Journal of Informetrics 4 (2010) 201–209

Contents lists available at ScienceDirect

Journal of Informetrics

journal homepage: www.elsevier.com/locate/joi

Measuring a journal's input rhythm based on its publication–reference matrix

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ARTICLE INFO

Article history:
Received 29 August 2009
Received in revised form 3 November 2009
Accepted 4 November 2009

Keywords:
Rhythm sequences
Publication–reference matrices
Relative reference factor

ABSTRACT

The difference among journal reference characteristics in various fields causes a field-based difference in their citation counts. For the purpose of improving indicators used in cross-field evaluations it is necessary to continue explorations corresponding to the characteristics of journal references. Such an exploration would offer new clues for solving the problem of cross-field journal evaluation. During the past years studies of the rhythm of science have obtained some achievements: constructing various types of publication–citation matrices (in short: *p–c* matrices), creating a series of rhythm indicators, studying the fundamental mathematical properties of rhythm sequences and exploring some journals' rhythm sequences. Rhythm indicators can be applied to many studies, if the system is a source–item system with two time dimensions, ensuring the construction of a *p–c*-like matrix, then such a study is theoretically feasible. In this article we create a journal's publication–reference matrix (*p–r* matrix). Based on the *p–r* matrix the rR' indicator is defined, which is used to measure the so-called input rhythm of a journal. As two case studies, the input rhythms of the *Journal of the American Society for Information Science and Technology* and of the *Journal of Documentation* are presented and analyzed.

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1. Introduction

A recent article (Neuhaus & Daniel, 2009) reveals considerable differences of publication activity and citation habits among fields. Its results also show that citation habits vary extensively not only between fields but also within fields. A new reference standard for citation analysis is suggested. This study draws our attention once more to the old problem of diversity of citation habits over fields and the necessity of normalization or standardization of evaluation indicators (Glänzel, 1996). In fact, to solve this problem scientometricians have put forward indicators such as ISSRU's NMCR indicator (Braun, Glänzel, & Schubert, 1985; Schubert & Braun, 1986; Schubert, Glänzel, & Braun, 1983; Schubert, Glänzel, & Braun, 1989) and CWTS's *CpP/JCSm* and the crown indicator *CpP/FCSm* (Moed, 2005; Moed, Glänzel, & Schmoch, 2005; van Raan, 2006). The key methodology is to compare the actor's observed value with a journal's or field's expected value.

Basic research can be considered as an input–output system. The process occurs as follows: research results, codified as articles and acknowledged as references, are inputs for a new article. Outputs consist of the citations that this new article

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doi:10.1016/j.joi.2009.11.002

receives over time (Liang & Rousseau, 2008). It is the difference among journal reference characteristics of various fields that causes the difference in their citation counts. Usually the longer the article's reference list, the higher the average citations per paper (Abt, 2000; Uzun, 2006), all other aspects (field, journal, type of document) being the same. We note that there do exist bibliometric indicators related to the reference characteristics, such as the "journal citing half-life" and "aggregate citing half-life", which have been used in the Journal Citation Reports (Thomson Reuters). For the purpose of improving indicators used in cross-field evaluations it is necessary to continue explorations corresponding to the characteristics of journal references. Such an exploration would offer new clues for solving problems related to cross-field research evaluations.

Since 2005 a series of new indicators called rhythm indicators (and *R*-sequences) has been proposed. Various *R*-sequences have been determined for the journals *JASIS*(*T*) (*Journal of the American Society for Information Science and Technology*; formerly *Journal of the American Society for Information Science*), *Nature* and *Science* (Liang, 2005, 2007; Liang, Rousseau, & Fei, 2006). Egghe, Liang, and Rousseau (2008) further studied the fundamental mathematical properties of these rhythm sequences. An article and the citations it received after its publication form a cited–citing relation. Here, the original article is the cited actor, while through their reference lists other articles are the citing actors. Symmetrically, an article and the references in the article's reference list form another relation, the citing–cited relation. Here, the article is the citing actor and the references are the cited actors. Naturally, one can ask: can *R*-cluster indicators be used to study the citing–cited relation, i.e. the relation between the journal articles and their references? Does such an *R*-sequence pattern reflects another rhythm of science, one we could call the input rhythm?

The answer is positive. Theoretically, rhythm indicators can be created and calculated based on any source–item matrix. All the *R*-cluster indicators are created based on various types of publication–citation (*p*–*c*) matrices (Liang & Rousseau, 2007). In a *p*–*c* matrix the publications are sources, the citations received by the publications are items. A journal's publications and their references form another source–item relationship: the publications are sources, their references are items. Thus, we may construct the publication–reference matrix for a journal (a field, an institute, etc.), and calculate the *R*-sequences based on the publication–reference matrix, which reflects the input rhythm of the journal (the field, the institute, etc.).

In this article we create the rhythm indicator for measuring a journal's input rhythm, and illustrate the measure to two journals: *JASIS*(*T*) and *JDOC*.

2. Methodology: *p–r* matrix and the *rR*' indicator

2.1. The p–c matrix and its corresponding R' indicator

First, let us review the *p*–*c* matrix and the creation of the R' indicator (Liang, 2005) taking a journal as an example. This will help us to understand the new *p*–*r* matrix and the definition of the new rR' indicator.

Table 1 is a *p*–*c* matrix of a journal. In this example years are numbered from 1 to 9. The symbol P_i denotes the number of articles published in the year *i*, *i* = 1, . . ., 9. In general we consider *n* years: *i* = 1, . . ., *n*. The symbol C_{ij} denotes the number of citations received in the year *j* by items published in the year *i* (hence $j \geq i$). All the C_{ij} cover a triangular area. When the citation window has a limitation $k_{max} = w$, $w = n$, also the number of used publication years, *i*, is restricted: $i \leq n - w + 1$. In this case the used C_{ij} values form a parallelogram, covering only $n - w + 1$ rows and *w* diagonals, as in the gray part of the matrix in Table 1 (with $w = 4$).

In Liang (2005) the *R* and R' indicators were, respectively, created based on a triangular citation widow and a parallelogram citation window. Correspondingly, the method used to define the *R* indicator is called the triangle method, the one used to define the R' indicator the parallelogram method. Here, we only show how to define the R' indicator using the parallelogram method.

We denote the rhythm indicator R' as a time series of ratios $R'_i = O'_i/E'_i$, $i = 1, \ldots n - w + 1$. The numerator, denoted as O'_i, is an actual (observed) citation value (see mathematical formula below), while the denominator of each ratio, denoted as E'_i (see mathematical formula below) is an expected citation value. Indeed, the E'_i can be considered as publication-weighted

Table 1
p–*c* matrix of a journal with $w = 4$.

			Citing year *j*								
			2000 1	2001 2	2002 3	2003 4	2004 5	2005 6	2006 7	2007 8	2008 9
Publication year *i* and number of publications P_i of a journal											
2000	1	P_1	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}
2001	2	P_2		C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}
2002	3	P_3			C_{33}	C_{34}	C_{35}	C_{36}	C_{37}	C_{38}	C_{39}
2003	4	P_4				C_{44}	C_{45}	C_{46}	C_{47}	C_{48}	C_{49}
2004	5	P_5					C_{55}	C_{56}	C_{57}	C_{58}	C_{59}
2005	6	P_6						C_{66}	C_{67}	C_{68}	C_{69}
quad 2006	7	P_7							C_{77}	C_{78}	C_{79}
2007	8	P_8								C_{88}	C_{89}
2008	9	P_9									C_{99}

Table 2
p–r matrix of a journal.

			Cited year *j* (reference's publication year) and R_{ij}									
			2008	2007	2006	2005	2004	2003	2002	2001	2000	...
			1	2	3	4	5	6	7	8	9	...
Publication year *i* and number of publications P_i of a journal												
2008	1	P_1	R_{11}	R_{12}	R_{13}	R_{14}	R_{15}	R_{16}	R_{17}	R_{18}	R_{19}	...
2007	2	P_2		R_{22}	R_{23}	R_{24}	R_{25}	R_{26}	R_{27}	R_{28}	R_{29}	...
2006	3	P_3			R_{33}	R_{34}	R_{35}	R_{36}	R_{37}	R_{38}	R_{39}	...
2005	4	P_4				R_{44}	R_{45}	R_{46}	R_{47}	R_{48}	R_{49}	...
2004	5	P_5					R_{55}	R_{56}	R_{57}	R_{58}	R_{59}	...
2003	6	P_6						R_{66}	R_{67}	R_{68}	R_{69}	...
2002	7	P_7							R_{77}	R_{78}	R_{79}	...
2001	8	P_8								R_{88}	R_{89}	...
2000	9	P_9									R_{99}	...

sums of isochronous (using citations of the same age) impact factors (Egghe et al., 2008). The sequence $R'_1, R'_2, \ldots, R'_n$ is called the R'-sequence. The R'-sequence is a time series of the journal's performance. It will be interpreted as an aspect of the internal rhythm of a journal's evolution.

The symbols O'_i and E'_i are defined as follows:

$$O'_i = \sum_{j=i}^{i+w-1} C_{ij}$$

$$E'_i = P_i \sum_{k=1}^{w} C'_k$$

with

$$C'_k = \frac{\sum_{j=1}^{n-w+1} C_{j,j+k-1}}{\sum_{j=1}^{n-w+1} P_j}$$

2.2. The p–r matrix and its corresponding rR' indicator

Now, we create a journal's publication–reference matrix (hereafter *p–r* matrix for short). See Table 2, where years are just for illustrative purposes. If we assume that all publications in this *p–r* matrix are journal articles, then P_i denotes the number of articles published in year *i*, and R_{ij} denotes the number of referenced articles published in year *j* and cited by the articles published in year *i*.

Comparing *p–r* matrices with *p–c* matrices, we see that they have one important difference: usually, the *p–r* matrix is not a square matrix and the data R_{ij} do not form a triangular window, but a trapezium. Suppose that the year we consider is year *Y* and that we explore *n* citing years (we go back to year $Y - n + 1$). If now, during this period of *n* citing years the publication year of the oldest reference item (at the time of publication) is $m + 1$ years, then the non-empty part of the *p–r* matrix is certainly included in a parallelogram covering *n* rows and *m* diagonals. Usually $m \gg n$. The cited year could be traced to the very early times, even more than 100 years ago. This could theoretically also be done for publication data of some old journals. On the assumption that the reference's time span for year *i* and each P_i are the same, for instance, *w* years, then, all the R_{ij} form a parallelogram, instead of a trapezium (see Table 3).

Next, we define the rhythm indicator based on the *p–r* matrix shown in Table 3. We already know that when defining the rhythm indicators based on a *p–c* matrix two methods are employed. One is to define the *R* indicator based on a triangular citation window, the other is to define the R' indicator based on a parallelogram citation window. Since we can always divide a window of data from the *p–r* matrix in the form of a parallelogram, we select the parallelogram method when introducing the *R*-cluster indicators in the study of the publication–reference relationship. Of course, the triangle method is also valid. In practice, however, it is highly unlikely that the *p–r* matrix has a triangular form, because for all the publication years the references always look backward for many years. So, when introducing the *R*-cluster indicators in the study of the *p–r* matrix we only use the parallelogram method. Recall that in Egghe et al. (2008) it is shown that the parallelogram approach has the better properties. To keep the unification with the former rhythm indicator studies we use the symbol rR' representing the indicator defined based on a *p–r* matrix and a parallelogram citation window. Considering a time period of length *n* and a window of length *w*, the new indicator rR' indicator is defined as follows.

rR' is defined as a time series of ratios $rR'_i = O'_i / E'_i$, $i = 1, \ldots n - w + 1$. The denominator of each ratio, denoted as E'_i, is an expected reference value, while the numerator, denoted as O'_i, is an actual (observed) reference value. The sequence $rR'_1, rR'_2, \ldots, rR'_n$ is called the rR'-sequence.

Table 3
p–r matrix of a journal with $w = 6$.

			Cited year *j* (reference's publication year) and R_{ij}													
			2008 1	2007 2	2006 3	2005 4	2004 5	2003 6	2002 7	2001 8	2000 9	1999 10	1998 11	1997 12	1996 13	1995 14
Publication year *i* and number of publications P_i of a journal																
2008	1	P_1	R_{11}	R_{12}	R_{13}	R_{14}	R_{15}	R_{16}								
2007	2	P_2		R_{22}	R_{23}	R_{24}	R_{25}	R_{26}	R_{27}							
2006	3	P_3			R_{33}	R_{34}	R_{35}	R_{36}	R_{37}	R_{38}						
2005	4	P_4				R_{44}	R_{45}	R_{46}	R_{47}	R_{48}	R_{49}					
2004	5	P_5					R_{55}	R_{56}	R_{57}	R_{58}	R_{59}	$R_{5,10}$				
2003	6	P_6						R_{66}	R_{67}	R_{68}	R_{69}	$R_{6,10}$	$R_{6,11}$			
2002	7	P_7							R_{77}	R_{78}	R_{79}	$R_{7,10}$	$R_{7,11}$	$R_{7,12}$		
2001	8	P_8								R_{88}	R_{89}	$R_{8,10}$	$R_{8,11}$	$R_{8,12}$	$R_{8,13}$	
2000	9	P_9									R_{99}	$R_{9,10}$	$R_{9,11}$	$R_{9,12}$	$R_{9,13}$	$R_{9,14}$

The symbols O'_i and E'_i, $i = 1, \ldots n - w + 1$, are defined as follows:

$$O'_i = \sum_{j=i}^{i+w-1} R_{ij}, \quad E'_i = P_i \sum_{k=1}^{w} R'_k$$

with

$$R'_k = \frac{\sum_{j=1}^{n-w+1} R_{j,j+k-1}}{\sum_{j=1}^{n-w+1} P_j}$$

Here R'_k denotes the average number of references published *k*-years earlier than the publication year of the articles. Stated otherwise, we may say that the reference's age is *k*-years, where $k = 1$ points to the publication year of the article. R'_k is the key measure in the construction of the rR'-indicator.

One may notice that the expected values are calculated based on the publication and reference data of all the examined articles, no matter what the article's publication year and no matter what the reference's publication year (but within the chosen window). Therefore, the expected value can be considered as a benchmark. The ratio $rR'_i = O'_i/E'_i$ measures year by year how actual values correspond to or differ from the expected value, forming a kind of rhythm of the journal's citing behaviour.

3. The relative reference factor

Recall that the *w*-year diachronous impact factor of journal *J* is defined as (Ingwersen, Larsen, Rousseau, & Russell, 2001):

$$IMP_w(Y, J) = \frac{\sum_{j=1}^{w-1} C_{Y,Y+j-1}(J)}{P_Y(J)}$$

Here *Y* denotes a particular year and $P_Y(J)$ denotes the number of publications in the year *Y*.

In a similar way we define a *w*-year relative reference factor for the year *Y* and journal *J*, denoted as $REF_w(Y, J)$ as:

$$REF_w(Y, J) = \frac{\sum_{k=1}^{w} R_{Y,Y+k-1}(J)}{P_Y(J)}$$

where $P_Y(J)$ denotes the number of articles published in year *Y* in journal *J*, and $R_{Y,m}(J)$ denotes the number of references of articles published (in journal *J*) in the year *Y*, that are published in year *m*. We usually do not include the letter *J*, when the journal is clear from the context or when this is of no importance. The *w*-year relative reference factor is the average number of references per article, included in journal *J* in the year *Y*, that are published between the years $Y - w + 1$ and the year *Y* (included). This *w*-year relative reference factor will turn out to be the key element for characterizing the baseline for rR'-sequences, namely the constant rR'-sequence.

4. A characterization of the constant *rR*'-sequence

Similar to the main result of Egghe et al. (2008) we have the following theorem.

Theorem. *A p–r matrix has a constant rR′ sequence (with window w) if and only if its w-year relative reference factor is constant.*

Table 4
JASIS(T)'s *p*–*r* matrix (1973–2008).

Year	P_i	R_{ij}														
		2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	...
2008	177	84	455	674	615	534	461	439	354	334	293	303	225	196	177	
2007	179		66	297	666	629	629	567	470	475	399	340	281	253	174	
2006	163			38	196	495	587	542	437	476	377	372	301	247	239	
2005	121				26	124	388	437	412	388	339	315	223	220	175	
2004	100					10	224	378	339	345	344	244	199	185	145	
2003	103						29	197	329	337	304	275	236	213	188	
2002	105							32	216	399	371	308	260	192	190	
2001	99								44	208	300	306	288	186	199	
2000	105									18	176	364	387	330	265	
1999	124										45	201	364	348	269	
1998	95											10	136	261	265	
1997	91												18	82	238	
1996	79													15	118	
1995	61														22	
...	...															
1973	51															

Proof. In order to prove the theorem we first prove the rearrangement equality $\sum_{i=1}^{n-w+1} O_i' = \sum_{i=1}^{n-w+1} E_i'$.

By $R_k' = \left(\sum_{j=1}^{n-w+1} R_{j,j+k-1} / \sum_{j=1}^{n-w+1} P_j\right)$, we have $\sum_{j=1}^{n-w+1} R_{j,j+k-1} = R_k' \sum_{j=1}^{n-w+1} P_j$. Summing for $k=1$ to w, yields

$$\sum_{k=1}^{w}\left(\sum_{j=1}^{n-w+1} R_{j,j+k-1}\right) = \sum_{k=1}^{w}\left(R_k' \sum_{j=1}^{n-w+1} P_j\right).$$

The left hand side of this equation is nothing but the sum of all R_{ij} in the parallelogram window of the *p*–*r* matrix, hence it is equal to $\sum_{i=1}^{n-w+1} O_i'$. The right hand side clearly is equal to $\sum_{i=1}^{n-w+1}\left(P_i \sum_{k=1}^{w} R_k'\right) = \sum_{i=1}^{n-w+1} E_i'$.

We note that if the rR' sequence is constant, then this constant must be equal to 1. Indeed, let $rR_i' = (O_i'/E_i') = K$ for $i = 1, \ldots n-w+1$ where K is a constant. Then $O_i' = KE_i'$ for $i = 1, \ldots n-w+1$. By the rearrangement equality we know that $\sum_{i=1}^{n-w+1} O_i' = \sum_{i=1}^{n-w+1} E_i'$, hence K must be equal to 1.

$$1 = rR_i' = \frac{O_i'}{E_i'} = \frac{\sum_{j=1}^{i+w-1} R_{ij}}{P_i \sum_{k=1}^{w} R_k'} = \frac{\sum_{s=1}^{w} C_{i,i+s-1}}{P_i \sum_{k=1}^{w} R_k'} = \frac{REF_w(i)}{\sum_{k=1}^{w} R_k'}$$

Hence, if the rR' sequence is constant then $REF_w(i)$ is constant. Conversely, if $REF_w(i)$ is constant, then the rR' sequence is constant and $REF_w(i) = \sum_{k=1}^{w} R_k'$, for each $i = 1, \ldots n-w+1$. □

5. The *p*–*r* matrix of *JASIS(T)* and its *rR′* sequence

By searching the data in the Web of Science (Thomson Reuters) we created the *p*–*r* matrix of *JASIS*(*T*). Only research articles are included. The publication time span is 1973–2008, a total of 36 years. Table 4 shows a section of the *p*–*r* matrix.

Table 5 lists *JASIS*(*T*)'s rR'-sequences with citation window $w = 20$, $w = 10$ and $w = 6$, respectively. Fig. 1 shows the corresponding curves. It is very clear that all the rR' curves have increasing trends, though with some fluctuations. The three rR'-curves are interweaved.

Looking at the details of the curves we observe that in some years the rR' values fluctuate violently. For example, for $w = 10$ the lowest rR' value (0.47) occurred in 1987, however, only one year earlier, namely in 1986, the rR' value is almost double, reaching 0.85. Yet, the number of publications P_i for 1986 and 1987 is the same, namely 39. Why does such a violent fluctuation happen? Considering the fact that the E_i'-values for 1986 and 1987 are the same, the direct explanation is that the O_i'-value for 1986 is much higher than for 1987. But why does this happen? It must be that the average number of references per article in 1986 is much larger than in 1987. Again, why is the average number of references per article in 1986 much larger than in 1987? One reason could be that the average number of pages per article in 1986 is longer than in 1987. However, this hypothesis is wrong. The total number of pages for the 39 articles published in 1986 is 327, while the total number of pages for the 39 articles published in 1987 is 348, which is even more. Another hypothesis is that for the publication year 1986 there are much more highly citing articles than for 1987, and these highly citing articles cite more

Table 5
JASIS(T): rR' sequences based on p–r matrix (1973–2008).

Year	P_i	$w = 20$			$w = 10$			$w = 6$		
		O'_i	E'_i	rR'_i	O'_i	E'_i	rR'_i	O'_i	E'_i	rR'_i
1973	51	635	1245.8	0.51	537	933.3	0.58	376	615.5	0.61
1974	40	599	977.1	0.61	514	732.0	0.70	379	482.7	0.79
1975	36	494	879.4	0.56	427	658.8	0.65	308	434.4	0.71
1976	36	422	879.4	0.48	356	658.8	0.54	245	434.4	0.56
1977	42	576	1026.0	0.56	469	768.6	0.61	308	506.8	0.61
1978	35	488	855.0	0.57	405	640.5	0.63	289	422.4	0.68
1979	40	476	977.1	0.49	369	732.0	0.50	261	482.7	0.54
1980	44	688	1074.8	0.64	590	805.2	0.73	452	531.0	0.85
1981	42	769	1026.0	0.75	596	768.6	0.78	405	506.8	0.80
1982	50	730	1221.4	0.60	522	915.0	0.57	335	603.4	0.56
1983	42	818	1026.0	0.80	631	768.6	0.82	427	506.8	0.84
1984	34	538	830.6	0.65	410	622.2	0.66	284	410.3	0.69
1985	41	898	1001.5	0.90	672	750.3	0.90	458	494.8	0.93
1986	39	768	952.7	0.81	610	713.7	0.85	435	470.6	0.92
1987	39	484	952.7	0.51	332	713.7	0.47	232	470.6	0.49
1988	48	674	1172.5	0.57	524	878.4	0.60	363	579.3	0.63
1989	39	963	952.7	1.01	697	713.7	0.98	421	470.6	0.89
1990	56	1175	1368.0	0.86	750	1024.9	0.73	450	675.8	0.67
1991	74	1430	1807.7	0.79	1021	1354.3	0.75	630	893.0	0.71
1992	64	1511	1563.4	0.97	1112	1171.3	0.95	735	772.3	0.95
1993	47	1043	1148.1	0.91	755	860.1	0.88	505	567.2	0.89
1994	71	1947	1734.4	1.12	1461	1299.4	1.12	1017	856.8	1.19
1995	61	1359	1490.1	0.91	1022	1116.4	0.92	672	736.1	0.91
1996	79	1672	1929.8	0.87	1221	1445.8	0.84	795	953.4	0.83
1997	91	1994	2223.0	0.90	1438	1665.4	0.86	862	1098.2	0.78
1998	95	2460	2320.7	1.06	1800	1738.6	1.04	1119	1146.4	0.98
1999	124	2630	3029.1	0.87	2031	2269.3	0.89	1442	1496.4	0.96
2000	105	2887	2564.9	1.13	2186	1921.6	1.14	1540	1267.1	1.22
2001	99	2514	2418.4	1.04	1927	1811.8	1.06	1332	1194.7	1.11
2002	105	2973	2564.9	1.16	2270	1921.6	1.18	1586	1267.1	1.25
2003	103	3012	2516.1	1.20	2260	1885.0	1.20	1471	1243.0	1.18
2004	100	3075	2442.8	1.26	2413	1830.1	1.32	1640	1206.8	1.36
2005	121	3871	2955.8	1.31	2872	2214.4	1.30	1775	1460.2	1.22
2006	163	5255	3981.8	1.32	3821	2983.0	1.28	2295	1967.0	1.17
2007	179	6169	4372.6	1.41	4538	3275.9	1.39	2854	2160.1	1.32
2008	177	5809	4323.8	1.34	4243	3239.3	1.31	2823	2136.0	1.32
Total	2612	63,806	63,806	31.43	47,802	47,802	31.72	31,521	31,521	32.13

younger literature published within the period 1977–1986 than that the 1987 articles do with respect to the 1978–1987 literature. We checked the citation data and found that the latter hypothesis is correct. See Table 6.

In order to explain the result shown in Table 6 we should further investigate the difference between the topics studied in *JASIS*(*T*)'s in 1986 and in 1987. This aspect is left for further investigations.

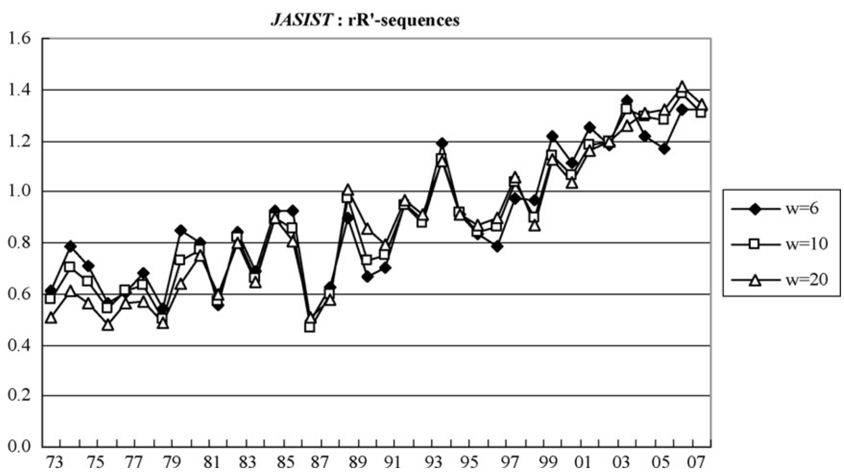

Fig. 1. rR'-sequences of JASIS(T) (1973–2008).

Table 6
JASIS(*T*): Citing behaviour in 1986 and 1987 ($w = 10$).

Citing year	Cited year (reference publication year)											Total
	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	
1986		0	87	104	102	77	65	59	29	41	46	610
1987	4	30	64	51	46	37	36	20	28	16		332

Table 7
JDOC's *p*–*r* matrix (1955–2008).

Year	P_i	R_{ij}													
		2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	...
2008	39	4	33	92	158	130	144	115	95	97	86	73	55	49	
2007	39		6	57	110	149	147	140	114	131	108	76	69	61	
2006	32			1	47	146	110	91	90	67	51	62	41	44	
2005	32				7	58	77	84	85	91	63	64	59	56	
2004	23					7	46	51	44	55	36	27	30	19	
2003	28						30	107	122	110	100	81	92	64	
2002	30							17	109	132	146	118	102	78	
2001	28								9	123	116	84	78	69	
2000	26									8	90	117	137	105	
1999	29										11	139	121	85	
1998	17											7	87	96	
1997	30												11	57	
1996	15													7	
...	...														
1955	9														

6. The *p*–*r* matrix of *JDOC* and its *rR*′ sequences

By searching the data in the Web of Science (Thomson Reuters) we created the *p*–*r* matrix of *JDOC*. Only research articles are included. The publication time span is 1955–2008, a total of 54 years. Table 7 shows a section of the *p*–*r* matrix.

Table 8 lists *JDOC*'s *rR*′-sequences with citation windows $w = 20$, $w = 10$ and $w = 6$, respectively. Fig. 2 shows the corresponding curves. Similar to the case of *JASIS*(*T*), all the *rR*′ curves have clear increasing trends, while the fluctuations are even heavier than for *JASIS*(*T*). Also here the three *rR*′-curves are interweaved.

Again we find that in some periods the *rR*′ values fluctuate violently. For example, for $w = 20$ the *rR*′ value in 1972 is only 0.50, while in the next year the *rR*′ value is as high as 1.17, then just one year later in 1974 the *rR*′ value went down to 0.78; the *rR*′ value in 2003 is 1.74, in 2004 the *rR*′ value went down to 0.93, in 2005 the *rR*′ value ascended to 1.43. Another comparison is carried out between the *rR*′ value in 1972 and that in 1976. In both years the journal published 18 articles. However, the 1972s *rR*′ value is 0.55, only three years later in 1976 it reached 1.34. Table 9 gives the explanation to the above phenomenon. Table 9 is similar to Table 6 in form, but Table 9 denotes the reference year not by the actual year but by *k*. Here, *k* refers to the reference's age, with *k* = 1 pointing to the publication year.

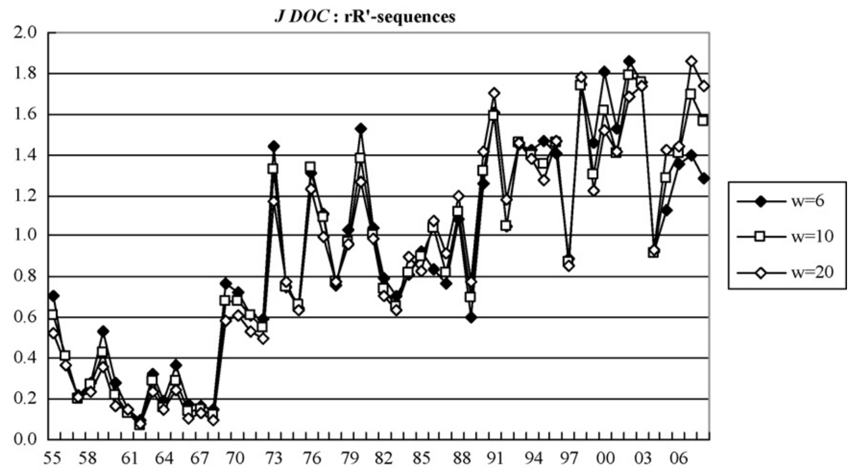

Fig. 2. *rR*′-sequences of J DOC (1955–2008).

Table 8
J DOC: rR' sequences based on p–r matrix (1955–2008).

Year	P_i	$w = 20$			$w = 10$			$w = 6$		
		O'_i	E'_i	rR'_i	O'_i	E'_i	rR'_i	O'_i	E'_i	rR'_i
1955	9	94	180.2	0.52	86	141.2	0.61	71	100.6	0.71
1956	13	96	260.3	0.37	83	203.9	0.41	53	145.3	0.36
1957	11	46	220.3	0.21	35	172.5	0.20	27	122.9	0.22
1958	9	43	180.2	0.24	38	141.2	0.27	28	100.6	0.28
1959	11	78	220.3	0.35	74	172.5	0.43	66	122.9	0.54
1960	10	34	200.3	0.17	34	156.9	0.22	31	111.7	0.28
1961	10	30	200.3	0.15	21	156.9	0.13	17	111.7	0.15
1962	15	24	300.4	0.08	17	235.3	0.07	16	167.6	0.10
1963	13	62	260.3	0.24	58	203.9	0.28	47	145.3	0.32
1964	17	50	340.4	0.15	41	266.7	0.15	36	190.0	0.19
1965	24	116	480.6	0.24	110	376.5	0.29	98	268.2	0.37
1966	22	48	440.6	0.11	48	345.1	0.14	44	245.8	0.18
1967	19	50	380.5	0.13	45	298.0	0.15	36	212.3	0.17
1968	16	31	320.4	0.10	30	251.0	0.12	27	178.8	0.15
1969	19	221	380.5	0.58	202	298.0	0.68	163	212.3	0.77
1970	14	171	280.4	0.61	150	219.6	0.68	113	156.4	0.72
1971	20	215	400.5	0.54	191	313.7	0.61	136	223.5	0.61
1972	18	181	360.5	0.50	156	282.3	0.55	119	201.1	0.59
1973	17	398	340.4	1.17	355	266.7	1.33	274	190.0	1.44
1974	23	360	460.6	0.78	271	360.8	0.75	192	257.0	0.75
1975	16	203	320.4	0.63	167	251.0	0.67	116	178.8	0.65
1976	18	443	360.5	1.23	377	282.3	1.34	264	201.1	1.31
1977	11	220	220.3	1.00	189	172.5	1.10	136	122.9	1.11
1978	16	249	320.4	0.78	196	251.0	0.78	136	178.8	0.76
1979	12	230	240.3	0.96	183	188.2	0.97	138	134.1	1.03
1980	9	229	180.2	1.27	195	141.2	1.38	154	100.6	1.53
1981	16	315	320.4	0.98	251	251.0	1.00	186	178.8	1.04
1982	13	184	260.3	0.71	151	203.9	0.74	115	145.3	0.79
1983	13	166	260.3	0.64	133	203.9	0.65	103	145.3	0.71
1984	15	270	300.4	0.90	193	235.3	0.82	136	167.6	0.81
1985	13	217	260.3	0.83	184	203.9	0.90	134	145.3	0.92
1986	9	193	180.2	1.07	147	141.2	1.04	84	100.6	0.84
1987	15	275	300.4	0.92	194	235.3	0.82	129	167.6	0.77
1988	15	359	300.4	1.20	262	235.3	1.11	182	167.6	1.09
1989	10	155	200.3	0.77	109	156.9	0.69	67	111.7	0.60
1990	11	311	220.3	1.41	228	172.5	1.32	155	122.9	1.26
1991	13	443	260.3	1.70	325	203.9	1.59	234	145.3	1.61
1992	16	378	320.4	1.18	262	251.0	1.04	187	178.8	1.05
1993	11	321	220.3	1.46	252	172.5	1.46	178	122.9	1.45
1994	13	359	260.3	1.38	285	203.9	1.40	207	145.3	1.43
1995	17	434	340.4	1.27	361	266.7	1.35	279	190.0	1.47
1996	15	442	300.4	1.47	343	235.3	1.46	235	167.6	1.40
1997	30	514	600.8	0.86	410	470.6	0.87	298	335.2	0.89
1998	17	608	340.4	1.79	463	266.7	1.74	332	190.0	1.75
1999	29	712	580.7	1.23	590	454.9	1.30	474	324.0	1.46
2000	26	790	520.7	1.52	658	407.8	1.61	525	290.5	1.81
2001	28	795	560.7	1.42	618	439.2	1.41	479	312.9	1.53
2002	30	1015	600.8	1.69	843	470.6	1.79	624	335.2	1.86
2003	28	976	560.7	1.74	771	439.2	1.76	550	312.9	1.76
2004	23	429	460.6	0.93	331	360.8	0.92	239	257.0	0.93
2005	32	914	640.8	1.43	644	501.9	1.28	402	357.6	1.12
2006	32	923	640.8	1.44	706	501.9	1.41	485	357.6	1.36
2007	39	1450	781.0	1.86	1038	611.7	1.70	609	435.8	1.40
2008	39	1354	781.0	1.73	954	611.7	1.56	561	435.8	1.29
Total	960	19,224	19,224	48.62	15,058	15,058	49.07	10,727	10,727	49.66

Table 9
JDOC: citing behaviour in 1972 and 1976 ($w = 10$).

Citing year	Cited year (reference publication year)											Total
	P_i	$K=1$	$K=2$	$K=3$	$K=4$	$K=5$	$K=6$	$K=7$	$K=8$	$K=9$	$K=10$	
1972	18	14	23	25	26	22	9	11	12	7	7	156
1976	18	12	57	55	60	47	33	33	34	22	24	377

7. Conclusion and discussion

From the viewpoint of applications the rhythm indicators have another methodological significance: rhythm indicators can be applied to many rhythm studies. They are meaningful if the system is a source–item system with two time dimensions, ensuring the construction of a *p*–*c*-like matrix. The application to the study of journal references is an actual example. Apart from the study of a journal's input rhythm, the method explained here can also be used to study the input rhythm of a research group (or an institute, a field, etc.) based on the group's (or institute's, or field's) publication–reference matrix.

The fluctuation of *JDOC*'s rR' sequence is heavier than that of *JASIS*(*T*). This is easy to explain: *JDOC*'s annual publication scale is much smaller than *JASIS*(*T*). Before the year 2001 *JDOC* published about 20 articles a year. Only in recent years the number of *JDOC*'s annual articles is greater than 30. In 1999 *JASIS*(*T*)'s annual number of articles already exceeded the figure of 100.

Though we have found an explanation for the heavy fluctuation of *JASIS*' rR' values in the years 1986–1987 we are still very surprised by this phenomenon. Although the size of the *JASIS* sample is large enough, the rR' values in these adjoining years still vary so quickly. Why is this? Is it due to a change in research topics covered by the publications in those years? This problem is worth to be studied in depth. One reviewer offers the suggestion that there may exist an upper limit to the degree to which citation behaviours within or between fields can be standardized when developing cross-field bibliometric indicators. We offer the study of (heavy) fluctuations in the rhythm sequences as a suggestion for further examination.

Acknowledgements

The authors thank reviewers for useful comments on an earlier version. The work presented in this paper is sponsored by the National Natural Science Foundation of China (Project 70673019).

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