The current issue and full text archive of this journal is available on Emerald Insight at:
https://www.emerald.com/insight/0022-0418.htm

Intellectual structure of information science 2011–2020: an author co-citation analysis

Dangzhi Zhao
University of Alberta, Edmonton, Canada, and
Andreas Strotmann
ScienceXplore, Bad Schandau, Germany

Received 20 June 2021
Revised 2 August 2021
Accepted 9 August 2021

Abstract

Purpose – This study continues a long history of author co-citation analysis of the intellectual structure of information science into the time period of 2011–2020. It also examines changes in this structure from 2006–2010 through 2011–2015 to 2016–2020. Results will contribute to a better understanding of the information science research field.

Design/methodology/approach – The well-established procedures and techniques for author co-citation analysis were followed. Full records of research articles in core information science journals published during 2011–2020 were retrieved and downloaded from the Web of Science database. About 150 most highly cited authors in each of the two five-year time periods were selected from this dataset to represent this field, and their co-citation counts were calculated. Each co-citation matrix was input into SPSS for factor analysis, and results were visualized in Pajek. Factors were interpreted as specialties and labeled upon an examination of articles written by authors who load primarily on each factor.

Findings – The two-camp structure of information science continued to be present clearly. Bibliometric indicators for research evaluation dominated the Knowledge Domain Analysis camp during both fivr-year time periods, whereas interactive information retrieval (IR) dominated the IR camp during 2011–2015 but shared dominance with information behavior during 2016–2020. Bridging between the two camps became increasingly weaker and was only provided by the scholarly communication specialty during 2016–2020. The IR systems specialty drifted further away from the IR camp. The information behavior specialty experienced a deep slump during 2011–2020 in its evolution process. Altmetrics grew to dominate the Webometrics specialty and brought it to a sharp increase during 2016–2020.

Originality/value – Author co-citation analysis (ACA) is effective in revealing intellectual structures of research fields. Most related studies used term-based methods to identify individual research topics but did not examine the interrelationships between these topics or the overall structure of the field. The few studies that did discuss the overall structure paid little attention to the effect of changes to the source journals on the results. The present study does not have these problems and continues the long history of benchmark contributions to a better understanding of the information science field using ACA.

Keywords Author co-citation analysis, Information science, Intellectual structure, Bibliometrics, Citation analysis, Citation network analysis

Paper type Research paper

Introduction

The intellectual structure of information science (IS) as defined by core IS journals in the field of library and information science (LIS) has been the focus of a series of studies covering a long continuous time period (since 1972) using the same data source and a similar author co-citation analysis (ACA) methodology (White and McCain, 1998; Zhao and Strotmann, 2008a, b, 2014).

These studies found IS to consist of two largely separated camps, one focusing on information representation, retrieval, users and use (information retrieval – IR camp), and the other on quantitative studies of science and technology (knowledge domain analysis – KDA camp). While this two-camp structure has been a constant feature of the intellectual structure of the IS field, research areas within each camp and their interrelationships have been evolving continuously over the years.

Journal of Documentation
Vol. 78 No. 3, 2022
pp. 728-744

0022-0418
DOI 10.1108/JD-06-2021-0119

The present study brings this line of studies up to date and attempts to identify evolving patterns of IS intellectual structure during the past decade (2011–2020) using an ACA methodology comparable to that of the previous studies in this series.

This study will contribute to a better understanding of the evolving IS field. Although many studies of the LIS field have been carried out in recent years, most studies used term-based methods to identify individual research topics in LIS and their evolution over time but did not examine the interrelationships between these topics or the overall structure of the field (e.g. the clear two-camp structure throughout). The few citation-based studies that did discuss the overall intellectual structure of IS in addition to individual research topics paid little attention in research design and interpretation of results to the effect of changes to the source journals on the results.

Related studies

While general bibliometric profiling of research fields has been performed for many research fields, bibliometric studies of intellectual structures of research fields have tended to concentrate on LIS and a few other research fields, likely due in part to higher requirements by this type of studies for both the researchers' knowledge of the research fields being studied and their network analysis skills.

Such studies fall into two general categories: using existing methods and tools to examine the LIS field and using LIS as a sample research field to test new methods for studying intellectual structures of research fields. We will review these two types of studies published since the last study of the line of inquires (i.e. Zhao and Strotmann, 2014) that the present study is continuing.

Using existing methods and tools to examine LIS

Most such studies used term-based methods to identify individual research topics in LIS and their evolution over time but did not examine the interrelationships between these topics or the overall structure of the field (e.g. the two-camp structure). Here are some examples.

The most straightforward method is to examine top keywords ranked by frequency in a set of LIS journals. Thelwall and Maflahi (2015) analyzed words related to computing technologies in the titles, abstracts and keywords of forty years of articles in LIS-classified journals. Liu and Yang (2019) examined keywords in a set of LIS journals selected to showcase librarianship and research by librarians to "help practicing librarians and library science scholars gain a better understanding and considerable prediction on the research trends in the LIS field" (p. 278). Onyancha (2018) tracked author-supplied keywords in research articles published between 1971 and 2015 and found that LIS evolved from information systems design and management in the 1970s to encompass scientific communication, information storage and retrieval, information access, information and knowledge management, and user education by 2015.

Word co-occurrence analysis is another method used frequently. Sohaili *et al.* (2016) examined the intellectual structure of research on information behavior during 2006–2014 using a co-word analysis. Song *et al.* (2020) conducted a descriptor co-occurrence analysis and a burst analysis using CiteSpace to draw knowledge maps of LIS 2000–2019. They found that the focus of library science evolved from traditional to digital libraries and that of information science from information to data science. Mokhtarpour and Khasseh (2020) also used CiteSpace to conduct a co-word analysis of LIS research during 1990–2016 and found that "information seeking and retrieval" was the most important research focus. Through a word bibliographic coupling analysis, Hsiao and Chen (2020) identified 25 topics of LIS 2009–2018 categorized into six main research trends: scholarly communication and scientometrics, information behavior and information retrieval, applications of technology, library services and management, health information and technology, and computer science techniques.

The formal concept analysis method was used in Liu *et al.* (2015) to investigate the intellectual structure of LIS 2001–2013 by analyzing papers published in 16 prominent LIS journals. They identified nine main LIS research themes: bibliometrics, scientometrics and informetrics; citation analysis; information retrieval; information behavior; libraries; user studies; social network analysis; information behavior and webometrics.

The latent Dirichlet allocation topic model was used by Han (2020) to study the evolution of research topics in LIS between 1996 and 2019. They found that library science has become less prevalent over time and information retrieval has consistently been the dominant domain. Stable areas include bibliometrics, especially citation analysis, information seeking and information behavior. Information systems and organizational activities have been continuously discussed and have developed a closer relationship with e-commerce. Topics that occurred only once have undergone a change of technological context from the networks and Internet to social media and mobile applications. Another study using latent Dirichlet allocation was conducted by Figuerola *et al.* (2017). They examined titles and abstracts of 92,705 documents for the period 1978–2014 retrieved from library and information science Abstracts. They identified 19 dominant topics clustered into four main areas: process, information technology, library and specific areas of information application.

There were also a small number of studies that used citation-based methods. Here are some examples.

Following the study of the intellectual structure of IS during the first decade of the world wide web by Zhao and Strotmann (2008b) using a methodology that combined ACA and author bibliographic coupling analysis (ABCA), Yang *et al.* (2016) examined IS during the second decade of the Web (2006–2015) using ABCA. They found that the KDA camp became remarkably prominent, while the IR camp experienced a further decline in hard IR research and became significantly smaller. They also found that patent analysis and open access emerged during this period, and that mapping of science and bibliometric evaluation also experienced substantial growth. They did not explore whether these observations reflected a true picture of the IS field or were artifacts of changes in data sources, such as the journal Scientometrics becoming disproportionately larger in size than all the other journals in the dataset since results from bibliometric studies are affected substantially by field delineation (Zhao and Strotmann, 2015).

Li *et al.* (2019) used CiteSpace to conduct a document co-citation analysis of LIS 1989–2018. They identified six "research trends" in LIS: metrology research, open government, scientific evaluation, big data, social media and information system. Hou *et al.* (2018) conducted a document co-citation analysis of IS 1909–2016 and identified "emerging" topics such as scientific evaluation indicators, altmetrics, science mapping, bibliometrics, citation analysis and scientific collaboration. All these "emerging" topics had been identified in previous studies except for altmetrics.

Olmeda-Gómez *et al.* (2017) studied the Spanish information science field 1985–2014 using document co-citation analysis in addition to co-word analysis. Yang and Wang (2015) compared information science research between China and the rest of the world using author direct citation analysis. Chang *et al.* (2015) analyzed bibliographic coupling and co-citation in addition to keywords in 580 highly cited LIS articles to track changes in LIS research during four periods between 1995 and 2014. They found that "information seeking and information retrieval" and "bibliometrics" appeared in all four periods, and that the former was shrinking while the latter was growing.

Testing new methods for studying intellectual structures of research fields
Studies have tested what effect weighting the co-citation counting of authors by various features such as by the ordering of author names on the by-line (Bu *et al.*, 2018) or by the context and frequency of their mentions in the text (Bu *et al.*, 2020), may have on ACA. Little significant differences in results were found between weighted ACA and the classic ACA, indicating that that ACA is quite robust as noted in previous studies (Zhao and Strotmann, 2011). Zhao and Strotmann (2020) compared four weighting schemes for ACA. They found that in-text frequency-weighted counting performs as well as traditional counting in identifying major dimensions of the LIS field. Re-citation-based counting appears to highlight well-integrated specialties and weaken the presence of more fragmented ones compared to traditional counting. In-text frequency weighted re-citation counting which highlights "deep" impact appears to effectively zoom into the field to show intense streams of research within it but fail to identify major dimensions of the field. Kim *et al.* (2016) proposed an ACA method that takes into account citation sentences and locations in the text and found that this method enables the identification of distinct sub-fields of authors.

Classic first-author-based ACA and ABCA have been compared with all-author-based approaches. Song *et al.* (2021a, b) as well as Yang *et al.* (2016) compared first and all-author-based ABCA. Song *et al.* (2021a, b) explored differences between all-author-based ABCA and ACA in revealing the intellectual structure of a discipline. These studies confirmed findings in Zhao and Strotmann (2008b, c) regarding ACA vs ABCA or regarding all-author vs first-author based methods.

Yang *et al.* (2016) also compared ABCA with author keyword coupling analysis that they introduced. They found that author keyword coupling analysis appears to provide a less detailed picture, and more uneven sub-areas of a discipline structure. Hsiao and Chen (2020) also explored "Word bibliographic coupling" and concluded that their method can identify core research in different subject areas and help judge how similar different areas are. Zhang *et al.* (2018) tested a method for topic extraction from bibliometric datasets based on deep learning.

Methodology

We will essentially use the same methodology as in Zhao and Strotmann (2014), the latest study in the series that the present study continues. Unlike Zhao and Strotmann (2014), the present study will only use ACA to examine the intellectual structure of IS for two five-year time periods: 2011–2015 and 2016–2020. We will also compare the results with the previous five-year time period (i.e. 2006–2010) examined in Zhao and Strotmann (2014) to gain additional insight into the evolution of the IS field over time.

Data collection
In order to make these results comparable, we collected and analyzed data for the present study in much the same way as in Zhao and Strotmann (2008b, 2014). Specifically, we downloaded Web of Science full records (including cited references) for all articles published during the years 2011–2020 in the core IS journals listed in Table 1. These journals were a slightly shorter list of journals used to define the IS research field in all previous ACA studies of IS that the present study aims to update after removing proceedings, reviews and a journal that no long exists. Zhao and Strotmann (2015) discussed why focusing on the "article" type of journal publications is a good approach.

However, during the data collection process, we noticed that the journal Scientometrics, a core journal in the KDA camp of IS (as compared to the IR camp), has grown in size to become disproportionately larger than all the other journals in terms of the number of articles

Information science
• Information Processing and Management (940) • Journal of the Association for Information Science and Technology (and Journal of the American Society for Information Science and Technology) (1,681) • Journal of Documentation (604) • Journal of Information Science (626) • Library and Information Science Research (326) • Scientometrics (3,184)   ○ Or Journal of Informetrics (777)
Library automation
• Electronic library (579) • Information technology and libraries (191) • Library resources and technical services (141)
*Taken from White and McCain (1998, p. 330) with three titles removed
• Annual Review of Information Science and Technology • Proceedings of the American Society for Information Science and Technology (and Proceedings of the ASIST Annual Meeting) • Program – Automated Library and Information Systems

Table 1.
Journals used to define information science* (The number of articles published during 2011–2020 is in parentheses)

published per year. As seen from Table 1, Scientometrics published 3,184 articles during the ten years being studied, and the second largest journal only published 1,681 articles (compared to 836 vs 1,099 in these two journals in 2006–2010). Considering the effect of field delineation on results of citation analysis studies (Zhao and Strotmann, 2015), to hopefully obtain a more balanced view of the IS field, we also conducted an ACA with Scientometrics replaced by *Journal of Informetrics*, another core journal in the KDA camp of IS which published 777 articles from 2011 to 2020, a number more comparable to those in other specialty journals in the dataset.

We processed these two datasets to identify the most highly cited authors for each time period and to calculate their co-citation counts. Specifically, aiming for including 150 authors in each analysis to align with the previous study (Zhao and Strotmann, 2014) with which we will compare results, we took all names that have been cited 63+ times for 2011–2015 and 70+ times for 2016–2020, respectively, when *Scientometrics* was included. We removed all Chinese and Korean names as they each tend to represent multiple individuals (Strotmann and Zhao, 2012; Zhao and Strotmann, 2015), except for those that correspond to a dominant individual (e.g. ChenC, DingY, YanE, ZhouP, ZhaoD, JinB). This process resulted in 150 and 152 names for 2011–2015 and 2016–2020 respectively. The same process was applied to the dataset with Scientometrics replaced by *Journal of Informetrics*, resulting in 149 and 150 names for the two time periods from names that were cited 46+ or 49+ times, respectively.

For these highly cited authors, we constructed author-by-author matrices of co-citation counts. The diagonal values have the same meaning as off-diagonal values and were treated the same in the factor analysis routine.

Factor analysis

Each of these matrices was read into SPSS (version 26) and analyzed using SPSS factor analysis routine to explore the underlying structure of the interrelationships between the selected authors. Factors were extracted by principal component analysis (PCA), and the number of factors extracted was determined based on the scree plot and the total variance explained (Hair *et al.*, 1998). The scree plots suggested 11 or fewer factors. For the purpose of comparison, we extracted 11 factors from all input co-citation matrices. Appendix provides the scree plots and total variance explained for each number of factors. The model fits for the 11-factor models are summarized in Table 2. For example, an 11-factor model from the co-citation matrix for 2011–2015 explained 83.25% of the total variance, and the differences between observed correlations and correlations implied by the factor model were smaller than 0.05 for the most part (96%).

Visualization of factor structures

We applied an oblique rotation (SPSS Promax) to these factor models in the factor analysis, each resulting in a pattern matrix, a structure matrix and a component correlation matrix. To aid interpretation, the pattern matrix and structure matrix are visualized using the same technique as in Zhao and Strotmann (2014), which combines the informative features of both the pattern and structure matrices as well as citation impact into one map. Detailed information about this technique can be found in that study. The central idea is to directly visualize the factor analysis results as a bipartite network of authors and factors (specialties) linked to each other according to the loadings of authors on the factors.

Interpretation of results

We interpret factors as specialties. Factors are labeled upon an examination of articles written by authors who load primarily on each factor. A factor is labeled as "Undefined" if all loadings in this factor are lower than 0.7 and will not be interpreted. We use the number of authors who load primarily on a factor to indicate the size of the specialty that this factor represents and use the highest primary loading to indicate the distinctiveness of the specialty.

The component correlation matrix indicates how closely specialties are related to each other, which is also visible on the visualizations of factor structures. Each visualization is an uncluttered map with a stable layout, showing clearly the level of impact of each author (author node size), the prominence of each specialty (factor node size), the interrelationships between specialties and authors (map layout and node positions) and the memberships of authors in specialties (strengths of connecting lines).

An author's loading on a factor in the pattern matrix represents this author's unique contribution to the specialty that this factor corresponds to. The highest loading within a factor indicates the distinctiveness of the specialty. The number of authors who load primarily on a factor in the pattern matrix indicates the size of a specialty in terms of researchers associated with it, and this number divided by the total number of authors analyzed estimates the relative size (%Size) of the specialty. Please note that this size is different from the size of a factor node (circle) on the maps, which is the weighted sum of the citation counts of all authors in this factor as discussed in Zhao and Strotmann (2014). Both

Input matrix	Factor model	Total variance explained	% |nonredundant residuals| > 0.05
Scientometrics			
Co-citation counts 2011–2015	11-Factor	83.25%	4%
Co-citation counts 2016–2020	11-Factor	84.09%	4%
Journal of Informetrics			
Co-citation counts 2011–2015	11-Factor	81.99%	5%
Co-citation counts 2016–2020	11-Factor	81.46%	4%

Table 2. Factor models and their model fits

sizes indicate the relative prominence of a specialty, one by the number of authors working on the specialty and the other by these authors' collective citation impact.

Results and discussion

Comparison of two datasets

Table 3 provides the factors' labels, sizes and their levels of distinctiveness from ACAs for three time periods, 2011–2015 and 2016–2020 from the present study and 2006–2010 from Zhao and Strotmann (2014). Results from both datasets for the present study are provided for comparison.

Label	Size	%Size	Highest loading	Size	%Size	Highest loading
2011–2015						
	Journal of informetrics			Scientometrics		
Bibliometric indicators	45	30.2	1.19	39	26	1.25
Interactive IR	38	25.5	1.03	29	19.3	1.01
Mapping of science	22	14.8	1.08	22	14.7	1.11
Webometrics	6	4	0.98	9	6	1.02
Theoretical perspectives in IS	8	5.4	0.98	5	3.3	0.74
IR systems	8	5.4	0.98	6	4	1.00
Social network analysis	7	4.7	0.96	11	7.3	0.99
Information behavior	5	3.4	0.73			
Undefined	0	0				
Technology acceptance	4	2.7	0.97	6	4	1.05
Scholarly communication	6	4	0.71	3	2	1.16
Patent analysis of innovations				11	7.3	1.12
Research collaboration				9	6	0.71
2016–2020						
	Journal of informetrics			Scientometrics		
Bibliometric indicators	35	23.3	1.12	36	23.7	1.30
Interactive IR	22	14.7	1.09	18	11.8	1.05
Information behavior	23	15.3	1.08	15	9.9	1.00
Altmetrics	13	8.7	0.88	19	12.5	1.10
IR systems	14	9.3	0.87	8	5.3	0.96
Mapping of science	12	8	0.87	14	9.2	1.00
Theoretical perspectives in IS	10	6.7	0.97	6	3.9	0.83
Technology acceptance	7	4.7	0.97	3	2.0	0.94
Scholarly communication	5	3.3	0.79	7	4.6	0.99
Social network analysis	8	5.3	0.80	16	10.5	1.00
Undefined	2	1.3	0.60			
Patent analysis of innovations				10	6.6	0.80
2006–2010 (from Zhao and Strotmann, 2014)						
Information behavior				27	18	1.01
Bibliometric distributions (*h*-index)				22	14.7	1.07
Mapping of science				19	12.7	0.86
Relevance (interactive IR)				18	12	0.83
IR systems				16	10.7	0.95
Webometrics				11	7.3	0.89
Bibliometrics and sci and innovation systems (patent analysis)				10	6.7	0.75
Use of e-journals and other e-resources				9	6	0.72
IS theories and foundation				8	5.3	0.72
Knowledge management				5	3.3	0.72
Text categorization				5	3.3	0.73

Table 3. 11-factor results from ACA of IS 2011–2015 and 2016–2020 from two datasets

As was to be expected, the dataset that includes Scientometrics does show bias towards the KDA camp of IS as indicated by the smaller sizes of all specialties in the IR camp and by the identification of additional specialties in the KDA camp, compared to the dataset that includes *Journal of Informetrics* instead. The following discussions will therefore primarily use results from the latter dataset and will only mention results from the more biased dataset as needed.

This comparison highlights the robustness of ACA for identifying the overall intellectual structure in terms of major specialties and their interrelationships. It also provides an important reminder of the importance of proper field delineation, in particular its effect on the identification of small specialties. Interpretation of results must take into account these factors.

Two-camp structure and interrelationships between specialties

Figures 1 and 2 visualize the 11-factor models (after oblique rotation) extracted from the co-citation matrices, showing the intellectual structure of the IS field for the period 2011–2015 and 2016–2020, respectively.

Tables 4 and 5 show the component correlation matrices for 2011–2015 and 2016–2020, respectively, where the correlations indicate how closely specialties are related to each other. We will combine these maps with these correlation matrices when we discuss the interrelationships between specialties as not all relationships in higher dimensions can be clearly and truthfully shown on two-dimensional maps. We will focus our discussion on substantially close relationships indicated by correlations above 0.2. Such positive correlations are highlighted in yellow and negative ones in red in Tables 4 and 5 except for undefined factors.

As was to be expected, the intellectual structure of the IS field is largely consistent between these time periods and with previous time periods reported in White and McCain (1998) and Zhao and Strotmann (2008a, b, 2014) in terms of its two-camp structure and of major specialties identified. It is, however, substantially different between periods in terms of interrelationships between specialties, indicating changes in both scope and emphasis of major specialties.

The two-camp structure is very clear on the maps.

The KDA camp includes four core specialties during both five-year periods as shown on the maps: bibliometric indicators especially *h*-index and its variants for research evaluation, mapping of science, network analysis using bibliometric data and Webometrics/Altmetrics (quantitative study of scholarly communication using Web or social media data). These specialties were closely interrelated in 2011–2015 as shown by the substantial correlations between them but only related indirectly to each other through the bibliometric indicators specialty in 2016–2020. In particular, Webometrics/Altmetrics was fairly strongly correlated with all specialties in the KDA camp in 2011–2015 but only has a single strong correlation (with the Bibliometric Indicators specialty) in 2016–2020. These suggest that the Webometrics/Altmetrics specialty shifted focus towards evaluation and away from the network analysis aspect from 2011–2015 to 2016–2020.

The scholarly communication topic area, including studies on open access and scholars' use of e-resources and social media, had substantial correlations with three specialties in the KDA camp and with one specialty in the IR camp in 2011–2015. This suggests that it was largely part of the KDA camp but was bridging the two camps as scholars in this area often use citation analysis (which is part of the KDA camp) to study scholars' information use, a type of information needs and behavior (which is part of the IR camp). In 2016–2020, however, this topic area had no substantial correlations with any other specialty, but shared a few authors with the Altmetrics specialty, presumably through common interest in scholars' use of social media.

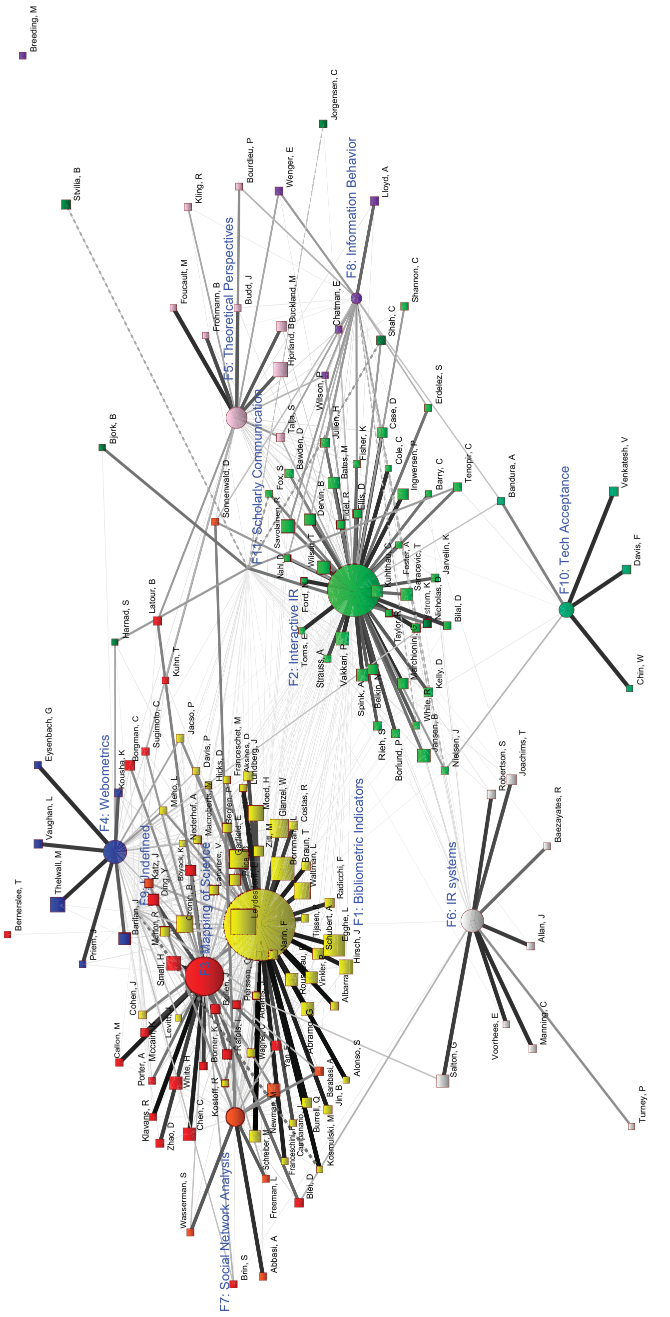

Figure 1.
Intellectual structure of information science 2011–2015

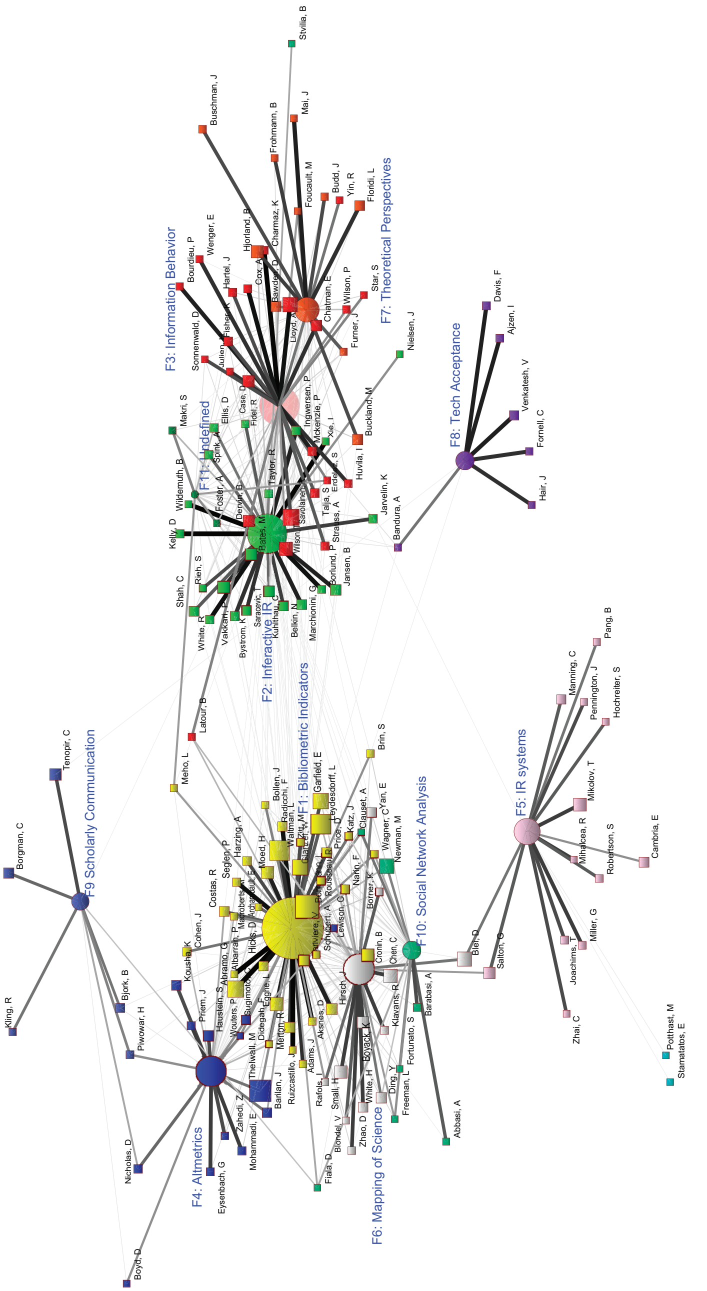

Figure 2.
Intellectual structure of information science 2016–2020

Table 4.
Component correlation matrix 2011–2015

Component	1	2	3	4	5	6	7	8	9	10	11
1:Indicators	1.000	-0.366	0.591	0.419	-0.042	-0.174	0.485	-0.148	0.426	-0.237	0.281
2:Interactive IR		1.000	-0.277	-0.064	0.397	0.226	-0.250	0.193	-0.120	0.273	-0.169
3:Mapping			1.000	0.382	0.131	0.039	0.530	-0.123	0.428	-0.167	0.259
4:Webometrics				1.000	0.079	0.039	0.224	-0.244	0.284	0.005	0.228
5:Theories					1.000	-0.042	-0.009	0.281	0.148	0.051	0.152
6:IR Systems						1.000	-0.041	-0.420	-0.124	-0.009	-0.335
7:SNA							1.000	-0.085	0.192	-0.185	0.129
8:Info Behavior								1.000	-0.079	0.064	0.358
9:Undefined									1.000	-0.026	0.142
10:Tech Accept										1.000	-0.089
11:Sch. Comm.											1.000

Table 5.
Component correlation matrix 2016–2020

Component	1	2	3	4	5	6	7	8	9	10	11
1:Indicators	1.000	-0.337	-0.301	0.442	-0.150	0.591	-0.222	-0.245	0.140	0.388	-0.076
2:Interactive IR		1.000	0.476	-0.107	0.022	-0.242	0.344	0.139	-0.054	-0.171	0.416
3:Info Behavior			1.000	-0.081	-0.166	-0.210	0.569	0.154	0.004	-0.187	0.321
4:Altmetrics				1.000	-0.108	0.101	-0.117	0.030	0.120	-0.016	0.055
5:IR Systems					1.000	0.045	-0.104	-0.104	-0.098	0.125	0.045
6:Mapping						1.000	-0.105	-0.190	0.134	0.411	-0.098
7:Theories							1.000	0.048	0.095	-0.219	0.190
8:Tech Accept								1.000	0.062	-0.170	0.022
9:Sch. Comm.									1.000	0.047	-0.110
10:SNA										1.000	0.094
11:Undefined											1.000

The theoretical perspectives in IS specialty in the IR camp has also been bridging the two camps through sociologists such as Kuhn and Latour as seen on Figures 1 and 2.

The IR camp was dominated by a single specialty interactive IR (information searching/seeking, relevance) during 2011–2015, but by two equal-sized specialties during 2016–2020: interactive IR and information behavior, as shown clearly on Figures 1 and 2. Theoretical perspectives in IS was also an integral part of the IR camp in both time periods as indicated by its location on the maps and substantial correlations with specialties in this camp. These core specialties of the IR camp were closely interrelated in 2016–2020, but it was the theoretical perspectives in IS specialty that connected the other two specialties in 2011–2015. Although some scholars recognized as in the information behavior specialty were placed in the interactive IR specialty in 2011–2015, these two specialties were not perceived as being closely related in 2011–2015 as indicated by their low correlation. It appears that 2011–2015 was an interesting time period for these two specialties that warrants a deeper analysis to help understand what happened.

The IR Systems (i.e. "hard" IR) specialty can be considered part of the IR camp in 2011–2015 as seen by its location on the map (Figure 1) and by its substantial correlation with the interactive IR specialty ("soft" IR) in Table 4. This is a picture that is consistent with those from previous time periods, where IR systems were a more distant part of the IR camp. In 2016–2020, however, a striking development is its drifting further away from the rest of the IR camp, showing stronger connections to the KDA camp than to the IR camp as shown on Figures 1 and 2. Table 5 shows that the IR systems specialty had no substantial correlations with any of the specialties in the IR camp or in IS as a whole in 2016–2020.

Similar to IR systems, technology acceptance was loosely part of the IR camp in 2011–2015 as indicated by a single substantial correlation with the interactive IR specialty and its location on Figure 1. It had no substantial correlations with any other specialty in 2016–2020 except for a single negative one with the bibliometric Indicators specialty, indicating that it was even more distant from the KDA camp than the IR camp.

Evolution of specialties in IS over time

Figure 3 summarizes the relative size information in Table 3 and shows changes of specialties in size over three five-year time periods.

The dominant specialty in the entire IS field is bibliometric indicators in the KDA camp, taking 30 and 23% of the IS field for the two five-year time periods, respectively, based on our dataset. Bibliometrics-based research evaluation was clearly a topic that generated heated discussions. This specialty went through a high point during 2011–2015 and cooled down a bit during 2016–2020 to a size that is still much larger than 2006–2010.

Citation network analysis went through a similar evolution. During 2011–2015, although the specialty mapping of science was only slightly larger than the previous period, a small but distinct specialty network analysis emerged. The former was dominated by authors within IS

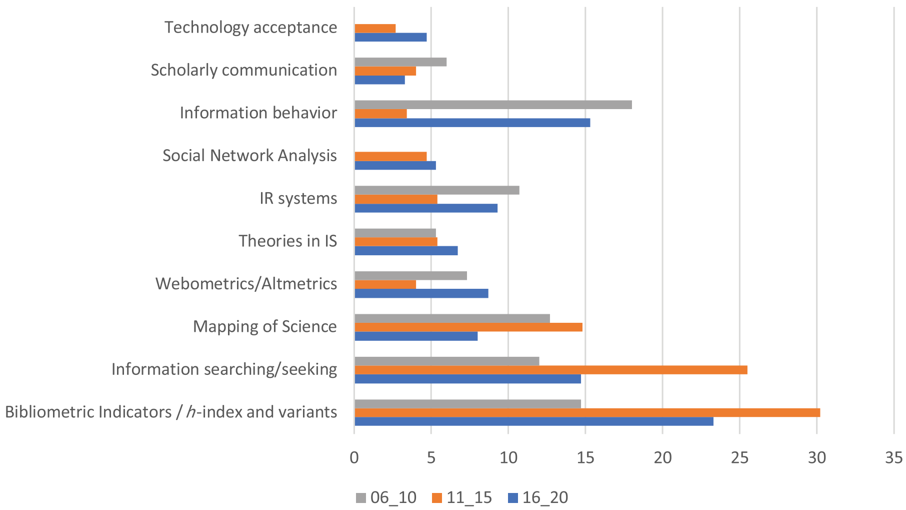

Figure 3.
Changes of specialties in size over three 5-year periods

doing co-citation analysis (e.g. WhiteH, McCainK, SmallH, ChenC and ZhaoD), whereas the latter by those doing network analysis outside of IS (e.g. BarabasiA, AbbasiA, WassermanS, NewmanM and FreemanL). It appears that studies on citation network analysis in the most recent time period (i.e. 2016–2020) were drawing less from IS scholars who originally introduced the various bibliometric methods for science mapping but more and more on external scholars for network analysis methods during the past decade.

Webometrics went through an opposite development compared to the two specialties discussed above. It further declined during 2011–2015 as predicted in Zhao and Strotmann (2014) but rebounded during 2016–2020 to a size that is even larger than that in 2006–2010. This renewed growth was due to a shift towards the study of Altmetrics, i.e. the study of alternative (to bibliometric) metrics for the purpose of research evaluation, which was made possible and appealing by the increasing use of social media in scholarly communication, thus essentially transforming Webometrics to Altmetrics. Considering the evaluative nature of Altmetrics, research evaluation was apparently even more dominant in IS during 2016–2020 (32%) than in 2011–2015 (30%).

The information behavior specialty declined sharply from 2006–2010 (18%) to 2011–2015 (3.4%), but re-gained its place as a distinct major specialty during 2016–2020. Several dominant (top loading) authors in this specialty during 2016–2020 (e.g. CharmazK, CoxA, MckenzieP and BourdieuP) did not make it to the top 150 most cited authors during 2011–2015. Other authors in this specialty during 2016–2020 (e.g. FisherK, JulienH and SavolainenR) were placed with medium loadings in the interactive IR specialty during 2011–2015.

The interactive IR specialty increased sharply from 2006–2010 (12%) to 2011–2015 (26%) but went back to its previous size during 2016–2020. The IR systems specialty declined further during 2011–2015 as predicted in Zhao and Strotmann (2014) but rebounded during 2016–2020 to a size comparable to that in 2006–2010.

Theoretical perspectives in IS has become a distinct specialty over the past decade and has been stable in size. Scholarly communication has been a small but persistent topic area in IS over the past 15 years. Technology acceptance, which was only identified as a separate topic area by the 16-factor model of IS 2006–2010 in Zhao and Strotmann (2014) but not by the 11-factor model, grew into a small but distinct topic area during 2011–2020. Knowledge management is one of the topics that were identified during 2006–2010 but disappeared during 2011–2020. This topic was identifiable in the IS field during the 2001–2010 decade (Zhao and Strotmann, 2008a, b, c, 2014) when it became a hot topic in the business and management fields but faded out of the IS field during the 2011–2020 decade as observed in the present study.

Comparison with findings from other studies

Comparing findings from bibliometric studies directly and in detail is only meaningful when the same or largely identical dataset is used as in the present study and in the series of studies that it continues. The reason is that results of bibliometric studies depend on how the research field being studied is defined and delineated, i.e. on the dataset collected and used (Zhao and Strotmann, 2015). Evidence for this was provided in the present study by the substantial differences in results that a single journal in the dataset makes. As presented earlier in this paper, all core specialties in the IR camp identified from the dataset that includes the journal Scientometrics are smaller and additional specialties in the KDA camp were identified, compared to the dataset that includes *Journal of Informetrics* instead. This bias towards the KDA camp produced by including Scientometrics is because this specialty journal is disproportionately larger than all the other specialty journals in the dataset.

Yang *et al.* (2016) delineated the IS field in a way identical to that in the series of studies that the present study is continuing, without addressing the bias discussed above. Many of their findings, such as “remarkably prominent” KDA camp, “substantial growth” of mapping of science, “significantly smaller” IR camp and addition of the patent analysis specialty to the period they studied, now appear to have been artifacts of this bias in the dataset instead of a true picture of the IS field.

All the other-related studies we reviewed either examined the LIS field as a whole instead of the IS subfield or delineated the IS field differently from the present study. For example, many studies did not include any bibliometrics journals. Comparisons with findings from these studies directly and in detail are therefore not meaningful. Still, we can see a general pattern that topic areas in the IS subfield identified from these studies were either too generic to be considered as specialty in the present study or were also identified in the present study.

For example, among the “emerging” topics identified by Hou *et al.* (2018) through a document co-citation analysis of IS 1909–2016, scientific evaluation indicators, Altmetrics and science mapping were identified in the present study as well; bibliometrics and citation analysis are too generic to be considered as specialty in the present study. Scientific collaboration was identified from the dataset biased towards the KDA camp.

Findings from Han (2020) and Hsiao and Chen (2020) about the IS field were quite generic as well partly because their datasets were collected to study the LIS field instead of focusing on the IS subfield. For example, they identified bibliometrics or Scientometrics as a single topic area instead of the several specialties in this area identified in the present study. They did identify information seeking/retrieval and information behavior for the periods they studied (i.e. 1996–2019 and 2009–2018, respectively), which is consistent with findings from the present study. Mokhtarpour and Khasseh (2020) also identified information seeking/retrieval as the most important research focus through a co-word analysis of LIS research during 1990–2016. Other findings from these studies and other studies on the LIS field (e.g. Figuerola *et al.*, 2017; Li *et al.*, 2019; Liu and Yang, 2019) were largely library-related and not comparable with findings from the present study.

Conclusions

The present study examined the intellectual structure of IS 2011–2020 and the changes in this structure from 2006–2010 through 2011–2015 to 2016–2020. This study continues a long line of author co-citation analysis studies of the intellectual structure of the IS field that have frequently been used as benchmarks in publications in the areas of knowledge domain analysis.

The two-camp structure of IS found in previous time periods continued to be clearly present during the time period examined in the present study – the KDA camp and the IR camp. Bridging between the two camps was only provided by the scholarly communication specialty during both time periods, and the Theoretical Perspectives in IS specialty was found to bridge during 2011–2015 but to be only strongly related to the IR camp during 2016–2020.

Bibliometric indicators for research evaluation dominated the KDA camp during both five-year time periods, whereas interactive information retrieval dominated the IR camp during 2011–2015 but shared dominance with information behavior during 2016–2020. The IR systems specialty drifted further away from the IR camp, now showing little connection to the rest of the IS field. The information behavior specialty experienced a deep slump during 2011–2020 in its evolution process. Altmetrics, which explores research evaluation based on indicators other than publications and citations, such as mentions in social media platforms, has grown to dominate the Webometrics specialty, a shift that stopped a declining trend of the Webometrics specialty, and brought it to a sharp increase during 2016–2020. Network science grew into its own sizable specialty and was represented by scholars outside of IS who developed theories and methods in social network analysis and large-scale network analysis that were found applicable in bibliometrics. After separating out these scholars, the science mapping specialty was left considerably reduced and became dominated by IS researchers who map various citation networks such as author co-citation networks.

Over 30% of the authors included in the present study were primarily associated with research on bibliometric or alternative indicators for research evaluation. This dominance was revealed from a dataset that alleviated the bias towards bibliometrics that would have been introduced by including the journal Scientometrics as this journal became disproportionately larger in size than all the other specialty journals in the dataset during the decade being studied. Field delineation is an important factor in science mapping (and in all bibliometric studies) and requires careful consideration in research design and in interpretation of results, as showcased in the present study.

References

Bu, Y., Wang, B., Chinchilla-Rodríguez, Z., Sugimoto, C.R., Huang, Y. and Huang, W.B. (2020), "Considering author sequence in all-author co-citation analysis", *Information Processing and Management*, Vol. 57 No. 6, doi: 10.1016/j.ipm.2020.102300.

Bu, Y., Wang, B., Huang, W.H., Che, S. and Huang, Y. (2018), "Using the appearance of citations in full text on author co-citation analysis", *Scientometrics*, Vol. 116, pp. 275-289, doi: 10.1007/s11192-018-2757-z.

Chang, Y.-W., Huang, M.-H. and Lin, C.-W. (2015), "Evolution of research subjects in library and information science based on keyword, bibliographical coupling, and co-citation analyses", *Scientometrics*, Vol. 105 No. 3, pp. 2071-2087, doi: 10.1007/s11192-015-1762-8.

Figuerola, C.G., García Marco, F.J. and Pinto, M. (2017), "Mapping the evolution of library and information science (1978–2014) using topic modeling on LISA", *Scientometrics*, Vol. 112 No. 3, pp. 1507-1535, doi: 10.1007/s11192-017-2432-9.

Hair, J.F., Anderson, R.E., Tatham, R.L. and Black, W.C. (1998), *Multivariate Data Analysis*, 5th ed., Prentice-Hall, Upper Saddle River, New Jersey.

Han, X. (2020), "Evolution of research topics in LIS between 1996 and 2019: an analysis based on latent Dirichlet allocation topic model", *Scientometrics*, Vol. 125, pp. 2561-2595, doi: 10.1007/s11192-020-03721-0.

Hou, J., Yang, X. and Chen, C. (2018), "Emerging trends and new developments in information science: a document co-citation analysis (2009–2016)", *Scientometrics*, Vol. 115, pp. 869-892, doi: 10.1007/s11192-018-2695-9.

Hsiao, T.M. and Chen, K.H. (2020), "The dynamics of research subfields for library and information science: an investigation based on word bibliographic coupling", *Scientometrics*, Vol. 125, pp. 717-737, doi: 10.1007/s11192-020-03645-9.

Kim, H.J., Jeong, Y.K. and Song, M. (2016), "Content- and proximity-based author co-citation analysis using citation sentences", *Journal of Informetrics*, Vol. 10 No. 4, pp. 954-966, doi: 10.1016/j.joi.2016.07.007.

Li, P., Yang, G. and Wang, C. (2019), "Visual topical analysis of library and information science", *Scientometrics*, Vol. 121, pp. 1753-1791, doi: 10.1007/s11192-019-03239-0.

Liu, G. and Yang, L. (2019), "Popular research topics in the recent journal publications of library and information science", *The Journal of Academic Librarianship*, Vol. 45 No. 3, pp. 278-287, doi: 10.1016/j.acalib.2019.04.001.

Liu, P., Wu, Q., Mu, X., Yu, K. and Guo, Y. (2015), "Detecting the intellectual structure of library and information science based on formal concept analysis", *Scientometrics*, Vol. 104 No. 3, pp. 737-762, doi: 10.1007/s11192-015-1629-z.

Mokhtarpour, R. and Khasseh, A.A. (2020), "Twenty-six years of LIS research focus and hot spots, 1990–2016: a co-word analysis", *Journal of Information Science*. doi: 10.1177/0165551520932119.

Olmeda-Gómez, C., Ovalle-Perandones, M.A. and Perianes-Rodríguez, A. (2017), "Co-word analysis and thematic landscapes in Spanish information science literature, 1985–2014", *Scientometrics*, Vol. 113, pp. 195-217, doi: 10.1007/s11192-017-2486-8.

Onyancha, O.B. (2018), "Forty-five years of LIS research evolution, 1971–2015: an informetrics study of the author-supplied keywords", *Publishing Research Quarterly*, Vol. 34 No. 3, pp. 456-470, doi: 10.1007/s12109-018-9590-3.

Sohaili, F., Shaban, A. and Khase, A. (2016), "Intellectual structure of knowledge in information behavior: a co-word analysis", *Human Information Interaction*, Vol. 2 No. 4, available at: http://hii.khu.ac.ir/article-1-2446-en.html (accessed 8 June 2021).

Song, Y., Wei, K., Yang, S., Shu, F. and Qiu, J. (2020), "Analysis on the research progress of library and information science since the new century", *Library Hi Tech*, Vol. ahead-of-print No. ahead-of-print, doi: 10.1108/LHT-06-2020-0126.

Song, Y., Wu, L. and Ma, F. (2021a), "A study of differences between all-author bibliographic coupling analysis and all-author co-citation analysis in detecting the intellectual structure of a discipline", *The Journal of Academic Librarianship*, Vol. 47 No. 3, doi: 10.1016/j.acalib.2021.102351.

Song, Y., Wu, L. and Qiu, J. (2021b), "A comparative study of first and all-author bibliographic coupling analysis based on Scientometrics", *Scientometrics*, Vol. 126, pp. 1125-1147, doi: 10.1007/s11192-020-03798-7.

Strotmann, A. and Zhao, D. (2012), "Author name disambiguation: what difference does it make in author-based citation analysis?", *Journal of the American Society for Information Science and Technology*, Vol. 63 No. 9, pp. 1820-1833.

Thelwall, M. and Maflahi, N. (2015), "How important is computing technology for library and information science research?", *Library and Information Science Research*, Vol. 37 No. 1, pp. 42-50, doi: 10.1016/j.lisr.2014.09.002.

White, H.D. and McCain, K.W. (1998), "Visualizing a discipline: an author co-citation analysis of information science, 1972–1995", *Journal of the American Society for Information Science*, Vol. 49, pp. 327-355.

Yang, S. and Wang, F. (2015), "Visualizing information science: author direct citation analysis in China and around the world", *Journal of Informetrics*, Vol. 9 No. 1, pp. 208-225.

Yang, S., Han, R., Dietmar Wolfram, D. and Zhao, Y. (2016), "Visualizing the intellectual structure of information science (2006-2015): introducing author keyword coupling analysis", *Journal of Informetrics*, Vol. 10 No. 1, pp. 132-150, doi: 10.1016/j.joi.2015.12.003.

Zhang, Y., Lu, J., Liu, F., Liu, Q., Porter, A., Chen, H. and Zhang, G. (2018), "Does deep learning help topic extraction? A kernel k-means clustering method with word embedding", *Journal of Informetrics*, Vol. 12 No. 4, pp. 1099-1117, doi: 10.1016/j.joi.2018.09.004.

Zhao, D. and Strotmann, A. (2008a), "Information Science during the first decade of the web: an enriched author co-citation analysis", *Journal of the American Society for Information Science and Technology*, Vol. 59, pp. 916-937.

Zhao, D. and Strotmann, A. (2008b), "Evolution of research activities and intellectual influences in information science 1996–2005: introducing author bibliographic coupling analysis", *Journal of The American Society for Information Science and Technology*, Vol. 59, pp. 2070-2086.

Zhao, D. and Strotmann, A. (2008c), "Comparing all-author and first-author co-citation analyses of information science", *Journal of Informetrics*, Vol. 2, pp. 229-239.

Zhao, D. and Strotmann, A. (2011), "Counting first, last, or all authors in citation analysis: a comprehensive comparison in the highly collaborative stem cell research field", *Journal of The American Society for Information Science and Technology*, Vol. 62, pp. 654-676.

Zhao, D. and Strotmann, A. (2014), "The knowledge base and research front of Information science 2006–2010: an author co-citation and bibliographic coupling analysis", *Journal of the Association for Information Science and Technology*, Vol. 65 No. 5, pp. 996-1006.

Zhao, D. and Strotmann, A. (2015), *Analysis and Visualization of Citation Networks*, Morgan and Claypool Publishers, San Rafael, California.

Zhao, D. and Strotmann, A. (2020), "Telescopic and panoramic views of library and information science research 2011–2018: a comparison of four weighting schemes for author co-citation analysis", *Scientometrics*, Vol. 124 No. 1, pp. 255-270, doi: 10.1007/s11192-020-03462-0.

Appendix

The appendix contents are available in online for this article.

Corresponding author

Dangzhi Zhao can be contacted at: dzhao@ualberta.ca