Assigning Credits to Multiple Contributors of a Scholarly Output Using Arithmetic Series

Asif Iqbal, Quentin Cheok, and Malik M. Nauman

***Abstract*—As the academic world is focusing deeply on quantification of contributions brought about by researchers, it becomes imperative to assign true and deserving credits to the individuals. Modern-day databases do not account for the number of contributors or sequence number of a contributor in the contributors' list while assigning credit of a scholarly output. As such, every contributor of a researcher-studded output gets the same credit as does the sole contributor of a single-author output. The current work presents a mathematical method to assign credits based on the number of contributors, the sequence of the contributor in the contributors list (if so required), and the magnitude of commendation achieved per unit time by the scholarly output. The concept of arithmetic series is utilized to materialize the idea of true assignment of credits. A case study is also provided to elaborate working of the mathematical method.**

***Index Terms*—Credit share, h-index, governing factor, arithmetic progression, rating index.**

I. Introduction

Public dissemination of findings is a key requirement of a research work. Thanks to the advancements in computation and information technology, quantification of contributions by the researchers has become easy. Unfortunately, the methods, currently in use, for assigning credits to individual contributors are not doing justice. The popular research-level rating indices, such as h-, g-, and i10-index do not account for the number of contributors or the sequence number of a researcher in their evaluations. Such an anomaly leads to unfair distribution of credits to the contributors. For instance, every contributor of a publication, cited 100 times and coauthored by 10 researchers, gets exactly the same credit as does the sole contributor of a single-author publication which is also cited 100 times. Such unjust distribution of credits also encourages the unethical practice of including the names of non-contributors in the contributors list along with the expectation of returning the favor in future publications [1]. Another inherent frailty is that the indices do not consider the time elapsed after publication of a scholarly output while ascribing citations to it [2].

H-index is defined as a highest number h such that the given contributor has authored at least h scholarly articles that have each been cited at least h times [3]. The definition does not give any significance to the number of coauthors of a publication. Similarly, g-index is defined as the largest number g such that the top g publications together have received at least g^2 citations [4]. Once again, there is no involvement of number of coauthors, time elapsed after the date of publication, or contributors' sequence in evaluation of the index.

A modified index, h_m, is proposed which takes multiple authorship into account [5]. The author claims it to be a more practicable index as it fractionalizes the number of publications, rather than the citations. Yet, the method does not take time elapsed after date of publication or order of authorship into account. Pure h-index has also been introduced based on various possibilities of considering the contributor's sequence number in the contributors list, such as total counting, proportional counting, fractional counting, and geometric counting [6]. C-index is put forward which evaluates the scholarly output of a researcher, or a journal based on the quality and quantity of the received citations [7].

Sequence-determines-credit is the most employed norm for assigning credits to the multiple contributors of a scholarly output with the first contributor getting the largest chunk whereas the last bagging the smallest [8]. On the other hand, equal-contribution norm assigns equal credits to all the contributors. Other less commonly employed norms are first-last-author-emphasis and percent-contribution-indicated [8]–[10]. Although this work covers application of the first two norms only, others can also be accommodated in the mathematical method. The percent-contribution-indicated norm should have precedence over the sequence-determines-credit approach to get a truer distribution [11]. Regrettably, a very few journals publish author contribution details, making this approach impractical. Obviously, it is more meaningful to describe the contribution of a given coauthor rather than stating the researcher-in-question is the coauthor number 8 (say) in an output collectively authored by 15 (say) coauthors [12]. Various contributory roles from coauthors have been classified which include, but are not limited to: conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing (original draft), writing (review and editing), visualization, and funding acquisition [13]. Various credit assignment schemes are reviewed along with assessments of their pros and cons [14]. The authors have categorized these schemes as linear, curve, and others. Polynomial weight assignment scheme has been put forward for dividing credits among multiple coauthors of a paper [15]. The credit share among the coauthors is controlled by a weight control parameter. Its unit value yields equal distribution among all the coauthors.

The brief review of the published work in this context suggests that a mathematical approach is required that would assign credits to the contributors based on the number of contributors per scholarly output, average number of citations received by the output per year, and the sequence of

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the researcher in the contributors list if sequence-determines-credit is the norm to be followed. This is to be clarified that the presented work focuses on determination of true credit assigned to a particular contributor of a published article and that the evaluation (or re-evaluation) of an author-level rating index, such as modified h- or g-index, is out of the scope.

II. Mathematical Method

Following three governing principles will be followed to develop the mathematical method:

1) The summation of the credits assigned to the individual contributors of a scholarly output is firmly equal to the output's credit.
2) The output's credit is equal to the total number of citations divided by the number of years passed after its publication.
3) Equal credits are awarded to all the contributors of an output if the equal-contribution norm is followed. On the other hand, the individual credits are so awarded that the first contributor in the list gets the highest share and the difference of the credits between any two consecutive contributors remains constant throughout the contributors list if the sequence-determines-credit norm is followed. Application of other credit assignment norms is outside the scope of this paper.

The first governing principle guarantees that the collective credit gained by all the coauthors should not be more than the output's credit. In this respect, the sole contributor of a single-author output should get the entire credit. The second principle tends to eliminate the negative effect of the early stage of a young researcher's career. Undoubtedly, a scholarly output gathers an increasing number of citations along the time, thus, older outputs see a higher level of commendation. Therefore, the aspect of time should be included in the quantification process to ensure equity for all the researchers. Finally, the third governing principle puts up the only two justifiable approaches of dividing the credit of an output among its multiple contributors when the source has not specified the respective contributory shares.

A. The Formula

This sub-section presents derivation of a mathematical formula, based on the principle of an arithmetic series, to work out the credit shares of the contributors of a scholarly output in compliance to the third governing principle. Suppose the number of contributors and the sequence number of the given researcher are n and m, respectively. The following mathematical relationship (based on arithmetic series) gives the quantification of a contributor's credit share:

$$a_n = a_1 - (n-1)d \tag{1}$$

Where d is the common arithmetic difference between the credit shares of any two consecutive contributors in the list and a_1 is the credit share of the first contributor. The value of d should be so adjusted to deter an exceedingly high or low difference between the credit shares of the first and the last contributors. Let:

$$d = \frac{g}{n(n-1)} \tag{2}$$

Where g is "governing factor", whose value varies between 0 and 1. g governs the credit difference between the first and the last contributors of a scholarly output. The following relationship is obtained by inserting the value of d from equation (2) in equation (1):

$$a_n = a_1 - \frac{g}{n} \tag{3}$$

A finite arithmetic series yields its sum according to the following formula:

$$S_n = (a_1 + a_n)\frac{n}{2} \tag{4}$$

Taking the credit shares of the contributors as fractions, S_n should be equal to 1 in accordance with the first governing principle. By substituting the value of a_n from equation (3) in equation (4), we get:

$$S_n = \left(a_1 + a_1 - \frac{g}{n}\right)\frac{n}{2} = 1$$

$$a_1 = \frac{2+g}{2n} \tag{5}$$

Finally, the credit share of the given researcher, located at sequence number m (between 1 and n) in the contributors list, can be obtained by substituting $n = m$ and replacing the values of d and a_1 from equations (2) and (5), respectively, in eq (1).

$$a_m = \frac{2+g}{2n} - \frac{(m-1)g}{n(n-1)} \tag{6}$$

Equation (6) presents the mathematical relationship, following the sequence-determines-credit norm, for calculating the fractional credit share of a contributor located at position m in the contributors list consisting of n number of contributors.

III. Working

The equal-distribution norm is easiest to manage. Substituting $g = 0$ in equation (6) would lead to $a_m = 1/n$, which means every contributor would get a fractional credit share equal to the reciprocal of the scholarly output's total number of contributors. For instance, every coauthor of an article authored by 10 contributors would earn 10% credit of the publication.

The sequence-determines-credit norm may lead to various distributions of credits among the contributors depending on the value of governing factor g. Tables I and II present the uniformly decreasing distributions of fractional credit shares of a scholarly output among its contributors for $g = 0.1$ and 0.3, respectively. The distributions are carried out for $n = 2$, 3, … 12, as arranged along the rows of the two tables. The rows of the tables show uniformly decreasing fractional credit shares while moving from the first contributor to the last. Furthermore, as required, all the credit shares in the rows sum up to 1.

It is also observable that the fractional credit share of the first contributor decreases as the number of contributors increases (moving down the column) but always remains more than the other contributors of the same scholarly output (moving along the row). Moreover, a contributor at the mid position of a contributors list shown as an odd-numbered row ($n = 3, 5, 7, \ldots$) of Table I ($g = 0.1$) secures the same share as the one in the same numbered row of Table II (g = 0.3). It can, thus, be stated that the distribution of the fractional credit shares is centered at the contributor located in the mid of the contributors' list.

TABLE I: UNIFORMLY DECREASING DISTRIBUTION OF FRACTIONAL CREDIT SHARES (NUMBER OF CONTRIBUTORS = 2 TO 12) AGAINST G = 0.1

n	Sequence number of the researcher in authors list (*m*)												Sum
	1	2	3	4	5	6	7	8	9	10	11	12	
2	0.525	0.475											1
3	0.350	0.333	0.317										1
4	0.263	0.254	0.246	0.238									1
5	0.210	0.205	0.200	0.195	0.190								1
6	0.175	0.172	0.168	0.165	0.162	0.158							1
7	0.150	0.148	0.145	0.143	0.140	0.138	0.136						1
8	0.131	0.129	0.128	0.126	0.124	0.122	0.121	0.119					1
9	0.117	0.115	0.114	0.113	0.111	0.110	0.108	0.107	0.106				1
10	0.105	0.104	0.103	0.102	0.101	0.099	0.098	0.097	0.096	0.095			1
11	0.095	0.095	0.094	0.093	0.092	0.091	0.090	0.089	0.088	0.087	0.086		1
12	0.088	0.087	0.086	0.085	0.084	0.084	0.083	0.082	0.081	0.081	0.080	0.079	1

TABLE II: UNIFORMLY DECREASING DISTRIBUTION OF FRACTIONAL CREDIT SHARES (NUMBER OF CONTRIBUTORS = 2 TO 12) AGAINST G = 0.3

n	Sequence number of the researcher in authors list (*m*)												Sum
	1	2	3	4	5	6	7	8	9	10	11	12	
2	0.575	0.425											1
3	0.383	0.333	0.283										1
4	0.288	0.263	0.238	0.213									1
5	0.230	0.215	0.200	0.185	0.170								1
6	0.192	0.182	0.172	0.162	0.152	0.142							1
7	0.164	0.157	0.150	0.143	0.136	0.129	0.121						1
8	0.144	0.138	0.133	0.128	0.122	0.117	0.112	0.106					1
9	0.128	0.124	0.119	0.115	0.111	0.107	0.103	0.099	0.094				1
10	0.115	0.112	0.108	0.105	0.102	0.098	0.095	0.092	0.088	0.085			1
11	0.105	0.102	0.099	0.096	0.094	0.091	0.088	0.085	0.083	0.080	0.077		1
12	0.096	0.094	0.091	0.089	0.087	0.084	0.082	0.080	0.078	0.075	0.073	0.071	1

It is imperative to look into the effects of the governing factor on the distribution of the fractional credit shares. Table III presents the differences between the fractional credit shares of the first and the last authors in respect of n = 2, 7, and 12, with governing factor increasing from 0 to 1 at an increment of 0.2. An increase in governing factor increases the difference between the fractional credit shares of the first and the last authors in all the three cases. Reasonably, the absolute difference values are higher for the publications involving a lower number of contributors, whereas the percentage differences are same for the three cases. A very high value of governing factor yields an irrationally high difference of credit shares between the contributors. For a reasonable distribution, governing factor should be kept between 0.1 and 0.5. A high value of governing factor suits the contributors listed near the beginning of the contributors list whereas a low value favors the ones located near the end.

IV. CASE STUDY

Table IV presents the publication data in respect of two imaginary scholars. Scholars A and B have published 7 and 8 scholarly outputs (articles), respectively, in the period 2015 – 2021. The credit of an article is calculated by dividing the number of citations received by the number of years passed since its publication. The percentage share of this credit is awarded to the scholar by considering the number of contributors involved and the sequence number of the scholar in the contributors list.

The working is shown in Table V using g = 0.3. The total scholar credit (or scholar rating) is obtained by adding the respective scholar credits (shown in the last column of the table) for each of the two scholars. As for the given case, scholars A and B secure cumulative credits of 32.86 and 36.07, respectively. It seems that the latter has outperformed the former, but this is to be noted that the comparative result is significantly dependent on the selected value of governing factor. Keeping all the data presented in Table IV unchanged, the variations observed in the cumulative credits of the two scholars with respect to the alterations carried out in governing factor are shown in Table VI.

TABLE III: DIFFERENCES BETWEEN THE FRACTIONAL CREDIT SHARES OF THE FIRST AND THE LAST CONTRIBUTORS FOR THE NUMBER OF CONTRIBUTORS EQUAL TO 2, 7, AND 12 AGAINST THE 6 VALUES OF GOVERNING FACTOR

g	*n* = 2		*n* = 7		*n* = 12	
	Difference	Percentage difference	Difference	Percentage difference	Difference	Percentage difference
0	0	0	0	0	0	0
0.2	0.1	18%	0.029	18%	0.017	18%
0.4	0.2	33%	0.057	33%	0.033	33%
0.6	0.3	46%	0.086	46%	0.05	46%
0.8	0.4	57%	0.114	57%	0.067	57%
1	0.5	67%	0.143	67%	0.083	67%

TABLE IV: ASSUMED DATA REGARDING PUBLICATIONS OF TWO HYPOTHETICAL SCHOLARS*

Publication Number	Scholar A				Scholar B			
	n	*m*	Citations received	Published on	*n*	*m*	Citations received	Published on
1	5	2	156	Apr 15, 2015	6	5	113	Sep 30, 2015
2	3	1	63	Feb 1, 2017	2	2	155	Mar 1, 2016
3	12	4	239	Dec 15, 2017	9	9	234	Dec 1, 2016
4	2	1	40	May 31, 2018	4	2	92	June 30, 2017
5	1	1	15	Jan 1, 2019	8	3	55	Apr 30, 2018
6	8	6	22	Sep 15, 2020	2	1	23	Feb 1, 2019
7	3	3	7	May 15, 2021	3	2	12	Nov 30, 2019
8	-	-	-	-	6	5	18	Jan 31, 2021

* Dec 1, 2021 is taken as the current date.

TABLE V: EVALUATION OF OUTPUTS' CREDITS, SCHOLARS' FRACTIONAL CREDIT SHARES, AND SCHOLARS' CREDITS AGAINST THE PUBLICATION DETAILS PROVIDED IN TABLE V. GOVERNING FACTOR = 0.3

Scholar	Article number	Time elapsed (years)	Citations	Article's credit (citations per year)	Scholar's fractional credit share	Scholar's credit
A	1	6.64	156	23.51	0.215	5.05
A	2	4.83	63	13.04	0.383	5.00
A	3	3.96	239	60.29	0.089	5.37
A	4	3.51	40	11.41	0.575	6.56
A	5	2.92	15	5.14	1.000	5.14
A	6	1.21	22	18.17	0.117	2.12
A	7	0.55	7	12.78	0.283	3.62
B	1	6.18	113	18.30	0.152	2.78
B	2	5.76	155	26.93	0.425	11.44
B	3	5.00	234	46.77	0.094	4.42
B	4	4.42	92	20.79	0.263	5.46
B	5	3.59	55	15.31	0.133	2.04
B	6	2.83	23	8.12	0.575	4.67
B	7	2.01	12	5.98	0.333	1.99
B	8	0.83	18	21.61	0.152	3.28

TABLE VI: VARIATIONS IN THE CUMULATIVE CREDITS OF THE SCHOLARS WITH RESPECT TO THE DIFFERENT VALUES OF GOVERNING FACTOR (THE DATA PRESENTED IN TABLE IV RELATES)

g	Cumulative credit (Scholar A)	Cumulative credit (Scholar B)
0	31.44	38.48
0.1	31.92	37.68
0.2	32.39	36.88
0.3	32.86	36.07
0.4	33.33	35.27
0.5	33.81	34.47
0.6	34.28	33.67
0.7	34.75	32.87
0.8	35.22	32.06

The table shows that the cumulative credit of scholar A is increasing while that of B is decreasing as the value of governing factor is increased from 0 to 0.8, with the former overtaking the latter at somewhere between g = 0.5 and 0.6. The reason attributed to this observation is that researcher A appears in the contributors lists of the high citation outputs much closer to the beginning of the contributors lists than does researcher B. Thus, a high and low values of governing factor favor researchers A and B, respectively. The first row represents the equal-credit norm in which all the contributors of a publication receive equal credits, irrespective of their positions in the contributors list.

The merit of the work presented can be assessed from the credits assignment of the publications numbered 1, 3, and 6 of scholar A and 1, 3, 5, and 8 of scholar B. Had the tactic of working out a scholar's credit based on the number of contributors and the scholar's position in the contributors list not been employed, all the contributors would individually have taken the whole credits of the publications. For instance, scholar A would have gained superficial 60.29 credits instead of true 5.37 for their publication number 3. Moreover, an aged scholarly output would have gained higher standing based simply on the collective number of citations received throughout the time elapsed after its appearance. Resultantly, the scholarly credit assignment approach put forward in this work righteously addresses the matter of considering the number of contributors, sequence number of the scholar in the contributors list, and the time passed after publication of the output in awarding the bona fide credit.

V. CONCLUSION

The factors concerning number of contributors of a scholarly output, time elapsed after its publication, and sequence number of the given researcher in the contributors list are often ignored while evaluating author-level scholarly output metrices. As a result, the quantifications result in incorrect and higher-than-deserving values of the researchers' contributions. This paper has put forward a more appropriate approach for truer assignment of credits to the contributors by applying the mathematics of an arithmetic series. The resulting mathematical formula can be used for applying equal-credit and sequence-determines-credit norms of credit assignments by controlling the value of governing factor. A zero value of the factor leads to an equal division of an article's credit to all its contributors whereas a positive value causes a uniformly decreasing distribution. Moreover, the presented evaluation approach quantifies an article's credit as the average number of citations received per year. The novel credit assignment method not only assures fairer assignment of scholarly credits to the contributors but also dejects the improper trend of including names of non-contributors in the scholarly outputs' lists of contributors.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

AI performed conceptualization, investigation, methodology, validation, draft writing, and supervision; QC performed data curation, investigation, and review; MMN performed visualization, validation, and resources; all authors had approved the final version.

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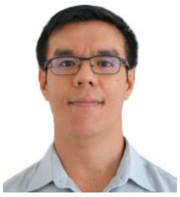

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