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Growing with collaboration: footprint of WISE Lab

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Abstract
The paper explores the development of WISE Lab during the past 15 years from three complementary perspectives: citation aging characteristics, themes evolution and academic collaboration, based on the research results produced by WISE Lab. The results show that, the half-life of the papers in WISE Lab reaches about 5 years, and the highly cited papers have a longer impact than mainstream papers; WISE Lab is focused on six themes, "Knowledge mapping", "Visual analysis", "Scientometrics", "Patentometrics", "Information retrieval", and "Innovation management", which developed alternately over time; WISE Lab is greatly driven by collaboration, and Prof. Liu contributed in a central way to the team cohesion, his academic spirit and thought influenced widely.

Keywords WISE lab · Citation aging · Theme evolution · Collaboration · Knowledge mapping · Prof. Zeyuan Liu

Introduction

Webometrics-Informetrics-Scientometrics-Econometrics Lab (WISE Lab) is affiliated to the Institute of Science of Science and S&T Management in Dalian University of Technology (DUT), China, and it is a research center with the interest of quantitative analysis on science of science. WISE Lab was established by Prof. Zeyuan Liu and Dr. Hildrun Kretschmer jointly in 25th September, 2005. The prosperity of WISE Lab embodies Prof. Liu's

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development philosophy, that is "Measurable science, unmeasurable wisdom; International collaboration, collective young and old". We commemorate him deeply with this article.

WISE Lab firstly introduced the concept and approach of "Knowledge Mapping" to China, and promoted the research in science of science, scientometrics and S&T management in China to a new stage, which was highly praised by Eugene Garfield as "one of the main scientometrics research center in the world" (2009). So far, seven full-time professors, five full-time associated professors and nine part-time professors or visiting scholars are employed in WISE Lab, and over 400 master and doctorate students have been educated in WISE Lab till now.

Prof. Liu's contribution is irreplaceable as the founder and leader of WISE Lab. He first proposed the concept and the framework of "knowledgemetrics" (Liu 1999), first established a theoretical system of Chinese science of science (Liu 2006), first constructed the public course "Principles of Science of Science" for science and engineering postgraduates in China's university (2012), first introduced the concept and analyzing tools of"mapping knowledge domain"to China, and promoted greatly to the popularization of mapping methodology in Chinese academia. He has consistently devoted himself into theoretical research and discipline construction of science of science, and founded China's first doctoral program to cultivate China's own doctoral students in science of science and S&T management in 2002, and which especially pushed the development of scientometrics in China.

Dr. Hildrun Kretschmer, as one of the founder of WISE Lab, could not be ignored in the process of internationalization for WISE Lab, she and her husband, Mr. Theo Kretschmer, made a deep friendship with Prof. Liu. They leave their words here.

Science and Friendship

At the first COLLNET conference in September 2000, our close scientific cooperation began. It was Prof. Zeyuan Liu who made me offer to work for the "Dalian University of Technology" these days.

The results of this cooperation were

- *5 students of the university have successfully defended their doctorate,*
- *founding the institute "WISE LAB" at the Dalian University of Technology,*
- *organizing and conducting the "Fifth International Conference on Webometrics, Informetrics and Scientometrics (WIS) & Tenth COLLNET Meeting"-2009 and "15th International Conference on Webometrics, Informetrics and Scientometrics (WIS) & 20th COLLNET Meeting"-2019 in Dalian.*

Many lectures by Prof. Zeyuan Liu at the 20 COLLNET conferences and the publications in the journal "Scientometrics" and the "COLLNET-Journal" have contributed significantly to the further development of our scientific branch.

We will always remember him.

Hildrun and Theo Kretschmer

This paper firstly explores the development of WISE Lab from the general point of view in order to figure out its competitiveness and influence. Then, through a more in deep analysis of the aging of the papers' citations, it highlights the research impact of the laboratory. Research topics of WISE Lab and their dynamics are more specifically clarified in a further step. Finally, the last part of the paper focuses on the collaboration trends of WISE Lab whilst identifying the most influential researchers of the laboratory.

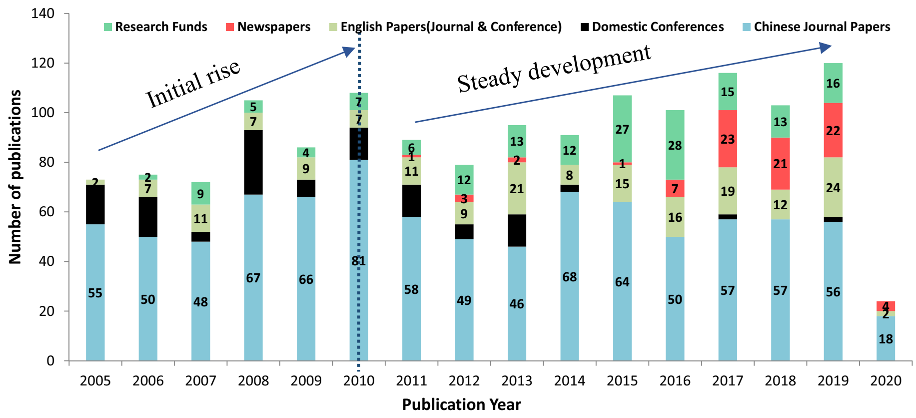


Fig. 1 An overview of WISE Lab publications (2005–2020. 05). For the newspaper, we also include 67 articles released through academic official accounts on WeChat Chinese social channel since 2016

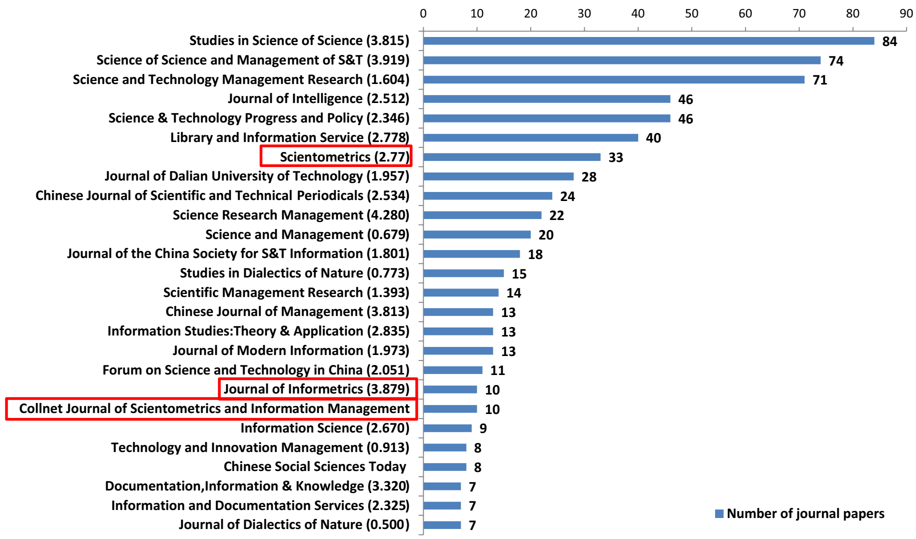


Fig. 2 Top 26 journals with largest number of papers (66.5% of all journal papers). The journal impact factors in brackets are reported by CNKI or WoS; The journals in red are in English and the rest in Chinese

Increasing competitiveness and influence of WISE Lab

WISE Lab has gone through roughly two development periods, the initial rise period (2005–2010) and the steady development period (2011–2020) (Fig. 1). Over 160 national research projects, 15 books and 1240 scientific papers have been produced from WISE Lab since its establish in 2005, including 1060 Chinese papers and 180 English papers (Fig. 1) There are 890 Chinese journal papers and 89 English journal papers, and most of the papers are published in journals with high impact factors in science and technology management (Fig. 2).

Increasing domestic academic influence Two factors should be considered concerning the decreasing number of domestic conference papers showed in Fig. 1. Firstly, as far as some important domestic conferences would prefer to recommend several excellent conference papers to publish in journals, rather than to publish them in conference proceedings indexed in CNKI in recent years. Secondly, more and more WISE Lab members were invited to be conference keynote speakers without having to submit papers. Accordingly, the number seemed to decrease, but the academic influence increased by the fact.

Enhancing international academic participation The number of English papers is increasing significantly, especially those published in the high-quality journals and conferences, especially in the fields of Scientometrics and Information Science. Some WISE Lab members have joined in some international academic organizations to participate international cooperation deeper.

Emphasizing application whilst taking into account academics Applying theoretical research to guide practice also reflects growing to mature for an academic institution in a sense. With the increasing number of research projects and social media reports, WISE Lab is strengthening its academic and social competitiveness and influence.

Aging characteristics of citations to WISE Lab

Modeling distribution of citations to scientific papers is crucial for understanding how the science develops within a certain community (Brzezinski 2015). 971 journal papers out of all the 979 journal papers are indexed in CNKI (CNKI is the brief name of National Knowledge Infrastructure, which is the most famous and largest Chinese digital documents database) or Web of Science. The citation distribution of all the 971 journal papers from 2005 to 4th May 2020 is showed in Figure 3, and it clearly represents a heavy tail distribution that could be modelled by a power-law model. Equivalent to Lotka's law in nature science and Zipf's law in linguistics, Pareto's law is a power law distribution with ad-hoc parameter settings used in economics (Gabaxi 2009). In our data set, the citation distribution is fitted well with the Pareto's power law $y = cx^{-r}$, where y is the amount of papers, x is the citation counts, and the two constants are $c = 565.91$ and $r = 1.451$ respectively.

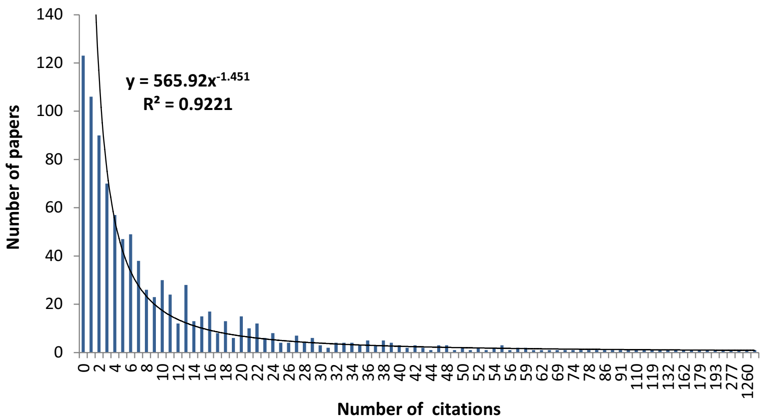


Fig. 3 The citation distribution for all the journal papers

Understanding the citation aging of papers published in different periods is of great significance to select appropriate citation time window for scientific research evaluation (Glänzel and Moed 2013). Nine-year is selected as the citation window period in this work according to Glänzel et al.'s (1995, 2016) research on the suitable citation time window for analyzing the aging process of documents in different disciplines. Additionally, we selected four subperiods, 2005–2006, 2007–2008, 2009–2010, and 2011–2012, to show the maturing and decline process of citations through the life-time analysis. A generic matrix of life-time analysis based on these 2 settings is shown in Table 1.

The lifetime is reflected by *relative annual citation frequency (RCF)* formulas are as follows:

$$RCF_{P_{ki}} = \frac{C_{ij}}{\sum_{j=1}^{9} C_{ij}}$$

where, C_{ij} denotes the number of citations of a paper P_{ki} ($i = 1, 2, 3, 4, 5, 6, 7, 8$; $k = 1, 2, \ldots n$) in year j ($j = 1, 2, 3, 4, 5, 6, 7, 8, 9$) after publication, and n means the total number of papers published in each time slice, two years are taken as a time slice here.

In order to show the life-time trend for the papers published in recent years, we calculated the *RCF* of papers published in 2013–2018 respectively according to the following formulas:

$$RCF_{P_{ki}} = \frac{K_{ij}}{\sum_{j=1}^{m} K_{ij}}$$

where K_{ij} denotes the number of citations of a paper P_{ki} ($i = 9, 10, 11, 12, 13, 14$; $k = 1, 2, \ldots n$) in all the year j (j=1, 2, …, m) after publication, and n means the total number of papers published in each time slice, one year being taken as a time slice here.

The *RCF* value of each paper ranges from 0 to 1, the papers published each year are divided into 10 groups of equal distance (i.e. 0.5) according to their *RCF* value. The representative *RCF* value in year i is calculated through the method of group weighting because of the *RCF* value calculated each year presents a power-law distribution, and the formula is following:

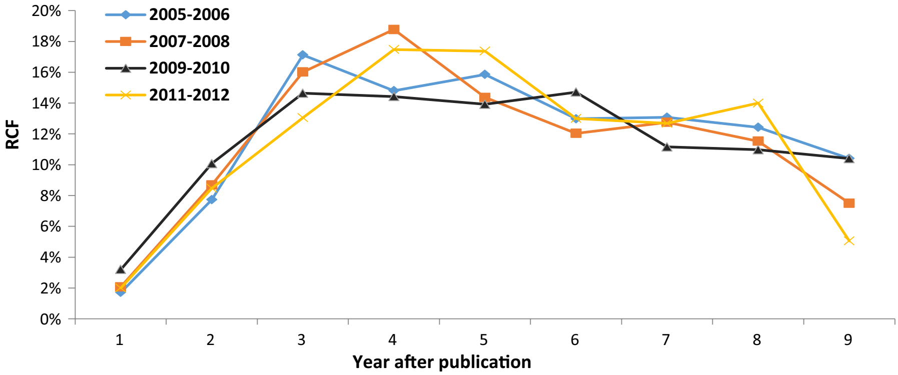
$$RCF_i = \sum_{h=1}^{10} MR_h \times w_h$$

where MR_h denotes the median *RCF* value of group h, and the weight of a group is taken as the ratio between of the number of papers in the group and the total number of papers in year i.

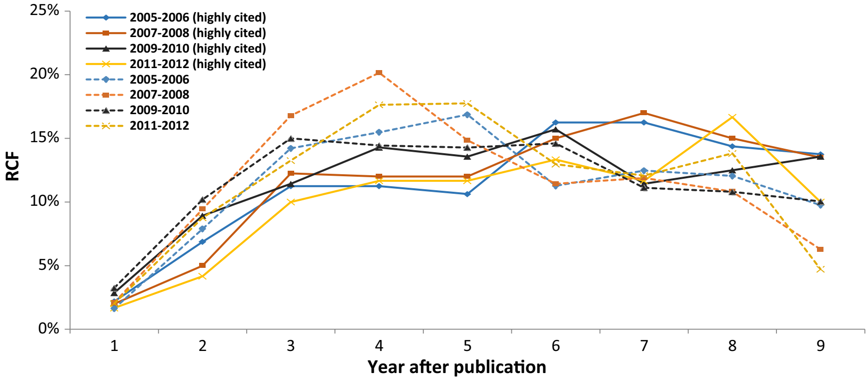
The life-time curve of citations with respect to all citations after nine years to 451 papers published in 2005–2012 with at least one citation during the nine years after publication is showed in Fig. 4a. Here, we are more interested in the lifetime of highly cited papers (with more than 40 citations) in WISE Lab, because the citations of 6.6% (64/971) highly cited papers (detailed in Appendix 1) account for 57% of the total (9079/15944). Figure 4b presents the life-time of highly cited papers (solid line) vs. the papers with less than 40 citations (dotted line) respectively, which reveals that the maturing and decline process of highly cited papers with more than 40 citations is slower than those of other papers with less citations. The value of *RCF* peaks around 6–8 years for highly cited papers (Fig. 4b), which is significantly longer than the overall 3–5 years on average. Interestingly,

Table 1 A principle matrix of life-time analysis

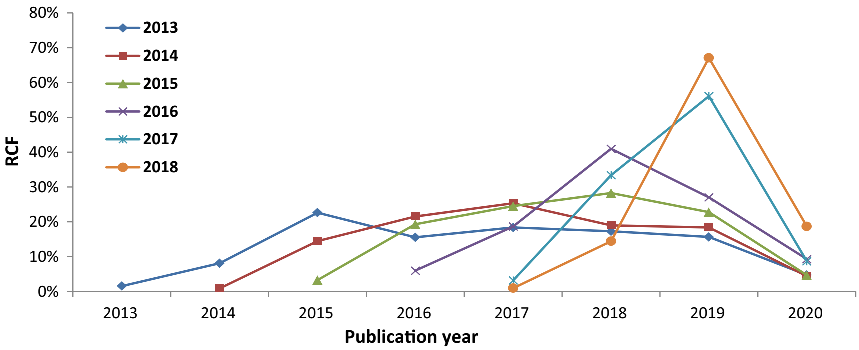
Publication year															
Time slice	Nine-year (Num. highly cited journal papers/all journal papers)									m-year (Num. all journal papers)					
		2005–2006 (16/99)		2007–2008 (20/118)		2009–2010 (14/139)		2011–2012 (6/95)		2013 (49)	2014 (67)	2015 (60)	2016 (45)	2017 (53)	2018 (44)
		2005	2006	2007	2008	2009	2010	2011	2012						
Citing year	i	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	2005	C11													
	2006	C12	C21												
	2007	C13	C22	C31											
	2008	C14	C23	C32	C41										
	2009	C15	C24	C33	C42	C51									
	2010	C16	C25	C34	C43	C52	C61								
	2011	C17	C26	C35	C44	C53	C62	C71							
	2012	C18	C27	C36	C45	C54	C63	C72	C81						
	2013	C19	C28	C37	C46	C55	C64	C73	C82	K11					
	2014		C29	C38	C47	C56	C65	C74	C83	K12	K21				
	2015			C39	C48	C57	C66	C75	C84	K13	K22	K31			
	2016				C49	C58	C67	C76	C85	K14	K23	K32	K41		
	2017					C59	C68	C77	C86	K15	K24	K33	K42	K51	
	2018						C69	C78	C87	K16	K25	K34	K43	K52	K61
	2019							C79	C88	K17	K26	K35	K44	K53	K62
	2020								C89	K18	K27	K36	K45	K54	K63



a All journal papers published between 2005 and 2012 with at least one citation.



b Highly cited journal papers (more than 40 citations) vs. journal papers with citations less than 40 (2005-2012).



c All journal papers published between 2013 and 2018 with at least one citation .

Fig. 4 Life-time curve of citations with respect to all citations received nine years after publication

this time-to-peak is also longer than the one observed for journal papers in fields of Chemistry, Social sciences and Engineering, ranging from 4 to 6 years to reach the peak value of *RCF* (Glänzel et al. 2016). The results indicate that the impact of the highly cited papers of WISE Lab papers last very significantly longer than usual, especially for the publication

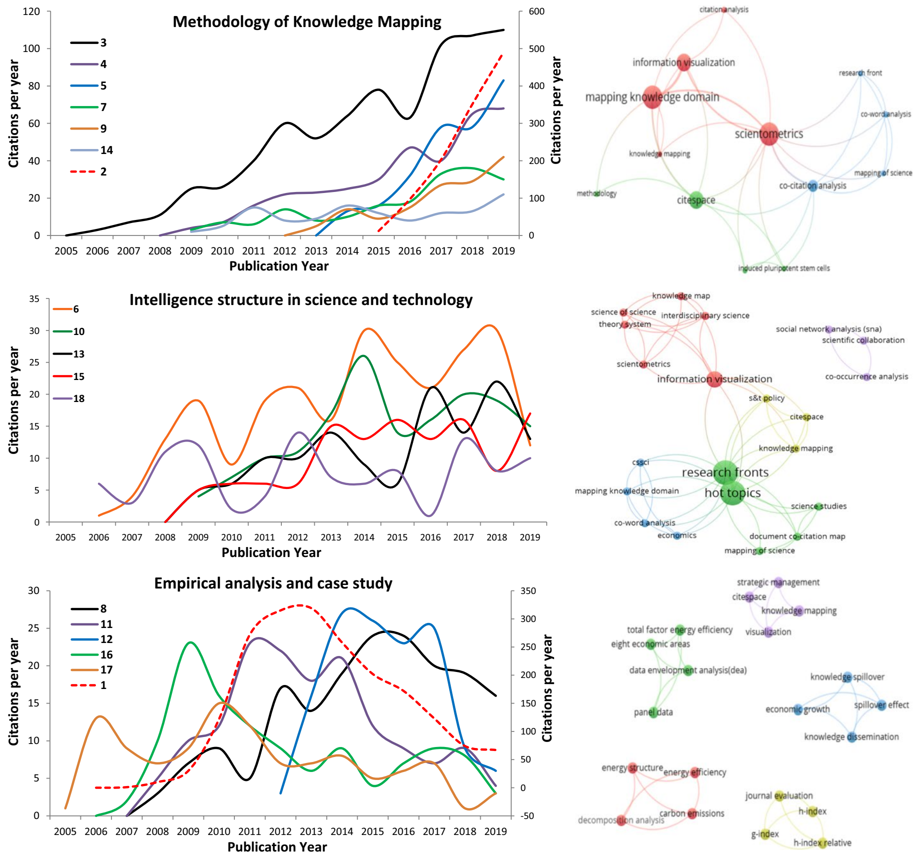


Fig. 5 Citation trends of the highly cited papers. The citations of paper 1 and paper 2 are marked on the right ordinate because of the high frequency of citations. Topic related co-keywords networks (right part of the figure) are build up with the help of keywords of the topic related papers using VOSviewer tool (VOSviewer 2020).

years 2005–2006 and 2007–2008. The patterns of life-time curve with variable citation window for the all cited papers published between 2013 and 2016, as shown in Fig. 4c, are very similar to the ones of the cited paper published before 2013 with 9-year citation windows, where the value of *RCF* peaks around 3–4 years after publication, while the years 2017 and 2018 are still increasing in the first 2 year after publication.

We then investigate what topics of the highly cited papers are stretching the lifetime of the research in WISE Lab. For that purpose, the top 18 highly cited papers, including 15 Chinese papers and 3 English papers, with more than 100 citations until May 12th, 2020 are selected to make a citation timeline (Fig. 5). The numbers presented in the legend correspond to the paper "No.s" of main papers presented in Appendix 1.

Three types of citation trends can be observed in Fig. 5: rising up, always alive and falling down. Three topics corresponding to the different types of citation trends are presented in the figure associated with their corresponding papers. As it can be observed, the papers focusing on the methodology of knowledge mapping are rising up, showing a sustainable high impact with increasing citations. The papers strengthen on the intelligence structure in science and technology, including hot topics and research fronts, are always alive with a more stable number of citations per year. Some empirical and case studies show a falling down trend, such as decomposition analysis on carbon emissions, mapping knowledge of some fields, data envelopment analysis of total factor energy efficiency, etc.

Theme evolution in WISE Lab

One of the main aims of WISE Lab during its development was the strengthening of quantitative study on Science of Science, taking the whole of S&T knowledge and its activities as the research object and exploring the basic laws of the development of S&T. In a complementary way, WISE Lab was also aiming at developing S&T policy. To more clearly highlight the main topics dealt by WISE Lab, we choose to perform co-keywords analysis.

Firstly, the spelling errors that occurred in 1,107 papers with keywords are fixed. Secondly, the synonyms in the keywords are merged to have more consistent results. Finally, some generic keywords which do not provide any useful information are removed. After the cleaning, there are 2,602 remaining keywords in 1,107 papers. Using a co-occurrence threshold of 4, we used VOSviewer tool to finally build co-keywords network that includes 160 keywords dispatching in 6 dominant topics identified by the tool as separate word clusters. Around the "Knowledge Mapping", four methodological topics, "Visualization", "Scientometrics", "Patentometrics" and "Information retrieval", and one applied topic, "Innovation Management". The network resulting of the co-keywords analysis are presented in Fig. 6.

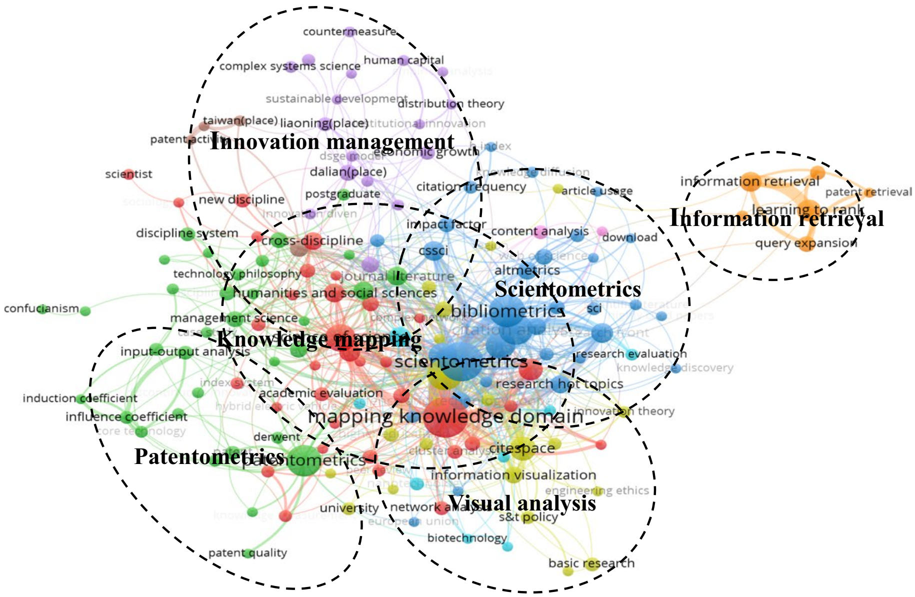


Fig. 6 Research topics around Scientometrics in WISE Lab from 2005 to 2020 (including160 nodes and 689 links). VOSviewer tool clusters the nodes in the mapped network in such a way that a cluster comprises a group of closely related nodes without any overlap with any other clusters. The different identified word clusters (i.e. topics) are highlighted with different colors.

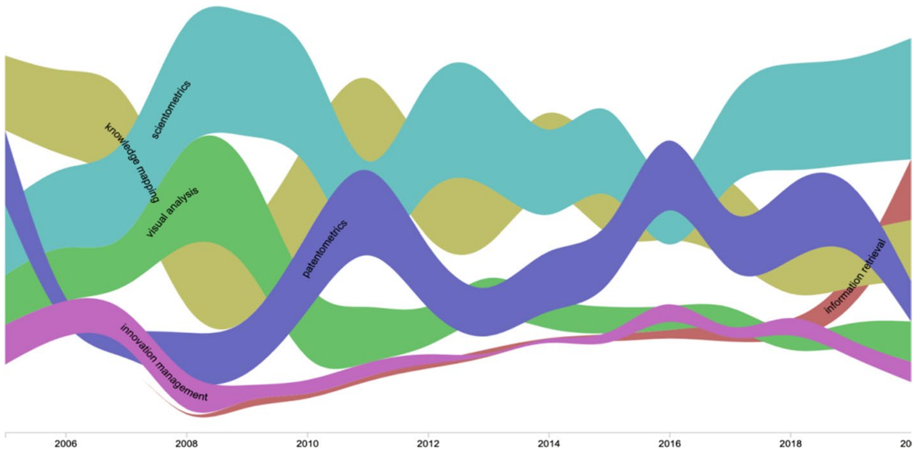


Fig. 7 The topic evolution in WISE Lab from 2005 to 2020

In a second step, a topic dynamic evolution model is proposed to track the topics changes in WISE Lab during the period of 2005–2020. For that purpose, we rely on the list of topic words associated to the different VOSviewer's word clusters (i.e. topics). We label a paper with a topic whenever it shares topic words with the said topic (same paper may be labeled with more than one topic). After that step, 267 papers on mapping knowledge domain, 192 papers on patentometrics, 323 papers on scientometrics, 162 papers on visual analysis, 60 papers on innovation system, and 24 papers on information retrieval are found. The heat $\beta_{i,t}$ of each topic i in publication year t is defined as $\beta_{i,t} = n_{i,t}/K_i$. The number of papers in topic i in publication year t is denoted as $n_{i,t}$, and the total number of papers in i is denoted as K_i. Fig. 7 shows the evolution of six topics according to the changing heat of each topic $\beta_{i,t}$ where, the research topics are represented by belt of different colors, the heat degree of a topic at a given year is marked with the width of the belt, and the higher the heat, the upper the belt position. Figure 7 presents an interesting theme evolution in WISE Lab with fluctuations, the details of each of the 6 research topics evolution being shown in Fig. 8.

As it can been seen in Fig. 7, "Knowledge mapping" represents one of the most prominent topic from the beginning of the establishment of WISE Lab. Explanation of that follows: WISE Lab is affiliated with the Institution of Science of Science and S&T Management in DUT, which was founded in the 1980s and originated from the specialty of dialectics of nature. In the 1980s, research emphasized more on qualitative study, such as the philosophy of S&T, sociology of science the history of S&T, rather than on quantitative study. However, the development of philosophy of science obviously could not meet practical requirements, and the S&T would be separated from the reality if it is only viewed through a simplified "ideal" model. Hence, it is a kind of fixed blind faith rather than a scientific point of view to compare the reality with theory. As opposite, Prof. Liu, the founder of WISE Lab, thought that the "Management Science" should be strengthened in order to make the Science of Science to be useful in S&T practice, that is, to emphasize its quantitative research, which would also lead this discipline to maturity. Scientometrics was already a well-established discipline focused on quantitative methodology, but what really leads Liu to turn to "Knowledge Mapping" is a piece of news issued from American scientists that were interested in mapping science. Said piece of news, published in

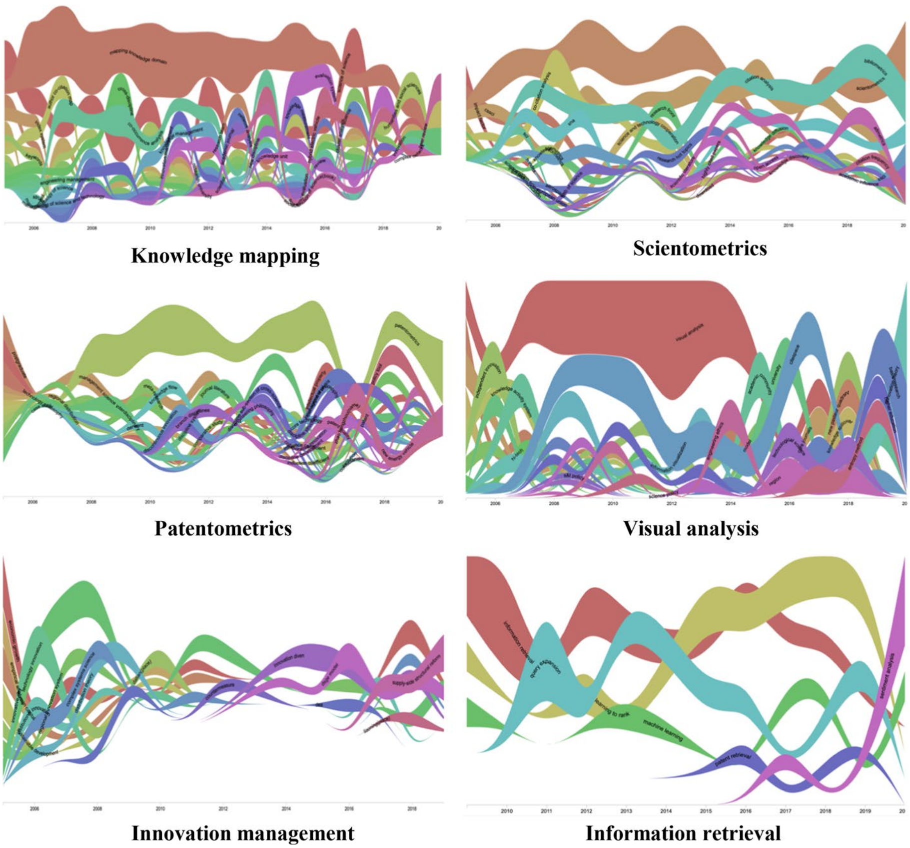


Fig. 8 Detailed views of the 6 main research topics evolution in WISE Lab from 2005 to 2018

Reference News (a Chinese newspaper) at April 10th, 2004, showed that the structure of a research field and its development process might well be highlighted by entities connection analysis basing on the scientific literature. It should be noted that the research of China's science of science just started from the modern science and technology system studies proposed by Tsien (1979). As an important follower of Tsien's thought, Liu decided to lead a new path in China's science of science. That is why the WISE Lab's research started from the link of science of science with mapping knowledge domain.

The general trend of "Visual analysis" is parallel to "Knowledge mapping" except the burst from 2006 to 2008 with the increase of "Scientometrics". "Knowledge mapping" and "Visual analysis" are actually 2 similar topics, but they have had specific differences during the evolution of WISE Lab. It is interesting that "Knowledge mapping" was initially considered as mapping disciplinary structure, accordingly to the fact that scientific papers from existing database, such as SCI and CNKI, were taken as the major research object. However, driven by the leading interest in WISE Lab, namely, highlighting connection between science, technology and economy, the domain of knowledge mapping was no longer limited to science. Consequently, WISE Lab research tends to use more terms related to information visualization and also exploit specific visualization tools, like CiteSpace (Chen 2019), which improves the visual analysis to an important extend. It also refers to keywords like "new Pasteur quadrant", "knowledge spillover", "innovation theory" that more directly relates to "Visual analysis" and consequently form a specific topic.

On its own side, "Scientometrics" has kept a steady development as an active research field of WISE Lab. It formed two main periods, the first rising up with the emerging of "citation analysis", "hot topic", "research frontier" and "scientific cooperation" around 2009, and second rising up with "bibilometrics", "altometrics", "SNA", and "scientific literature" around 2012 (Fig. 8).

"Patentometrics" experienced a sudden falling down during the period of 2006–2008 and has had a new burst in 2011 due to the increase of "Management Science", which promotes patentometrics research among science, technology and economy. As it can been seen on Fig. 8, the research of "intellectual property" and "policy tool" raise up at the highest ranks followed by "patentometrics" in 2016 and 2018 respectively.

"Information retrieval" formed with the emergence and development of scientific big data from 2007, and highlighted in recent years because many algorithms have been applied in this field, such as "machine learning", "query expansion", "learning to rank" and "sentiment analysis" (Fig. 8), which lead to deeper content analysis in science of science. Furthermore, "learning to rank" attracts more attention from 2014 to 2019, and "sentiment analysis" is expected to have higher growth in a near future.

Comparatively, the heat of "Innovation management" is always keeping steady trend with keywords such as "technology innovation", "organization innovation", "distribution theory" and "dsge model" (Fig. 8). The research on "Innovation management" is more theoretical and combining scientometrics and innovation management has always been an indispensable part of research in WISE Lab. It is expected to enrich and develop the theory of innovation management with the help of quantitative study.

WISE Lab collaboration with performance

The development of WISE Lab has been mainly driven by collaboration as show in Fig. 9. Hence, the co-authored papers account for 92.23% of all the papers, with 2–4 authors and most collaborations happening between teachers and students. Moreover, the co-authorship size has followed a steady and slow increasing trend. Finally, there are 150 different institutes, including 21 international institutes that have been cooperate partners of WISE Lab.

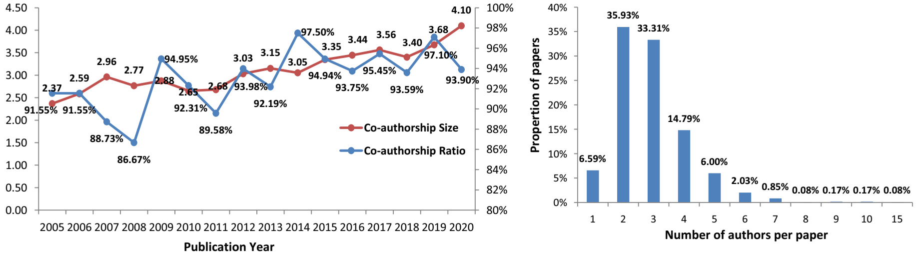


Fig. 9 Proportion of co-authorship and distribution of the co-authorship size in WISE Lab. Here we exclude two papers collected by conference abstracts compilations, which are viewpoints collections, including respectively 30 authors and 11 authors.

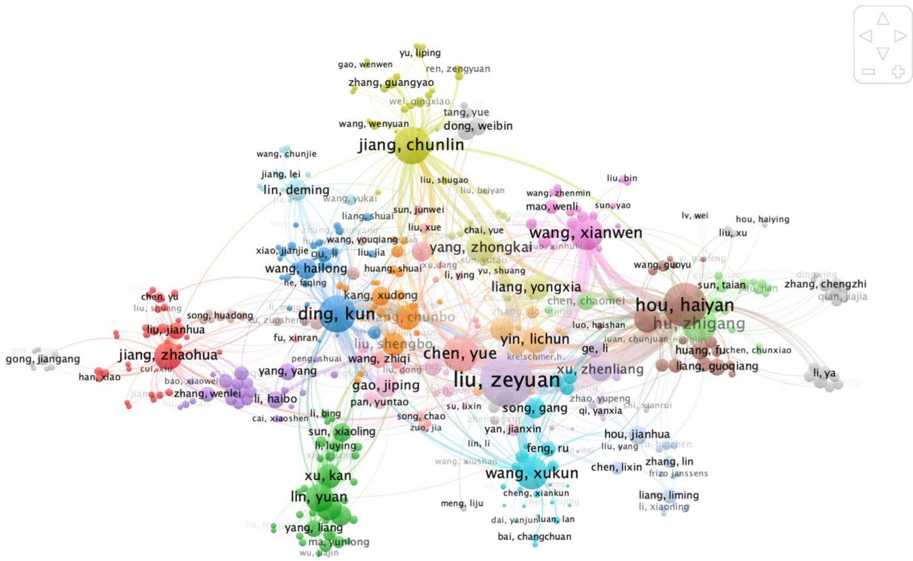


Fig. 10 Global co-author network of WISE Lab mapped by VOSviewer. The size of the circle is directly proportional to the betweenness of the node, and the same color indicates that the research topic is similar.

The global cooperation network produced by 1168 journal and conference papers out of 1,240 scientific papers that are indexed in CNKI or WoS[1], which involves 582 authors and 1,811 author pairs (Fig. 10). We find out that the co-author network is remarkably centered on Prof. Liu, as well as some sub-communities being centered on some other WISE Lab members revolve around Prof. Liu as satellites.

Generally, a closely connected research team with a strong cooperation network will lead to more cooperative behaviors, easier knowledge flow and better team performance, while a loosely connected research team often faces to some problems such as the lack of information, the lack of emotional support and the lower job satisfaction.

Three indicators, Average Degree <K>, Average Distance <D>, Average Betweenness <B> and Average Cluster Coefficient <C> are used for reflecting the structure of WISE Lab collaboration networks, and the formulas are expressed as following:

$$\text{Average Degree}: \langle K \rangle = \frac{\sum_{i=1}^{N} \text{degree}(i)}{N} = 2L/N$$

where N denotes the number of nodes, and L represents the number of edges.

$$\text{Average Distance}: \langle D \rangle = \frac{1}{\frac{1}{2}N(N+1)} \sum_{i \geq J} d_{ij}$$

where d_{ij} denotes the length between two nodes.

[1] Because we focus on co-authorship, we chose to remove the papers that appear as isolated nodes in the network. These papers represent 72 of the 1240 initial papers exploited to build up the network. So, we finally only consider the 1168 remaining ones.

$$\text{Average Betweenness: } \langle B \rangle = \sum_{i \neq v \neq j} \frac{\sigma_{ij}(v)}{\sigma_{ij}}$$

where σ_{ij} is the total number of shortest path from node i to node j and $\sigma_{ij}(v)$ is the number of those paths that pass through v.

Clustering coefficient is introduced by Watts and Strogatz (Watts and Strogatz 1998). For a given node i the local clustering coefficient is the number of triangles connected to this node $\left|C_3(i)\right|$ divided by the number of triples centered on it:

$$C_i = \frac{2\left|C_3(i)\right|}{k_i(k_i - 1)}$$

where k_i is the degree of the node i. The Average clustering coefficient $\langle C \rangle$ for the whole graph is the average of the local values:

$$\text{Average Cluster Coefficient : } \langle C \rangle = \frac{\sum_{i=1}^{N} C_i}{N}$$

Average Degree <K>, which gives the average number of links per node, is a good quantitative measurement for connectivity of a graph. Hence, it can show how many collaborators an author has on average; *Average Distance <D>* is defined as the average number of steps along the paths for all possible pairs of network nodes. It is a measure of the degree of dispersion of each node on the network; *Average Betweenness <B>* illustrates the degree of the closeness of the global network; *Average Cluster Coefficient <C>* is defined as the average of the local clustering coefficients of all the vertices, which measures the extent to which my friends are friends with one another.

The results of these measures are listed by research topic in Table 2. For the global network, the distribution of degree fits the power-law, the average distance is 4.3636, the average cluster coefficient being 0.8937, therefore the co-author network is a small-world and a scale-free network (Barabási et al. 1999; Newman and Watts 1999; Watts and Strogatz 1998).

The co-author network of the 6 WISE Lab topics all have approximate features (Table 2). Except for "Information retrieval", for all the other topics, the average degrees are all less than 3.0, the average distances are all around 3.5, the average cluster coefficients are all more than 0.8, the average betweennesses distribute in the range from 0.32 to 0.42 and the degree distributions fit the power-law. Accordingly, they are all small-world and scale-free networks. The co-author network of the research topics *Information Retrieval* is the smallest network, as well as each author has 3.3214 cooperators, the average distances are 2.9502, the average cluster coefficient is smaller than others, the average betweenness is larger than others, and the degree distribution also fits power-law.

On one side, not only the global co-author network but also the disparate co-author networks for different research topics of WISE Lab are all small-world and scale-free networks. It means that the cooperation of WISE Lab is extremely compact, the cooperation links being focused on some core authors, those being connected by some other authors with high betweenness. Moreover, the co-authorship is changed in accordance with the transformation of research themes. On the other side, the cooperation with excellent scholars outside of WISE Lab also affects the research themes, the cooperation with Prof. H Kretschmer, Prof. Chaomei Chen, Prof. Wolfgang Glanzel, Prof. Ronald Rousseau, Prof. Jean-Charles Lamirel, Prof. Jin Chen, Prof. Hongfei Lin, et al. improves the

Table 2 Details of the co-authorship network for different research topics

Research Topic	Nodes N	Edges M	Average Degree $< k >$	Average Distance $<L>$	Average Cluster Coefficient $<C>$	Average Betweenness $<L>$	Rank of betweenness of Prof. Liu
Science mapping	180	450	2.5000	3.7750	0.8956	0.3863	2
Scientometrics	211	569	2.6967	3.6763	0.8862	0.4149	2
Patentometrics	156	354	2.2692	3.7758	0.8765	0.3311	1
Visual Analysis	128	299	2.3359	3.7966	0.8383	0.4137	1
Innovation management	63	188	2.9841	3.5212	0.8264	0.3247	1
Information Retrieval	28	93	3.3214	2.9502	0.8078	0.5053	N/A
Global	414	1247	3.0121	4.3636	0.8937	0.2599	1

development of WISE Lab in Scientometrics, visualization, innovation management, information retrieval and machine learning. Prof. Liu bridged the global cooperation network as an important scholar with high rank of betweenness in WISE Lab.

Team cohesion, as the foundation of team competitiveness, is one of the key factors for the team performance. Carron et al. (1985) described the cohesion as the dynamic process of a group uniting and maintaining the overall tendency in the process of pursuing group goals. In social network analysis (SNA), the harmonic mean of the entries in the distance matrix (that is the normalized sum of the reciprocal of all the distances) is a distance-based cohesion measure called compactness. This has a value of 1 when the network is a clique (everyone is adjacent) and zero when the network is entirely made up of isolates. In an undirected network, the following formula is used for calculating the compactness value:

$$C = \frac{\frac{n(n-1)}{2}}{\sum_{i=1}^{n} \sum_{j=i+1}^{n} \frac{1}{d_{ij}}}$$

where d_{ij} denotes the distance between node i and note j. Usually, the number of papers, citations, and H-index, etc. is usually used to evaluate a scientist's performance, but here we are more interested in Prof. Liu's contribution to the team cohesion. Accordingly, the indicator C_i that measures the contribution of the member i to the team cohesion C is calculated as the network compactness change when ignoring member i in the network. The results are showed in Table 3.

Prof. Liu has the highest $C_i$value (0.031), indicating that he contributed the most to the cohesion of the co-authored network of WISE Lab. In addition, Prof. Liuis not only the

Table 3 Members' contribution to the team cohesion (ranked by C;) compared with H-index, number of highly cited papers (Num-highly) , citations per paper (CPP) and number of papers (Num-papers)*

Member code**	C*i*	H-index	Num-highly	CPP	Num-papers
M1 (Prof. Liu)	0.031	36	29	30.40	280
M2	0.029	20	6	8.01	160
M3	0.025	13	2	23.66	113
M4	0.024	17	4	6.53	162
M5	0.021	19	11	12.03	140
M6	0.016	8	0	6.35	23
M7	0.015	8	1	7.89	36
M8	0.014	23	11	16.02	127
M9	0.014	25	11	27.83	107
M10	0.012	9	1	7.11	35
M11	0.010	20	10	41.73	81
M12	0.008	14	3	26.54	80
M13	0.008	16	4	10.10	80
M14	0.003	4	0	2.38	16
M15	0.001	9	1	4.75	52
C (all members)	0.351	48	64	13.86	1168

* We only count the 1168 journal and conference papers indexed in CNKI and WoS

** We only list the 15 full-time researchers of WISE Lab, denoted by the member code "M1", "M2", ..., "M15", which is listed in order of the value of cohesion Ci most productive author of WISE Lab, who has published 280 papers[2] (in journals and conferences) indexed by CNKI and/or WoS, but also a very high impact researcher, whose H-index is 36, and an average number citations per paper of 30.40.

Conclusion

The rapid development of WISE Lab in the past 15 years looks like a miracle. Hence, 15 books and 1240 scientific papers have been produced since its establishment in 2005. The largest share (71.8%) of the 1240 produced papers is published in high impact domestic journals, which are indexed in CNKI, and international contribution indexed in WoS also account for 10.1%.

Our life-time analysis revealed that the research results of WISE Lab have great vitality, particularly for the highly cited papers for which the maturing and decline process of citations is much slower than that of the mainstream papers, as well as it is much slower than that of general scientific domains like related social science domain, indicating their important impact.

Additionally, we have shown that highly cited papers could be divided into three categories with different citation distribution patterns. On the one side, the papers focusing on the methodology of knowledge mapping show a sustainable high impact with increasing citations, showing the prominent impact of this important research domain for which WISE Lab has clear leadership. On the other side, the papers strengthen on the intelligence structure in science and technology are always alive with a more stable number of citations per year, while some empirical and case studies show a falling down trend.

Our analysis of the theme evolution of WISE Lab from 2005 to 2020 revealed that the research topics of the all the papers published by WISE Lab could be divided into main topics, those being "Knowledge mapping", "Visual analysis", "Scientometrics", "Patentometrics" and "Information retrieval", and "Innovation management". While the all 6 topics have evolved over time, "Knowledge mapping" and "Scientometrics" topics both showed a burst in 2005, because WISE Lab began at that period the quantitative research with knowledge mapping methodology from the perspective of mapping the structure of modern science and technology, which itself corresponded to a philosophical understanding of knowledge mapping. In recent years, with the development of big scientific data, WISE Lab focused more on altmetrics and machine learning, which alternatively promoted the development of "Scientometrics" and "Information retrieval" research topics.

Finally, our analysis of co-authorship of WISE Lab showed that the operating mode of WISE Lab is greatly driven by collaboration, 92.23% of all the papers being co-authored and the co-authorship size having a steady and slow increasing trend. Our construction of the global co-authorship network also clearly highlighted that Prof. Liu has been the central actor of the laboratory surrounded by some sub-communities being centralized to some other WISE Lab members as the satellites. We additionally performed a team cohesion analysis on co-authorship network that permitted us to confirm that Prof. Liu contributed the most to the team cohesion of WISE Lab. This new part of our work thus led us to show that Prof. Liu played a very central role in the laboratory construction and development.

[2] As a member of WISE Lab. The papers of Prof. Liu published before 2005 are not considered here.

The principle “Learn to be an Excellent Teacher; Act as an Exemplary Person” was practiced by Prof. Liu for his whole life. He has influenced many scholars by his persistent pursuit for the course of Science of Science, his meticulous spirit for academic work, and his self-discipline and generosity. He is not only a respected mentor and colleague, but also a greatly admired friend to the academia. Prof. Liu’s sudden passing means a major loss for WISE Lab, and the shock on the entire team is significant. But fortunately, Prof. Liu has been the soul of WISE Lab, a good cooperation development trend has been formed in WISE Lab, and we are confident that the team will inherit Prof. Liu’s academic thoughts and spirits to promote the development of WISE Lab continuously.

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Appendix

See Table 4.

Table 4 Highly cited journal papers by WISE Lab (Citations in CNKI&WoS >=40, retrieval time: 2020. 05.12)

No.	Cited Freq	Title	Authors	Source	Pub Year
1	1954	Decomposition Model and Empirical Study of Carbon Emissions for China, 1995- 2004	Xu Guo-quan, Liu Ze-yuan, Jiang Zhao-hua	China Population, Resources and Environment	2006
2	1260	The Methodology Function of Mapping Knowledge Domains	Chen Yue, Chen Chao-mei, Liu Ze-yuan, Hu Zhi-gang, Wang Xian-wen	Studies in Science of Science	2015
3	755	The Rise of Mapping Knowledge Domain	Chen Yue, Liu Ze-yuan	Studies in Science of Science	2005
4	355	History and Theory of Mapping Knowledge Domains	Chen Yue, Liu Ze-yuan, Chen Jin, Hou Jian-hua	Studies in Science of Science	2008
5	277	Review on The Application of Citespace At Home and Abroad	Hou Jian-hua, Hu Zhi-gang	Journal of Modern Information	2013
6	248	Mapping of Science Studies, The Trend of Research Fronts	Hou Hai-yan, Liu Ze-yuan, Chen Yue, Jiang Chun-lin, Yin Li-chun, Pang Jie	Science Research Management	2006
7	186	Quantitative Analysis on The Research Front of International Scientometrics Based on Mapping of Knowledge	Hou Hai-yan, Liu Ze-yuan, Luan Chun-juan	Science Research Management	2009
8	179	Research on Visualization of The Evolution of Strategic Management Front	Hou Jian-hua, Chen Yue	Studies in Science of Science	2007
9	166	Emerging trends in regenerative medicine: a scientometric analysis in CiteSpace	Chen, Chaomei; Hu, Zhigang; Liu, Shengbo; Tseng, Hung	*Expert Opinion on Biological Therapy*	2012 WoS
10	162	Visualization Analysis of The Hot Domains and The Research Edge In The Field of S&T Policy	Luan Chun-juan, Hou Hai-yan, Wang Xian-wen	Studies in Science of Science	2009
11	153	Total Factor Energy Efficiency of China's Eight Economic Regions From 1998 To 2005—Based on Analysis of Provincial Panel Data	Xu Guo-quan; Liu Ze-yuan	Forum on Science and Technology in China	2007
12	133	Economy Papers Map of Co-Occurrence Analysis Based on CSSCI	Jiang Chun-lin, Du Wei-bin, Li Jiang-bo	Journal of Intelligence	2008
13	132	Towards an explanatory and computational theory of scientific discovery	Chen, Chaomei; Chen, Yue; Horowitz, Mark; Hou, Haiyan; Liu, Zeyuan; Pellegrino, Donald	*Journal of Informetrics*	2009 WoS

Table 4 (continued)

No.	Cited Freq	Title	Authors	Source	Pub Year
14	125	The structure of scientific collaboration networks in Scientometrics	Hou, Haiyan; Kretschmer, Hildrun; Liu, Zeyuan	*Scientometrics*	2008 WoS
15	119	Introduction To H-Index and G-Index for Journal Academic Impact Evaluation	Jiang Chun-lin, Liu Ze-yuan, Liang Yongxia	Library and Information Service	2006
16	111	Knowledge Spillover Effect and Its Economic Explanation	Sun Zhao-gang, Xu Yu-sen, Liu Ze-yuan	Science of Science and Management of S&T	2005
17	106	Thinking About The Construction of "Science of Science"Theory System—The Report About The Progress Of"Science of Science"Which Based on Scientometrics In China and Foreign Countries	Liu Ze-yuan	Studies in Science of Science	2006
18	91	Connection and stratification in research collaboration: An analysis of the COLLNET network	Yin Li-chun; Kretschmer, Hildrun; Hanneman, Robert A.; Liu Ze-yuan	*Information Processing & Management*	2006 WoS

The English journals are marked by *italic line* followed by publication year with 'WoS'

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