VARIATION IN CITATION BASED FRACTIONAL COUNTING OF AUTHORSHIP

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ABSTRACT

Existing indexing methods do not consider the variation among number of citations received by publications of authors. In this paper, we propose variation in citation based fractional V_f-index which not only consider the number of authors but also the variation factor in the number of citations. V_f-Index considers the consistency in received citations of publication in addition to their quality and quantity for indexing. We have used Co-efficient of quartile deviation for calculation of variation in received citations because it is sensitive for both skewed and un-skewed data. We have used real world data for validation purpose and have used fractional h- and g-index as our baseline indexing methods. We compared the results of our proposed method with baseline methods and have analyzed that our intuition has clear impact on the authors indexing. Author on higher index in fractional index gets impacted by V_f-index and its rank changes accordingly. Baseline methods do not considers variation factor and it is possible that authors with inconsistent citations receive high index value but if we use variation factor then our results will be more consistent. More the Co-efficient of quartile deviation lower the consistency and thus lower indexing.

Key Words: *Fractional Counting of Authorship, Citation Variation, Co-Author Network*

INTRODUCTION

Scientific work of researchers published in conferences or journals require methods to quantify the work of all these authors and to find the author with high quality research work. Different indexing methods have been proposed which are based on quantity (the number of publications) and quality (the number of citations) of publications. There are number of methods for the assessment of researcher's productivity in the literature survey. These methods for ranking of authors use different criteria such as citations, time, the number of authors and the rank of authors etc. so we categorized literature review based on different aspects. Classification is shown in Figure 1. It has been established from literature, that methods of feature subset selection have significant impact on results of learning and classification methods[1]. In the same way, the ranking criterions can impact the results of ranking and indexing significantly.

With the passage of time research has been done on indexing methods, so every method has some limitations which have been removed or addressed by indexing methods proposed later. J.E Hirsch[2] proposed h-index which is used to find out productivity of authors by considering number of citations and number of publications. Beside some advantages of the h-index, some limitations were identified in[3,4]. It is not useful for new

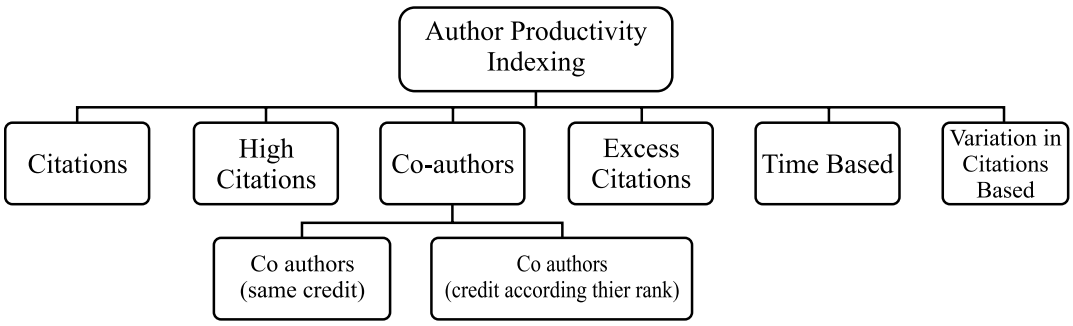

Figure 1. A classification of Author Ranking/Indexing methods

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researchers because their publications and citations are less. Some methods are more sensitive for highly cited papers like g-index. L. Egghe[5] proposed g-index to remove limitation of h-index based on high citations. It is as simple as h-index, but it is favorable for highly cited papers i.e. it gives more weightage to highly cited papers so its value is always greater or equal to h-index. With some modifications of h-index, several other indices are available in literature such as A-index and R-Index proposed by Jin[6], Jin[7], index proposed by Cabrerizo et al.[8]. There are several indices which are based on time, for example, m-quotient by Burrell[8] AR-index by Jin[5] h –index sequence and h-index matrices by Liang[10].

There are some indices based on excess citations, for example, h^2-index by Zhang[11], k-index and w-index by Anania and Caruso[12]. Perianes-Rodriguez and Ruiz-Castillo discussed the effect of multiplicative and fractional counting methods on co-authored publications[13]. Ruiz-Castillo and Waltman discussed the effect of normalization of citation impact indicators based on a field of a paper[14]. Aksnes et al. explored the empirical analysis of two different techniques of whole counts and fractional counts for calculation of national citation indicators[15]. Anegon et al. presented a method for choosing the research guarantor or corresponding author for co-authored papers[16]. Ruscio et al. presented a criteria which depicts conceptual, practical and empirical issues such as correction of calculation, understanding, impact on rewards and incentives, effect off extreme scores, and validation[17]. All the methods discussed so far considered different aspects like time, number of citations, time etc. to rank author, but they do not consider the number of authors for author ranking purpose. However, we found some further indices that take the number of authors in consideration while ranking. Some of these methods give same credit to all co-authors while others give different credit according to their rank. For example, Batista et al.[18] proposed h_I-index, if there is only one author in all publications, in that case h_I=h. Egghe[19] proposed fractional h-index and fractional g-index. Schreiber[20] introduced h(m) index, pure h-index by Wan et al.[21], and P-Index by Aziz and Rozing[22].

Several iterative methods based on the links structure of the academic networks have also been proposed in literature the ranking of authors. A variation of the original PageRank algorithm based on co-author graphs, was proposed incorporating the number of citations as well[23]. Customized versions of PageRank[24] were applied for expert finding and topic modeling[25-30]. Several methods proposed weighted version of state-of-the-art PageRank method for ranking of authors[31-39]. Methods for conference mining and academic recommendations were proposed in literature using topic modeling[40,41].

Variation in citation based index means an index method which uses variation in number of received citations to quantify the work of researchers for ranking purpose. We have done detailed literature survey and observed that none of existing indexing method has discussed this problem. We selected this issue as our proposed idea for ranking of authors. After applying this method we will be able to differentiate between the works of authors having differences in their citations received. Our proposed method doesn't only consider no of publications, authors, citations but also their variation in number of received citations. None of above mentioned methods has considered the variation among number of citations received by publications of researchers. To handle this issue, we proposed variation in citation based fractional index denoted by V_f which does not only consider the number of authors but also the variational factor in number of citations. The V_f-index considers the consistency in received citations of publications in addition to their quality and quantity for indexing. The V_f-index gives high weightage to most recent publications of authors by dividing number of citations of publications by life time of publications. After this calculate variation of received weightage by using coefficient of quartile deviation. We have used coefficient of quartile deviation for calculation of variation in received citations because it is robust for both skewed and data. For final ranking, we divide number of citations of each publication by variation value.

METHODOLOGY

We used fractional h and g-index as our baseline methods. In the analysis, we compared the results of our proposed method with baseline methods and have analyzed that it has clear impact on the researchers ranking. Formula used for calculating simple h-index proposed by[2] is given below:

$$h = \sqrt{\frac{N_c T}{a}} \quad (1)$$

In above formula N_c used for total number of citations received by articles where "a" is proportionality constant and its value lies between 3 and 5. Normally 4 are selected as a constant value because average number of publications of any authors is 2. Suppose author A have six publications PB1, PB2, PB3, PB4, PB5, PB6 which

Table 1. Calculation of H-index of author A

Index	Rank of publications with respect to its citations	Name of publications	Total citations of the paper
	1	PB1	30
	2	PB6	10
	3	PB3	9
H-index	4	PB5	6
	5	PB4	2
	6	PB2	1

receive citations 30, 1, 9, 2, 6 and 10 respectively. To find out h-index for author A, first arrange publications in their decreasing order of citations received. In Table 1 h-index is calculated by using formula (1).

Advantages of the h-index are given in[5]. It is powerful indicator because it is not affected by only increase in publications. It doesn't only measure peak performance but also calculates durable performance. It combines citations and publications. By adding uncited papers its value doesn't effect. Limitations are also given in[4]. It is not useful for new researchers because their publications and citations are less. It permit researchers to rest, because even if not of their paper publish, their citations rate increase. It is based on long time observations. Value of h-index doesn't increase by number of papers published by authors. It is not beneficial for highly cited papers[2].

L. Egghe[4] proposed g-index to remove limitation of h-index and it contains all the plus points of h-index. Highly cited papers are used to calculate h-index and once highly cited article used in calculation of h value this article doesn't use further in calculation of h-index although citations of articles increased by passage of time. g-index removes this limitation. It is as simple as h-index, but it is favorable for highly cited papers i.e. it gives more weightage to highly cited papers so its value is always greater or equal to h-index. To calculate g-index, rank articles in descending order of citations received. g-index is defined as:

"g-index is highest rank g such that sum of first g papers received at least g^2 citations. Or it is calculated by formula (2) given below.

$$\sum Cit \geq g^2 \tag{2}$$

In the above formula, g is publication rank and Cit is received citations at rank g.

Example of g-index is given in Table 2, in this example

Table 2. Calculation of H-index and G-index for author A1

Index	R	P	TC	∑TC	R2
	1	PB4	20	20	1
	2	PB3	10	30	4
	3	PB7	9	39	9
	4	PB2	8	47	16
	5	PB8	6	53	25
H-index	6	PB1	6	59	36
	7	PB5	6	65	49
G-index	8	PB9	5	70	64
	9	PB6	5	75	81

publications P of researcher "A1" is given. R denotes rank of publications P, TC denotes total number of citations, ∑TC represent cumulative sum of received citations. h and g-index is calculated by using formula (2) and (3).

In this example h-index is equal to 6, while g-index is equal to 8 because $\sum TC \geq G^2$ for this rank and at rank 9 this condition hold false.

Limitation of g-index is that it doesn't consider life time of researchers[4].

2.1. Fractional h and g index using fractional citation counts

Let ϕ (i) denote no's of authors and y(i) is number of citations then author receive score $\frac{y(i)}{\phi(i)}$, arrange table in decreasing order of score received, fractional h-index is defined as highest rank r= h_f such that $\frac{yh_f}{\phi(yh_f)}$ is greater than or equal to h_f. Mathematically h_f is defined as:

$$\frac{y(h_f)}{\phi(h_f)} \geq h_f \quad (3)$$

Similarly fractional g index denoted by is defined as largest rank r=g_f such that cumulative sum of is $\frac{yi}{\phi(i)}$ greater than or equal to the square of their rank. Mathematically g_f is defined as:

$$\sum_{i=1}^{g_f} \frac{yi}{\phi i} \geq g^2{}_f \quad (4)$$

Example of fractional h-index using citation count is given in Table 3.In this table score for each document

Table 3. Co-authorship information of an author

r	No of Authors ϕ(i)	No of Citations y(i)	Score y(i)/ϕ(i)
1	2	10	5
2	1	5	5
3	3	3	1
4	1	2	2
5	1	1	1
6	1	1	1

Table 4. Now rearrange obtain score in Table 3by decreasing order and calculate h_F using fractional citation counts.

Index	r	Score yi/ϕ(i)
	1	5
h_F	2	5
	3	2
	4	1
	5	1
	6	1

is obtained by dividing total no of citations on total number of authors.

2.2 Fractional h and g index using fractional paper counts

Fractional paper count method changes papers rank. Papers having m publishers then author obtains 1/m score. Rank of paper is changed like 1 is replaced by $\frac{1}{\phi(1)}$ rank 2 is replaced by $\frac{1}{\phi(1)}+\frac{1}{\phi(2)}$ and so on. Fractional h-index is defined as highest rank r= h_f such that cumulative sum of $\frac{1}{\phi(i)}$ is greater than or equal to their rank. Such that

Table 5. Calculation of h_f using fractional paper count by using information in Table 3

Index	r	C
	0.5	10
	1.5	5
h_F	1.8333	3
	2.8333	2
	3.8333	1
	4.8333	1

$$\sum_{i=1}^{k} \frac{1}{\phi(i)} \geq h_F \quad (5)$$

Similarly fractional g-index is the highest rank r=g_f like cumulative sum of square of $\frac{1}{\phi(i)}$ is less than or equal to their rank.

Example: Using information of Table 3 calculates fractional h-index by using method of fractional paper count. In table below r denotes documents ranks whereas C denotes total number of citations obtained by documents.

Limitations are that it requires rearrangement of publications into new order after dividing number of citations by number of authors[6]. Highly cited papers with many authors don't contribute to index because they are removing it from core after its rearrangement[5].

2.3 Proposed V_f-Index: Variation in Citation Based Fractional Index

Here we give our proposed method V_f-Index, where V stands for variation in number of received citation and f stands for fractional. Proposed method i.e. V_f-Index (h_{vf} and g_{vf}) does not only consider quantity, quality and number of authors but also variation in number of citations with respect to life time of publications. Following steps are used to calculate variation in citations based fractional h and g-index.

First of all, after counting the unique authors (same number of total publications, received citations and fractional h and g-index) in dataset count the number of papers written by authors. After that, calculate the number of citations of each publication of authors. Suppose *n* is number of authors in dataset, or each author from 1 to

n, consider *P* is number of publications of each author.

Further, for each publication, 1 to *P*, divide number of citations of each publication by life time of the same publication and assign weightage W_1 to each publication.

After getting this weightage, rank it in decreasing order. To take into account the variations in number of citations with respect to life time of the publications. For this purpose we use a very common statistical measure for relative variation, named coefficient of quartile deviation. It is more robust in the presence of extreme observations (citations). The formula for coefficient of quartile deviation is:

COQD = Q3-Q1/ Q3+Q1

We calculated this coefficient of quartile deviation from the data of W_1.

For final ranking, for i^{th} publication from 1 to P, get the S_1 score factor, which is obtained as the quotient of number of citations of i^{th} publication to the number of Authors (S_1 score), then divide this S_1 score by COQD based on W_1 to obtain final score named as S_2 of each publications.

Arrange S_2 in decreasing order. For each i^{th} publication from 1 to P, consider this decreasing sequence of S_2 and if: S_2 >= Rank of the Publication, we assign it our proposed variation based fractional h- index: h_{vf} = rank. To calculate g_{vf}-Index, we perform an extra step of calculating the cumulative sum of S_2 score for each publication at rank i. If square of rank >=Cumulative sum of S_2, then, g_{vf} = rank

We repeat the same procedure for different authors, the author who has greater h_{vf} and g_{vf} will be preferred over others.

Table 6. Co-authorship information of First Researcher

R	c_j	a_j	y_j	$S_i=c_j/a_j$	$W_i=c_j/y_j$
1	94	3	1	31.333	94
2	74	5	1	14.8	74
3	72	3	1	24	72
4	68	11	2	6.1818	34
5	53	6	4	8.8333	13.25
6	53	3	3	17.6666	17.66667
7	50	7	5	7.1428	10
8	42	5	2	8.4	21
9	33	5	6	6.6	5.5
10	33	2	4	16.5	8.25
11	29	2	2	14.5	14.5
12	27	4	1	6.75	27
13	26	7	1	3.7142	26
14	25	2	2	12.5	12.5
15	22	2	3	11	7.333333
16	16	4	1	4	16
17	13	2	3	6.5	4.333333
18	11	4	4	2.75	2.75
19	9	7	1	1.2857	9
20	6	3	1	2	6
21	3	5	1	0.6	3

Table 7. Co-authorship information of Second Researcher

R	c_j	a_j	$S_1=c_j/a_j$	y_j	$W_1=c_j/y_j$
1	134	6	22.3333	2	67
2	131	5	26.2	2	65.5
3	93	4	23.25	5	18.6
4	84	4	21	4	21
5	63	5	12.6	2	31.5
6	56	4	14	1	56
7	52	6	8.6666	2	26
8	50	5	10	3	16.66667
9	47	4	11.75	2	23.5
10	32	7	4.5714	1	32
11	32	5	6.4	2	16
12	29	6	4.8333	3	9.666667
13	24	5	4.8	3	8
14	19	4	4.75	3	6.333333
15	17	4	4.25	1	17
16	13	4	3.25	4	3.25
17	13	4	3.25	4	3.25
18	10	4	2.5	4	2.5
19	8	4	2	3	2.666667
20	8	7	1.1428	2	4
21	2	4	0.5	1	2

Table 8. Calculation of h_f and h_{vf}, g_f and g_{vf} for First Researcher

Index	R	s_1	cumulative sum of s_1	$s_2=s_1/COQD$	R^2	s_2 in ascending order	Cumulative sum of s_2
	1	31.333	31.333	55.9418	1	55.9418	55.94
	2	24	55.333	42.84949	4	42.84949	98.78949
	3	17.6666	72.9996	31.54187	9	31.54187	130.3314
	4	16.5	89.4996	29.45903	16	29.45903	159.7904
	5	14.8	104.2996	26.42385	25	26.42385	186.2142
	6	14.5	118.7996	25.88823	36	25.88823	212.1025
	7	12.5	131.2996	22.31744	49	22.31744	234.4199
h_F	8	11	142.2996	19.63935	64	19.63935	254.0593
	9	8.8333	151.1329	15.77093	81	15.77093	269.8302
	10	8.4	159.5329	14.99732	100	14.99732	284.8275
	11	7.1428	166.6757	12.75272	121	12.75272	297.5802
h_{vf}	12	6.75	173.4257	12.05142	144	12.05142	309.6317
g_F	13	6.6	180.0257	11.78361	169	11.78361	321.4153
	14	6.5	186.5257	11.60507	196	11.60507	333.0203
	15	6.1818	192.7075	11.03696	225	11.03696	344.0573
	16	4	196.7075	7.141582	256	7.141582	351.1989
	17	3.7142	200.4217	6.631316	289	6.631316	357.8302
	18	2.75	203.1717	4.909838	324	4.909838	362.74
g_{vf}	19	2	205.1717	3.570791	361	3.570791	366.3108
	20	1.2857	206.4574	2.295483	400	2.295483	368.6063
	21	0.6	207.0574	1.071237	441	1.071237	369.6775

Table 9. Calculation of h_f and h_{vf}, g_f and g_{vf} for Second Researcher

Index	R	s_1	R_2	cumulative sum of s_1	$s_2=s_1$/COQD	s_2 in ascending order	Cumulative sum of s_2
	1	26.2	1	26.2	43.06377	43.06377	43.063
	2	23.25	4	49.45	38.21499	38.21499	81.27799
	3	22.3333	9	71.7833	36.70825	36.70825	117.98624
	4	21	16	92.7833	34.51677	34.51677	152.50301
	5	14	25	106.7833	23.01118	23.01118	175.51419
	6	12.6	36	119.3833	20.71006	20.71006	196.22425
	7	11.75	49	131.1333	19.31295	19.31295	215.5372
h_F	8	10	64	141.1333	16.43655	16.43655	231.97375
	9	8.6666	81	149.7999	14.2449	14.2449	246.21865
h_{vf}	10	6.4	100	156.1999	10.5194	10.5194	256.73805
	11	4.8333	121	161.0332	7.94428	7.94428	264.68233
	12	4.8	144	165.8332	7.889546	7.889546	272.571876
g_F	13	4.75	169	170.5832	7.807364	7.807364	280.37924
	14	4.5714	196	175.1546	7.513807	7.513807	287.893047
	15	4.25	225	179.4046	6.985536	6.985536	294.878583
	16	3.25	256	182.6546	5.341	5.34188	300.219583
g_{vf}	17	3.25	289	185.9046	5.341	5.34188	305.560583
	18	2.5	324	188.4046	4.1091	4.109139	309.669683
	19	2	361	190.4046	3.2873	3.287311	312.956983
	20	1.1428	400	191.5474	1.8783	1.878369	314.835283
	21	0.5	441	192.0474	0.8218	0.821828	315.657083

Table 10. Summary of both researchers

Scientist	Indices (h_f, g_F)		Variation (COQD based on W_1)	Indices (h_{vf},g_{vf})
R_1	h	8	0.560156	12
	g	13		19
R_2	h	8	0.608413	10
	g	13		17

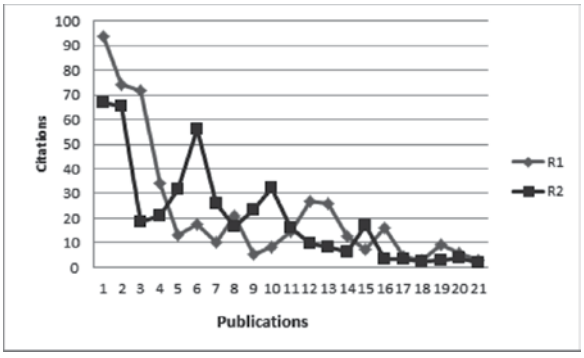

Figure 2. Comparison of Received Citations of both researchers

RESULTS AND DISCUSSIONS

We take an example in which two authors have same number of total publications, received citations and fractional h and g index. In such cases one cannot differentiate between their works to conclude which author is more efficient. Hence, existing methods cannot differentiate the work of both these authors because these methods don't take into account variation factor.

Tables 6 and 7 give publications and citations detail of two researchers. In these tables *R* denotes the rank of publications *P*, C_j denotes total numbers of citations and a_j denotes total number of authors and y_j denotes life time of publications of author publication. Document score S_1 is obtained by dividing citations to the number of authors of each publication.

To calculate simple fractional h and g-index denoted by h_f and g_f for both researches rearrange Table 6 and Table 7 and make new tables Table 8 and Table 9, by decreasing order of S_1 for both authors respectively. In tables 8 and 9 R^2 is square of publication rank R and $\sum S$ is cumulative sum of documents score. The bold values

in each row of table 8 and 9 show respective indices for both authors respectively. Both authors have similar h_f and g_f indices, but different h_{vf} and g_{vf} indices.

It is clear from above tables and especially Table 10, that both researchers have same fractional h and g-index. These indices are unable to calculate the consistency of their research work. To differentiate the work of these authors one interesting point is to consider variation in number of citations. Incorporating the concept of variation in citations, our proposed indices, depict that first researcher is better than second researcher.

In figure 2 comparison of received weightage of both the authors are made, and from that figure it is clear that variation in number of citations of first researcher is less than second one. So we can say that productivity of first researcher is stable than second one.

CONCLUSION

We studied different indexing methods, and determined that none of existing methods have considered variation in citations factor of their work for ranking purpose. Proposed method is very efficient method to quantify author's work because it does not only consider number of authors but also their consistency in their work's citations. It helps us to differentiate the work of authors who have same h_f and g_f indices.

On comparison we found that the proposed methods provide better results than the existing methods. Through comparison we found our proposed method provide the increased index value for those authors who remained consistent in received citations.

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