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Iterative weighted EM and iterative weighted *EM′*-index for scientific assessment of scholars

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Abstract
In the field of scientific assessment of scholars, there were several metrics has been given by the scholars. From the list of indices, the h-index is widely accepted for the scientific evaluation of scholars. However, the h-index has several limitations, especially in the case of consideration of excess citation count. In this context, the e-index and EM-index have been proposed. The e-index only considers the excess citation count, while the EM-index considers both core and excess citation count. *"The EM-index is the square root of the sum of the EM-index component"*. In this index, every component has equal importance. But how can we consider every component equally? The first element and the 100th elements can not be identical. This article discussed the iterative weighted EM-index to address this issue. To consider the impact of all cited atricles, the multidimensional h-index and the *EM′*-index were proposed. The multidimensional h-index has not considered the excess citation count and also not come up with any global index value. The *EM′*-index overcomes this issue, but this index follows the same pattern as the EM-index suffers. Further to accomplish the above-discussed issue, the iterative weighted *EM′*-index also discussed in this article. An empirical study has been performed on 82 scholars' publications and citation data. From the empirical research, we concluded that this could be an effective solution in the scientific assessment of scholars.

Keywords Iterative weighted EM-index · Iterative weighted *EM′*-index · EM-index · H-index · *EM′*-index · Tail citation · Excess citation

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Introduction

In the year of 2005, the h-index has been proposed by the (Hirsch 2005), which sets a benchmark in the scientific assessment of scholars. But the proposed h-index has suffered from several limitations that have been pointed by a lot of research. To deal with the limitation of the h-index various research has been conducted (Egghe 2006a, b, 2007; Jin et al. 2007; Jin 2007; Schreiber 2008; Rousseau and Ye 2008; Schubert 2011), but still some of the issues are not addressed till now. The main limitation of the h-index is the ignorance of excess and tail citation count. To consider the excess citation count, the g-index (Egghe 2006b), the e-index (Zhang 2009) and the EM-index (Bihari and Tripathi 2017) and to consider the tail article, the multidimensional h-index (García-Pérez 2009) and consideration of tail with excess-citation count the EM'-index (Bihari and Tripathi 2017) has been designed.

Although the EM-index successfully covers the importance of excess citation count and the EM'-index, it successfully covers the significance of excess and tail citation count of scholars. *"The EM and EM′ is the square root of the sum of the value of their components."* In these indexes, all components are treated equally; though, the component at level 1 is never equal to the 100th level. The same concept has been addressed in Todeschini and Baccini (2016) that gives the iteratively weighted h-index iw(h) to the component of the multidimensional h-index. The given weight mechanism is the alternative infinite series. In iw(h)-index, the series is limited to the number of the component of multidimensional h-index. A similar approach has been applied in this article with the components of the EM and $EM^{'}$-index. Here the series is also limited to the number of components of the EM and $EM^{'}$-index.

As we know that the single index considers only one parameter to appraise the scientific influence of scholars, so instead of a single parameter, the combination of different parameters helps in giving the best alternative solution (Van Leeuwen et al. 2003; Martin 1996). The proposed method is the mixture of the properties of iteratively weighted h-index (Todeschini and Baccini 2016) with the EM-index and the EM'-index respectively. The EM and $EM^{'}$-index is the combination of the properties of the h-index, e-index, and the multidimensional h-index. The proposed method has been tested with the 82 scholars data that has been used in Bihari and Tripathi (2017).

This article constitutes four sections; the first section discusses the introduction of the article. The second section discusses the theoretical approach of the proposed method, along with the experimental result and analysis. Section 3 discusses the iterative weighted EM'-index along with the empirical result analysis, and Sect. 4 concludes the proposed article.

The iterative weighted EM-index

To consider the impact of the highly cited article, (Zhang 2009) proposed the e-index and to consider the impact of tail articles' citation count, the multidimensional h-index (García-Pérez 2009) has been proposed. Although, the e-index did not take into account the complete citation count of core articles'. This can be used with h-index, then it may be useful in the scientific impact of scholars. To consider excess citation efficiently, the EM-index has been proposed by Bihari and Tripathi (2017), which is the fusion of the theory of h-index, e-index, and multidimensional h-index. But the problem with EM-index is that it gives equal importance to each component of the EM-index. It is not fair, we can not consider first and the last component equally; this has already been addressed in iteratively weighted h-index (iw(h)) (Todeschini and Baccini 2016). Taking together the concept of EM-index

and iw(h)-index, the iterative weighted EM-index is going to present that estimate the performance of scholars.

Definition *"The iterative weighted EM-index of a scholar is the iterative weighted sum of the components of the EM-index."*

The Mathematical formula of the iterative weighted EM-index is as follows:

$$iw_{EM} = \sum_{c=1}^{m} \frac{EM_c}{c} \tag{1}$$

where iw_{EM} is the iterative weighted EM-index, m is the total number of components of the EM-index, and EM_c is the cth component of the EM-index. The iterative weighted EM-index follows the properties of EM-index; the only difference is the production of the final value. The EM-index is the square root of the sum of the component, and the iterative weighted EM-index is the iterative weighted sum of the component value. In this index, we can give the influence of component value in terms of the iterative increment that suppresses the square root over the equal sum. During the EM-index computation, it has been observed that if the author has less excess citation with high h-index, then the EM-index penalizes that author. This happens due to the square root of the sum of the component value. The proposed index address this issue.

To demonstrate the iterative weighted EM-index, we have consider the author **Fred Y. Ye (ID=23)** publication and their citation details (given in Table 1).

Author has total 29 articles with following citation count {50, 45, 33, 30, 24, 23, 17, 12, 11, 10, 8, 8, 7, 6, 6, 6, 5, 4, 3, 2, 2, 1, 1, 1, 1, 1, 1, 1, 1 } and the h-index is 10. The first ten articles' citation count is required for computation of EM and iterative weighted EM-index. Table 1 shows the author's core article citation count and computation process of the component of the iterative weighted EM-index. The component's value of the iterative weighted EM-index is {10, 7, 6, 4, 3, 3, 2, 2, 2, 2, 2, 1}. The first component value is the original h-index value and the subsequent components value is the h-index value from the excess citation count. The value given in the column headed iEM2 is the substractrd value of column headed iEM1 and the component value of iEM1. This process

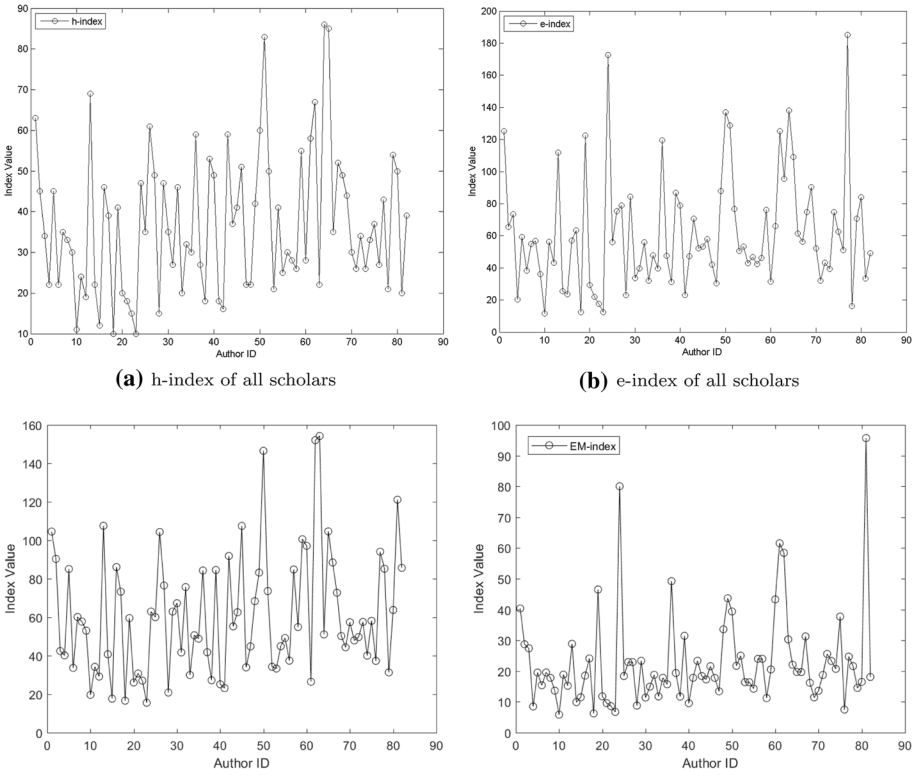
Table 1 Iterative weighted EM-index of author **Fred Y. Ye (ID=23)**

Rank	iEM1	iEM2	iEM3	iEM4	iEM5	iEM6	iEM7	iEM8	iEM9	iEM10	iEM11	iEM12	iEM13
1	50	40	33	27	23	20	17	15	13	11	9	7	5
2	45	35	28	22	18	15	12	10	8	6	4	2	0
3	33	23	16	10	6	3	0	–	–	–	–		
4	30	20	13	7	3	–	–	–	–	–	–		
5	24	14	7	1	–	–	–	–	–	–	–		
6	23	13	6	0	–	–	–	–	–	–	–		
7	17	7	0	–	–	–	–	–	–	–	–		
8	12	2	–	–	–	–	–	–	–	–	–		
9	11	1	–	–	–	–	–	–	–	–	–		
10	10	0	–	–	–	–	–	–	–	–	–		
Component	10	7	6	4	3	3	2	2	2	2	2	2	1

will contitue till the all citation counts are exhausted or only one article has the citation count or the all articles has only 1 citation count (As similar to the EM-index). The iterative weighted EM-index is calculated using the component of iw_{EM}-index as follows: $10\times1+7\times\frac{1}{2}+6\times\frac{1}{3}+4\times\frac{1}{4}+3\times\frac{1}{5}+3\times\frac{1}{6}+2\times\frac{1}{7}+2\times\frac{1}{8}+2\times\frac{1}{9}+2\times\frac{1}{10}+2\times\frac{1}{11}+2\times\frac{1}{12}+1\times\frac{1}{13}=18.96$. The iterative weighted EM-index is 18.96; however the EM-index is 6.78 only. The EM-index is giving lower value due to the square root of the sum of the component value. The proposed index gives a higher index value than the h-index and EM-index.

Experimental analysis of iterative weighted EM-index

This section deal with the experimental analysis of iterative weighted EM-index with h-index, iteratively weighted h-index, e-index, and EM-index. To do this, we have considered a total of 82 scholars data that has been used in Bihari and Tripathi (2017). The data set contains the author's publications and citation details, mostly working on scientometrics and bibliometrics. The h-index, iteratively weighted h-index, e-index, EM-index and iterative weighted EM-index of all scholars is shown in Fig. 1.



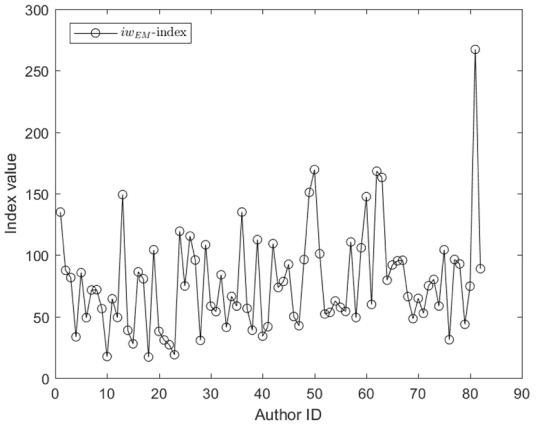
(a) h-index of all scholars

(b) e-index of all scholars

(c) Iteratively weighted h-index of all scholars

(d) EM-index of all scholars

Fig. 1 The h-index, e-index, iteratively weighted h-index, EM-index, and iterative weighted EM-index of for the data set of 82 scholar (Bihari and Tripathi 2017)



(e) iw_{EM}-index of all scholars

Fig. 1 (continued)

The EM-index considers excess citation count and provides additional information when the comparison between scholar has been made. In literature, we have stated that the EM-index gives equal weight to all components of the EM-index that is logically not correct. Instead of providing the same weight, the iterative weight mechanism offers a better influence of each element. The iterative weighted EM-index gives iterative weight to the components. This method provides a better result than that of the EM-index. To prove the previous statement, the iterative weighted EM index and the EM index is comparatively analyzed in Table 2 with their corresponding rank.

Table 2 Comparative analysis of iterative weighted EM-index with EM-index of all 82 scholars

Author ID	Scholar Name	EM-index	Rank	iw_{EM}-index	Rank
1	J. E. Hirsch	40.35	9	134.95	9
2	Ronald Rousseau	28.71	17	87.56	29
3	Michael S. Rosenberg	27.42	18	81.67	33
4	Miguel A. García-Pérez	8.54	78	33.45	74
5	Lutz Bornmann	19.54	38	85.71	31
6	Ruediger Mutz	15.43	58	49.11	64
7	Daniel HD	19.52	39	71.54	43
8	Marek Kosmulski	17.83	48	71.80	42
9	Fiorenzo Franceschini	13.67	63	56.40	55
10	Ash Mohammad Abbas	5.92	82	17.44	81
11	Sergio Alonso	18.87	41	64.43	47
12	Francisco Javier Cabrerizo	15.26	59	49.24	62
13	Enrique Herrera-Viedma	28.88	16	149.20	6
14	Jörn Altmann	9.95	73	38.78	71

Table 2 (continued)

Author ID	Scholar Name	EM-index	Rank	iw_{EM}-index	Rank
15	Alireza Abbasi	11.45	69	27.82	78
16	Josep Domingo-Ferrer	18.49	44	86.33	30
17	Vicenç Torra	24.08	22	80.71	34
18	Raf Guns	6.32	81	17.07	82
19	Santo Fortunato	46.51	6	104.26	18
20	Raj Kumar Pan	11.83	66	37.93	72
21	Domenico A. Maisano	9.54	75	30.88	76
22	Luca Mastrogiacomo	8.66	77	27.04	79
23	Fred Y. Ye	6.78	80	18.96	80
24	Linton C Freeman	80.07	2	119.43	10
25	Serge GALAM	18.36	45	74.88	39
26	Wolfgang Glänzel	22.91	29	115.45	11
27	András Schubert	22.93	28	96.01	22
28	Nils T. Hagen	8.72	76	30.58	77
29	Anne-Wil Harzing	23.32	25	108.36	15
30	Roger Brumback	11.45	70	58.49	52
31	Paul Wouters	14.97	60	53.99	57
32	Mark Fine	18.81	42	83.98	32
33	Rodrigo Costas	11.70	67	41.22	69
34	Maria Bordons	17.80	49	66.38	44
35	Carlos Pecharroman	15.75	57	58.52	51
36	Matthew O. Jackson	49.24	5	135.00	8
37	Dimitrios Katsaros	19.34	40	56.63	54
38	Clint D. Kelly	11.66	68	38.87	70
39	Michael Jennions	31.48	13	112.55	12
40	András Telcs	9.59	74	34.03	73
41	Sune Lehmann	17.80	50	41.75	68
42	Andrew D. Jackson	23.32	26	109.30	14
43	Benny Lautrup	18.36	46	73.60	41
44	Judit Bar-Ilan	17.32	52	78.53	37
45	Guang-Hong Yang	21.54	33	92.48	26
46	Duncan Lindsey	17.80	51	50.01	61
47	Yu-Hsin Liu	13.38	65	42.54	67
48	Ben R Martin	33.59	12	96.37	21
49	Steve Lawrence	43.66	7	151.02	5
50	C Lee Giles	39.34	10	169.50	2
51	Henk F. Moed	21.68	31	101.10	19
52	Berwin Turlach	25.02	20	52.07	60
53	Ludo Waltman	16.37	55	53.40	58
54	Nees Jan van Eck	16.40	54	62.71	48
55	Christoph Bartneck	14.32	62	57.48	53
56	JOHN IRVINE	24.00	24	54.18	56
57	Anthony (Ton) F.J. van Raan	24.02	23	110.68	13
58	Gangan Prathap	11.27	72	49.20	63

Table 2 (continued)

Author ID	Scholar Name	EM-index	Rank	iw_{EM}-index	Rank
59	Mauno Vihinen	20.49	35	105.95	16
60	Adamantios Diamantopoulos	43.30	8	147.50	7
61	Heidi Winklhofer	61.54	3	59.84	49
62	Loet Leydesdorff	58.41	4	168.25	3
63	Richard S J Tol	30.32	15	163.13	4
64	Çağan Hakkı Şekercioğlu	22.07	30	79.55	36
65	Albert Zomaya	19.75	36	91.94	27
66	Yannis Manolopoulos	19.62	37	95.34	24
67	Roberto Todeschini	31.26	14	95.77	23
68	Jayant Vaidya	16.22	56	66.20	45
69	Hendrik P. van Dalen	11.40	71	48.26	65
70	Kène Henkens	13.64	64	64.78	46
71	Peter Jacso	18.71	43	52.67	59
72	Johan Bollen	25.53	19	75.05	38
73	Herbert Van de Sompel	23.26	27	80.19	35
74	Aric Hagberg	20.74	34	58.53	50
75	Stan Wasserman	37.70	11	104.29	17
76	Birger Larsen	7.55	79	31.20	75
77	Gerhard Woeginger	24.72	21	96.40	20
78	Claes Wohlin	21.63	32	92.76	25
79	Morten Schmidt	14.56	61	43.68	66
80	Weiguo Fan, Patrick Fan	16.52	53	74.69	40
81	Mark Newman	95.73	1	267.31	1
82	Blaise Cronin	18.11	47	88.88	28

From Table 2, it can be seen that the index value is increased in the iterative weighted EM-index. That proven the effectiveness of iterative weighted EM-index over the EM-index. For further clarification, a critical analysis has been carried out on all those scholars whose EM-index value is similar, as described below.

1. If we consider the scholar **Steve Lawrence (ID=49)** and **Adamantios Diamantopoulos (ID=60)** for comparison, then we can see that their EM-index value is almost similar i.e, **43.66** and **43.30** with corresponding rank **7** and **8** respectively. However their corresponding iterative weighted EM-index value as well as their rank gone up and their corresponding iterative weighted EM-index value is **151.02** and **147.50** with corresponding rank **5** and **7** respectively.
2. Another similar example we can see, if we consider **Anne-Wil Harzing (ID=29)** and **Andrew D. Jackson (ID=42)**. Both scholar having equal **23.32** EM-index value with corresponding rank **25** and **26**. While the iterative weighted EM-index value of the corresponding authors' are **108.36** and **109.30** with rank of **15** and **14** respectively. Here it

can be seen that the rank of scholars is increased and we can find a significant difference between both scholars.

3. Another similar example we can see, if we consider the scholar **Wolfgang Glänzel (ID=26)** and scholar **Mauno Vihinen (ID=59)**. Both scholars gain their rank in iterative weighted EM-index.
4. The only 3 author secure the same rank **9**, **80** and **1** in both indices, i.e, Scholar ID **1**, **23** and **81**.
5. Total **35** scholars' rank decreases, and total **44** scholars gain their rank, and three scholars retain their rank.
6. Scholar **Heidi Winklhofer (ID=61)** loss their maximum rank. In EM-index scholar have rank **3** while in iterative weighted EM-index his rank decreases with **46** and he got rank **49**.
7. Another bright part of the iterative weighted EM-index, scholar **Mauno Vihinen (59)** and **Blaise Cronin (ID=82)** ranks' increase significantly with 19. In EM-index, scholars have rank 35 and 47 respectively, while in iterative weighted EM-index, their ranks are 16 and 28, respectively.The difference between EM-index and iteratively weighted EM-index rank is shown in Fig. 2.

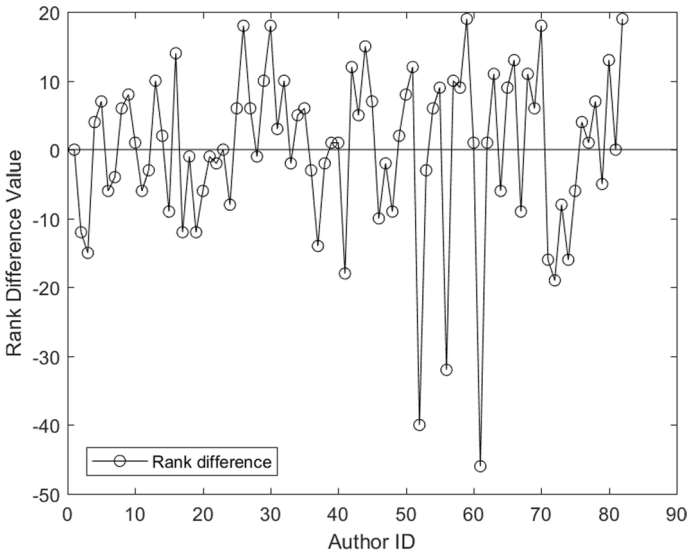


Fig. 2 EM-index and Iterative weighted EM-index rank difference of all scholars

It can be clearly seen from the above discussion that the proposed iterative weighted EM-index gives a superior impact over the EM-index. While as we know that the EM-index considers only h-core elements on the assessment of scholars and gives the impact of highly cited articles. To overcome this issue, the EM'-index has been proposed (Bihari and Tripathi 2017), which considers both cores as well as tail articles citation with consideration of excess citation count. But as similar to the EM-index, EM'-index gives equal weighted to all component's value, that is not fair. In this context, we have considered a similar weighted mechanism and named iterative weighted EM'-index, which is described in the next section.

Iterative weighted $EM' - index$: an extension of iterative weighted EM-index

The proposed iterative weighted EM-index consider only a few amounts of highly cited articles for scientific assessment of scholar and left the huge number of publication that has a good amount of citation. To consider that article, the multidimensional h-index (García-Pérez 2009), two-sided h-index (García-Pérez 2012), tapered h-index (Anderson et al. 2008) and the EM'-index (Bihari and Tripathi 2017). The above-mentioned indices try to consider the all cited publication in the scientific assessment of scholars. The EM'-index is the latest among all indices. This index considers all cited publications and gives a set of component values along with the global index value. As similar to the EM-index, the EM'-index gives equal credit to all component value that is not fair. We can not consider all components equally. In this context, we have considered an iterative weighted mechanism and proposed iterative weighted EM'-index.

Definition *"The iterative weighted EM'-index of a scholar is the iterative weighted sum of the components of the EM'-index."*

The Mathematical formula of the iterative weighted EM'-index is as follows:

$$iw_{EM'} = \sum_{c=1}^{m} \frac{EM'_c}{c} \tag{2}$$

where $iw_{EM'}$ is the iterative weighted EM'-index, m is the total number of element of the EM'-index and EM'_c is the c^{th} component of the EM'-index. The proposed index follows the all properties of the EM'-index for the computation of component of the index. The only difference is in the production of global index value. The EM'-index is the square root of the sum of component value and penalizes all those scholars who have long tail as well as high h-index value. The iterative weighted mechanism has been adopted, to address this issue. To demonstrate the iterative weighted EM'-index, we have consider the author **Fred Y. Ye (ID=23)**, publication and their citation details (given in Table 3)

Table 3 Iterative weighted EM'-index of author **Fred Y. Ye (ID=23)**

Rank	iEM1	iEM2	iEM3	iEM4	iEM5	iEM6	iEM7	iEM8	iEM9	iEM10	iEM11	iEM12
1	50	40	32	26	20	15	11	8	5	3	2	1
2	45	35	27	21	15	10	6	3	2	2	1	1
3	33	23	15	9	6	5	3	3	2	2	1	1
4	30	20	12	6	6	4	3	2	2	1	1	1
5	24	14	7	6	5	3	2	2	1	1	1	1
6	23	13	7	6	5	3	2	2	1	1	1	1
7	17	8	6	6	4	2	2	1	1	1	1	1
8	12	8	6	6	3	2	1	1	1	1	1	1
9	11	7	6	5	3	2	1	1	1	1	1	1
10	10	7	6	5	2	1	1	1	1	1	1	1
11	8	6	5	4	2	1	1	1	1	1	1	1
12	8	6	5	3	2	1	1	1	1	1	1	1
13	7	6	4	2	1	1	1	1	1	1	1	1
14	6	5	3	2	1	1	1	1	1	1	1	1
15	6	4	2	2	1	1	1	1	1	1	1	1
16	6	3	2	1	1	1	1	1	1	1	1	1
17	5	2	2	1	1	1	1	1	1	1	0	0
18	4	2	1	1	1	1	1	1	1	0	0	0
19	3	2	1	1	1	1	1	1	0	0	0	0
20	2	1	1	1	1	1	1	1	0	0	0	0
21	2	1	1	1	1	1	1	0	0	0	0	0
22	1	1	1	1	1	1	0	0	0	0	0	0
23	1	1	1	1	1	0	0	0	0	0	0	0
24	1	1	1	1	0	0	0	0	0	0	0	0
25	1	1	1	1	0	0	0	0	0	0	0	0
26	1	1	1	1	0	0	0	0	0	0	0	0
27	1	1	0	0	0	0	0	0	0	0	0	0
28	1	1	0	0	0	0	0	0	0	0	0	0
29	1	0	0	0	0	0	0	0	0	0	0	0
Component	10	8	6	6	5	4	3	3	2	2	1	1

The author has a total of 29 articles with h-index 10 (First component value), the EM-index is 6.78, the iterative weighted h-index is 18.96, the EM'-index is 7.14 and the iterative weighted EM'-index is 20.57. The computation process of the iterative weighted EM'-index is similar to the iw_{EM}-index. The component of the $iw_{EM'}$-index are {10, 8, 6, 6, 5, 4, 3, 3, 2, 2, 1, 1 }. The index value = $10\times1+8\times\frac{1}{2}+6\times\frac{1}{3}+6\times\frac{1}{4}+5\times\frac{1}{5}+4\times\frac{1}{6}+3\times\frac{1}{7}+3\times\frac{1}{8}+2\times\frac{1}{9}+2\times\frac{1}{10}+1\times\frac{1}{11}+1\times\frac{1}{12}=20.57$. This comparative result states that the proposed iterative weighted EM'-index gives a better result than other indices. The iterative weighted EM'-index of all scholars is shown in Fig. 3. To prove the effectiveness of iterative weighted EM'-index over the iterative weighted EM-index, we made a comparative analysis of all authors that is shown in Fig. 4. Further, we made a rank based comparative analysis of iterative weighted EM'-index with iterative weighted EM-index and EM'-index. The comparative analysis is shown in Fig. 5.

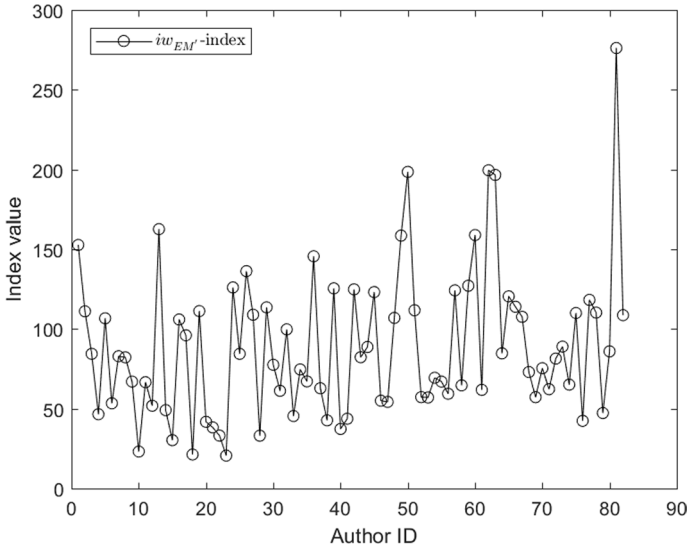


Fig. 3 The iterative weighted EM'-index for the data set of 82 scholar (Bihari and Tripathi 2017)

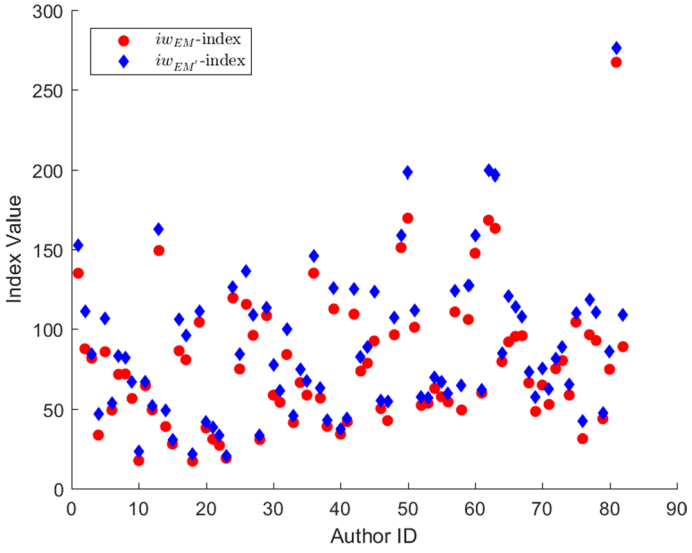
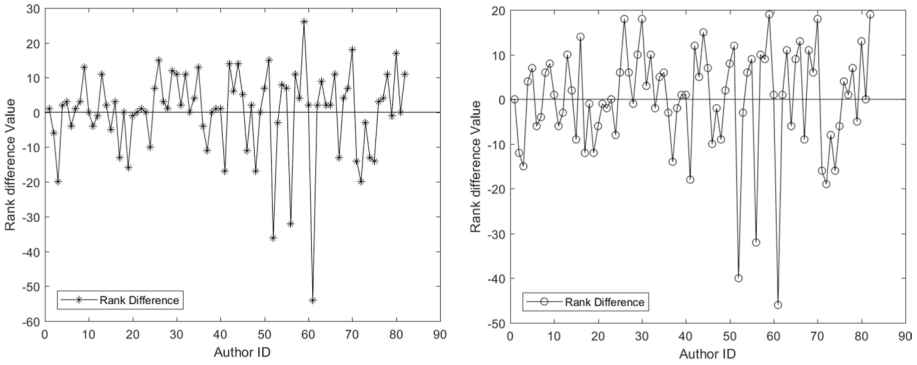


Fig. 4 Comparative EM-index and iterative weighted EM'-index of all scholars



(a) Rank difference of all scholars between $EM^{'}$-index and iterative weighted $EM^{'}$-index

(b) Rank difference of all scholars between iterative weighted EM-index and iterative weighted $EM^{'}$-index

Fig. 5 A rank difference comparative analysis of iterative weighted $EM^{'}$-index with $EM^{'}$-index and iterative weighted EM-index for the data set of 82 scholar (Bihari and Tripathi 2017)

When we compare the iterative weighted $EM^{'}$-index with $EM^{'}$-index, then we found that total 26 authors losses their rank, total 8 authors' retains their rank, while total 48 author gain their rank. Author **Mauno Vihinen (ID=59)** gains their rank with 26 rank ($EM^{'}$-index rank–37 and iterative weighted $EM^{'}$-index rank –11) and author **Heidi Winklhofer (ID=61)** losses maximum 54 rank ($EM^{'}$-index rank–3 and iterative weighted $EM^{'}$-index rank –57). It can be easily seen in Fig. 5a. Further, if we compare the iterative weighted $EM^{'}$-index with iterative weighted EM-index, then we found that total 36 authors gains their rank, total 9 authors retains their rank and total 37 authors losses their rank. Author **Guang-Hong Yang (ID=45)** and **Albert Zomaya (ID=65)** gains their rank with 10 (i.e, maximum) while author **Ben R Martin (ID=48), Heidi Winklhofer (ID=61)** and **Stan Wasserman (ID=75)** losses their rank with 8 (i.e, maximum). It can be easily seen in Fig. 5b.

To prove the effectiveness of proposed indices with h-index, EM-index, and $EM^{'}$-index, we have done a rank based comparative analysis. That shows the effectiveness of the proposed method over the above-mentioned indices. The rank-based comparative analysis of h-index, EM-index, $EM^{'}$-index, iw_{EM}-index, and $iw_{EM'}$-index for all 82 scholars shown in Table 4.

Table 4 A rank based comparative analysis of h-index, EM-index, $EM^{'}$-index, iw_{EM}-index, and $iw_{EM'}$-index for all 82 scholars

ID	h-index	Rank (h)	EM-index	Rank (EM)	$EM^{'}$	Rank ($EM^{'}$)	iw_{EM}	Rank (iw_{EM})	$iw_{EM'}$	Rank ($iw_{EM'}$)
1	63	7	40.36	9	41.19	9	134.95	9	152.70	8
2	45	27	28.72	17	30.17	17	87.56	29	111.07	23
3	34	42	27.40	18	27.60	18	81.67	33	84.41	38
4	22	61	8.49	78	13.04	71	33.45	74	46.51	69
5	45	28	19.52	39	23.30	33	85.71	31	106.69	30
6	22	62	15.39	58	16.67	62	49.11	64	53.38	65
7	35	38	19.54	38	21.17	41	71.54	43	82.89	40
8	33	44	17.80	50	20.05	45	71.80	42	82.22	42
9	30	47	13.64	63	16.12	64	56.40	55	67.00	51
10	11	80	5.83	82	8.43	80	17.44	81	23.12	80

Table 4 (continued)

ID	h-index	Rank (h)	EM-index	Rank (EM)	EM'	Rank (EM')	iw_{EM}	Rank (iw_{EM})	$iw_{EM'}$	Rank ($iw_{EM'}$)
11	24	60	18.84	41	19.26	48	64.43	47	66.61	52
12	19	72	15.23	59	16.00	65	49.24	62	51.86	66
13	69	5	28.86	16	31.58	16	149.20	6	162.64	5
14	22	63	9.90	73	13.64	69	38.78	71	49.10	67
15	12	79	11.49	69	11.70	74	27.82	78	30.25	79
16	46	25	18.52	44	23.11	34	86.33	30	105.96	31
17	39	34	24.10	22	26.68	20	80.71	34	96.04	33
18	10	81	6.24	81	7.35	81	17.07	82	21.27	81
19	41	32	46.50	6	46.93	6	104.26	18	111.22	22
20	20	69	11.79	66	12.21	73	37.93	72	41.76	74
21	18	73	9.59	74	11.58	75	30.88	76	38.24	75
22	15	77	8.60	77	10.15	78	27.04	79	33.12	77
23	10	82	6.71	80	7.07	82	18.91	80	20.57	82
24	47	22	80.07	2	80.23	2	119.43	10	126.05	12
25	35	39	18.38	45	19.65	46	74.88	39	84.41	39
26	61	8	22.93	28	24.90	25	115.45	11	136.27	10
27	49	20	22.91	29	24.25	29	96.01	22	108.93	26
28	15	78	8.77	76	9.27	79	30.58	77	33.07	78
29	47	23	23.35	25	23.79	32	108.36	15	113.56	20
30	35	40	11.40	71	17.80	55	58.49	52	77.52	44
31	27	53	14.93	60	16.70	60	53.99	57	61.22	58
32	46	26	18.79	42	20.54	43	83.98	32	99.75	32
33	20	70	11.75	67	13.19	70	41.22	69	45.40	70
34	32	46	17.83	48	18.65	50	66.38	44	74.62	46
35	30	48	15.72	57	16.67	61	58.52	51	67.14	49
36	59	10	49.23	5	49.66	5	135.00	8	145.59	9
37	27	54	19.36	40	20.15	44	56.63	54	62.81	55
38	18	74	11.70	68	12.61	72	38.87	70	42.68	72
39	53	15	31.46	13	32.43	14	112.55	12	125.47	13
40	18	75	9.54	75	10.49	77	34.03	73	37.28	76
41	16	76	17.83	49	18.19	54	41.75	68	43.70	71
42	59	11	23.35	26	24.33	28	109.30	14	124.83	14
43	37	36	18.38	46	19.42	47	73.60	41	82.28	41
44	41	33	17.29	52	18.92	49	78.53	37	88.69	35
45	51	17	21.56	33	26.66	21	92.48	26	123.13	16
46	22	64	17.78	51	18.30	52	50.01	61	54.99	63
47	22	65	13.42	65	15.23	66	42.54	67	54.27	64
48	42	31	33.57	12	34.03	12	96.37	21	106.94	29
49	60	9	43.67	7	44.35	7	151.02	5	158.55	7
50	83	4	39.36	10	40.94	10	169.50	2	198.54	3
51	50	18	21.70	31	23.04	36	101.10	19	111.74	21
52	21	67	25.00	20	25.36	24	52.07	60	57.24	60
53	25	59	16.40	54	16.73	59	53.40	58	57.03	62
54	30	49	16.37	55	17.29	56	62.71	48	69.40	48

Table 4 (continued)

ID	h-index	Rank (h)	EM-index	Rank (EM)	EM'	Rank (EM')	iw_{EM}	Rank (iw_{EM})	$iw_{EM'}$	Rank ($iw_{EM'}$)
55	28	51	14.28	62	17.06	57	57.48	53	67.01	50
56	26	56	23.98	24	24.41	27	54.18	56	59.37	59
57	55	13	24.00	23	24.70	26	110.68	13	124.22	15
58	28	52	11.22	72	16.88	58	49.20	63	64.63	54
59	58	12	20.52	35	22.83	38	105.95	16	127.11	11
60	67	6	43.29	8	43.73	8	147.50	7	158.93	6
61	22	66	61.55	3	61.56	3	59.84	49	61.81	57
62	86	2	58.42	4	59.56	4	168.25	3	199.57	2
63	85	3	30.30	15	33.41	13	163.13	4	196.62	4
64	35	41	22.05	30	22.63	39	79.55	36	84.71	37
65	52	16	19.72	36	26.72	19	91.94	27	120.47	17
66	49	21	19.65	37	24.21	30	95.34	24	113.95	19
67	44	29	31.27	14	31.95	15	95.77	23	107.61	28
68	30	50	16.19	56	18.33	51	66.20	45	72.99	47
69	26	57	11.45	70	14.14	68	48.26	65	57.22	61
70	34	43	13.60	64	16.49	63	64.78	46	75.39	45
71	26	58	18.73	43	20.62	42	52.67	59	62.23	56
72	33	45	25.55	19	26.29	23	75.05	38	81.42	43
73	37	37	23.28	27	24.06	31	80.19	35	88.94	34
68	30	50	16.19	56	18.33	51	66.20	45	72.99	47
69	26	57	11.45	70	14.14	68	48.26	65	57.22	61
70	34	43	13.60	64	16.49	63	64.78	46	75.39	45
71	26	58	18.73	43	20.62	42	52.67	59	62.23	56
72	33	45	25.55	19	26.29	23	75.05	38	81.42	43
73	37	37	23.28	27	24.06	31	80.19	35	88.94	34
74	27	55	20.71	34	21.33	40	58.53	50	65.10	53
75	43	30	37.71	11	38.13	11	104.29	17	110.02	25
76	21	68	7.48	79	11.40	76	31.20	75	42.37	73
77	54	14	24.70	21	26.46	22	96.40	20	118.24	18
78	50	19	21.61	32	23.07	35	92.76	25	110.28	24
79	20	71	14.53	61	15.03	67	43.68	66	47.26	68
80	39	35	16.49	53	18.22	53	74.69	40	85.96	36
81	88	1	95.72	1	95.93	1	267.31	1	276.23	1
82	47	24	18.08	47	22.83	37	88.88	28	108.66	27

From Table 4, it can be seen that the author **Mark Newman (ID=81)**, secure rank **1** in all cases. Author **Adamantios Diamantopoulos (ID=60)** secure rank 6 in iterative weighted EM'-index and also secure equal rank in h-index. A total of 5 authors gain their rank when the iterative weighted EM-index has been used. Author **C Lee Giles (ID=50)**, **Michael Jennions (ID=39)**, **Anne-Wil Harzing (ID=29)**, **Maria Bordons (ID=34)** and **András Telcs (ID=40)** gain their rank in iterative weighted EM-index. The above statement highlights that the proposed index is in the line of previous indices. To find the

Table 5 Result of spearman rank correlation between h-index, e-index, iw(h)-index, EM-index, EM'-index, iw_{EM}-index, and $iw_{EM'}$-index

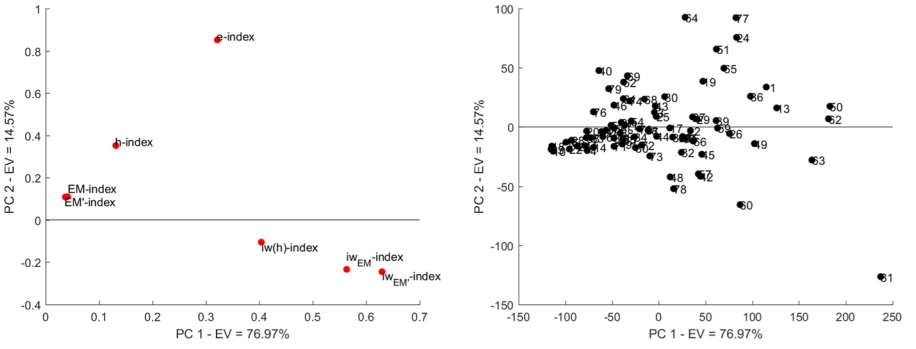
	h	e	iw(h)	EM	EM'	iw_{EM}	$iw_{EM'}$
h	1	0.86	**0.97**	0.76	0.81	**0.97**	**0.99**
e	0.86	1	0.77	**0.95**	**0.95**	**0.95**	**0.91**
iw(h)	**0.97**	0.77	1	0.67	0.75	**0.91**	**0.95**
EM	0.76	**0.95**	0.67	1	**0.98**	0.87	0.83
EM'	0.81	**0.95**	0.75	**0.98**	1	0.89	0.87
iw_{EM}	**0.97**	**0.95**	**0.91**	0.87	0.89	1	**0.99**
$iw_{EM'}$	**0.99**	**0.91**	**0.95**	0.83	0.87	**0.99**	1

The score above 90% given in bold

correlation between indices, we performed the Spearman rank correlation between the indices. The result of the spearman rank correlation is shown in Table 5.

From Table 5, it can be seen that the proposed index having a high correlation with all indices h-index, e-index, iw(h), EM and EM'-index. The EM-index has a minimum correlation with h-index, i.e., 0.76, and the iterative weighted EM'-index has a high correlation with iterative weighted EM-index and h-index, i.e., 0.99. So, we can say that the proposed indices are in the line of already existing indices. Based on Table 5, we can conclude that the proposed indices could be used as an effective alternative of h-index, EM-index, and EM'-index.

Further, the principal component analysis test has been done on all 82 scholars data that has 7 variables, h-index, e-index, iw(h)-index, EM-index, EM'-index, iw_{EM}-index and $iw_{EM'}$-index. We have computed four principal components that explaining total variance is 98.52% of the total variance. Figure 6 shows the score and loading of the first and second principal components.

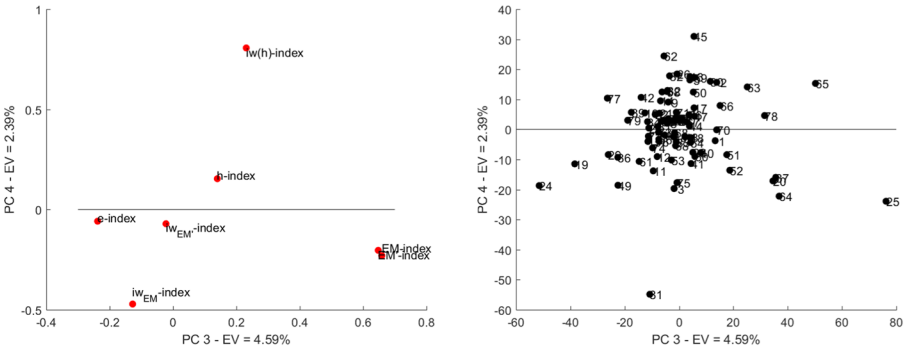


(a) The loading plot of first and second PCs with total 91.54% of total variance.

(b) The distribution of score of first and second PCs for all 82 scholars

Fig. 6 The Loading and score plot of first and second PCs for the data set of 82 scholar (Bihari and Tripathi 2017)

Figure 6a shows the loading of the first and second PC of the data. All variables present in the same positive sign that indicates global scientometrics quality, then the right side of the Fig. 6b indicates the best scholar. Similarly, it can also be seen that the proposed indices (iw_{EM}-index and $iw_{EM'}$-index) has the significant difference with h-index, e-index, EM-index and EM'-index. These PCs also highlights that the iw_{EM}-index and $iw_{EM'}$-index as well as the EM and EM'-index are highly correlated. From Fig. 6b, it can also be observed that there are four scholars (ID=60, 62, 63, and 81) that have a significant difference in their score, it happens due to his/her scientometrics quality. Scholar 60 and 81 have a significant difference in the second PC, the high value for 60, and a low value for 81. This happens due to the index value in EM-index and $iw_{EM'}$-index. Similarly, it can also be observed that the scholar 64 and 77 present at the top of the graph, which highlights high influence scholar, it happens due to the good index value in h-index, iw(h)-index, and $iw_{EM'}$-index. The loading and score plot for third and fourth PCs is shown in Fig. 7.



(a) The loading plot of third and fourth PCs with total 6.98% of total variance.

(b) The distribution of score of third and fourth PCs for all 82 scholars

Fig. 7 The Loading and score plot of third and fourth PCs for the data set of 82 scholar (Bihari and Tripathi 2017)

Figure 7a is the loading plot of the next two third and fourth PCs that explains a total of 6.98% of the total variance. From Fig. 7a, it can be observed that the behavior of e-index is different from the other indices (it present on the negative side of the plot). Similarly, it can also be observed that the h-index plays a remarkable role in the third PCs. The h-index and iw(h) present at the top of the graph, and the rest of the elements are present at the bottom of the graph. Figure 7a also highlights that the EM and $EM^{'}$-index are highly correlated as similar to the loading plot of first and second PCs; however, the proposed indices are not much correlated like EM and $EM^{'}$-index. Figure 7b shows the corresponding score plot of all 82 scholars. From Fig. 7b, it can easily be seen that the scholar 65 and 25 have a significant difference in the third PCs, this happens, because scholar 65 having high h-index, iw(h) and $iw_{EM'}$-index value than the scholar 25, but scholar relatively lower e-index and EM-index. Similarly, we can also see that scholar 45 present at the top of the graph and scholar 81 present at the bottom of the graph. This happens because author 81 having a higher index value in almost all components as compared to scholar 45. From the above discussion, it can be concluded that the EM-index and $EM^{'}$-index as well as iw_{EM}-index and $iw_{EM'}$-index is highly correlated. The EM and $EM^{'}$-index are highly correlated as compared to the correlation between iw_{EM}-index and $iw_{EM'}$-index.

Conclusions

In the field of scientometrics, there are several indices has been developed for scientific assessment of scholar. This article discusses a new measure that considers both excess and tail article citation count. The proposed indices are the extension of EM-index and $EM^{'}$-index. In EM-index, every component has equal importance, but we can not consider the first and 100th components equally. In this article, we have considered the importance of component and gives their importance based on their rank and proposed two indices iterative weighted EM-index and iterative weighted $EM^{'}$-index. To prove the effectiveness of proposed indices, a total of 82 scholars' data has been considered for experimental analysis. The experimental analysis highlights that more than 50% of scholars rank is improved. To prove the effectiveness of the proposed method over the h-index, e-index, iw(h)-index, EM-index, and $EM^{'}$-index, the spearman rank correlation, and principal component analysis has been done. Both analyses highlight that the proposed indices are highly correlated with the other indices. Based on the experimental analysis, we can conclude that the proposed indices could be used as an effective alternative of h-index, EM-index, and $EM^{'}$-index.

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