

Journal as markers of intellectual space: Journal co-citation analysis of Information Retrieval area, 1987–1997

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A journal co-citation analysis of fifty journals and other publications in the information retrieval (IR) discipline was conducted over three periods spanning the years of 1987 to 1997. Relevant data retrieved from the *Science Citation Index* (SCI) and *Social Science Citation Index* (SSCI) are analysed according to the highly cited journals in various disciplines, especially in the *Library & Information Science* area. The results are compared with previous research that covered the data only from the *Social Science Citation Index* (SSCI). The analysis reveals that there is no distinct difference between these two sets of results. The results of current study show that IR speciality is multi-disciplinary with broad relations with other specialities. The field of IR is a mature field, as the journals used for research communication remained quite stable during the study period.

Introduction

Publication is an integral part of the scholarly process that would be rendered incomplete and valueless without it. Journal becomes an important forum to present latest research findings and contributions towards the scientist's prestige and reputation. Its history indicates the contribution of science and scholarly research. Journal's outputs contribute not only to the progress of the discipline as a science but to the wider community as well (*Doreian*, 1988). Professional scientific journals are a vital channel in the communication system of contemporary science (*Ziman*, 1968). Thus, evaluating journals with respect to their importance within the framework of formal scientific communication is necessary.

Journals as one of scholarly media to disseminate scholarly information are critical to an academic discipline. Information Retrieval (IR) field is a discipline concerned with the representation, storage, organisation, and accessing of information systems (*Salton and McGill*, 1983). The rapid developments in 1980s and 1990s in the form of personal

computers, networking, Internet has results in the arrival of the "information highway", that is characterised by a rapid increase in the number and variety of information sources in different media. Efficient use of these information resources and the means of choosing the 'best' information are becoming increasingly significant. There are a number of journals that are the primary formal channels for communicating theories, methods, and empirical results to the IR scientific communities. Thus, they may usefully indicate changing research fronts and disciplinary transitions. The citations at the journal level should reflect longer-term, more underlying changes or stability in the relationships within and between disciplines.

Bibliometric method, demonstrating subject relatedness, is a delectable way of studying the organisation of specific disciplines (*White and McCain, 1989, Everett and Pecotich, 1991*). In the early 1970s, *Small (1973)* introduced the concept of co-citation analysis as a potentially productive method of examining the cognitive/intellectual structure of scientific specialities. From then on, communication patterns of scientific specialities have been studied in terms of co-citations among authors, articles, journal or keywords (*Small and Griffith, 1974; McCain, 1984 and 1991; Braam et al., 1991*). Journal co-citation analysis can help the researcher to study the structure of scholarly disciplines through the published literature (*McCain, 1991*). In a number of studies, it has been shown that journal-to-journal citations can be used as an operational indicator for the disciplinary organisation of the sciences (e.g. *Doreian, 1988; Tijssen and van Raan, 1990; Everett and Pecotich, 1991; McCain, 1991; Borgman and Rice, 1992; Leydesdorff and Cozzens, 1993*).

The objective of this study is to map the journal's role in the scholarly communication process of the IR field and its changes over time by using journal co-citation analysis during the period of 1987–1997. The preliminary version of this paper has been presented in the 7th ISSI conference (*Ding et al., 1999*). The data used in that study were only based on the *Social Science Citation Index*. Subsequently, in order to explore the virtual scholarly communication of IR field, we extended our data set by including data from the *Science Citation Index (SCI)*. This paper reports the journal co-citation study based on this new additional set of data. Some results are found to be slightly different from those reported earlier in the conference, and these differences have been discussed whenever appropriate.

This study has been conducted from two angles: one from the journals from various disciplines which were highly cited by IR researchers and the other specifically from the library and information science journals which were highly cited by IR researchers. Thus, this study not only traces the scholarly communication positions of the journals in IR field but also shows the status of Library and Information Science journals in the IR field.

Method

Data gathering

In the previous research (Ding et al., 1999), data were collected from the *Social Science Citation Index* (SSCI) for the period of 1987-1997. In the current study, this data set is extended by including data from *Science Citation Index* (SCI) for the same period. In total, 3,325 source papers were selected from 971 source journals with 78,785 citations during the period of 1987-1997. Two databases (Source Database and Citation Database) were set up based on these IR papers.

Selection of journals

Fifty highly cited journals (including some highly cited regular annual publications and proceedings, henceforth called VAR journals) from different specialties were selected as the VAR journal sample (Table 1). Fifty highly cited Library and Information Science journals (including some highly cited regular annual publications and proceedings, henceforth called LIS journals) were selected as the LIS journal sample (Table 2). The criteria to identify LIS journals are based on its existence in the LISA CD-ROM (*Library and Information Science Abstracts*) and the journal's research scope. Some journals have changed their names during this 11-year period and these journals are normalised by using current new names. All the 50 highly cited VAR journals and LIS journals were checked for journal name changes according to ISI's journal name change lists and journal databases of Nanyang Technological University & National University of Singapore.

Retrieval of co-citation frequencies and compilation of raw co-citation matrix

The co-cited journal retrieval is based on Citation Database (mentioned previously). Each of the journals in the journal set (Table 1 or Table 2) was searched. The frequency with which each journal was co-cited with the other journals in the same set was obtained through the intersection of all possible $(n(n-1)/2)$, where $n=50$. Then a specifically built Foxpro program transferred these pairs of co-citation frequencies into raw data matrix, so that two 50×50 raw data matrix of VAR journal and LIS journal can be obtained automatically.

Table 1
Fifty highly cited VAR journals by IR researchers

Journal name	Citation frequency	Acronym
<i>Journal of the American Society for Information Science</i>	2461	JASIS
<i>Information Processing & Management</i>	2051	IPM
<i>Psychological Review</i>	1090	PSY REV
<i>Proceedings of the Annual International ACM SIGIR Conference</i>	1066	SIGIR
<i>Communications of the Association for Computing Machinery</i>	956	COMM ACM
<i>Optics Letters</i>	901	OPT LETT
<i>Journal of Documentation</i>	867	J DOC
<i>Journal of Experimental Psychology: Learning, Memory, and Cognition</i>	766	J EXP PSY LEA
<i>Applied Optics</i>	575	APPL OPTICS
<i>Science</i>	541	SCIENCE
<i>Journal of Verbal Learning and Verbal Behavior</i>	527	J VERB LEARN VERB BE
<i>Memory & Cognition</i>	521	MEM COGNITION
<i>Proceedings of the ASIS annual meeting</i>	500	P ASIS
<i>Applied Physics Letters</i>	489	APPL PHYS LETT
<i>Journal of Applied Physics</i>	473	J APPL PHYS
<i>IEEE Transactions on Magnetics</i>	451	IEEE T MAGN
<i>Journal of Personality and Social Psychology</i>	404	J PERS SOC PSYCHOL
<i>International Journal of Man-machine Studies</i>	374	INT J MAN MACH STUD
<i>Annual Review of Information Science and Technology</i>	364	ANN REV INF SCI
<i>Physical Review</i>	343	PHYS REV
<i>Nature</i>	342	NATURE
<i>Journal of Experimental Psychology: General</i>	316	J EXP PSY GEN
<i>Journal of Information Science</i>	290	J INFO SCI
<i>Journal of Experimental Psychology: Human Learning and Memory</i>	284	J EXP PSY HUM
<i>Journal of the Optical Society of America</i>	268	J OPT SOC AM
<i>Cognitive Psychology</i>	266	COGN PSY
<i>Physical Review Letters</i>	246	PHYS REV LETT
<i>Proceedings of the National Academy of Science of USA</i>	243	P NATL ACAD SCI USA
<i>ACM Transactions on Database Systems</i>	240	ACM T DATA SYS
<i>Journal of Experimental Psychology</i>	240	J EXP PSY
<i>Journal of Memory and Language</i>	239	J MEM LANG
<i>Journal of Chemical Information and Computer Sciences</i>	229	J CHEM INF COMP SCI
<i>Optical Communication</i>	226	OPT COMMUN
<i>ACM Transactions on Information Systems</i>	225	ACM T INFO SYS
<i>Psychological Bulletin</i>	212	PSY BULL
<i>Journal of the American Chemical Society</i>	198	J AM CHEM SOC
<i>Library Quarterly</i>	190	LIBR Q
<i>Online and CD-ROM Review</i>	186	ONLINE CDROM REV
<i>Computer</i>	181	COMPUTER
<i>Artificial Intelligence</i>	170	ARTIF INTELL
<i>IEEE Transactions on Software Engineering</i>	167	IEEE T SOFTWARE ENG
<i>Neuropsychologia</i>	159	NEUROPSYCHOLOGIA
<i>Proceedings of Annual Symposium on Computer Applications in Medical Care</i>	158	P ANN S COMP AP
<i>Computer Journal</i>	158	COMPUT J
<i>IEEE Transactions on System, Man, and Cybernetics</i>	154	IEEE T SYST MAN CYB
<i>Bulletin of the Medical Library Association</i>	151	B MED LIBR ASS
<i>IEEE Transactions on Information Theory</i>	140	IEEE T INFO THEO
<i>Journal of the Association for Computing Machinery</i>	139	J ACM
<i>Brain Research</i>	137	BRAIN RES
<i>Chemical Physics Letters</i>	136	CHEM PHYS LETT

Table 2
Fifty highly cited LJS journals by IR researchers

Journal name	Citation frequency	Acronym
<i>Journal of the American Society for Information Science</i>	2461	JASIS
<i>Information Processing & Management</i>	2051	IPM
<i>Proceedings of the Annual International ACM SIGIR Conference</i>	1066	SIGIR
<i>Journal of Documentation</i>	867	J DOC
<i>Proceedings of the ASIS annual meeting</i>	500	P ASIS
<i>International Journal of Man-Machine Studies</i>	374	INT J MAN MACH STUD
<i>Annual Review of Information Science and Technology</i>	364	ANN REV INF SCI
<i>Journal of Information Science</i>	290	J INFO SCI
<i>Journal of Chemical Information and Computer Sciences</i>	229	J CHEM INF COMP SCI
<i>ACM Transactions on Information Systems</i>	225	ACM T INFO SYS
<i>Library Quarterly</i>	190	LIBR Q
<i>Online CD-ROM Review</i>	186	ONLINE CDROM REV
<i>Artificial Intelligence</i>	170	ARTIF INTELL
<i>Bulletin of the Medical Library Association</i>	151	B MED LIBR ASS
<i>Library Information Science Research</i>	130	LISR
<i>Program: Automated Library and Information Systems Online</i>	122	PROGRAM
<i>Online</i>	120	ONLINE
<i>Canadian Journal of Information and Library Science</i>	120	CANA J INFO SCI
<i>RQ</i>	114	RQ
<i>Information Systems</i>	114	INFO SYS
<i>Information Technology and Libraries</i>	110	INFO TECH LIBR
<i>College & Research Library</i>	108	COLL RES LIB
<i>Knowledge Organization</i>	107	KNOW ORGAN
<i>Database</i>	94	DATABASE
<i>Library Trends</i>	94	LIBR TRENDS
<i>Library Resources & Technical Services</i>	91	LIBR RESO TECH SER
<i>Cataloging & Classification Quarterly</i>	90	CATA CLASS Q
<i>ASLIB Proceedings</i>	89	ASLIB P
<i>Electronic Library</i>	83	E LIBR
<i>TREC</i>	79	TREC
<i>Methods of Information in Medicine</i>	69	METHOD INFORM MED
<i>International Journal of Information Management</i>	65	INT J INFO MANA
<i>Byte</i>	66	BYTE
<i>Library Hi Tech</i>	65	LIBR HI TECH
<i>IEEE Expert</i>	57	IEEE EXPERT
<i>Journal of Academic Librarianship</i>	54	J ACAD LIBR
<i>AI Magazine</i>	53	AI MAG
<i>Scientometrics</i>	47	SCIENTOMETRICS
<i>Journal of the American Medical Informatics Association</i>	47	J AM MED INFO ASS
<i>Libri</i>	37	LIBRI
<i>Library Journal</i>	35	LIBR J
<i>Hypermedia</i>	34	HYPERMEDIA
<i>Special Libraries</i>	33	SPEC LIBR
<i>School Library Media Quarterly</i>	33	SCH LIBR MEDIA Q
<i>Information Services & Use</i>	32	INFO SERV & USE
<i>Drexel Library Quarterly</i>	28	DREXEL LIBR Q
<i>Emedia Professional</i>	28	CDROM PROFESSIONAL
<i>Journal of Librarianship and Information Science</i>	26	J LIBR
<i>American Libraries</i>	25	AM LIBR
<i>Law Library Journal</i>	24	LAW LIBR J

Conversion to correlation matrix

In the raw co-citation matrix, the off-diagonal cells were filled with raw co-citation frequencies of row and column journals, which makes the upper and lower half-matrices identical. We treated the diagonal cells of the matrix as missing data. Then, Pearson's correlation coefficients with pairwise deletion were used to convert raw co-citation matrix into a correlation matrix.

Multivariate analysis of correlation matrix

When raw data matrix is converted into a correlation matrix, multivariate methods can be used to analyse the correlation matrix. In general, two approaches of multivariate analysis have been used to display the inter-journal relationships, namely: cluster analysis and multidimensional scaling (McCain, 1991).

In multidimensional scaling techniques (MDS), SPSS's ALSCAL (Norusis, 1997) was chosen to scale the correlation matrix with 0.001 S-stress convergence, 0.005 Minimum S-stress value and 30 Minimum iterations. In cluster analysis, agglomeration schedule with Ward's method is chosen as the statistics of hierarchical clustering analysis. Each cluster was named based on the nature and research scope of these journals in the cluster.

Results

Different journals display different status in specific specialties. In this paper, we shall discuss the journal's role in the scholarly communication process of IR field from two points of view. First, is the role of the journals from various disciplines, which were highly cited by IR researchers. Second is the LIS journals' role in the IR field and their changes over time.

VAR journals

In order to exhibit the VAR journals' scholarly communication positions during the whole period of 1987–1997 and their changes over this period, the Multidimensional scaling maps for the whole 11-year period and for two different periods (1987–1991, 1992–1997) were generated by SPSS with good fit (Figs 1, 2 and 3). So that not only the general overview of the IR field during the whole 11-year period but also its changes

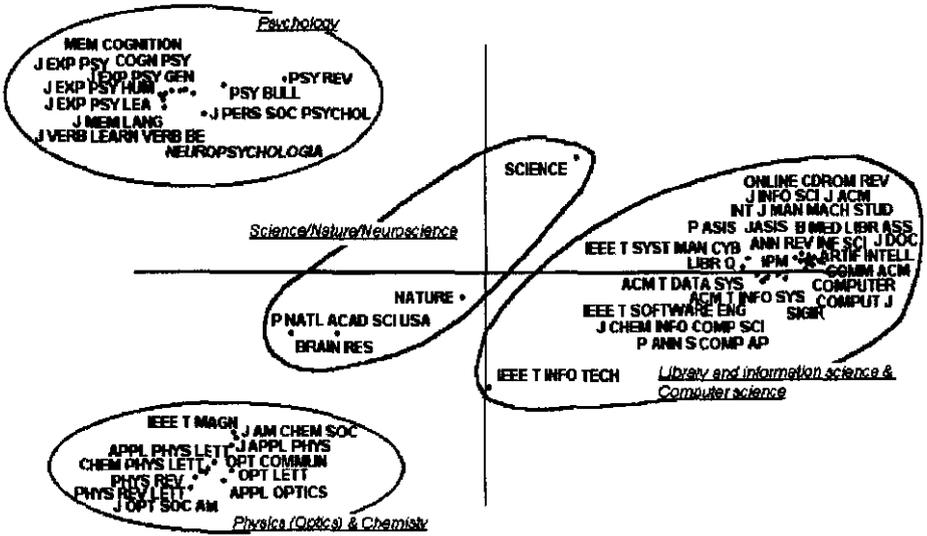


Fig. 2. MDS map of VAR journals highly cited in IR research (1987-1991)

The two periods' MDS maps are more or less similar as the whole 11-year period MDS map. The positions of these groups also do not shift much. Psychology, and Physics (Optics) & Chemistry groups occupy the left side of the map, and Library and Information Science & Computer Science group the right part of the map. Only the position of Science/Nature/Neuroscience group during the 1987-1991 period is slightly different from that of the two other time periods.

Most of the journals' positions did not change much during the three periods, especially the whole 11-year period and 1992-1997 period. Furthermore, the LIS & computer science group itself seems to be rather stable both in terms of its composition, and in terms of its relation to relevant environments. All these demonstrate the stability of IR field during the period of 1987-1997. Although the psychology group, Science/Nature/Neuroscience group and Physics (Optics) & Chemistry group are separated far away from Library and Information Science & Computer Science group in the two opposite side of the map, the fixed locations of these groups form the stable intellectual structure of multidisciplinary characteristics of IR field.

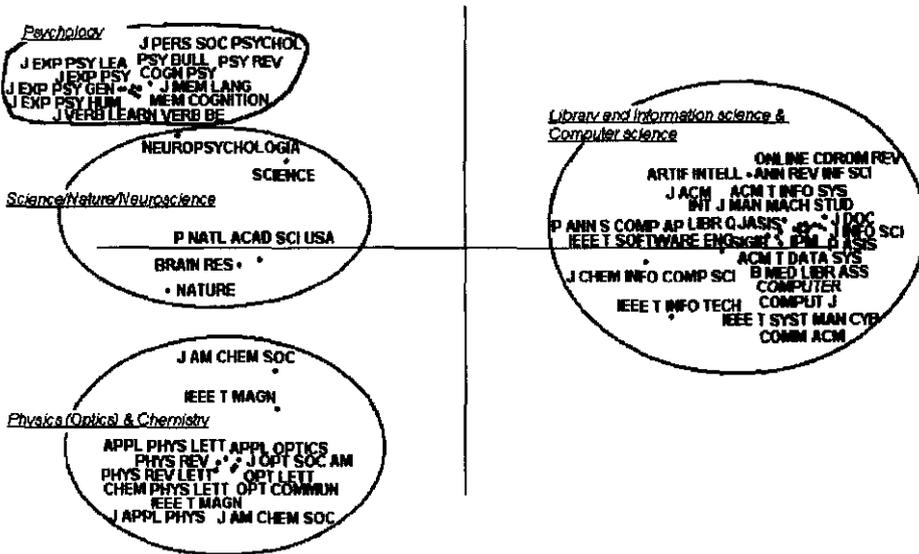


Fig. 3. MDS map of VAR journals highly cited in IR research (1992-1997)

Comparing with the maps (see Appendix, Figs A1, A2 and A3) produced in previous research based only on SSCI data only (Ding et al., 1999), we can identify a new cluster (physics (optics) & chemistry) that has surfaced in the current research as a result of including the SCI data. In addition, the Computer Science group and Library and Information Science group have merged together. The positions of clusters and also the other journals in three periods' maps were almost the same in both researches.

Based on the cited VAR journals (Figs 1, 2 and 3) by IR researchers, we can find that journals from Library and Information Science, Psychology, Physics, Chemistry and Computer Science areas are most prominently present during each period. This suggests that IR is strongly related to Computer Science, Physics, Chemistry, Psychology, and Neuroscience whose techniques are increasingly used as methods in IR specialty. Besides that, we can also find journals from theory-oriented disciplines, such as, Cognitive Science, Neuroscience and so on, and journals from application-oriented disciplines such as, Medical Science, Chemical Science, Physics, Computer Science, and so on.

The interesting point is that areas represented by VAR journals are very broad (Figs 1, 2 and 3), and even include Management Science, Consumer Science, Gerontology, Medical Science, Optical Science, Magnetic Science and so on. This indicates that IR techniques are more and more used in other specialties, at the same time, more and more techniques from numerous specialties are bestowed in the IR field. This shows the multi-disciplinary nature of the IR specialty.

LIS journals

Fifty highly cited LIS journals were selected as the research sample (Table 2). Similar data processing techniques, mentioned in the above for the VAR journals, were used to generate journal co-citation maps for three different periods (1987–1997, 1987–1991, 1992–1997) in order to mark LIS journals' role in the IR field and their changes over time (Figs 4, 5 and 6).

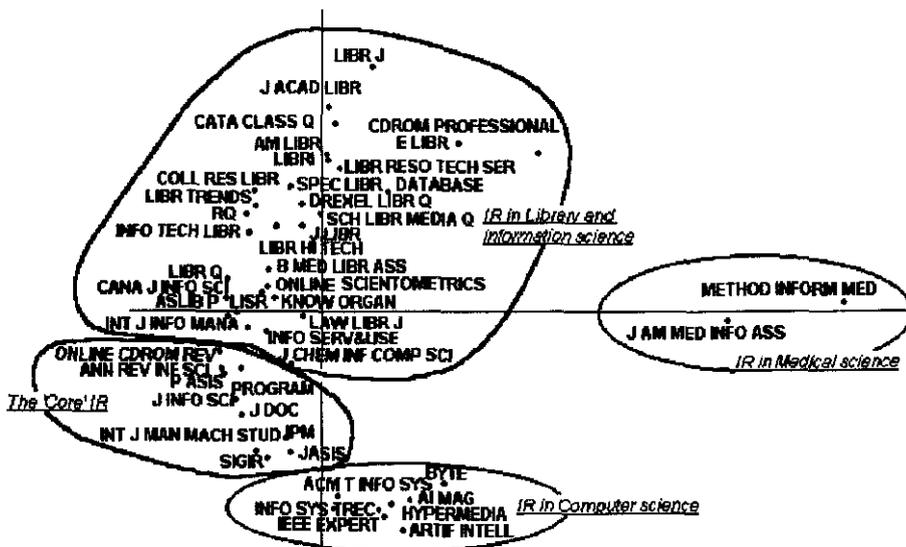


Fig. 4. MDS map of LIS journals highly cited in IR research (1987–1997)

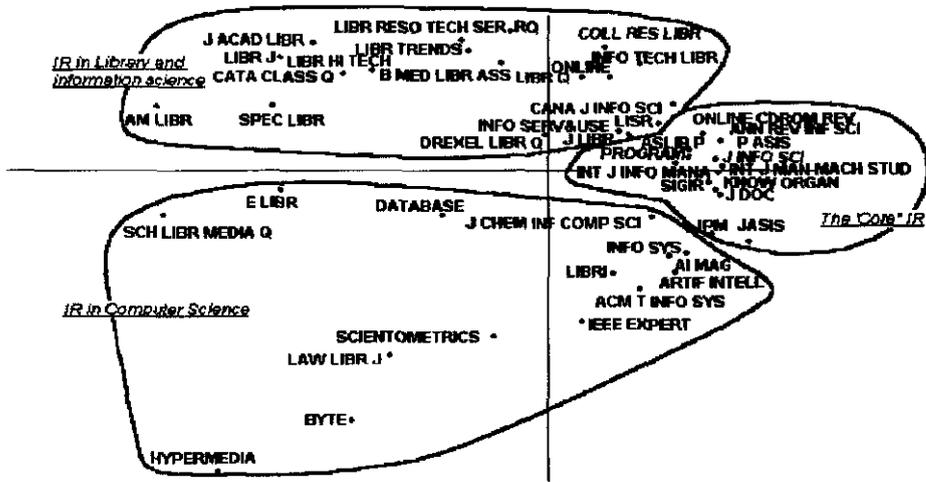


Fig. 5. MDS map of LIS journals highly cited in IR research (1987-1991)

Figure 4 shows the information about the LIS journals' role in the scholarly communication process of IR field during the whole 11-year period. *CD-ROM Professional*, *Journal of the American Medical Informatics Association*, *Methods of Information in Medicine* and *TREC* are not in Fig. 5 because they have no citing and cited relations with any other journal in the LIS journal sample during this period (1987-1991). Journals with high co-citation linkage are located together and those representing weak co-citation linkage are placed further apart by the mapping program. We can see four groups in these maps of three periods. There are clusters of journals representing IR researches, LIS research, Computer Science research and Medical Science research. The 'core IR' group is represented by the journals, which are most important in LIS field, and the 'IR in Library and Information Science' group includes the group of journals more focusing on Library and Information Science field, 'IR in Computer Science' group contains the group of journals from Computer Science area and 'IR in Medical Science' comprises group of journals from medical field.

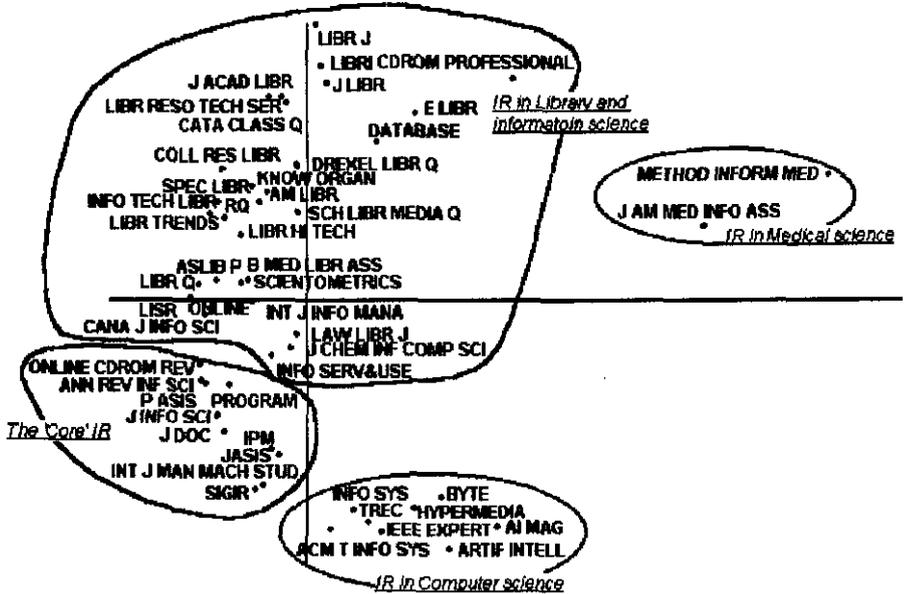


Fig. 6. MDS map of LIS journals highly cited in IR research (1992-1997)

In these four clusters, we can easily find some journals focusing on chemical science, medical science and law, which indicates that LIS theory and techniques, especially IR theory and techniques are successfully employed to manage the chemical, medical and law information. Especially in the periods of 1987-1997 (Fig. 4) and 1992-1997 (Fig. 6), one cluster of 'IR in Medical Science' appears in both periods and occupies the right core of both the maps. The remaining cluster represents the application of Computer Science into IR field or shows the close relationship of Computer Science and IR.

Here, we find that 'IR in Computer Science' group is located very close to the 'Core IR' group which links 'IR in Computer Science' group to 'IR in Library and Information Science' group. These results are coincident with the maps in the first part (Figs 1, 2 and 3) which also show that computer science group is very near to the IR group. Some journals in 'IR in Library and Information Science' and the 'core IR' groups also publish papers on Computer Science or in areas of common interest. It means that there

are some common interests between Computer Science and LIS. In other words, LIS and Computer Science disciplines have close relationship between each other, and the IR field is one of the most active research areas in both Computer Science and LIS.

Comparing Figs 5 and 6 with Fig. 4, we can find that the maps are similar. The same three clusters were repeated in these three maps (Figs 4,5 and 6). Although some journals' positions in the two period's maps are different, the structure of the clusters does not change. Each of three clusters has its own fixed journal set during different periods, for example: *Information Processing & Management*, *Journal of the American Society for Information Science* and *Journal of Documentation*, and so on in the 'Core IR' group; *Special Libraries*, *Library Resources & Technical Services* and *Cataloging & Classification Quarterly* and so on in 'IR in Library and Information Science' group; *ACM Transactions on Information Systems*, *BYTE*, *IEEE Expert* and so on in 'IR in Computer Science' and so on. We can therefore conclude that LIS journals' role in scholarly communication process of IR field does not alter much.

The citing patterns of journals in the environment of IR journals are also stable. From Table 2, we can find that *Journal of the American Society for Information Science*, *Information Processing & Management*, *Proceedings of the Annual International ACM SIGIR Conference*, *Journal of Documentation*, *Proceedings of the ASIS Annual Meeting*, *International Journal of Man-Machine Studies*, *Annual Review of Information Science and Technology*, *Journal of Information Science*, and so on, are highly cited in IR field.

The specialty development and changes can be indicated by gradual changes in the journal-set representing the specialty in various periods. If there is no stable journal-set representing a specialty, the specialty can be considered as in a 'preparadigmatic' or critical phase; contrarily if the journal-set remains relatively stable over time, this suggests that the specialty is more mature and established (*van den Besselaar and Leydesdorff*, 1996). In each period, IR factors contain the stable journal-set and maintain the relative coherence. From this point of view, IR can be considered as a maturing specialty. This implies that the theories and methods of IR are more focused and accepted by a specific community of researchers.

The maps produced by the LIS journal set are somewhat different from these produced earlier by roughly the same journal set based on the data retrieved from SSCI (see Figs 4, 5, 6 and A4, A5 and A6) (*Ding et al.*, 1999). However, the contents of the various groups in the maps of the two sets do not differ too much.

Discussion

Journal co-citation analysis was applied to map the VAR journals' and LIS journals' role in scholarly communication process of IR field during 1987–1997 and their changes over time. Base on this research, journal co-citation mapping produced clear, coherent, and reasonable results. It bears a high resemblance with the author co-citation map of IR (Ding, 1998; Ding et al., 1999a).

Journal co-citation network of VAR journals manifests the stability of the citing and cited environment of VAR journals. Computer Science, Psychology, Physics (Optics), Chemistry and Science/Nature/Neuroscience play an important role in IR field. The VAR journal co-citation mapping does not change over time. Furthermore, the IR group itself is rather stable both in terms of its composition, and in terms of its relation to relevant environments. The stability of IR field during the period of 1987–1997 was demonstrated by current research.

Specialties related to IR field are very broad, including theory-oriented factors (Psychology, Cognitive Science, Neuroscience, Science/Nature and so on) and application-oriented factors (Computer Science, Physics, Chemistry, Online IR, Management Science, Consumer Science and so on), as well as Management Science, Consumer Science, Gerontology, Medical Science and so on. So, we can conclude that IR specialty is multi-disciplinary specialty.

Based on the journal co-citation analysis of LIS journals, we found that the citing and cited LIS journal environment also remained stable and did not change much over time. The journal co-citation mapping of LIS journals indicated that IR has close relationship with Computer Science, and LIS theory and techniques, especially IR theory and techniques are successfully employed to manage the chemical, medical and law information. We noted that the following journals consistently appeared in the 'core IR' clusters during three periods and with high citation frequency in Table 2 as the 'core' of core journals in the IR field: *Journal of the American Society for Information Science*, *Information Processing & Management*, *Proceedings of the Annual International ACM SIGIR Conference*, *Journal of Documentation*, *Proceedings of the ASIS Annual Meeting*, *International Journal of Man-Machine Studies*, *Annual Review of Information Science and Technology*, and *Journal of Information Science*. This research also indicates that IR can be considered as a maturing specialty during the period of 1987–1997 because of the stable IR journal-set during this period.

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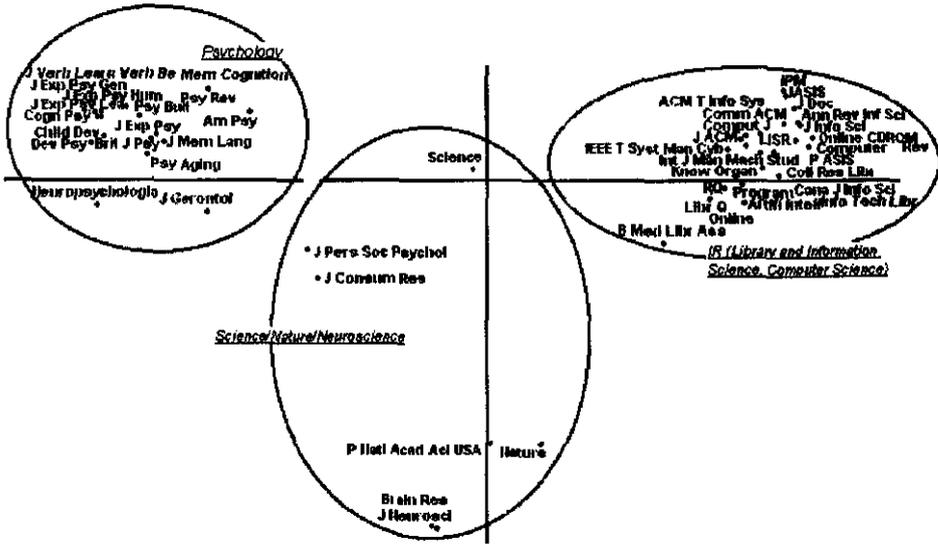


Fig. A2. MDS map of VAR journals highly cited in IR research (1987-1991)

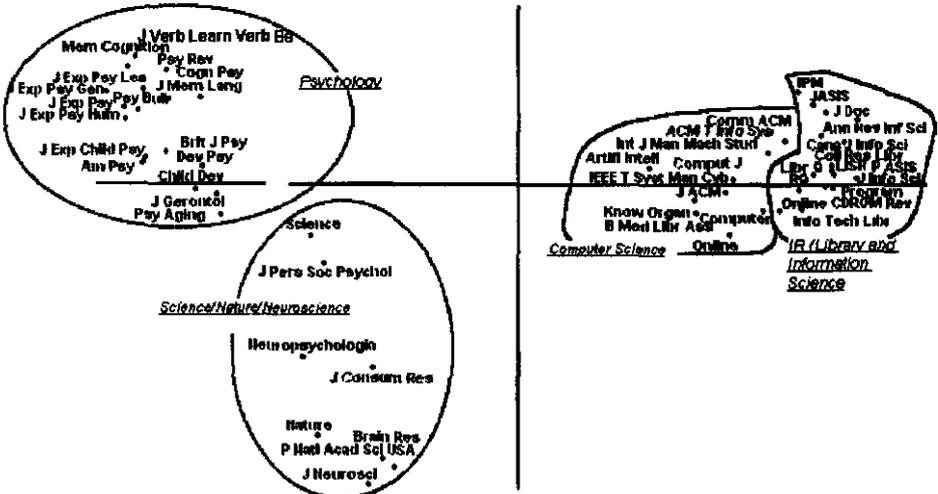


Fig. A3. MDS map of VAR journals highly cited in IR research (1992-1997)

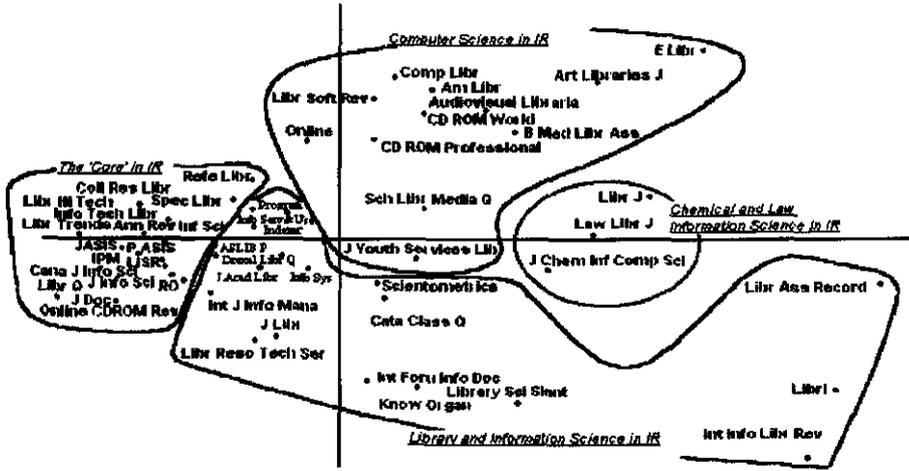


Fig. A4. MDS map of LIS journals highly cited in IR research (1987-1997)

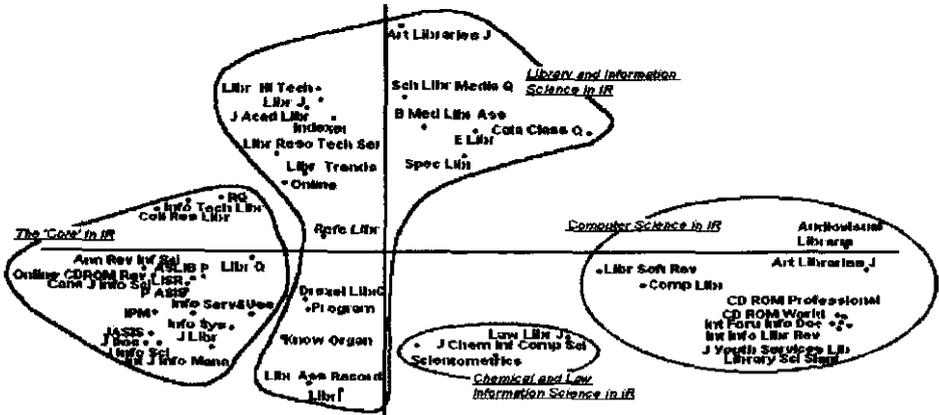


Fig. A5. MDS map of LIS journals highly cited in IR research (1987-1991)

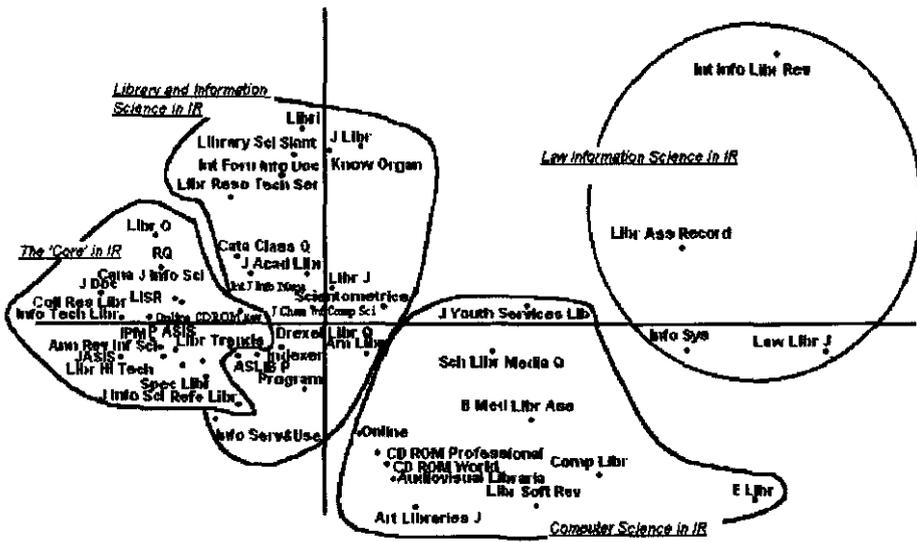


Fig. A6. MDS map of LIS journals highly cited in IR research (1992-1997)

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