Intellectual Structure and Infrastructure of Informetrics: Domain Analysis from 2001 to 2010

계량정보학의 지적구조 분석 연구: 2001-2010년 연구영역 분석

Jae Yun Lee*
Sanghee Choi**

ABSTRACT

Since the 1990s, informetrics has grown in popularity among information scientists. Today it is a general discipline that comprises all kinds of metrics, including bibliometrics and scientometrics. To illustrate the dynamic progress of this field, this study aims to identify the structure and infrastructure of the informetrics literature using statistical and profiling methods. Informetrics literature was obtained from the *Web of Knowledge* for the years 2001-2010. The selected articles contain least one of these keywords: 'informetrics', 'bibliometrics', 'scientometrics', 'webometrics', and 'citation analysis.' Noteworthy publication patterns of major countries were identified by a statistical method. Intellectual structure analysis shows major research areas, authors, and journals.

초 록

1990년대부터 계량정보학은 정보학자들 사이에서 주목을 받는 분야로 발전해오면서 현재 계량서지학, 사이언토메트릭스 등 모든 계량학을 포괄하는 개념으로 인식되고 있다. 계량정보학의 역동적인 발전을 조명하기 위하여 이 연구에서는 계량정보학 연구출판물을 기반으로 하여 이 분야의 지적구조를 분석하고자 하였다. 적용된 기법은 통계적 기법과 프로파일링 기법이다. 데이터 수집을 위해서는 SCI 데이터베이스를 이용하였으며 2001년부터 2011년까지의 Web of Knoewledge 데이터베이스에서 다음과 같은 5개의 질의를 가지고 데이터를 수집하였다: 'informetrics', 'bibliometrics', 'scientometrics', 'webometrics', 'citation analysis.' 프로파일링 기법으로 주요 주제, 저자, 저널별로 지적구조도를 제시하였으며 계량정보학 연구를 수행한 주요 국가, 기관, 저자도 분석되었는데 미국과 영국이 이 분야 연구를 주도하고 있으며 M. Thelwall이 10년동안 생산성이 가장 높은 저자인 것으로 나타났다.

Keywords: informetrics, intellectual structure, keywords profiling, journal profiling, author profiling
계량정보학, 지적구조, 키워드 프로파일링, 저널 프로파일링, 저자 프로파일링

---

* Associate Professor, Kyonggi University, Department of Library & Information Science (memexlee@kgu.ac.kr)
** Assistant Professor, Catholic University of Daegu. Department of Library Science(shchoi@cu.ac.kr)
■ Received : 17 May 2011 ■ Revised : 24 May 2011 ■ Accepted : 12 June 2011
■ Journal of the Korean Society for Information Management, 28(2): 11-36, 2011.
〔DOI:10.3743/KOSIM.2011.28.2.011〕

1. Introduction

Since information scientists began to quantify research trends within scientific publications, numerous research areas have been recognized. Various quantitative techniques have produced 'bibliometrics', 'scientometrics', 'informetrics', 'webometrics', and 'citation analysis.' All of these terms embrace quantitative concepts but target different subjects and are of different scopes. However, Hood and Wilson (2001) have noted considerable confusion among the terminologies of bibliometrics, informetrics, and scientometrics. They presented this observation at the Fourth International Conference on Bibiliometrics, Informetrics, and Scientometrics (1993). According to Glanzel and Schoepflin's paper 'Two Decades of SCIENTOMETRICS' (2001), the confusion might stem from authors' synonymous use of 'bibliomentrics' for all three subject areas.

Overall, 'bibliometrics', 'scientometrics', 'informetrics', 'webometrics', and 'citation analysis' are component areas of the study of the dynamics of disciplines based on their publications. The term 'informetrics' can used to refer to all of them.

Based on this assumption, this study explores literature of these areas to discover significant patterns and phenomena. Accordingly, two informetrics methods were independently used. In the first stage, a statistical examination was conducted upon informetrics articles found via a search of the citation index database *Web of Knowledge*, to identify the productivity of each country and institution. The statistical status of research subjects and journals were also analyzed. In the second stage, intellectual structures of informetrics were derived using a Pathfinder network algorithm and a clustering-based network algorithm. The result visually represents the important keywords of research, major researchers, and core journals that were discovered.

2. Previous studies

Of these related concepts, bibliometrics was the first tool used to discover phenomena within academic research. Bibliometrics is defined as a quantitative analysis of publications to ascertain specific patterns. The first study in this field emerged in the 1990s, when Cattell conducted an analysis of a biographical directory of American men of science. Published at five-year intervals, it traced the research activities of thousands of American scientists (Godin 2007). Cattell introduced a framework for measuring science from two aspects: quality and quantity. The number of scientists per nation, referred to as 'productivity', was quickly recognized as a quantitative indicator that could explain trends. After this ground breaking work, the major concepts of bibliometrics were explored by many information scientists.

However, Eugene Garfield (1955) had already compiled 'an association of ideas index' from a large-scale study of citation relationships. This approach mimicked bibliographical traditions, but shifted into a new focus on citation (Moris & Martens 2008). Based on Garfield's study, the *Science Citation Index* to date the most influential source for citation analysis research was developed. Wouters (1999) describes the *Science Citation Index* as the start of citation culture. However, machine indexing of the written representations of scientific activity has had both intended and unintended consequences for the practice of science. Since Garfield (1955) first introduced the notion of checking citations in order to measure one document's influence on subsequent ones, citation analysis has contributed to discoveries of significant phenomena in numerous scientific fields and to the development of notable indicators such as impact factor and h-index. Impact factor, a tool that aids discovery of the popularity or authority of an academic journal, has proven useful in spite of several problems, for example ignorance of non-English publications.

The H-index (Hirsch 2005) is based on the assumption that "A scientist has index h the h of his or her Np paper has at least h citations each and the other (Np-h) papers have ≤ citations each" (Hirsch 2005). This equation immediately attracted information scientists' interest and began to be widely explored. Originally, h-index was an indicator of the scientific output of a researcher, but now is applicable to an institute or country as well. According to Hood and Wilson (2001), scientometrics is related to and has overlapping interests with bibiliometrics and informatrix and has typically been defined as the 'quantitative study of science and technology.' According to Brookes (1990), scientometrics has become fruitful in science policy studies. Another notable definition explains scientometrics as the study of the quantitative aspects of science as a discipline or economic activity (Tague-Sutcliffe 1992).

Informetrics, the most recent metric concept, was proposed by Nacke to cover the part of information science that considers the measurement of information phenomena (Hood & Wilson YEAR), the application of mathematical methods to the problems of bibliometrics and parts of information retrieval theory. However, this term surfaced after bibliometrics and scientometrics as abroad concept that could be applicable to both bibliometrics and scientometrics. Brooks (1990) noted that informetrics is a general term for bibliometrics and scientometrics, even though scientometrics generally refers to policy studies and bibliometrics is connected more to library studies.

In the definition of informetrics suggested by Tague-Sutcliffe (1992), the characteristics of information are clearly articulated in ways that reflect the relationship between bibliometrics and scientometrics.

Since informetrics began to garner attention as a macro discipline in the early 1990s, it has been widely recognized as the most generally applicable term by researchers in all three metric areas.

Webometrics, an emerging subfield of informetrics, is often called 'cybermetrics' or 'link analysis.' Informetrics researchers (NAMES, DATES) have mentioned it as one of the new trends in informetrics that applies informetric analysis to Web publications.

3. Data Collection and Methodology

Data was collected through a search of the Web of Science. The time span was limited to 2001-2010. The submitted search query was as follows:

[Query : TOPIC=(citation analysis OR bibliometrics OR informetrics OR scientomerics OR webometrics) refined by Document Type=(ARTICLE OR PROCEEDINGS PAPER OR REVIEW) Timespan=2001-2010. Databases=SCI-EXPANDED, SSCI, A&HCI]

The search yielded 1,715 articles statistical citation analyses were performed onitems that cited these articles. Table 1 shows a statistical status of each query term in the search result. Of the 1,715 articles, 915 articles contained the topic term 'citation analysis.' The second biggest group was 'bibliometrics' (661), followed by 'scientometrics' (257), 'informetrics' (108), and 'webometrics' (97). These topic terms also appeared in the same articles the number of co-occurrences is shown in table 1. Citation analysis appeared with bibliometrics (154) more than any other term. Bibliometrics, which was the most co-occurring term with informetrics, scientometrics, and webometrics, also co-occurred most with every other term: citation analysis (154), informetrics (24), scientometrics (61), and webometrics (25). This means that bibliometrics is the most widely applied term for similar concepts. In this study, frequencies of articles and citations were investigated in 1,715 articles.

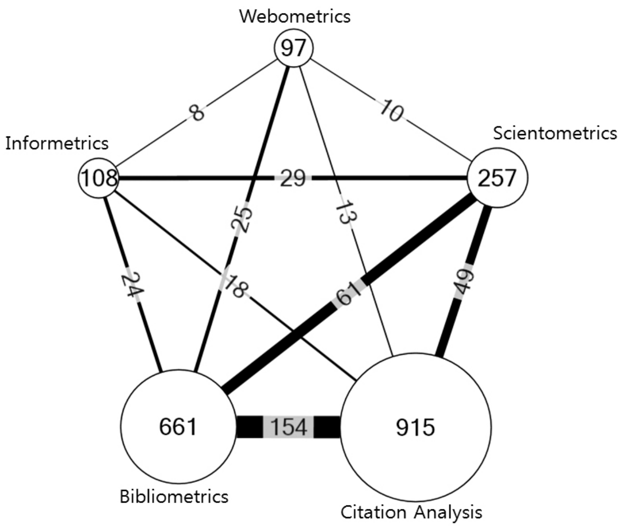
In figure 1, the relationship between query terms is clearly displayed. The number inside each circle is the number of articles searched by the query term. Because citation analysis, bibliometrics, and scientometrics comprise a large portion of metrics research, this portion is strongly connected to others.

As above, most of the articles contain one or two terms. However, some contain more. Bar-Ilan's (2008) review of informetrics contains all 5 of the query terms. Seven papers include all 4 query terms except from webometrics. These papers, like Bar-Ilan's, can be called reviews; one of them is a famous work by Hood and Wilson, "The literature of bibliometrics, scientometrics, and informetrics" (2001).

Although the popularity of each term and the relationships between terms differ, all of the terms refer to the same research discipline: informetrics. As described at the beginning of this paper, informetrics

<Table 1> Search results of 5 queries and query pairs

	Citation Analysis	Bibliometrics	Informetrics	Scientometrics	Webometrics
Citation Analysis	915				
Bibliometrics	154	661			
Informetrics	18	24	108		
Scientometrics	49	61	29	257	
Webometrics	13	25	8	10	97



<Figure 1> Search results by 5 queries and intersections

is regarded as a general concept that comprises all of the others. This definition is clearly declared in "Informetrics at the beginning of the 21st century: A review" (Bar-Ilan 2008), which uses all 5 terms. Accordingly, this study uses informetrics to represent all of the related terms.

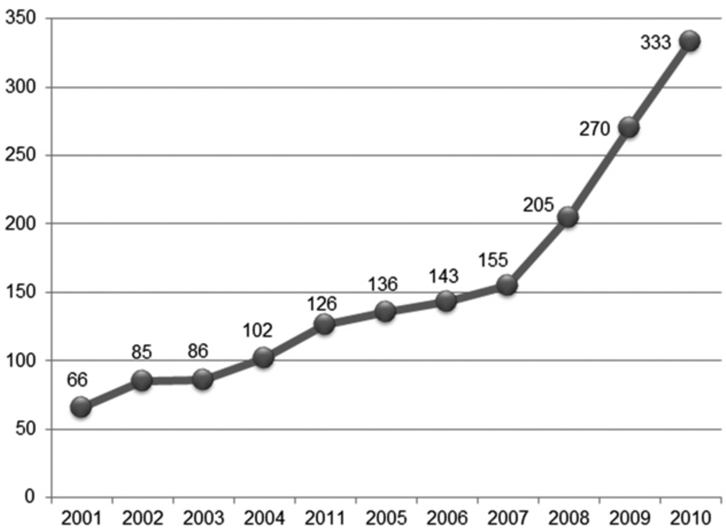
Highly cited papers in informetrics were also investigated. The most-cited title is "Scholarly communication and bibliometrics" in *ARIST*. The top 10 cited papers are shown in table 2.

In the retrieved data set, the number of publications was investigated chronologically. A notable increase began in 2007 and the number of publications doubled in 2010. As seen in figure 2, the three years from 2007 to 2010 were an important period for informetrics researchers. It is anticipated the number of papers might increase greatly after 2010.

To discover intellectual structures of informetrics research in detail, Pathfinder network algorithms (Schvanveldt 1990) and a cluster-based network (CBnet) algorithm (Lee 2007; 2008) were used. To do a cluster-based network analysis, a cosine similarity matrix was produced by articles' terms. With the matrix, centroid clustering generated CBnet-CENT (Cluster-Based Network with Centroid method). Although the Pathfinder network is a reliable method by which to present intellectual structures, it sometimes fails to clearly show relationships at the macro level. CBnet is complementary to the Pathfinder network method. CBnet-CENT has proved competent to offset the limitations of Pathfinder network analysis in several studies, for example Korean science map research (Lee 2007) and domain analysis of digital library research (Lee, Kim, and Kim 2010). CBnet-CENT helps to group meaningfully connected concepts in the intellectual structure generated by Pathfinder network algorithms.

〈Table 2〉 Top 10 cited papers in the retrieved set

Times cited	Author(s)	Title	Source	Pub year
123	Borgman, CL; Furner, J	Scholarly communication and bibliometrics	*Annual Review of Information Science and Technology*	2002
114	Glanzel, W; Moed, HF	Journal impact measures in bibliometric research	*Scientometrics*	2002
112	Kostoff, RN; Scaller, RR	Science and technology roadmaps	*IEEE Transactions on Engineering Management*	2001
108	Lance, CE; Butts, MM; Michels, LC	The sources of four commonly reported cutoff criteria - What did they really say?	*Organizational Research Methods*	2006
91	Thelwall, M	Extracting macroscopic information from Web links	*Journal of the American Society for Information Science and Technology*	2001
87	Lee, KP; Schotland, M; Bacchetti, P; Bero, LA	Association of journal quality indicators with methodological quality of clinical research articles	*JAMA-Journal of the American Medical Association*	2002
84	Cronin, B	Bibliometrics and beyond: Some thoughts on web-based citation analysis	*Journal of Information Science*	2001
84	Bjorneborn, L; Ingwersen, P	Perspectives of webometrics	*Scientometrics*	2001
80	Parker, AJR; Wessely, S; Cleare, AJ	The neuroendocrinology of chronic fatigue syndrome and fibromyalgia	*Psychological Medicine*	2001
78	Antelman, K	Do open-access articles have a greater research impact?	*College & Research Libraries*	2004



〈Figure 2〉 The number of informetrics articles by year

4. Statistical analyses

4.1 Statistical analysis at research entity level

Research productivity and impact were statistically analyzed at three entity levels: country, institute, and individual.

4.1.1 Research output and impact at the national level

Within the collected data, the number of articles and cites for each country was investigated categorized. Table 3 shows the productivity of informetrics research at the national level.

The country publishing the most informetrics articles was the USA (506 papers), followed by the

〈Table 3〉 Number of papers and citation indices by countries (more than 0.5%)

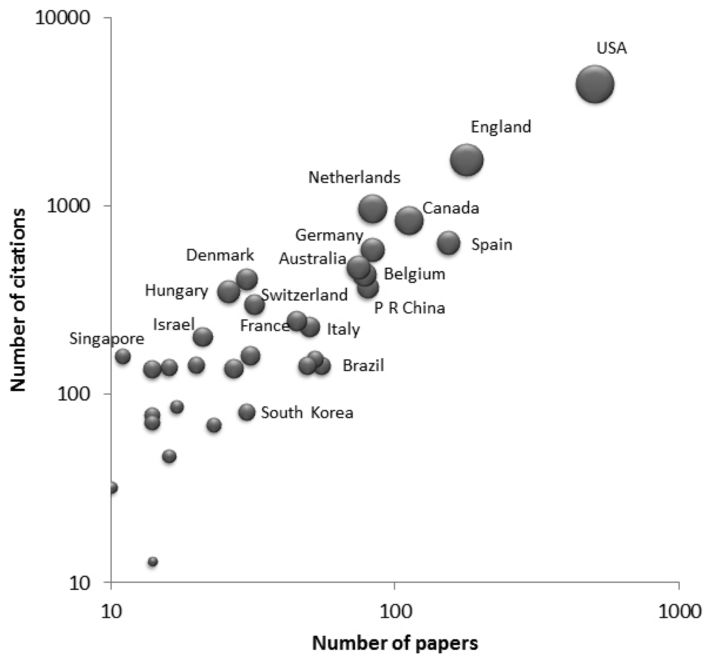
COUNTRY	#Papers	Total cites	h-index	hs-index
USA	506	4,460	31	227.4
England	178	1,755	23	147.8
Spain	154	637	12	56.0
Canada	112	839	17	93.4
Netherlands	83	965	18	106.9
Germany	83	588	12	64.8
Peoples R China	80	370	10	43.6
Belgium	78	434	12	51.1
Australia	74	470	12	59.4
Brazil	55	142	7	25.7
Taiwan	52	155	6	24.5
Italy	50	229	8	34.6
India	49	142	7	23.4
France	45	246	8	35.9
Switzerland	32	301	9	44.8
Sweden	31	161	8	30.8
Denmark	30	409	10	56.6
South Korea	30	81	6	17.8
Japan	27	138	8	28.2
Hungary	26	351	11	53.9
Turkey	23	69	5	15.8
Israel	21	203	8	37.2
Greece	20	143	6	24.4
Iran	17	86	4	15.9
New Zealand	16	139	6	26.4
South Africa	16	47	4	11.9
Finland	14	136	7	28.6
Mexico	14	78	5	18.1
Austria	14	71	5	16.8
Malaysia	14	13	2	4.0
Singapore	11	159	5	24.5
Wales	10	32	3	8.0

UK (178), Spain (154), Canada (112), Netherlands (83), and Germany (83). In terms of cites, the ranking of countries slightly changes. The ranking of Spain declined from 3rd to 5th and most of Asian countries including China, Taiwan and India have relatively low cite numbers. h-index and hs-index reflect the change of countries' status in the cites ranking. Figure 3 provided a more clear view for major countries' productivity and impact in the informetrics research.

USA and England achieved dominant positions from the both aspects, the number of papers and citations. Netherlands, Denmark, Hungary and Israel are located in the left upper area of the figure 3. It means they have a considerable impact on the informetrics research with comparatively small number of papers.

Among the Asian countries, Singapore shows high number of citations. A paper published by Singapore authors is averagely cited 14 times, which is the highest citation number per article among countries in the table 3.

Table 4 presents countries comprise more than 3 percent in each query result. USA maintains the highest research production in three query results: 'citaion analysis', 'bibliometrics', and 'scientometrics.' Belgium has published articles using a term, 'informertrics' more than any other countries. England is the most productive country in the 'webometrics' area because it has M. Thelwall, one of the most productive author publishing webometrics and internet related researches.



〈Figure 3〉 Number of papers and citations by countries (more than 5%)
※ Node size is proportional to h-index.

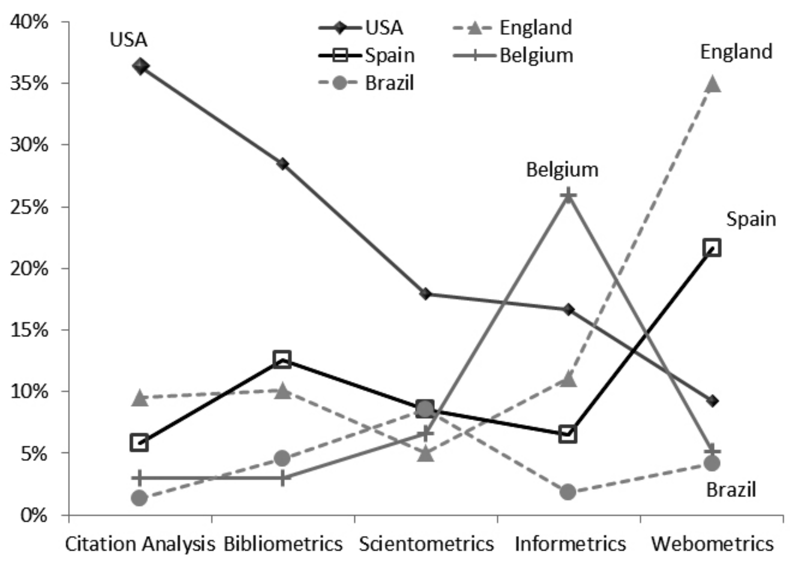
<Table 4> Countries more than 3 percent in each query result

Citation Analysis			Bibliometrics			Informetrics			Scientometrics			Webometrics		
TOTAL	915		TOTAL	661		TOTAL	108		TOTAL	257		TOTAL	97	
USA	333	36.4%	USA	188	28.4%	Belgium	28	25.9%	USA	46	17.9%	England	34	35.1%
England	87	9.5%	Spain	83	12.6%	USA	18	16.7%	Spain	22	8.6%	Spain	21	21.6%
Canada	82	9.0%	England	67	10.1%	England	12	11.1%	Brazil	22	8.6%	USA	9	9.3%
Spain	53	5.8%	Germany	38	5.7%	P R China	8	7.4%	India	21	8.2%	Canada	8	8.2%
Australia	47	5.1%	Australia	36	5.4%	Spain	7	6.5%	Netherlands	19	7.4%	S Korea	7	7.2%
P R China	46	5.0%	Italy	34	5.1%	Australia	6	5.6%	P R China	18	7.0%	P R China	5	5.2%
Germany	42	4.6%	Canada	31	4.7%	Israel	6	5.6%	Belgium	17	6.6%	Belgium	5	5.2%
Netherlands	40	4.4%	France	31	4.7%	S Africa	5	4.6%	Taiwan	16	6.2%	Denmark	5	5.2%
Taiwan	29	3.2%	Brazil	30	4.5%	France	4	3.7%	Germany	14	5.4%	Brazil	4	4.1%
Belgium	27	3.0%	Netherlands	27	4.1%	Netherlands	4	3.7%	England	13	5.1%	France	4	4.1%
			India	26	3.9%				Hungary	12	4.7%	Germany	3	3.1%
			Belgium	20	3.0%				Canada	8	3.1%	Iran	3	3.1%

As seen in figure 4, the research specialty of major countries differs. England and Spain stand out in 'webometrics' and so does Brazil in 'scientometrics.' Again, 'informetrics' is a preferred topic area for Belgian researchers.

4.1.2 Research output and impact at the institutional level

46 institutions from all over the world have published more than 10 papers in the last decade. The most productive institution is Wolverhampton Univ in England and it has produced 53 articles.



<Figure 4> Major countries' share of each query

〈Table 5〉 Number of papers and citation indices by institutions (more than 10 papers)

INSTITUTION	COUNTRY	#Papers	Total cites	h-index	hs-index
Wolverhampton Univ	England	53	791	15	92.3
Indiana Univ	USA	39	601	14	80.7
Univ Granada	Spain	33	193	8	32.6
Off Naval Res	USA	32	326	12	52.1
Katholieke Univ Leuven	Belgium	31	238	10	40.5
CSIC	Spain	31	83	5	16.2
Univ Western Ontario	Canada	26	420	12	67.5
Leiden Univ	Netherlands	25	447	13	69.4
Drexel Univ	USA	23	355	9	49.7
Univ Antwerp	Belgium	22	64	5	14.2
Hungarian Acad Sci	Hungary	20	216	10	42.2
Univ Valencia	Spain	20	49	5	13.1
Royal Sch Lib & Informat Sci	Denmark	19	311	8	43.6
Univ New S Wales	Australia	18	134	5	24.0
Univ Sheffield	England	18	92	5	18.4
Univ Amsterdam	Netherlands	17	147	6	26.2
Univ Alberta	Canada	16	115	6	24.1
Univ Roma Tor Vergata	Italy	16	37	3	9.0
Univ Zurich	Switzerland	15	181	7	32.7
Univ Toronto	Canada	14	85	6	19.8
Natl Inst Sci Technol & Dev Studies	India	13	86	6	19.8
Univ Hasselt	Belgium	13	31	4	9.8
Univ Tokyo	Japan	13	54	4	13.0
Georgia Inst Technol	USA	12	153	5	22.8
Univ N Carolina	USA	12	108	5	21.6
Univ Newcastle	Australia	12	81	5	17.8
Univ Calif Los Angeles	USA	12	159	4	20.5
Univ Malaya	Malaysia	12	12	2	4.0
ETH	Switzerland	11	161	5	25.8
Limburgs Univ Ctr	Belgium	11	69	5	16.8
Harvard Univ	USA	11	35	4	10.6
Yeungnam Univ	South Korea	11	26	3	7.9
Wuhan Univ	Peoples R China	11	14	2	4.2
Cornell Univ	USA	10	152	6	28.9
NYU	USA	10	172	6	28.4
Hebrew Univ Jerusalem	Israel	10	69	5	17.8
Bar Ilan Univ	Israel	10	134	4	21.9
Peking Univ	Peoples R China	10	25	4	8.0
UCL	England	10	61	4	13.6
Univ Arizona	USA	10	52	4	12.9
Univ Loughborough	England	10	89	4	17.1
Asia Univ	Taiwan	10	15	3	6.0
Univ Nacl Autonoma Mexico	Mexico	10	65	3	13.0
Natl Chengchi Univ	Taiwan	10	17	2	5.2
Natl Res Council Italy	Italy	10	8	2	2.8
Univ Sao Paulo	Brazil	10	4	1	1.0

The five leading institutions belong to USA, England, Belgium and Spain. These countries co-incides with the countries analyzed from the statistical analysis of national productivity. However, both the h-index and the hs-index scores of Spanish institutions are comparatively low. For example, University of Granada ranked third in the list of the number of papers falls down to the 8th in the h-index and to the 11th in the hs-index.

<Table 6> Number of papers and citation indices by authors (more than 9 (0.5%) papers)

AUTHOR	#papers	Total citations	h-index	hs-index
Thelwall, M	52	761	14	87.9
Kostoff, RN	34	438	12	59.3
Egghe, L	31	117	7	23.2
Glanzel, W	19	279	10	46.0
Aguillo, IF	19	72	5	16.3
Ho, YS	17	83	4	14.8
Ortega, JL	17	66	4	13.8
Abramo, G	16	37	3	9.0
D'Angelo, CA	16	37	3	9.0
Leydesdorff, L	15	147	6	26.2
Wilson, CS	15	118	4	20.1
de Moya-Anegon, F	15	111	6	22.6
Vaughan, L	13	317	10	54.7
Rousseau, R	13	81	6	20.0
Willett, P	13	49	4	11.8
Bar-Ilan, J	12	193	8	37.2
Daniel, HD	12	214	7	35.6
Smith, DR	12	81	5	17.8
Park, HW	11	26	3	7.9
White, HD	10	217	6	32.6
Bornmann, L	10	184	6	30.7
Kajikawa, Y	10	50	4	13.0
Burrell, QL	10	51	4	12.4
Aleixandre-Benavent, R	10	20	3	7.6
Gonzalez-Alcaide, G	10	10	2	4.4
Guan, JC	9	80	5	18.7
Zhao, DZ	9	70	4	15.5
Lau, CGY	9	67	4	15.2
Debackere, K	9	61	4	14.5
Marx, W	9	55	4	13.4
Garg, KC	9	52	4	13.0

4.1.3 Research output and impact at the individual level

31 authors published more than 9 papers during the time period. Table 6 showed the most productive author in the metrics areas was M. Thelwall from University of Wolverhampton, England. He has published 52 papers since 2001. His publication make up most of articles produced by University of Wolverhampton (53). The author in the second place was Ronald. N. Kostoff from MITRE, USA, followed by the L. Egghe (31), W. Glanzel (19), and I.F. Aguillo (19).

The h-index value of the top most 10 authors ranged from 7 to 14. Again Thelwall's h-index and hs-index scores were also ranked on the top of the list. Therefore, Thelwall is a highly influential researcher with full productivity. On the contrary, the h-index score of L. Vaughan was in the third place with the comparatively small number of paper. He published 13 papers which had been cited 317 times and among them 10 papers have been cited more than 10 times.

4.2 Statistical analyses by research subject

4.2.1 Research output at the subject class level

To identify the subject areas of informetrics researches, this study used the subject classes provided by Web of Science. These classes are the subject categories of the journals in which the informetrics articles were published.

According to Table 7, 'Information Science & Library Science' (51.08%) is the most dominant subject category for informetrics publication, followed by 'Computer Science, Interdisciplinary Applications' (19.42%) and Computer Science, Information Systems (17.67%). These three categories are major subject classes making up 88.17% of the paper numbers.

Overall at least 9 papers were published in 45 subject categories from science to social science. It means informetrics has been recognized as a tool or methodology rather than a research topic in various fields.

In addition, the growth of each subject class from 2001 to 2010 was analyzed using Growth Index (Lee et al. 2011). Growth Index (GI) is an indicator to identify research trend. If the ratio of publications recently published goes higher, the growth index score becomes closer to 1. On the contrary, if the ratio of recently published papers decreases, growth index value goes down to 0. In general, GI value over 0.5 indicates the number of publications is on an increasing trend.

Table 8 shows top 20 subject classes listed by GI scores. 'Nursing' had the highest GI score, 0.83. The subject class ranked second was 'Environmental Sciences' (0.804) followed by 'Planning & Development' (0.705). The subject classes ranked by GI index do not coincide with those ranked by the number of papers. According to the table 8, informetrics researches increase in new domains such as 'Nursing' and 'Environmental Sciences.' GI scores higher than 0.8 verify a significant growth in informetrics research productivity of these fields.

<Table 7> Number of papers in each subject class (more than 0.5%)

Subject Class	Record Count	% of 1715
Information Science & Library Science	876	51.08%
Computer Science, Interdisciplinary Applications	333	19.42%
Computer Science, Information Systems	303	17.67%
Management	105	6.12%
Business	84	4.90%
Multidisciplinary Sciences	44	2.57%
Planning & Development	43	2.51%
Public, Environmental & Occupational Health	40	2.33%
Economics	27	1.57%
Operations Research & Management Science	27	1.57%
Engineering, Industrial	26	1.52%
Environmental Sciences	23	1.34%
Biology	20	1.17%
Clinical Neurology	20	1.17%
Education & Educational Research	20	1.17%
Medicine, General & Internal	20	1.17%
Nursing	20	1.17%
Social Work	20	1.17%
Psychiatry	18	1.05%
Psychology, Multidisciplinary	18	1.05%
Computer Science, Software Engineering	17	0.99%
Health Care Sciences & Services	17	0.99%
Computer Science, Theory & Methods	15	0.87%
Medical Informatics	15	0.87%
Pharmacology & Pharmacy	15	0.87%
Surgery	15	0.87%
Communication	14	0.82%
Computer Science, Artificial Intelligence	14	0.82%
Psychology, Clinical	14	0.82%
Social Sciences, Interdisciplinary	14	0.82%
Chemistry, Multidisciplinary	13	0.76%
Ecology	13	0.76%
Environmental Studies	13	0.76%
Business, Finance	12	0.70%
Geography	11	0.64%
Oncology	11	0.64%
Psychology, Applied	11	0.64%
Sociology	11	0.64%
Respiratory System	10	0.58%
Chemistry, Analytical	9	0.52%
Mathematics, Applied	9	0.52%
Medicine, Research & Experimental	9	0.52%
Rehabilitation	9	0.52%
Sport Sciences	9	0.52%
Statistics & Probability	9	0.52%

<Table 8> Growth Index (GI) of each subject class

Subject class	#papers	GI	Ranks in GI
Nursing	20	0.830	1
Environmental Sciences	23	0.804	2
Planning & Development	43	0.705	3
Public, Environmental & Occupational Health	40	0.704	4
Biology	20	0.698	5
Education & Educational Research	20	0.686	6
Business	84	0.677	7
Operations Research & Management Science	27	0.676	8
Clinical Neurology	20	0.667	9
Economics	27	0.658	10
Multidisciplinary Sciences	44	0.642	11
Psychology, Multidisciplinary	18	0.641	12
Management	105	0.639	13
Information Science & Library Science	876	0.634	14
Medicine, General & Internal	20	0.633	15
Computer Science, Interdisciplinary Applications	333	0.631	16
Social Work	20	0.573	17
Psychiatry	18	0.563	18
Engineering, Industrial	26	0.551	19
Computer Science, Information Systems	303	0.544	20

4.2.2 Research output at the journal level

Table 9 presents 20 core journals of informetrics. The leading journal in number of papers was Scientometrics. It published 17.67% of total articles. The journal ranked in the second place is Journal of the American Society for Information Science and Technology. These two journals have published more than 100 articles in the last decade. Journal of Informetrics, Journal of Information Science and Information of Information Science were also included in top 5 journals. However, compared with top two journals, the number of papers was not so impressive.

4.2.3 Research output at the keyword level

This study analyzed Keyword plus field from Web of Science, which is the controlled keyword field. Although it was defined a controlled field, the level of authority control was not sufficient. Therefore we totaled frequencies of all keywords after singular and plural forms, and synonyms were properly processed.

Table 10 lists frequencies and GI index scores of keywords that appeared in more than 17 papers with GI scores.

The most frequently appeared keyword was ‘Science’ (304), followed by Citation Analysis (171), 〈Table 9〉 Number of papers by journals (more than 0.5%)

Source Title	Record Count	% of 1715
Scientometrics	303	17.67%
Journal of the American Society for Information Science and Technology	111	6.47%
Journal of Informetrics	67	3.91%
Journal of Information Science	48	2.80%
Information Processing & Management	47	2.74%
Malaysian Journal of Library & Information Science	30	1.75%
Technological Forecasting and Social Change	26	1.52%
College & Research Libraries	18	1.05%
Profesional de la Informacion	17	0.99%
Journal of Documentation	16	0.93%
Research Evaluation	16	0.93%
Research Policy	15	0.87%
Revista Espanola de Documentacion Cientifica	14	0.82%
Journal of Academic Librarianship	13	0.76%
Journal of the Medical Library Association	13	0.76%
Current Science	11	0.64%
Online Information Review	10	0.58%
Perspectivas em Ciencia da Informacao	10	0.58%
Social Work in Health Care	10	0.58%
Aslib Proceedings	9	0.52%

〈Table 10〉 Keywords with Growth Index

Keyword Plus	FRQ	GI	Keyword Plus	FRQ	GI
Science	304 (1)	0.689 (34)	Model	51 (17)	0.574 (60)
Citation Analysis	171 (2)	0.595 (54)	Patterns	50 (18)	0.664 (41)
Impact	169 (3)	0.688 (35)	Cocitation	48 (19)	0.580 (56)
Journals	146 (4)	0.692 (31)	Communication	48 (19)	0.562 (61)
Publication	120 (5)	0.717 (21)	Management	45 (21)	0.650 (45)
Indicators	116 (6)	0.721 (19)	Systems	44 (22)	0.719 (20)
Information	96 (7)	0.580 (58)	Ranking	43 (23)	0.700 (27)
Bibliometrics	82 (8)	0.532 (64)	Collaboration	42 (24)	0.743 (17)
Citation	81 (9)	0.716 (22)	Performance	42 (24)	0.799 (6)
Quality	81 (9)	0.689 (33)	Knowledge	41 (26)	0.681 (37)
Index	66 (11)	0.749 (14)	Internet	40 (27)	0.477 (70)
Impact Factors	64 (12)	0.608 (50)	Library	37 (28)	0.542 (63)
World-Wide-Web	58 (13)	0.697 (28)	h-Index	35 (29)	0.933 (1)
Articles	57 (14)	0.781 (10)	Information-Science	34 (30)	0.607 (51)
Networks	57 (14)	0.710 (23)	Innovation	34 (30)	0.733 (18)
Technology	53 (16)	0.659 (43)	University	33 (32)	0.662 (42)

* Table 10 continued on next page

<Table 10> Keywords with Growth Index (continued from previous page)

Keyword Plus	FRQ	GI	Keyword Plus	FRQ	GI
Links	32 (33)	0.513 (66)	Faculty	21 (52)	0.611 (49)
Field	31 (34)	0.681 (36)	Scholarly Communication	21 (52)	0.527 (65)
Productivity	31 (34)	0.666 (38)	Scientific Journals	21 (52)	0.772 (11)
Databases	30 (36)	0.693 (30)	Self-Citation	21 (52)	0.577 (59)
Discipline	30 (36)	0.782 (9)	Behavior	20 (56)	0.561 (62)
Scientometrics	29 (38)	0.606 (52)	Economics	20 (56)	0.631 (47)
Trends	29 (38)	0.790 (8)	Informetrics	20 (56)	0.746 (15)
Webometrics	28 (40)	0.492 (67)	Scientific Literature	20 (56)	0.654 (44)
Authors	27 (41)	0.666 (40)	Sites	20 (56)	0.483 (68)
Author Cocitation	26 (42)	0.580 (57)	Bibliometric Indicators	19 (61)	0.746 (15)
Output	26 (42)	0.873 (4)	Search	19 (61)	0.840 (5)
Google Scholar	24 (44)	0.927 (2)	Tool	19 (61)	0.753 (13)
Search Engines	24 (44)	0.478 (69)	United-States	19 (61)	0.709 (24)
Classification	23 (46)	0.645 (46)	Countries	18 (65)	0.691 (32)
Distributions	23 (46)	0.755 (12)	Scopus	18 (65)	0.923 (3)
Intellectual Structure	23 (46)	0.694 (29)	Social-Sciences	18 (65)	0.600 (53)
Perspective	23 (46)	0.707 (25)	Authorship	17 (68)	0.666 (38)
Research Performance	23 (46)	0.625 (48)	Bibliometric Analysis	17 (68)	0.791 (7)
Scientists	22 (51)	0.702 (26)	Space	17 (68)	0.590 (55)

* The number in parentheses is the ranking.

Impact (169), Journals (146), Publication (120) and Indicators (116). These terms appeared more than 100 times.

As seen in GI Indice, 'h-index' had the highest GI score (0.933). Google Scholar (0.927), Scopus (0.923), Output (0.873), Search (0.840), and Performance (0.799) showed a notable growth. It means performance evaluation using various tools becomes an attractive topic for many researchers. Among 70 keywords, GI scores of 66 keywords are more than 0.5. Thus, most of keywords listed were on a increasing trend. The keywords that had lower GI scores than 0.5 were Webometrics, Sites, Search Engines, and Internet. All of these keywords were related to webometrics and they seemed on a decreasing trend.

5. Intellectual structure

5.1 Keyword map

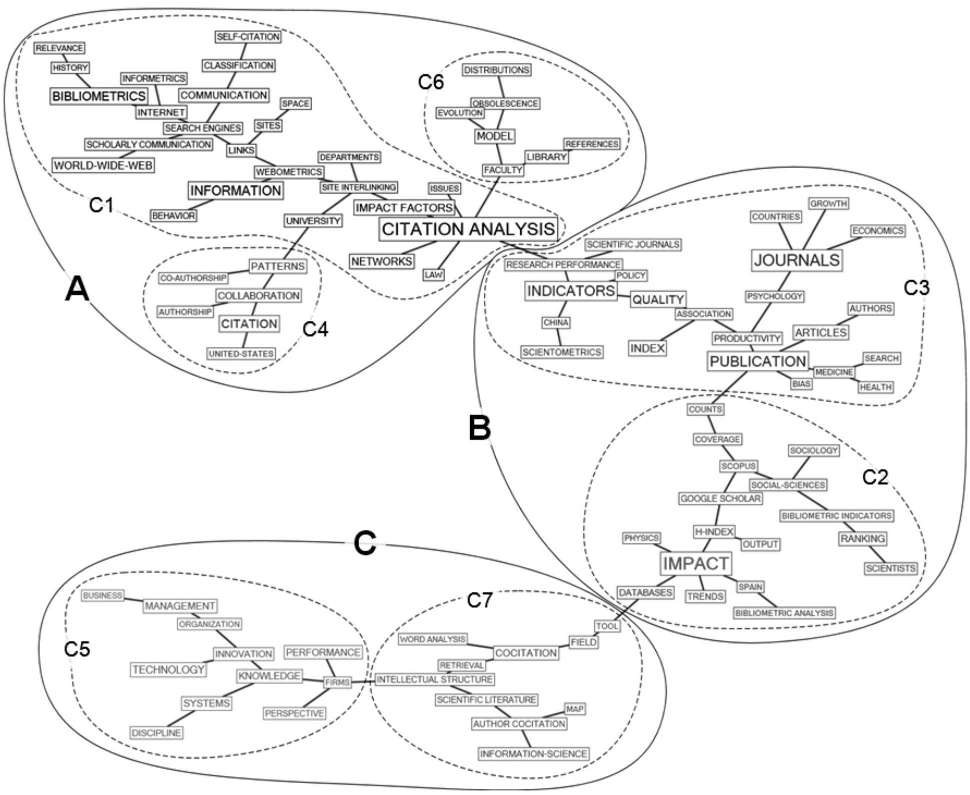
To identify a intellectual structure with keyword, co-word analysis was conducted with the controlled keywords which had appeared at least more than 12 times. Total number of keywords with the frequency above 12 is 99, but 'Science' was excluded from the analysis of keywords. As 'Science' appeared 304 times in the 17% the analyzed papers, it was considered a general term which could not be a determining factor for subject analysis. In result, co-occurrence of 98 keywords were analyzed.

In the first step of mapping keywords, co-occurrence vectors of keywords were generated. Using the vectors, we produced second-order correlation matrix and clustered it with a hierarchical clustering method, within group average clustering. The clustering result presented CBnet-WAVE of keywords in Figure 5. The number of generated clusters was determined at the threshold, 3 and 7 based on the coefficient of variation for the size of a cluster. In figure, the clusters generated at the threshold 3 were presented with A, B, and C. The sub-clusters at the threshold 7 were titled from C1 to C7.

According to figure 5, cluster A had three sub-categories: informetric theories (C6), webometrics (C1), and collaboration (C4). Cluster B seemd to be related to indicators and databases for evaluating research outputs, especially in the aspect of ranking. It consisted of two sub-clusters: a cluster about traditional journal evaluation (C3) and a cluster about new indicators and databases for research publication such as h-index, Scopus, Google Scholar (C2).

Cluster C was a research domain analysis area. It included research policy cluster (C5) and intellectual structure analysis in LIS (C7). In detail, research policy of C5 seemed to be more related the innovation and C7 contained various factors for intellectual analysis such as methodology, tools, and subjects.

Table 11 presented core keywords of each cluster.



〈Figure 5〉 Keyword clusters map using CB-net

〈Table 12〉 Core keywords of each cluster with authors and papers

Cluster		Core keywords	Related authors	Title of related papers
A	C1	• CITATION ANALYSIS • BIBLIOMETRICS • INFORMATION • IMPACT FACTORS • INTERNET	• Thelwall, M • Vaughan, L • Harries, G • Aguillo, IF • de Moya-Anegon, F	The connection between the research of a university and counts of links to its web pages: An investigation based upon a classification of the relationships of pages to the research of the host university
				Disciplinary differences in academic Web presence - A statistical study of the UK
				Do the Web sites of higher rated scholars have significantly more online impact?
				Interpreting social science link analysis research: A theoretical framework
				Comparative analysis of webometric measurements in thematic environments
	C4	• PATTERNS • COLLABORATION	• Thelwall, M • Harries, G	Hyperlinks as a data source for science mapping
				Quantifying the "goodness" of library history research: A bibliometric study of the 'Journal of Library History/Libraries & Culture'
	C6	• MODEL • OBSOLESCENCE • FACULTY	• White, HD • Egghe, L • Burrell, QL	Literature dynamics: Studies on growth, diffusion, and epidemics
				Symmetry and other transformation features of Lorenz/Leimkuhler representations of informetric data
				Scatter and obsolescence of journals cited in theses and dissertations of librarianship
B	C2	• IMPACT • H-INDEX • DATABASES • RANKING	• Thelwall, M • Daniel, HD • Willett, P • Oppenheim, C	Citation analysis and peer ranking of Australian social science journals
				Ranking of library and information science researchers: Comparison of data sources for correlating citation data, and expert judgments
				Using the Web for research evaluation: The Integrated Online Impact indicator
				Testing the calculation of a realistic h-index in Google Scholar, Scopus, and Web of Science for F. W. Lancaster
	C3	• PUBLICATION • JOURNALS • INDICATORS • ARTICLES • QUALITY	• Daniel, HD • Bornmann, L • Guan, JC • Smith, DR • Glanzel, W	Selecting manuscripts for a high-impact journal through peer review: A citation analysis of communications that were accepted by Angewandte Chemie International Edition, or rejected but published elsewhere
				A comparative study of research performance in computer science
				The actual citation impact of European oncological research
				The journal impact factor as a parameter for the evaluation of researchers and research
				Comparison and evaluation of domestic and international outputs in Information Science & Technology research of China
C	C5	• KNOWLEDGE • INNOVATION • MANAGEMENT	• Leydesdorff, L • Kostoff, RN • Debackere, K	What have scholars retrieved from Walsh and Ungson (1991)? A citation context study
				The scientometrics of a Triple Helix of university-industry-government relations
				Influencing scientists' collaboration and productivity patterns through new institutions: University research centers and scientific and technical human capital
	C7	• COCITATION • FIELD • AUTHOR COCITATION	• de Moya-Anegon, F • Glanzel, W • White, HD	Scholarly communication as a socioecological system
				Assessment of ontology-based knowledge network formation by Vector-Space Model
				Pathfinder networks and author cocitation analysis: A remapping of paradigmatic information scientists

It also provided representative authors and papers of the cluster.

Core keywords were extracted by two processes. In the first step, co-ccurrence matrix of keywords per cluster was generated. With the matrix, triangle betweeness centrality (Lee 2006c), a kind of weighted network centrality, was calculated per keyword. In the result of calculation, keywords with high scores were selected to represent the cluster which they belonged to. In addition, we investigated which papers contained the most keyword in the cluster and selected them as the representative papers for the cluster. The authors of them also became representative authors. The number of representatives was the square root of the number of keyword and it reflected the variation of cluster size. For example, the number of representative aufhors and papers for C1 is 5 because the cluster has 25 keywords.

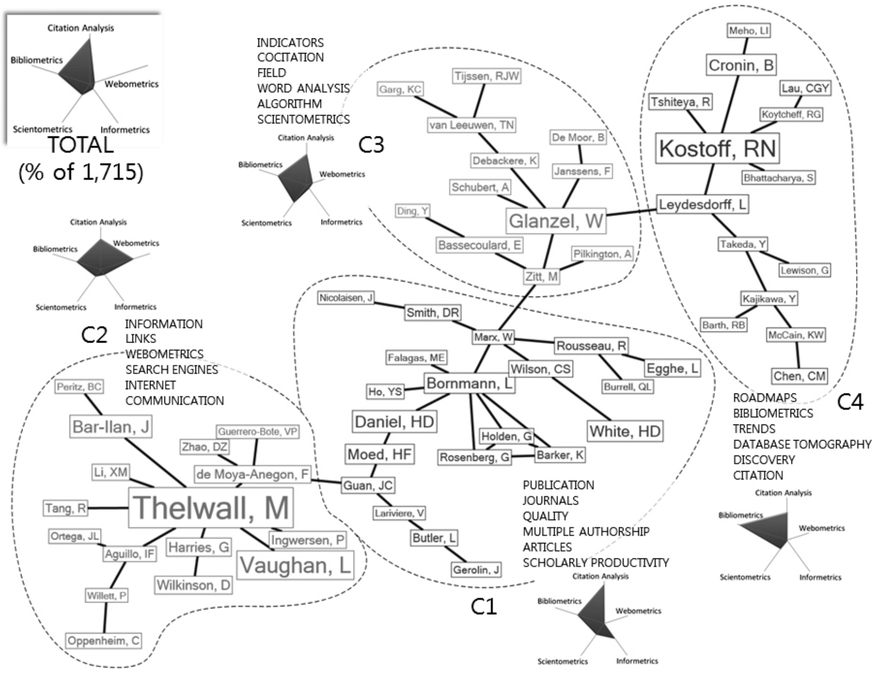
Mike Thelwall was selected as a representative author for three clusters showing his influence in the informetrics area. It proved that his researches widely ranged in this field. White, Harries, Glanzel, and de Moya-Anegon also represented two clusters.

5.2 Researcher map

To map researchers of informetrics, authors' name were collected from the author field of the 1715 articles. Commonly, the number of publications or citation are used to analyze relationship between authors or profile them (White & Griffith 1981; Lee 2008; Kim & Cho 2010; Lee, Kim, Ryoo 2010). However, in this study, hs-index was used to more effectively identify the influential authors among them because hs-index could combine the effect of both elements. Especially, hs-index is an effective tool to analyze the performance of researchers who were less cited due to the characteristics of their topics such as social scientists or researchers with domestic topics. Compared h-index, hs-index can more effectively analyze the research performance discriminating the influence of most cited papers. According to the hs-index of authors, top 62 authors were selected. With these authors, we generated a Pathfinder network of major researchers.

As seen in the figure 6, major researchers who had several links were M. Thelwall (8 links) in the cluster 2, L. Bornmann (7 links) in the cluster 1, W. Glanzel (5 links) in the cluster 3 and R.N. Kostoff (5 links) in the cluster 4. They were hubs of each cluster. Furthermore, this map presented authors who played a role of bridge between cluster. F. de Moya-Anegon and J.C. Guan connected C1 to C2 while W. Marx and M. Zitt, did C1 to C3. L. Leydesdorff also linked C3 to C4. It means that they researched both topics or the topic of their researches lied on the boarder of each cluster.

To show research topics of each cluster, core keywords were presented on the figure 5 next to the cluster which they belonged to. The core keywords were chosen in two steps. At first, the average frequency of keywords assigned to the authors within a cluster was examined. Then, the average frequency of keywords assigned to all authors was calculated. The score for major keywords per cluster was generated with a average keyword frequency for authors



<Figure 6> Pathfinder network of researchers

of the cluster subtracted from the average keyword frequency for all authors. By this means, the map could present innate topics of each cluster avoiding the emergence of a universal topic terms, such as 'Science.'

Table 12 listed the ration of the query result per each cluster. While the ratio of papers searched by 'citation analysis' was similar in each cluster, those of other queries changed according to the clusters. C1 had more papers searched by the query term 'Informetrics' than other query terms. C4 contained 'Bibliometrics' papers most and 'Scientometrics' seemed to be dominant in C3. Compared with others, the ratio of 'Bibliometrics' in C4 was quite high. It means than majority of bibliometrics researches appeared in C4. Each radial graph for the status

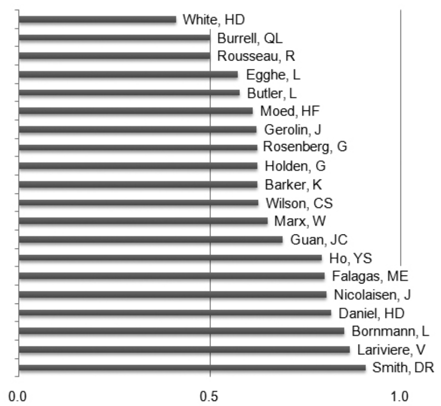
<Table 13> The ratio of the query result per cluster

Query	C1	C2	C3	C4	% of 1715
Citation Analysis	53.7%	41.8%	42.4%	37.9%	53.4%
Bibliometrics	38.0%	34.3%	41.3%	67.4%	38.5%
Scientometrics	18.0%	11.4%	29.3%	14.4%	15.0%
Informetrics	24.9%	8.5%	5.4%	0.8%	6.3%
Webometrics	0.5%	46.8%	8.7%	0.0%	5.7%

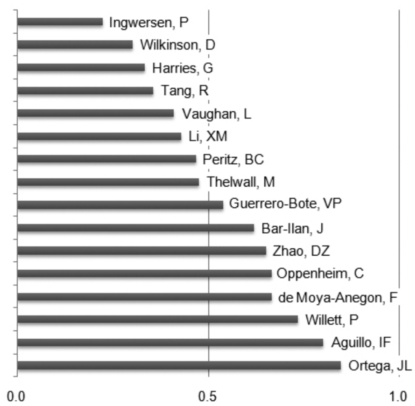
of 5 query terms was presented next to the cluster in figure 6.

Overall C1 is the research area for citation analysis on publications and L. Bornmann is the hub author. In C2, M. Thelwall is the landmark node and major research topics of authors connected to him are webometircs and internet. W. Glanzel is the hub of C3 and various topics appear comparatively evenly in this cluster. C3 also includes methodology for scientometrics such as co-citation and word analysis. C4 is the category for analysis of R&D strategy in the bibliometrics area and R. N. Kostoff is the landmark node.

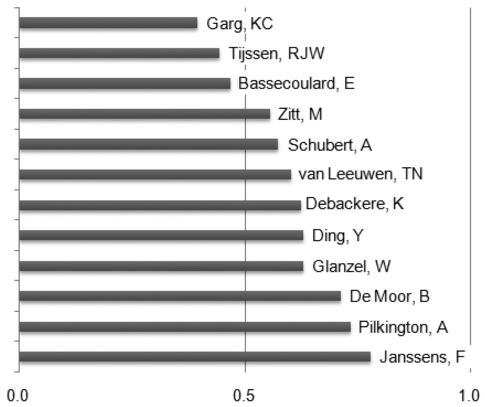
Figure 7 illustrated the growth of each researcher with GI. Researchers with significant GI scores were presented in each cluster. In C1, all researchers except H.D. White were on the increasing trend with GI scores higher than 0.5. The author with the highest GI score was D.R. Smith, followed by V. Lariviere, L. Bornmann, H.D. Daniel, J. Nicolaisen, and M.E. Falagas. These six followers showed notable research



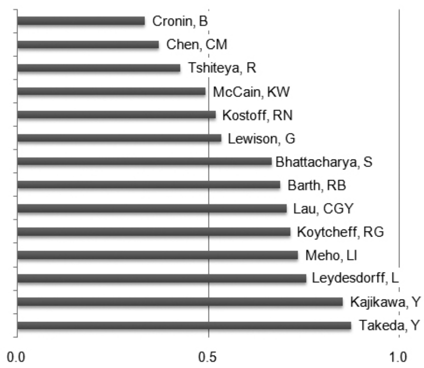
(a) GI of researchers in C1



(b) GI of researchers in C2



(c) GI of researchers in C3



(d) GI of researchers in C4

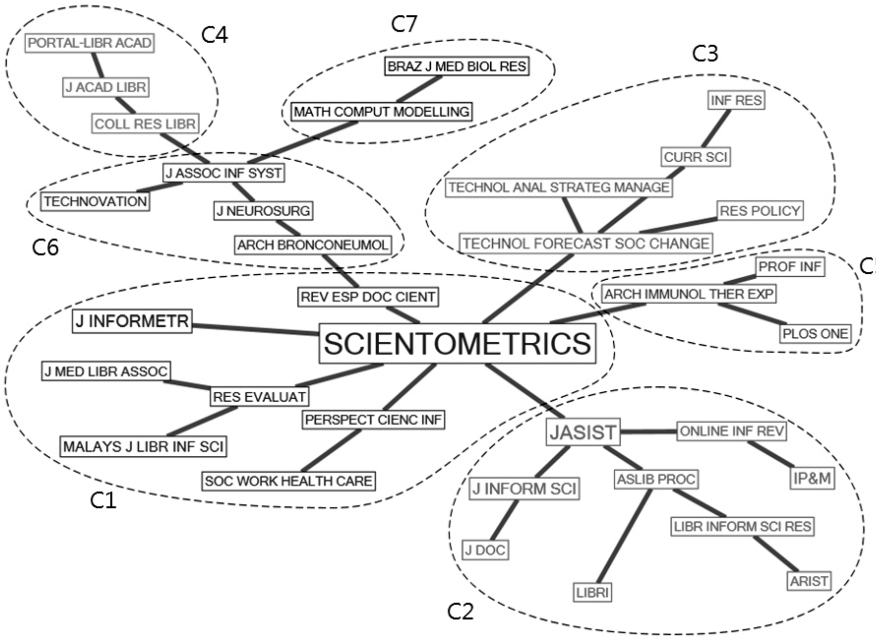
〈Figure 7〉 Researchs' GI by clusters

growth with GI scores higher than 0.8. On the contrary, C2 did not have many researchers with high GI Scores. Only two researchers had GI scores higher than 0.8 and 50% of all researchers were below the 0.5 In C3, 75% of researchers were above 0.5 but no authors with GI score higher than 0.8 appeared. In C4, Y. Takeda and Y. Kajikawa showed GI scores higher than 0.8 and 71.4% of all researchers were above the 0.5. Overall, the researchers of C1 showed most significant growth but the researchers of C2 seemed to be on the decreasing trend.

5.3 Journal map

For journal analysis, 34 journals were selected by the number of papers in the collection. Each journal contained at least 6 papers. To present a journal map of informetrics areas, journal profiling method was applied. Journal proximity matrics were generated with cosine similarity between journal keyword vectors. Using the matrix, centroid clustering and CBnet algorithm produced a structural network with 7 clusters.

The lankmark node of the journal network is '*Scientometircs*', which is also a main node of C1 in fugure 3. '*Scientometircs*' is shown to have expanded to 7 neighbor journals, *Revista Española de Documentación Científica, Journal of Informetrics, Research Evaluation, Perspectivas em Ciência da Informação, Journal of the American Society for Information Science and Technology, Archivum Immunologiae et Therapia Experimentalis*, and *Techno-*



〈Figure 8〉 Centroid clustering-based network (CBnet-CENT) of journals with 7 clusters *logical Forecasting and Social Change*. It is also a central node connected to 3 other clusters.

In C2, *JASIST* is a main node which is connected to *Journal of Information Science*, *ASLIB proceedings* and *Online Information Review*. Besides these clusters, clusters from C3 to C7 have no special landmark node. Most of keywords in the clusters are connected linearly.

The representative keywords assigned to a journal cluster are shown in Table 13 and the number of keywords is determined by the number of journals in the cluster. C1 have keywords related to citation analysis such as impact, publications, and indicators because it includes two major journals, *Scientometrics* and *Journal of Informetrics*. Many researches published in these journals were focused on citation analysis and impact of publication. In C2, core journals in library and information scinece such as *JASIST* and *IP&M* appeared with keywords information, internet, and communication. The focus of this cluster is webometrics as it is described by major keywords. Due to the journals of the science policy area, C3 contains innovation and technology. The main keyword for C4 is library and several journals of the library science appear in this cluster. Therefore C4 is a cluster for the library science. The subject area identified in C5 is research output evaluation with citation and C6 is a subject area where impact and ranking of journals were actively studied. Finally, C7 is a subject cluster related the ranking of scientist.

〈Table 14〉 Journal clusters and related keywords

Cluster		Journals	Related keywords
ID	Size		
C1	8	SCIENTOMETRICS, J INFORMETR, REV ESP DOC CIENT, MALAYS J LIBR INF SCI, RES EVALUAT, J MED LIBR ASSOC, SOC WORK HEALTH CARE, PERSPECT CIENC INF	SCIENCE, INDICATORS, IMPACT, PUBLICATION, CITATION ANALYSIS, JOURNALS, INFORMATION, CITATION
C2	9	JASIST, J INFORM SCI, J DOC, IP&M, ONLINE INF REV, ASLIB PROC, LIBRI, ANNU REV INFORM SCI TECH, LIBR INFORM SCI RES	SCIENCE, CITATION ANALYSIS, INFORMATION, IMPACT, BIBLIOMETRICS, INTERNET, COMMUNICATION, INFORMATION-SCIENCE, IMPACT FACTORS
C3	5	TECHNOL FORECAST SOC CHANGE, RES POLICY, TECHNOL ANAL STRATEG MANAGE, CURR SCI, INF RES	SCIENCE, BIBLIOMETRICS, INNOVATION, INDICATORS, TECHNOLOGY
C4	3	COLL RES LIBR, J ACAD LIBR, PORTAL-LIBR ACAD	JOURNALS, PATTERNS, LIBRARY
C5	3	PROF INF, ARCH IMMUNOL THER EXP, PLOS ONE	INDEX, CITATION, OUTPUT
C6	4	TECHNOVATION, J ASSOC INF SYST, ARCH BRONCONEUMOL, J NEUROSURG	JOURNALS, CITATION ANALYSIS, RANKING, IMPACT
C7	2	MATH COMPUT MODELLING, BRAZ J MED BIOL RES	RANKING, SCIENTISTS

6. Conclusion

This study identified the structure and infrastructure of the informetrics using statistical and profiling methods. The major finding follows as below.

A significant increase began in 2007. From 2007 to 2010 is an important period for informetrics researchers because the number of papers published in 2007 doubled in 2010.

USA published the most informetrics researches, followed by the European countries like UK and Spain. USA and England achieved dominant positions from the both aspects, the number of papers and citations. However, Netherlands, Denmark, Hungary and Israel showed they had a considerable impact on the informetrics research with comparatively small number of papers.

The most productive institution in informetrics area was Wolverhampton Univ in England, due to one of the most active researchers, M. Thelwall. He published 52 papers, which was 98% of all published papers from this institution. M. Thelwall was also the most productive author in the entire metrics fields and the author in the second place was Ronald. N. Kostoff from MITRE, USA.

The dominant subject class for informetrics publications was 'Information Science & Library Science', which was identified with the number of papers. GI index analysis also showed emerging subject areas for informetrics publication. The high GI scores of 'Nursing' and 'Environmental Sciences' showed a significant growth in informetrics research productivity.

In the analysis of informetrics structure by keywords, seven subject areas were identified: webometrics, new indicators and databases, journal evaluation, collaboration, research policy, informetric theories, and intellectual structure analysis in LIS.

As identified in the statistical analysis of researchers' productivity, M. Thelwall was the landmark node in the researcher network. He was linked 8 significant researchers, followed by L. Bornman, W. Glanzelm and R.N. Kostoff. They were major authors to represent each area of informetrics. However, in the aspect of growth index scores, M. Thelwall did not seem to be on the increasing trend.

In the journal map, '*Scientometrics*' was a key stone of the journal network. It was a main node expanded to 7 neighbor journals and 3 other clusters. Based on the intellectual structure analysis of journals, 7 subject areas were identified: citation analysis and impact of publication, webometrics, science policy, library science, research output evaluation, impact of journals, and scientists' ranking.

This study endeavors to provide a comprehensive view on the metrics areas. Furthermore, it suggested various informetrics methods for domain analysis. As a conclusion, a diversity in the analysis of this study contributed to identify major contributors and subject areas in the perspective of informetrics.

References

Bar-Ilan, J. 2008. "Informetrics at the beginning of the 21st century: A review." *Journal of Informetrics*, 2(1): 1-52.

Brookes, B. C. 1990. "Biblio-, Sciento-, Infor-metrics? What are we talking about?" In *Informetrics 89/90. Selection of Papers Submitted for the Second International Conference on Bibliometrics, Scientometrics and Informetrics, Amsterdam*, edited by L. Egghe, R. Rousseau. Netherlands: Elsevier, 31-43.

Garfield, E. E. 1955. "Citation indexed for science-new dimension in documentation through association of ideas." *Science*, 122(3159): 108-111.

Glänzel, W. and U. Schoepflin. 2001. "Two decades of SCIENTOMETRICS." *Scientometrics*, 50(2): 301-312.

Godin, B. 2005. "Measurement and statistics on science and technology: 1920 to the present." *Proceedings of the 11th DIS Annual Conference 2010*, 2nd-3rd September, Richardsbay, University of Zululand, South Africa.

Hirsch, J. E. 2005. "An index to quantify an individual's scientific research output." P*roceedings of the National Academy of Sciences of the United States of America*, 102(46): 16569-16572.

Hood, W. W. and C. S. Wilson. 2001. "The literature of bibliometrics, scientometrics, and informetrics." *Scientometrics*, 52(2): 291-314.

Kim, Hee-Jeon and Hyun-Yang Cho. 2010. "A study on intellectual structure using author co-citation analysis and author bibliographic coupling analysis in the field of social welfare science." *Journal of the Korean Society for Information Management*, 27(3): 283-306.

Lee, Jae Yun. 2006a. "Towards a new method for examining current domestic intellectual structure of knowledge domains." *Proceeding of the 13th Annual Conference of Korean Society for Information Management*, 145-152.

Lee, Jae Yun. 2006b. "A novel clustering method for examining and analyzing the intellectual structure of a scholarly field." *Journal of the Korean Society for Information Management*, 23(4): 215-231.

Lee, Jae Yun. 2006c. "Centrality measures for bibliometric network analysis." *Journal of the Korean Society for Library and Information Science*, 40(3): 191-214.

Lee, Jae Yun. 2007. "Making a science map of Korea." *Journal of the Korean Society for Information Management*, 24(3): 363-383.

Lee, Jae Yun. 2008. "Bibliographic author coupling analysis: A new methodological approach for identifying research trends." *Journal of the Korean Society for Information Management*, 25(1): 173-190.

Lee, Jae Yun, Hee-Jeon Kim, and Jong-Duk Ryoo. 2010. "Examining the intellectual structure of housing studies in Korea with text mining and factor analysis." *Journal of the Korean Society for Library and Information Science*, 44(2): 285-308.

Lee, Jae Yun, Heejung Kim, and Pan Jun Kim. 2010. "Domain analysis with text mining: Analysis of digital library research trends using profiling methods." *Journal of Information Science*, 36(2): 144-161.

Lee, Jae Yun, Pan Jun Kim, Dae-Shin Kang, Heejung Kim, So-Young Yu, and Woo Hyoung Lee. 2011. "Bibliometric analysis on LED research trends." *Journal of Informaton Management*, submitted.

Morris, Steven A. and Betsy Van der Veer Martens. 2008. "Mapping research specialties." *Annual Review of Information Science and Technology*, 42: 213-295. Edited by Blaise Cronin. Medford, NJ: Information Today.

Ryoo, Jong-duk and Eun-Ju Choi. 2011. "A comparison test on the potential utility between Author Profiling Analysis (APA) and Author Co-Citation Analysis (ACA)." *Journal of the Korean Society for Information Management*, 28(1): 123-144.

Schvaneveldt, R. W. (ed.) 1990. *Pathfinder Associative Networks: Studies in Knowledge Organization.* Norwood, NJ: Ablex.

Tague-Sutcliffe, J. M. 1992. "An introduction to informetrics." *Information Processing & Management*, 28(1): 1-3.

White, Howard D. and Belver C. Griffith. 1981. "Author cocitation: A literature measure of intellectual structure." *Journal of the American Society for Information Science*, 32(3): 163-171.

Wouters, P. 1999. '*The Citation culture*.' Ph.D dissertation. Department of Science Dynamics, Faculty of Chemistry, University of Amsterdam.