Communication

Author-Suggested, Weighted Citation Index: A Novel Approach for Determining the Contribution of Individual Researchers

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Abstract: A novel scientometric index, named 'author-suggested, weighted citation index' (A_w-index) is proposed to indicate the scientific contribution of any individual researcher. For calculation of the A_w-index, it is suggested that during the submission of a scholarly article, the corresponding author would provide a statement, agreed upon by all the authors, containing weightage factors against each author of the article. The author who contributed more to the article would secure a higher weightage factor. The summation of the weightage factors of all the authors of an article should be unity. The citation points a researcher receives from a scholarly publication is the product of his/her weightage factor for that article and the total number of citations of the article. The A_w-index of any individual researcher is the summation of the citation points he/she receives for all his/her publications as an author. The A_w-index provides the opportunity to the group of authors of a multi-authored article to determine the quantum of partial citations to be attributed to each of them. Through an illustrative example, a comparison of the proposed index with the major scientometric indexes is presented to highlight the advantages of the A_w-index.

Keywords: scientometric indexes; scholarly publications; scientific contribution of individual; author-suggested weighted citation index

1. Introduction

The scientific contribution made by a researcher is often approximated in terms of the impact of his/her scholarly publications. This has become an important parameter for appointment in academic positions, research collaboration, receipt of research grants, etc. [1–8]. The impact of the scholarly publications of a researcher is related to the citations of his/her publications quantified in terms of different scientometric indexes such as cumulative citations, h-index [9,10], i10-index [11], etc. The cumulative citations provide the total number of citations received by all of the scholarly publications of a researcher. The h-index of a researcher is defined as the highest value of h such that the researcher has at least h publications, each of that have been cited at least h times. On the other hand, the i10-index of a researcher indicates the number of publications authored by him/her with at least 10 citations. However, as these indexes do not adjust their values for multi-authored publications, sometimes they may put forward a misleading picture. In the present age of rising multi-authored publications [12–17], much research is devoted to determining the co-authorship-adjusted impact of a researcher. However, the scientific community is still divided on the methodology to be adopted to quantify the proportion of credit to be attributed to a particular author of a multi-authored scholarly article. Several indexes, such as, h_I-index [18], h_f-index [19], h_m-index [20,21], etc. have been proposed for determination of co-authorship-adjusted impact of a researcher. The h_I-index is determined by dividing the h-index by the average number of authors of the publications in the h-core (that is, in the h-index defining set of publications). To determine the h_f-index, fractional citations are derived by dividing the number of citations by the number of authors for each publication. The h_f-index is the number of publications of a

researcher for which the fractional citations are at least equal to h_f. For determination of the h_m-index, the publication list of a researcher is sorted by the number of citations with the publication having the highest number of citations ranked first. Then, the effective rank of a publication is determined as, $r_{eff}(r) = \sum_{n=1}^{r}[1/a(r)]$. Here, $a(r)$ is the number of authors of the rth ranked publication. The h_m-index is the value of the r_{eff} of the highest ranked publication for which the number of citations is not less than r_{eff}. There are more such imperial formulation-based approaches that provide partial citations to each author when a multi-authored scholarly article is cited in another article. L-index [22], k-index [23], eigenfactor-derived scoring system [24], hIa-index [25], RA-index [26], pure h-index [27] represent a few examples. The main drawback of these approaches is that all the authors of a multi-authored article are given equal weightage. In a slightly different approach, the Z-index [28,29] and the Ab-index [30] provide additional weightage to the first author and the corresponding author, and equal weightage to all other authors.

Recently many of the leading journals have made it compulsory to share the detailed description of the contributions of each author to the published article through Contributor Role Taxonomy (CRediT) [31–34]. From the analysis of CRediT statement of a large number of scholarly publications, it is observed that the contributions of all the authors are not always equal in a multi-authored publication. In view of this, a novel scientometric index in the form of the 'author-suggested, weighted citation index' (A_w-index) is proposed. The A_w-index is expected to quantify the scientific contribution of any individual researcher, taking his/her possible authorships in multi-authored publications into account with appropriate weightage suggested by the authors of the publications themselves.

2. Methods

The A_w-index requires the corresponding author to provide a 'contribution weightage statement', containing a weightage factor against each author of the article, during the submission process of any scholarly article. The 'contribution weightage statement' should be agreed upon by all the authors. Let N be the number of authors of a scholarly publication and the weightage factor of the ith author is w_i. Then, w_i should satisfy the following two conditions.

$$0 < w_i \leq 1, \tag{1}$$

$$\sum_{i=1}^{N} w_i = 1, \tag{2}$$

The author who contributed more to the article would secure a higher weightage factor. The author of a single-authored article would get a weightage factor equal to 1. Later, when an article would be cited, the article would receive 1 citation point for each citation. While calculating the A_w-index, the citation point would be distributed among the authors of the article based on the weightage factor.

For determination of the weightage factors of the authors of an article, intellectual impact should be given paramount importance. However, the co-authors may select a few additional parameters based on mutual agreement. For articles with fewer authors, the weightage factors for each co-author can be determined in a straightforward approach fulfilling the conditions mentioned above. However, when a large number of authors contribute to an article [12,14,15], the weightage factors of the authors may be determined through an indirect approach. For this scenario, it is proposed that the authors should be grouped based on the activities they are involved in. For example, one group may be involved in experimental works, the other group may be doing numerical simulations, another group may be involved in data acquisition, a group may be developing and validating a mathematical model, and so on. The weightage factors for each group would be determined first. After that, the weightage factor of a group would be further divided into the members of the group based on their contributions within the group. It may so happen that a particular researcher is involved in more than one group. Then, his/her total weightage factor for the article would be the summation of the weightage factors he/she would receive from different groups.

Now, consider a scholarly publication gets a total C number of citations. Then, the contribution of that publication to the A_w-index of the ith author would be $C \times w_i$ citation points. The A_w-index of any researcher would be the summation of the citation points he/she receives from all the articles in which he/she had contributed as an author or as a co-author.

Let X be the number of scholarly publications a researcher produces as author or co-author. His/her nth publication, for which the weightage factor of the researcher is w_n, receives a total C_n number of citations. Then the A_w-index of the researcher can be expressed by the following.

$$A_w - \text{index} = \sum_{n=1}^{X} C_n w_n \tag{3}$$

In Equation (3), w_n indicates the contribution factor and C_n indicates the quality factor as a better scholarly publication is expected to have higher citations. Through the summation of citation points of all the publications of the researchers, the quantity factor is also taken care of in the A_w-index. Thus, the A_w-index is expected to become a useful indicator of the scientific contribution of any individual researcher as it gives an estimate of the significance, importance, and broad impact of a researcher's cumulative scientific effort.

3. Results

Let R_1 to R_6 be a group of six researchers. They collectively produced ten scholarly publications designated as p_1 to p_{10}, each of which has at least two researchers from the group of six as authors. The lists of authors of the publications are given in Table 1. For simplicity, it is assumed that none of the six researchers considered for the present study have produced any other scholarly publication as authors or co-authors.

Table 1. Lists of authors for publications p_1 to p_{10}.

Publications	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9	p_{10}
Lists of Authors	$R_1,$ $R_2,$ $R_3,$ $R_4,$ $R_5,$ R_6	$R_1,$ $R_2,$ $R_3,$ R_6	$R_1,$ $R_3,$ $R_4,$ $R_5,$ R_6	$R_1,$ $R_2,$ $R_5,$ R_6	$R_1,$ R_6	$R_1,$ $R_3,$ R_6	$R_1,$ $R_2,$ $R_3,$ $R_5,$ R_6	$R_1,$ $R_5,$ R_6	$R_1,$ $R_4,$ $R_5,$ R_6	$R_1,$ $R_2,$ $R_3,$ $R_4,$ R_6

Now, for the determination of the A_w-index, the weightage factors of the researchers for the publications are required. It may be noted that the A_w-index is a new concept and presently the journals do not have the provision for submission of the 'contribution weightage statement' for the authors during the submission of scholarly articles. Hence, to illustrate the concept of the A_w-index, let us assume that the values of weightage factors, w, of the researchers for the publications are as given in Table 2. The number of citations received by the publications are also given in Table 2.

Now the A_w-indexes of the researchers considered for the present study are calculated using Equation (3) and plotted in Figure 1. Among the six researchers, R_6 has the highest A_w-index of 25.8. On the other hand, R_4 has the lowest A_w-index of 6.3. From Table 1, it can be observed that both R_1 and R_6 have contributed to all 10 scholarly publications under consideration. However, as R_6 contributed more than R_1 in most of the publications (see Table 2), A_w-index of R_6 is much higher than that of R_1. Again, R_2, despite having a lesser number of publications, has a higher A_w-index than R_1. This is because R_2 has a high proportion of contribution in the publications he/she features as co-author. This ability to include the proportion of contribution in the scientometric indexes of individual researchers is the main feature of A_w-index.

Table 2. Weightage factors of the researchers and number of citations for publications p_1 to p_{10}.

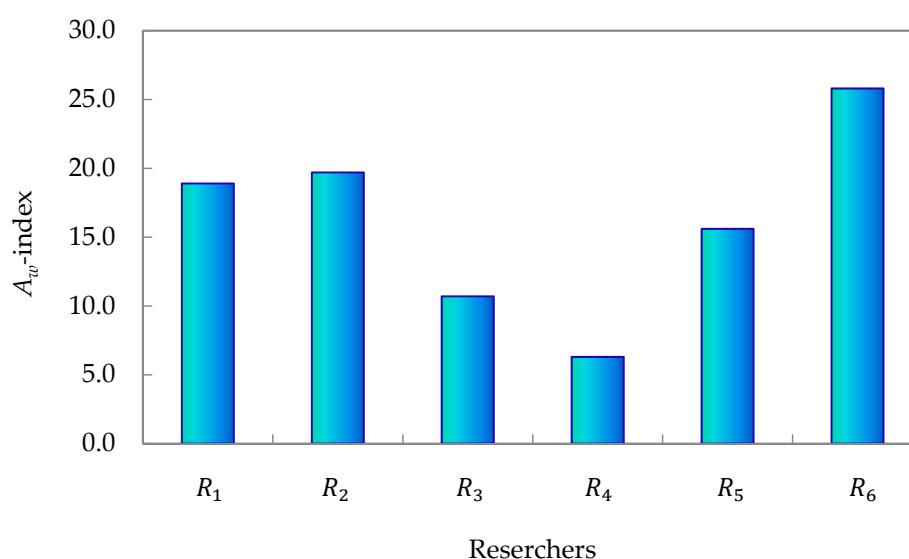| Author	Publication									
	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9	p_{10}
R_1	0.1	0.1	0.1	0.3	0.5	0.2	0.1	0.2	0.2	0.1
R_2	0.3	0.4	-	0.5	-	-	0.4	-	-	0.3
R_3	0.2	0.2	0.1	-	-	0.5	0.2	-	-	0.1
R_4	0.1	-	0.4	-	-	-	-	-	0.1	0.1
R_5	0.2	-	0.3	0.1	-	-	0.1	0.6	0.5	-
R_6	0.1	0.3	0.1	0.1	0.5	0.3	0.2	0.2	0.2	0.4
Number of Citations	7	10	6	9	12	6	10	5	15	17

Figure 1. A_w -index of the six researchers considered for present study.

Table 3 shows the comparison of A_w-index with the major scientometric indexes for the six researchers. Both the indexes that do not make adjustment for multi-authorship, such as cumulative citations, h-index, and $i10$-index, and the indexes that make adjustment for multi-authorship, such as h_I-index, h_f-index, and h_m-index are considered for the comparative study. Table 3 shows that all the indexes except the A_w-index have an identical value for the researchers R_1 and R_6. Only the A_w-index is able to quantitatively identify that R_6 contributed more than R_1 in most of their publications. Researcher R_2 ranked fourth among the group as per cumulative citations, h-index and h_I-index. In contrast, his/her rank is third as per $i10$-index and h_f-index. The h_m-index places him/her in the fifth spot. Although R_2 has a lesser number of publications, he/she put up more effort behind those publications than most of his/her co-authors. This ensures higher weightage factors for him/her in those publications (see Table 2). As commonly used bibliometric indexes, provide equal weightage to all the co-authors, they do not indicate the extra effort of R_2. On the other hand, the A_w-index gives recognition of the extra effort of R_2 and thus places him/her in the second spot among the group of researchers. The A_w-index combines (a) the research effort of an individual behind his/her publications with (b) the quality of his/her publications in terms of citation and (c) the quantity of his/her publications as it includes all of his/her publications in the calculation.

Table 3. Comparison of A_w-index with major bibliometric indexes.

Researchers	A_w-Index	Indexes Do not Make Adjustment for Multi-Authorship			Indexes Make Adjustment for Multi-Authorship		
		Cumulative Citations	h-Index	i-Index	h_I-Index	h_f-Index	h_m-Index
R_1	18.9	97	7	5	1.6	3	2.7
R_2	19.7	53	5	3	1.0	2	1.1
R_3	10.7	56	6	3	1.3	2	1.4
R_4	6.3	45	4	2	0.8	2	0.8
R_5	15.6	52	5	2	1.0	2	1.4
R_6	25.8	97	7	5	1.6	3	2.7

4. Discussions

The A_w-index is developed to enhance clarity in the attribution of credit to the researchers for the publications they produced as authors or co-authors. The A_w-index covers the quality and quantity of publications as well as the research effort of an individual researcher behind the publications. It is expected that upon adaptation by the journals collectively, the A_w-index could become a reliable indicator of the scientific contribution of individual researchers in the future. It is not possible to start using the A_w-index immediately, as the weightage factors of the authors of already published articles are not available with the journals. It is anticipated that the journals would take time and require review before they start asking the authors for submission of their weightage factors on contribution. A similar thing has happened with the attribution of contributorship. In the year 1997, Rennie et al. [35] proposed the concept of contributorship, ultimately leading to the development of CRediT [31] in 2014. Now, most of the leading journals are publishing author contributions statements with the articles. In the same line, it is presumed that the implementation of the A_w-index by the journals would take some time.

The concept of the weightage factor is expected to reduce the chances of denial of authorship on the ground of smaller contributions. When the contribution of a researcher in an article is small, instead of denying authorship, he/she may be given authorship with a smaller weightage factor. With the system of weightage factor in place, one researcher with a larger contribution would be more open to accept a smaller contributor as co-author because the effort of the larger contributor would be recognized with a higher weightage factor. However, and only if a smaller contributor fulfills the minimum requirements for authorship, he/she could be included as co-author with appropriate weightage factor. There are several guidelines for the minimum requirements for authorship [36–40]. However, a universal guideline in this regard is yet to be developed. It may be noted that the determination of minimum contribution for granting authorship is out of the present scope of this article.

In order to be sure about the correctness of the assigned weightage on contributions, the journals may frame a rule that makes submission of the 'contribution weightage statement' signed by all the co-authors compulsory during the initial submission of a manuscript. Alternatively, the journals may develop an automatic verification system through auto-generated e-mails. It may be noted that many journals already follow a system for verification of authorship of the submitted articles through auto-generated e-mails. The process of verification of the 'contribution weightage statement' can easily be integrated with that system.

Sometimes there may be conflict among the co-authors on different issues [41], including the distribution of the weightage factors. To avoid this, co-authors should discuss and agree on the goals of collaboration, roles of individuals, guidelines for authorship, contingencies and communication strategies, and methods for handling conflicts, including conflicts of interest [42], at the early phase of the research process. As the research progresses, the roles of co-authors may change and even co-authors may be added or

dropped. This may lead to variation in the expected weightage factor of a co-author. All such alterations should be done through open, honest, and respectful discussion [43].

The risk of a co-author agrees to a manipulated 'contribution weightage statement' under some kind of pressure cannot be completely ruled out. However, when the co-authors adhere to the best authorship practices and guidelines [38,44–47] this kind of situation would not occur. Moreover, studies to develop a more objective approach for determination of percentage contributions of the co-authors may be taken up in the future to avoid any manipulation or conflict.

5. Conclusions

To quantify the scientific contribution of any individual researcher, a new scientometric index, named A_w-index, is proposed. The concept of A_w-index is unique as it determines the weighted partial citations for each author of a multi-authored article based on the suggestion of the group of authors of the article. It is proposed that a statement containing a weightage factor against each author would be submitted during the submission process of any scholarly article. The weightage factor would be given to a particular author based on the quantum of the contribution of that author, and the statement of weightage factors would be approved by all the contributing authors. The A_w-index of an individual researcher would be the summation of the citation points, given by the product of his/her weightage factor, and the total number of citations for an article for all of his/her scholarly publications. The A_w-index is expected to provide an authentic evaluation of the scientific contribution of a researcher, as the group of researchers who produces an article is the best judge to determine the proportion of contribution made by each member of the group in the article. The method for calculation of the A_w-index of any individual researcher is described and, through an illustrative example, the effectiveness of the A_w-index is shown. A comparison among the A_w-index and other commonly adopted scientometric indexes is presented. It is shown that the A_w-index of a researcher depends upon the quality of his/her publications, the quantity of his/her publications, and the proportion of his/her contributions in those publications. The main drawback of A_w-index is that it cannot be calculated for the already published articles as, presently, the journals do not have the provision for submission of the statement containing weightage factors for the authors. However, upon adaptation by the journals collectively, A_w-index has the potential to become a reliable indicator of the scientific contribution of individual researchers in the future.

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