it is formed by the management journals, *Organization Science*, *Academy of Management Journal*, and *Administrative Science Quarterly*, where the first cites, and the last is cited by *Social Networks*. The journal is also cited by *Scientometrics*, *Social Science & Medicine*, and *Social Network Analysis and Mining*, which also have a more "social" orientation. The second part of the figure is represented by the journals that cite *Social Networks* intensively—natural sciences and general scientific journals *PLOS One, LNCS, Physica A*. These journals also cite long existing general scientific journals, such as *Nature*, *Science*, and *PNAS*. Another highly connected journal in this subgroup is *Physical Review E*.

Table 3 Journals with the highest fractional self-citation

#	Value	%	Journal	#	Value	%	Journal
1	**355.65**	**0.34**	SOC NETWORKS	16	18.35	0.17	ANIM BEHAV
2	**168.39**	0.22	COMPUT HUM BEHAV	17	17.03	0.12	AIDS BEHAV
3	**122.57**	0.09	LECT NOTES COMPUT SC	18	16.03	0.19	AM J COMMUN PSYCHO
4	57.75	0.13	PHYSICA A	19	14.87	0.10	INFORM SCI
5	43.00	0.14	SOC SCI MED	20	14.14	0.14	KNOWL-BASED SYST
6	42.18	**0.24**	J MED INTERNET RES	21	12.64	0.19	PROF INFORM
7	41.49	0.21	CYBERPSYCHOL BEHAV	22	12.35	**0.23**	COMUNICAR
8	33.16	0.05	PLOS ONE	23	12.00	0.18	BEHAV ECOL SOCIOBI
9	32.93	0.11	PHYS REV E	24	11.87	**0.25**	AM J EPIDEMIOL
10	30.22	0.13	SCIENTOMETRICS	25	11.01	0.11	DECIS SUPPORT SYST
11	24.16	0.14	P NATL ACAD SCI USA	26	10.58	0.14	J ETHN MIGR STUD
12	23.15	**0.26**	AM J SOCIOL	27	10.43	0.13	COMPUT EDUC
13	20.04	0.05	LECT NOTES ARTIF INT	28	10.31	0.18	SEX TRANSM DIS
14	19.31	0.12	EXPERT SYST APPL	29	10.19	**0.28**	NATURE
15	18.77	0.14	NEW MEDIA SOC	30	9.85	0.09	ORGAN SCI

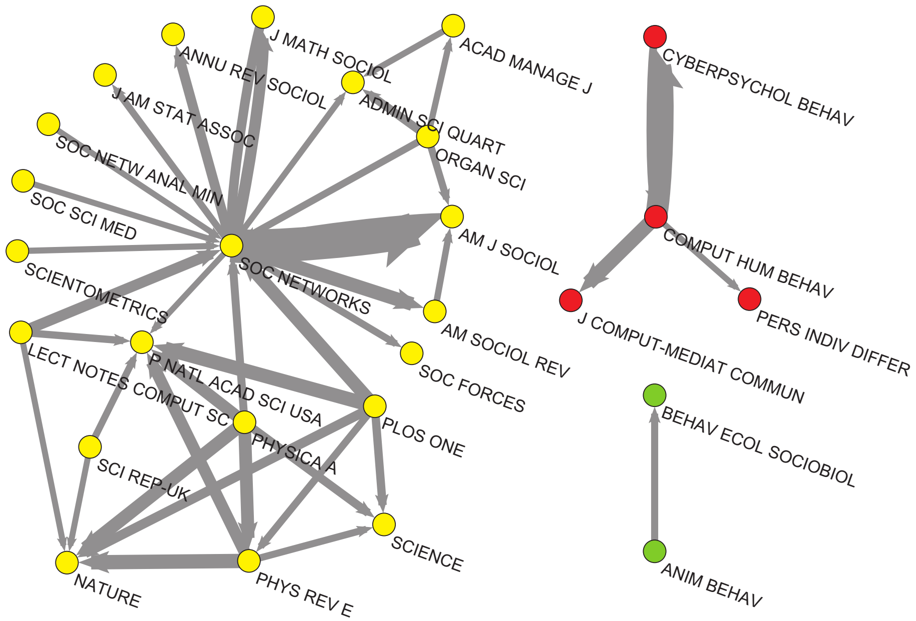

Fig. 7 JCiJ network: largest link weights

The journal *Computers in Human Behavior* forms a separate group, connected to *Cyberpsychology, Behavior, and Social Networking* (reciprocally, but with a larger intensity), as well as to *The Journal of Computer-Mediated Communications* and *Personality and Individual Differences*. These three cited journals can be seen as more general sources of information. It is interesting that this computer-oriented subgroup is not connected to *LNCS*, which is more connected to *Social Networks* and general scientific journals. Another pair of journals is *Animal Behaviour* citing *Behavioral Ecology and Sociobiology*, which again can be seen as a broader source for the more narrowly oriented journal on animal behavior.

Using the temporal not normalized network **JCJ** we traced the distributions of the number of incoming and outgoing citations for journals. Figure 8 shows the distribution of the overall number of citations given (left side) and received (right side) by *Social Networks* over time (loops are removed, note the different scales). In general, in all the years the journal is cited more than cites, but starting from 2005 the number of citations increases in both directions.

Figure 9 shows the distributions of citations from *Social Networks* to some journals belonging to the social sciences group (selected according to the largest link weights):

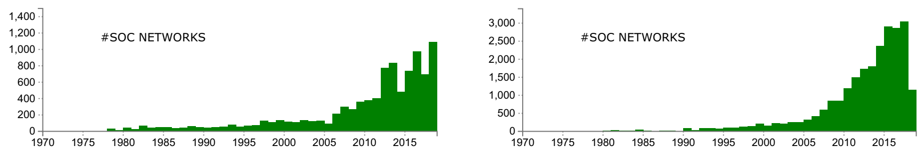

Fig. 8 *Social Networks*: number of citations given (left) and received (right)

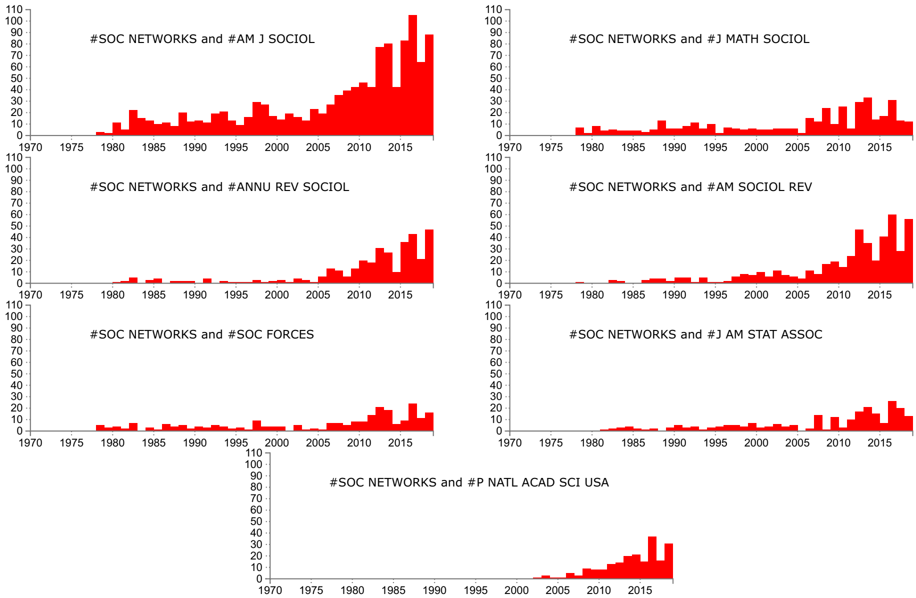

Fig. 9 *Social Networks*: citations *to* selected social science journals

The American Journal of Sociology, *The Journal of Mathematical Sociology*, *The Annual Review of Sociology*, *American Sociological Review*, *Social Forces*, *The Journal of American Statistical Association*. The absolute values of citations vary and grow over time, but this can also be the result of the growth in the number of published articles in these journals. However, citations of journals from the social sciences are constant, while for *PNAS* they appear after 2000 ("the invasion of the physicists").

Figure 10 shows the opposite picture: the distributions of citations of *Social Networks* by other journals (again, selected according to the largest link weights). In comparison to the distributions above, the citations of *Social Networks* by *The American Journal of Sociology* and *The Journal of Mathematical Sociology* are less constant and less intense. As with previous results, it may mean that these are the journals from the social sciences, which are important sources for *Social Networks*, and not vice versa. Citations of *Social Networks* by the natural science group of journals *Physica A*, *LNCS*, and *PLOS One* are more recent, but already intense (especially for the latter), which may mean that the journal is an important source for them. *Social Network Analysis and Mining*, representing the field of network analysis in general, established in 2011, also shows the intense usage of *Social Networks* as a source of information. In contrast, the appeal of *Social Networks* to *Social Science & Medicine* fluctuates.

For the normalized network **CiteJn** with fractional values, we used the *Islands approach* (Batagelj et al. 2014, p. 54–57) to produce link islands ("important" subnetworks). We searched for islands sized from 2 to 50, resulting in 195 islands (448 nodes of all the network, or 5.5%), with the largest island containing 50 nodes (10% of all nodes in the islands), and 67% being just pairs of nodes. The main island is presented in Fig. 11. Citations among journals in this island have a clear hierarchical structure. There are several main groups of journals: social sciences (on the right), computer science (on the left), physics (in the middle) and general scientific journals (at the bottom).

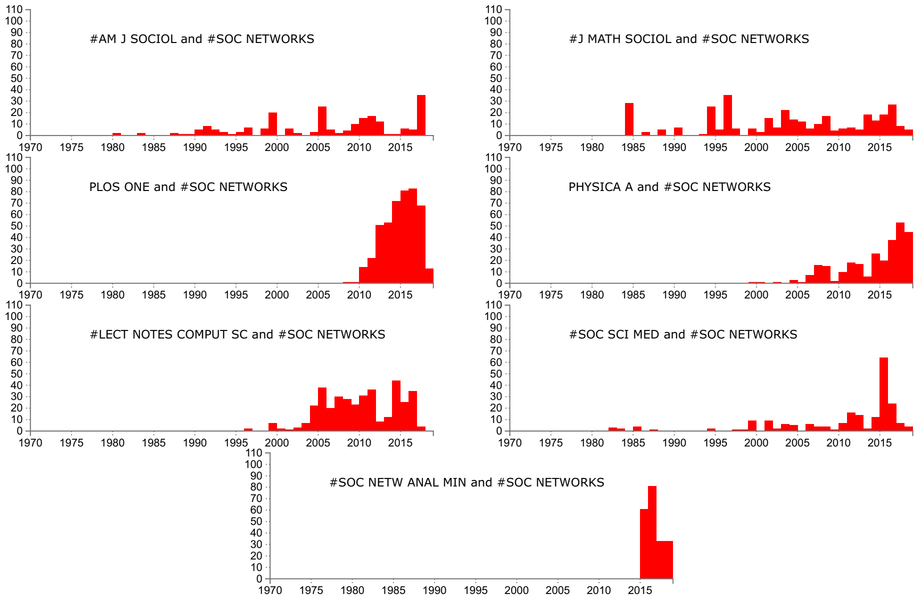

Fig. 10 *Social Networks*: citations *from* selected journals

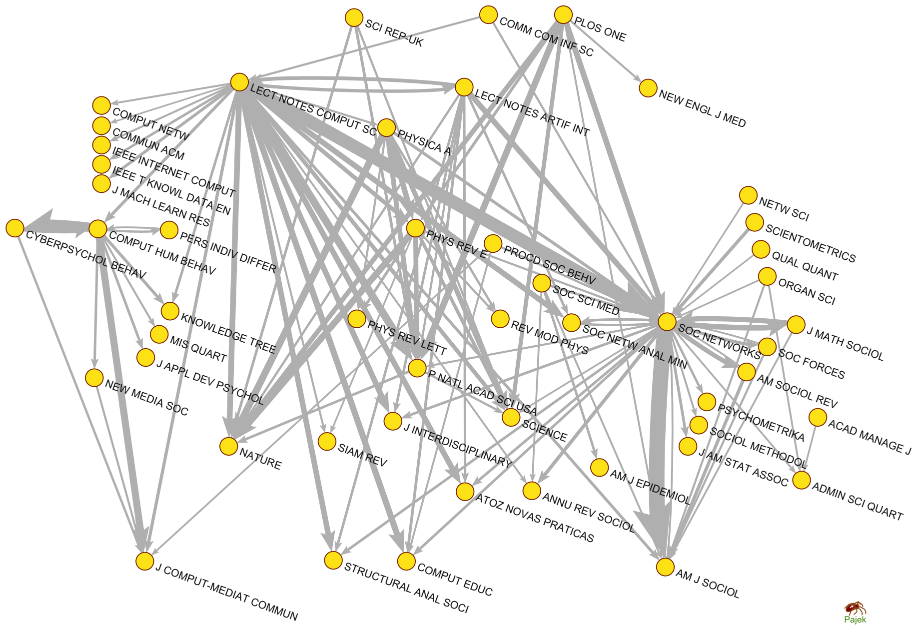

Fig. 11 Citations among journals—main island

In the computer science group of journals, the most citing is *LNCS*, which cites journals from all the groups. It also has an equal number of outgoing and incoming citations with the journal *Lecture Notes in Artificial Intelligence*, which also cites many journals from different fields. This allows us to identify these journals as interdisciplinary. Similar to the results in Fig. 7, another representative of the computer science group, *Computers in Human Behavior*, largely cites the journal *Cyberpsychology, Behavior, and Social Networking*, which also cites it back, and *Journal of Computer-Mediated Communication*, as well as other journals related to behavioral studies, information systems and media studies.

The group of journals from physics is represented by only three journals (*Physica A, Physical Review E*, and *Physical Review Letters*), with the first citing the others. *Physica A* and *Physical Review E* are also the journals that largely cite the general scientific journals *Nature* and *Science*. The traditional, older general scientific journals (*Nature, Science, Journal of Interdisciplinary Sciences, PNAS*) are cited by the newly emerged *PLOS One*.

In the social sciences group, the most citing journal is *Social Networks*, which is strongly linked to the *The American Journal of Sociology*, which also cites it back (however, to a lesser degree). The journal is reciprocally connected to the sociological journals *Journal of Mathematical Sociology, Social Forces*, and *American Sociological Review*, and also cites *Annual Review of Sociology*, and *Sociological Methodology*. It also has a reciprocal relations with *Social Network Analysis and Mining*, which is cited a lot by *LNCS*. *Social Networks* is also cited by other journals from the social sciences, computer science and physics. For this journal, most incoming citations come from *LNCS, Lecture Notes in Artificial Intelligence, PLOS One*, and *Physica A*. Thus, the journal itself cites mostly journals from the social sciences, but is cited by journals from other disciplines. There are also links from *LNCS* and *PLOS One* to the *American Journal of Sociology*.

Even though the subnetworks from Figs. 7 and 11 have different numbers of nodes, they represent similar groups of journals with similar patterns of incoming and outgoing citations. We identified the journals from the social sciences, computer science, natural sciences (physics), and general scientific journals. In both figures, it is clearly seen that the journal *Social Networks* acts as one of the main attractors for other journals.

However, the graph on Fig. 11 does not contain the group of journals from behavioral ecology and animal behavior, which are shown in Fig. 7. This group can be found in the group of other 30 islands ranging in size from 3 to 6 (altogether 110 nodes). One island includes the journals *Behavioral Ecology and Sociobiology* being cited by *Animal Behaviour* and *Behavioral Ecology*—the journals where articles on animal social networks are published (Maltseva and Batagelj 2019). The other 164 islands (328 nodes) consist of pairs of journals. These islands cover a wide range of disciplines, showing the variety of topics to which SNA is connected to: psychology; psychiatry; deviation; medicine; surgery; health; health policy; health disabilities; substance abuse and addiction; STD and AIDS; adolescence, sex; nursing; social work; archaeology and anthropology; language and sociolinguistics; economics and economic behavior; education; conflicts and peacekeeping; library science; ergonomics; transportation; migration; communication; demography, business and management; consumer behavior and marketing; information science; computing; engineering. As some of these journals come from the references of the hits, they do not necessarily apply SNA, but they act as sources of information for studies where it is applied.

Networks of bibliographic coupling between journals

The analysis of the structures of bibliographic coupling provides a way to look at the indirect relations between the journals publishing SNA; two works are considered linked, or coupled, when they reference the same third work (Kessler 1963). Direct citations between these works do not necessary exist. Shared citations suggest some content commonality between a pair of works, and the shared citation of several publications increases the likelihood of them sharing content (Batagelj et al. 2020). This approach can also be projected to the authors and journals, when the connections between these units are formed based on the works they wrote or published. Bibliographic coupling allows us to measure similarity (or dissimilarity) between each two units of analysis and identify the groups of units with similar citation patterns and thus which are close to each other according to their content. In the analysis below, we extract the subgroups of the journals publishing SNA having content similarity.

Network creation

The bibliographic coupling network **biCo**, counting the shared citations between each two works, is determined as:

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

$$\mathbf{biCo}_{pq} = \#\text{of works cited by both works } p \text{ and } q = \mid \mathbf{Cite}(p) \cap \mathbf{Cite}(q) \mid$$

Bibliographic coupling weights are symmetric: $\mathbf{biCo}_{pq} = \mathbf{biCo}_{qp}$.

The fractional approach cannot be directly applied to bibliographic coupling. We first consider the network

$$\mathbf{biC} = n(\mathbf{Cite}) * \mathbf{Cite}^T$$

which is not symmetric. For $\mathbf{Cite}(p) \neq \emptyset$ and $\mathbf{Cite}(q) \neq \emptyset$ it holds

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

and $\mathbf{biC}_{pq} \in [0, 1]$. $\mathbf{biC}_{pq}$ is the proportion of references that the work p shares with the work q. We have different options to construct normalized symmetric measures (Batagelj 2020b) using a mean of the values $\mathbf{biC}_{pq}$ and $\mathbf{biC}_{qp}$. Among them we selected to use the Jaccard index.

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

The Jaccard network **biCoj** links works to works. To link journals through a Jaccard network we compute the network **JCoj**:

$$\mathbf{JCoj} = n(\mathbf{WJ})^T * \mathbf{biCoj} * n(\mathbf{WJ}) = \mathbf{WJ}^T * \mathbf{biCoj} * \mathbf{WJ}, \text{because } n(\mathbf{WJ}) = \mathbf{WJ}$$

The values of the links from **biCoj** are redistributed in **JCoj**—the total sum of link weights is preserved:

$$\sum_{e \in E(\mathbf{JCoj})} \mathbf{JCoj}[e] = \sum_{e \in E(\mathbf{biCoj})} \mathbf{biCoj}[e]$$

We used the network **CiteR** in the computation. The produced Jaccard network **biCoj** contains a large number of links (62,079,457) and that is why the computation of the network **JCoj** is quite time consuming. In computing the network **JCoj** the network **WJr** was used. In this network, loops are deleted, bidirected arcs are converted to edges (with a summation of their values) before further analysis. After this simplification, the network **JCoj** contains 8943 nodes and 5,136,616 edges.

Bibliographic coupling between journals

In the network **JCoj**, the links between nodes mean similar coverage of content. The majority of link weights in this network were very low, and after a link cut at the level 1200, we obtained the network **Cj** with 41 nodes (Fig. 12). The obtained structure is formed mostly by journals from the fields of physics and computer science closely connected to each other. The following journals are particularly prominent: *Physica A, Physical Review E, LNCS, Lecture Notes in Artificial Intelligence*, and *PLOS One*. These results are similar to the ones obtained for the analysis of the literature on network clustering (Batagelj et al. 2020).

However, all these journals are strongly linked to *Social Networks*, which appears to be the only transition point connecting a large group of journals from the social sciences

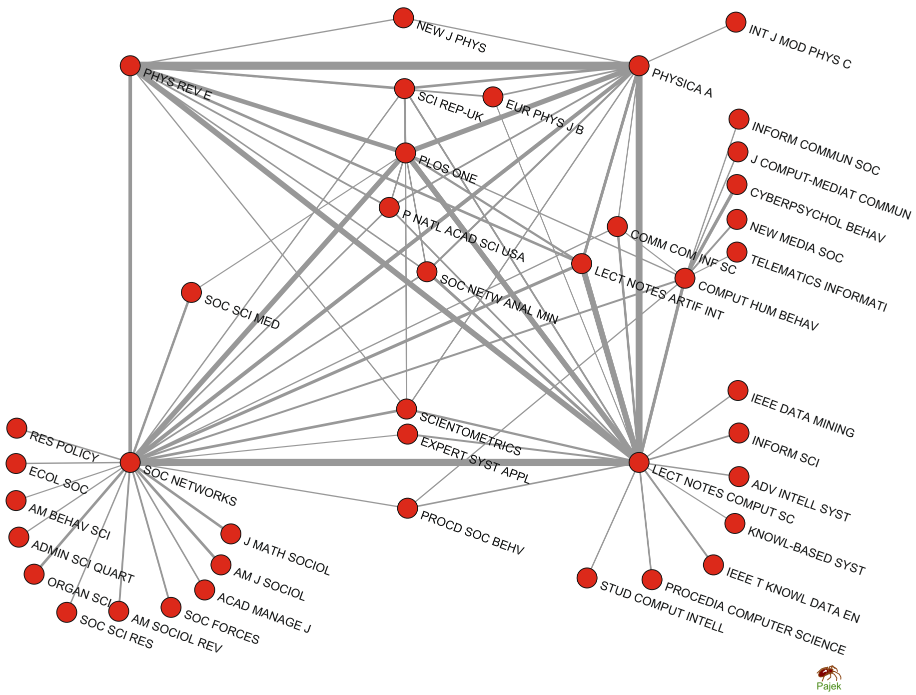

Fig. 12 **Cj** network: journals

with journals from sociology (*Journal of Mathematical Sociology, Social Forces, American Sociological Review, American journal of Sociology, Social Science Research)*, management (*Academy of Management Journal, Organization Science, Administrative Science Quarterly)*, and other disciplines (*American Behavioral Scientist, Ecology and Society, Research Policy*). Relatively strong ties go from this journal to *Social Science & Medicine*, and *Scientometrics*.

Among other prominent journals, only *LNCS* has a similar substructure, being a transition point for a set of journals from computer science working on data mining and computer systems (such as *Information Sciences*, *Knowledge-Based Systems*, *Studies in Computational Intelligence*) to other journals. Another subgroup is formed around another computer science journal—*Computers in Human Behavior*, being a transition point for *Information Communication and Society*, *Journal of Computer-Mediated Communication*, *Cyberpsychology, Behavior, and Social Networking*, *New Media & Society*, *Telematics and Informatics*. In comparison to the previous one, this group is oriented to the issues of communication, behavior and media systems (however, the two journals also have similar referencing patterns).

Interestingly, the two main representatives of physics journals, *Physical Review E* and *Physica A*, do not form similar disciplinary subgroups around them. Being linked to each other, they share a link with the *New Journal of Physics*; *Physica A* is also linked to the *International Journal of Modern Physics A* and *European Physical Journal B*. All other links of these two journals go beyond the borders of physics—to the group of general scientific, computer and social science journals.

The journals inside the square of the graph are linked to all the mentioned centers. Besides *PLOS One*, they are other general scientific journals (*PNAS, Scientific Reports UK*), *Scientometrics*, and *Social Network Analysis and Mining*. Despite its name, the latter is more focused on data mining in large networks and reflects a more computer science orientation (however, it is still linked to *Social Networks*).

Discussion and conclusion

This paper provides insight into the most prominent journals in the filed of SNA, and reveals their relationships to each other using direct and indirect approaches for link construction: direct citations between journals, and bibliographic coupling showing the similarities between journals according to common referencing and content. The analysis of the citation networks identifies the self-citation practices of prominent journals. The construction of the temporal versions of these networks allows us to trace the role of the selected journals through time, and look at the dynamics of the relations between the journals. Observing these structures, we pay special attention to the position of the SNA's main outlet *Social Networks*, and its evolution through time. Our dataset includes articles from WoS published up to July 2018, matching the query "social network*", intensively cited papers, and those published in the main SNA journals from WoS and published by the most prominent authors. We believe that our systematic and comprehensive approach to data collection and analysis provides important information for understanding the development of the field and identifies the disciplines where it is developing the fastest.

The results clearly show that the field is growing and expanding, which can be seen by the annual rise in the number of journals publishing papers in SNA: increasing slightly in the 1990s, it rose quickly around 2006, and even more quickly in 2015. The average number of papers on SNA per journal per year also shows growth, starting from the 2000s: until 2005 it was around 1.5 papers, in recent years it has reached the level of almost 3 publications per journal. However, the number of publications by journals is distributed in a scale-free form, and the set of journals with extra large numbers of publications can be identified. As we have shown, a better representation of the situation in the field can be seen from the distribution of the reduced network of works and journals, obtained from hits. The top identified journals publishing on SNA are *LNCS* and *Social Networks*. However, we should take into consideration that the first one is more of a mega-journal, or conference proceedings series, publishing the latest research developments in all areas of computer science, and in this sense it is not completely fair to compare its output with that of *Social Networks*. Other journals with the largest numbers of publications are computer science journals *Computers in Human Behavior* and *Lecture Notes in Artificial Intelligence*, physical *Physica A*, and general scientific journal *PLOS One*. The distribution of the original network of works and journals, obtained from hits and cited only publications, clearly shows the roots of SNA in social sciences—the journals from sociology, psychology, management, organizational sciences, etc. are often used as sources of information for the SNA papers, being cited a lot, but not containing SNA-related topics themselves. There are journals from other disciplines as well, which are seen as sources of information for SNA research, from the natural sciences (medicine, health studies, biology), computer science, and well-established general scientific journals *PNAS*, *Science*, and *Nature*.

The analysis of journal-to-journal structures of citation and bibliographic coupling allows us to determine the journals and disciplines in SNA which are the most prominent. In the simplest division, these journals belong to two groups—social and natural sciences—which are connected to each other through some journals taking positions of "transition points". The social sciences group is represented mainly by journals from sociology and management. The second group of journals mainly come from the fields of physics, computer science, or are general scientific journals. The journals from these groups interact with each other in different ways.

The social sciences group of journals is connected to all others mainly through *Social Networks*. Most of these journals are mainly *cited by* this source, and the reverse direction is less active and has fluctuated over time. The most intensively cited journals are the *American Journal of Sociology* and the *Journal of Mathematical Sociology*, which are also exceptions as they have some (less intense) citations of *Social Networks*. The first journal is also exceptional in the sense of being cited from outside the social sciences—from computer science and general scientific journals. The temporal distributions of the number of outgoing citations for *Social Networks* to the journals from social sciences is stable, with some growth in recent years. These results clearly show that the field of sociology, where SNA originally appeared, can be regarded as the basis for the studies in SNA in terms of their theoretical and substantive background, allowing the generation of ideas. It is not surprising that the reverse direction in citation is less active. The results of bibliographic coupling, showing the similarity between the journals from social sciences and *Social Networks*, also support this conclusion: they share a large amount of literature in their references, and thus they have a lot of common content.

The hierarchical structure of the ties is also typical for journals from natural sciences—physics, computer science and general scientific journals—which, in turn, mainly cite *Social Networks*. The journal-hubs, with a large number of outgoing citations, are *LNCS*, *Lecture Notes in Artificial Intelligence*, and *Computers in Human Behavior* in computer science, *Physica A* and *Physical Review E* in physics, and *PLOS One* in the general scientific journal group. The prominent journals from computer science also form structures cited exclusively by them, and these structures also appear in the results of bibliographic coupling. In comparison to this, journals from physics have almost no “satellites” from their own disciplines, and use mainly the general scientific journals (*Nature*, *Science*, *PNAS*) as their main sources. According to the results of the bibliographic coupling, they are similar to each other in their citation patterns and content, but also to such journals as *LNCS*, *PLOS One*, and *Social Networks*. We can conclude that these journals are very different from other physics journals and they have developed their own niche, which is less actively represented in other physics journals. In general scientific journals, the long established journals (*Nature*, *Science*, *PNAS*) are mostly used as sources for citations, while the newly established *PLOS One* is citing intensively—mainly them and *Social Networks*. That is why, among general scientific journals, it is only *PLOS One* that has common citation patterns and shared content with other journals publishing SNA.

It is interesting to observe small groups of journals belonging to some special disciplines, which are intensively represented in the dataset. The analysis revealed groups of journals on behavioral biology and sociobiology, which represent a separate island of works devoted to the studies of animal social networks. The appearance of this group in the study of the network of citations between works (Maltseva and Batagelj 2019) was rather surprising; the analysis in this paper confirms this result. These journals did not appear in the results of bibliographic coupling, which shows that they are very different in content, even though they use the same methodology in their research.

In accordance with previous studies, the aim of this research was to determine the position of SNA’s main outlet *Social Networks* in relation to the other journals. As mentioned above, *Social Networks* is very active in publishing literature on SNA. The temporal distribution of the journal output shows that it had explicit primacy up to the 2000s; in recent years its relative output has declined significantly due to the large number of papers published in other journals in the field. Since then, other journals have made a comparable relative output to the field, such as mega-journal *LNCS* (having the largest number of articles in our dataset), *PLOS One*, and *Physical Review E*. This is connected with the interest in social networks from other disciplines. *Social Networks* also demonstrates the largest values of self-citations, followed by the journal *Computers in Human Behavior*. This may mean that these journals are seen as important outlets and sources of information for the scholars applying SNA in their research fields.

The results of the citation and bibliographic analyses show that *Social Networks* takes a very coherent and important position among other journals. It is very much rooted in the journals from the social sciences in terms of the citations it makes, supporting the finding of Leydesdorff et al. (2008), and in terms of shared content, supporting the findings of Brandes and Pich (2011). Citing many journals from the social sciences, the journal is often cited by the journals outside this field (from natural and computer sciences). In SNA terms, it takes the position of a broker between the journals of social and natural sciences, which supports the earlier findings of Leydesdorff (2007) and the results of Batagelj et al. (2020) (even though they were obtained for specific datasets). We can conclude that the journal has a multidisciplinary citation environment, and connects the two groups of disciplines.

Taking into account the outlet of the current article, some reflections on the position of the *Scientometrics* journal among the others publishing articles in SNA can be of interest to its readers. Interestingly, the journal, not specifically devoted to SNA, appeared in all summary tables and resulting figures. It is in the middle of the second ten in the number of publications we got for the analysis, and it has quite moderate, but consistent input to the field, starting from the 1980s. The results of the citation analysis show that *Scientometrics* is using *Social Networks* as the source of information, citing it extensively. The bibliographic coupling reveals the structure where *Scientometrics* is connected with all other central journals publishing SNA (*Social Networks*, *LNCS*, *Physical Review E*, *Physica A*, and *PLOS One*), having a shared content with all of them. It should be noted that for our analysis, only papers in *Scientometrics* related to SNA were considered.

Once again, it should be explicitly emphasized that the results of the current study are inevitably connected to the data available in the WoS database. There are well-known journals on SNA not yet indexed in WoS, such as *Connections* (est. 1977), *Journal of Social Structure* (est. 2012), *Computational Social Networks* (est. 2014), *Applied Network Science* (est.2016), or *Online Social Networks and Media* (est.2017), which make a significant contribution to SNA, and their inclusion in the analysis could provide further understanding of the current development of the field. This can be one of the tasks for future analysis. Another direction for the research development is connected to the approach used here to temporal network analysis. Applied to the analysis of the large journal structures for the first time, it needs further development for the visualization of the results.

Appendix: synonymic referencing

Some problems associated with name recognition can occur in the dataset. The original network **WJ** had 70,425 journals. Due to inconsistencies in journal titles in different descriptions, it contained sets of nodes denoting *the same journal*. To get the list of these nodes, we constructed for each journal title its short code, which was formed out of the first two letters of each word in the journal's title,—such as `SONEANANMI` for `SOCIAL NETWORK ANALYSIS AND MINING`,—and then sorted them so that the journals with the same code were grouped together. We manually inspected all the journals with at least one of their names cited at least 200 times. To get these numbers we computed in Pajek the 2-mode network **Cite*WJc** and determined the vector **wIndegJ.vec** with weighted indegrees for journals. We obtained a list of candidates for inspection with 5482 titles. To additionally reduce the number of titles to inspect we considered only titles that appeared in at least 3 citations. This gave a list **journalK100.csv** with 3714 titles, that were manually

```
63656 1312696 10849 SONEAN    | SOCIAL NETWORK ANAL
63657 1330776 3     SONEAN    | SOCIAL NETWORKS ANAL
63658 1311789 645   SONEANMI  | SOC NETW ANAL MIN
63659 1313366 7     SONEANMI  | SOCIAL NETW ANAL MIN
63660 1315722 7     SONEANMI  | SOC NETW ANAL MINING
...
25340 1297450 195   HUREMA    | HUM RESOURCE MANAGE
25341 1298839 189   HUREMA    | HUMAN RESOURCE MANAG
25343 1304542 3     HUREMA    | HUMAN RESOURCES MANA
25344 1305503 67    HUREMA    | HUM RESOUR MANAGE
25345 1312370 222   HUREMA    | HUM RESOUR MANAGE-US
25352 1301632 189   HUREMAR   | HUM RESOUR MANAGE R
25353 1303129 5     HUREMAR   | HUM RESOUR MANAG R
...
4188 1299141 391    AMJGEPS   | AM J GERIAT PSYCHIAT
4189 1299905 23     AMJGEPS   | AM J GERIATRIC PSYCH
4190 1302259 12     AMJGEPS   | AMER J GERIATR PSYCHIATR
4191 1304932 14     AMJGEPS   | AM J GERIATR PSYCHIA
4192 1314551 7      AMJGEPS   | AM J GERIATR PSYCHIATRY
```

Fig. 13 Examples of different journal title writing

```
10524 1297183 50    COAC   | COMMUN ACM
10525 1311274 14141 COAC   | COMMUNICATIONS ACM
10062 1309889 12756 CA     | CACM
...
55366 1351847 54714 PSPOSC | PS POLITICAL SCIENCE
55768 1320199 23066 POSC   | POLITICAL SCI
55769 1320573 23440 POSC   | POLIT SCI
56082 1297982 849   PSSCPO | PS-POLIT SCI POLIT
56083 1298064 931   PSSCPO | PS-POLITICAL SCI POL
...
33087 1299216 2083  JAC    | J ACM
33550 1355703 58570 JACJA  | J ACM JACM
32955 1302464 5331  JA     | JACM
```

Fig. 14 Examples of different journal title writings with abbreviations

inspected. After checking, this list was reduced to 1688 titles. Some examples of the journal titles grouped according to their codes are presented in Fig. 13.

However, some journal titles can also appear in an abbreviated form based on their initials—for example, the *Journal of the American Statistical Association* could be coded as `JAMSTAS` according to its short title `J AM STAT ASS` and as `JA` according to its abbreviation `JASA`. That is why we also produced a list of frequent journal names of at most 5 letters, and chose all the cases that could be considered as abbreviations, such as `CACM, JACM, JASA, LNCS, NIPS, JASSS, IJCAI, BMJ, JOSS` and performed a manual search for the abbreviations of these journals in the original list of 70,425 journals. We grouped all the journal titles which included the same abbreviations—some examples are presented in Fig. 14 (there were different codes generated for different titles). The results of the search were added to the first list, and finally a list and the corresponding partition for network shrinking were produced. This resulted in a reduced list of 69,146 journals.

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