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MODERN BIBLIOMETRIC INDICATORS AND ACHIEVEMENTS OF AUTHORS

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Abstract. The paper deals with evaluation and impact of scientific works and their authors. Different bibliometric indicators are reviewed in this context. On the evaluation and impact of scientific papers influence many factors like self-citations, number of authors and publication type. Attention is paid also on the papers content which cannot be taken into account in the bibliometrics and is reflected in the content of citing works and in the peer reviews. The publication and citation in the Internet is briefly mentioned

1. Introduction

The bibliometrics provides quantitative methods for analysis of the scientific and technological literature and gives a number of numerical characteristics of authors publications and their citations [10, 25], known as bibliometric indicators, such as number of publications (total and for some period of time), number of publications in top journals, number of citations (total and for some period of time), citations per publication, top 5% citations, etc. Starting from 2005 Hirsch paper [15] there were introduced a number of new bibliometric indicators [1] like the Hirsch index h and different (Hirsch-like) indices that modify it in ways that compensate some of its disadvantages. Regardless of these measures, the peer judgements remain leading in taking decisions about the achievements of papers and their authors. On statistical level it is observed a correlation between assessment by different bibliometric indicators and quality judgment of peers [4, 24, 32]. This naturally suggests that the both methods should be used as complimentary to each other.

Section 2 points out some peculiarities of citing and concerns the problem of self-citations. Section 3 deals with some bibliometric indices. The Hirsch index, certain of its modifications and complimentary to it indices are recalled. Connections between citations and scientific achievements are discussed in Section 4. In Section 5 are presented some aspects of the problem on how the content of a paper may influence its evaluation and impact. The paper ends with a final discussion in Section 7.

2. Citing and Citation Lists

Normally any scientist builds his/her work on the base of earlier existing works and for this reason new works/publications cite the works they are build upon.

A deep analysis of this process is contained in [21] and more particular reasons for citing are presented in [13, Section 4.1]. In this sense the citation is part of the process of linking of a work with the preceding it knowledge. It is known that the more citations a published paper has, the more impact it has on the other authors [23]. For this reason the (number of) citations of a paper is a measure for its impact on other works and scientists and, consequently, the (number of) citations of the papers of an author is a measure for his/her impact.

An author may cites his/her own paper(s). Normally this happens when the author has previous publications on the subject(s) of the work where self-citations appear and he/she finds them essential in the context where they are cited. There are authors that intentional cite their own papers for, say, "non-scientific" reasons. As a result of this the general opinion is that the self-citation should be excluded in the citation analysis. The impact of a cited paper on the citing one depends on the contents of both works and until now has not be found a way to express this dependence numerically. A lot of authors make lists of works citing their own papers. This is not an easy task as there are tens of thousands of scientific journals, institutional/university annual reports, books etc. published e.g., monthly or annually. The easiest way to make such a list is via the Internet based databases like Google Scholar and Web of Science but the different database cover differently the different scientific fields and types of publications [10, pp 349–350] like journal articles, electronic preprints, books/monographs, conference reports, theses, etc. and give overlapping but not identical results [1, 2, 19, 31].

It is important to note that the data in a citation list should be publicly available as otherwise it is (almost) impossible to check/verify independently its trueness. The completeness of a citation list depends on the sources used and a particular citation list gives a lower limit on the works with non-zero citations and on the number of their citations.

We assume below that an author citation list includes all his/her published papers and in particular, these with zero number of citations.

3. Bibliometric Indicators

The bibliometric indications [25] are a known tool for measuring authors impact. Starting from 2005 there were introduced many new (bibliometric) indices, called

also metrics, whose purpose is to measure the influence of the authors on the ground of citations of his/her works. These indices can be described as bibliometric and their connection with the scientific impact of an author is indirect. It is based on statistical data analysis [5,6,24] as it cannot be revealed without knowing the content of the cited and citing papers. However, the usage of these indices has brought significant advance in this area compared to the previous analysis based, for instance, on author's total number of published works and their total number of citations.

Below we shall give an idea of some bibliometric indices which are known to give satisfactory results in certain fields.

3.1. The Hirsch Index

The 2005 paper of Hirsch [15] gave a new impulse to bibliometrics by defining the h-index, called nowadays the Hirsch index, as

> A scientists has index h if h of his/her N_p published papers have at least h citations each and the other $(N_p - h)$ papers have no more than h citations each.

(This is not the Hirsch original definition, but the one of September 2006 e-print.) If we arrange a list of the author's papers by descending number of their citations and c_i is the citations of the $i-$th paper in it (i is called the paper rank in this list), then

$$c_h \geq h \geq c_{h+1} \tag{1}$$

i.e., h is the maximal rank such that the corresponding to it paper has no less than h citations and the papers with greater ranks have maximum h citations. The Hirsch index received a lot of attention and found many applications as it combines in a single number quality, productivity and impact of the authors. In general it correlates with the other bibliometric indices [18].

The Hirsch index is applicable also to the groups of scientists united formally by a journal, country, institute/university etc. For instance, at http://www.scimagojr.com it is calculated for the journals and countries covered by the Scopus database http://www.scopus.com.

By our opinion, one of the ideas behind the h-index is the selection of some of the "top cited" papers of an author and to take their number as a measure of his/her publications impact which is confirmed a posteriori by the results in [30]. From this point of view the Hirsch index has two significant advantages: i) it adapts to

any particular author, hence being author-dependent and ii) it naturally defines the top cited papers as ones whose number of citations is no less that it.

3.2. Modifications of the Hirsch Index

The Hirsch index does not reflect many important data contained in any particular citation list. This has lead to the introduction of a lot of its variants each of which tries to take into account some features which the original Hirsch index misses to reflect [1, 6, 30].

3.2.1. Multiple Authorship

The Hirsch index h is insensitive to the number of the co-authors of the cited papers. If some or all of the first h papers in an author's list of papers (arranged by descending number of citations) have more than one author, then it is evident that in the h-index is incorporated also the work of authors different form the one whose list of citations is investigated. The correction of this unfairness with respect to the other authors (whose work is assigned to other person(s)) leads to a class of indices that reflects the number of authors of the cited papers.

The h_m index introduced by Schreiber [28] is defined via

$$c_{g(h_g)} \geq h_g \geq c_{g(h_g+1)} \tag{2}$$

with the choice $g = r_{\text{eff}}^{-1} \colon \mathbb{R}^+ \to \{1, \ldots, n\}$ for

$$r_{\text{eff}}^{-1} \colon r \mapsto r_{\text{eff}}^{-1}(r) = \sum_{i=1}^{r} \frac{1}{a_i} \tag{3}$$

where $r \in \{1, \ldots, n\}$, n is the number of all author's papers in the list, r_{eff}^{-1} is treated as an effective rank of the paper p_r with a_i authors. We should mention that here is used the hypothesis of equal contribution of all authors of a multiple author paper. In [29] the h_m-index is calculated for 26 particular cases, which shows strong correlation with the h-index but the arrangement of the persons according to the both indices is generally quite different.

In the Publish or Perish program user manual [1] is defined the normalized Hirsch index $h_{I,\text{norm}}$ (Individual normalized Hirsch index) which is defined similarly to the Hirsch index with the difference that now one uses $c_i^a := c_i/a_i$ instead of the citation number c_i, i.e., (cf (1))

$$c^a_{h_{I,\text{norm}}} \geq h_{I,\text{norm}} \geq c^a_{h_{I,\text{norm}}+1}. \tag{4}$$

[1] See http://www.harzing.com/pophelp/metrics.htm.

In words, the papers are ordered by the descending order of the citations divided by the corresponding number of authors and then the (normalized) Hirsch index is calculated. The author of these lines shares the opinion that the $h_{I,norm}$-index reflects the author achievements considerably better than the original Hirsch index and the h_m-index.

3.2.2. Missed Citations and Time Dependence

The only information about the number of citations contained in the Hirsch index h is that their total number is no less than h^2 (see (1)).

The g-index [11] of an author with citations list arranged by descending number of citations is the unique largest number g such that the total number of citations of the first g papers is greater than or equal to g^2. Its aim is to give more weight to papers with more citations and thus improving the h-index.

Similar aims persuades also [17, Table 2 on p 829] (see also the references given therein): the h^2-index, the A-index ($= \frac{1}{h}\sum_{i=1}^{h} c_i$), the R-index ($=\sqrt{Ah}$), the h_{w}-index, and the hg-index ($= \sqrt{gh}$).

Until now we have not touched the problem of the dependence of the citations on the time. The simplest way to fill this gap is the introduction of the age of the cited papers.

Suppose we have a citation list arranged by descending number of citations and t_i is the age of the paper p_i, $i = 1, \ldots, n$, counting from the first publication of this paper. Then the AR-index is $AR = \sqrt{\sum_{i=1}^{h} c_i/t_i}$ with h being the Hirsch index of the considered author. The AR-index may decrees with time.

In the program Publish or Perish are introduced three other indices that depend on the age of the cited work. [2] The age-weighted citation rate is $AWCR = \sum_{i=1}^{n} c_i/t_i$ where c_i and t_i are the citations and the age of the i-th paper and the sum is over all published papers, and the age-weighted index is $AW = \sqrt{AWCR} = \sqrt{\sum_{i=1}^{n} c_i/t_i}$. If the paper p_i has a_i authors, then the per-author modification of the $AWCR$ index is $AWCRpA = \sum_{i=1}^{n} c_i/(t_i a_i)$.

3.3. Conclusions

An analysis of some bibliometric indices [5, 6, 8] reveals that any one of them has its pros and cons and is useful in some cases and gives unsatisfactory consequences

[2] See http://www.harzing.com/pop.htm and http://www.harzing.com/pophelp/metrics.htm.

in other cases so that there is not a "best index" unless there are well defined criterion(s) what it must represent and what is the area of its application. Similarly, we have an intuitive understanding of "highly cited" papers of an author but without a rigorous definition of this concept we cannot do much.

The above points to the complexity of the problem of citation analysis and author's evaluation/impact based on it.

Our aim is the usage of citation analysis for making conclusions for the scientific impact/achievements of a scientist without going into the scientific content of the cited and citing papers. In this respect there are important arguments that are not purely bibliometric.

3.4. Self-Citations

When an author cites a paper and he/she is between the authors of this paper, we say that this is a self-citation for this author. Often this definition is broaden by saying that a citation is a self-citation if the intersection of the authors of the cited and citing works is not empty.

Good reasons why the self-citation should not be count are given at the beginning of [27, Section V] and we agree with them. Analysis of the self-citations and their influence on some bibliometric indices can be found in many papers like [3, 9, 12, 27]. It seems that the general opinions are that the self-citation should be excluded when evaluating the scientific impact of an author. The main reason for this is that it is more important the influence of author's works on other scientists and their papers than on the author himself/herself. Other important fact confirming the exclusion of self-citations is that they can be relatively easy manipulated in favour of one or another author.

3.5. The Number of Authors

Since we wont to make conclusions about a particular author whose citation list is analyzed, the number of authors of each his/her paper should be counted and taken into account. More precisely, his/her contribution/weight in any cited paper in his/her citation list should be presented and used for the citation analysis. If such an information is missing, we assume that his/her contribution in a paper is one divided by the number of all authors of the paper.

Another thing is the number of authors of citing works. If it is insignificant for some problem, then such a citation simply adds the number one to the number of citations to the cited paper. But if this number is important, then instead of counting

this paper once, we should consider replacing this weight (one) by the number of its authors or, more precisely, the number of its authors that are acquainted (and using) the cited paper, if the last number can be determined.

3.6. Different Editions/Versions of a Published Work

From bibliometric point of view any separate publication of a work is a different published paper no matter if there is a difference between the publications. But there is also a different point of view. For example, two identical editions of a book are different publications but from scientific point of view the second edition simply supplies more copies of the book as it does not contain different content. Similarly, a lot of works are published in journals and then appear in an identical form in collections of papers. Besides, there are books/monographes translated in different languages which, excluding some (introductory) remarks and comments by the publishers/translators, are identical by their content. Evidently these are different publications that are copies of one and the same work form scientific point of view. Moreover, a work can have essentially different publications like preprints, electronic prints, conference reports and journal versions that have identical content and differ possibly only in the presentation of the material (e.g., differently numbered equations and permutations of parts of the text).

So, we face a problem: in a citation list may be presented different publications which are identical from scientific view point. Our opinion is that such publications should be identified under a single work title.

Unfortunately there is not a strict criterion when two different publications should be considered identical. For instance, adding essentially new results to a previously published work can be considered as resulting into a new work, but a renumbering/pemutating the sections and/or equations in it does not change it for the science.

3.7. Different Types of Publications

Are there reasons for assigning different weights for citation in or citing from different types of publications? Here and below by publication types we shall understand such as: monograph/book, textbook, booklet, originals research article, review paper, collection of original or already published papers, handbook, encyclopedia, simple list of papers on some subject(s), and so on.

Consider first citing papers of different types. Are there reasons to assign different weights to them without knowing their particular content? Consider for instance a citation in an original research work. If one wants simply to cite in it a particular result, e.g., an equation, then a random choice of a paper containing it is sufficient.

However, if the author wants not only to mention work containing the result, but also to pay a tribute to author(s) that have first found it, then a priority will be given to papers that historically mentioned the result for the first time. So, without knowing the content of a citing paper we cannot assign in an abstract way different weights to the cited papers depending on the type of the citing ones.

Consider now cited papers of different types. It is generally accepted opinion, e.g., in annual reports and personal CVs, that books/monographes weight more then other publication types, a chapter in a book is heavier than a research article and so on. But what are the reasons for such a rating? Nowadays a new result normally appears first as a research (journal) article, (electronic) preprint, conference report or in some combinations of these publications types and in this respect one cannot give more weight to some of them. However, on one hand, a research article is often considered more "stable" and reliable than a preprint or conference report, but, on other hand, a preprint, especially if it is electronic, spreads quite quickly and reaches the audience before a journal article and as a result it is a common practice a preprint to be cited without mentioning its journal version, if any. Further, if an author of a new already published result continuous to work on it, then it is possible that he/she will write a review paper, chapter of a book or a whole book that contains this result and its developments. If this happens, then these publications are often more cited than the original ones as they normally explain the result more widely and in connection with other items. In this way, the last type of publication receive more weight in the form of citations and there is not a need this to be done by other means. Of course, publishing a book or a review paper is considered as a good achievement of the author but it may not contain results belonging to its author(s), however, again, there is not a need to assign to it more weight as the only objective criterion is the usage of the work by other authors which, in our case, is reflected by its citations.

In conclusion, we share the opinion that without knowing the content of a citing/cited work it should not be assigned different weights to different types of publications.

3.8. Quality of Publication Carrier

It is a general opinion that it is significant where a particular work is published. Consider two examples:

- There are peer review and not peer review journals. The former are considered as a better place for publication. Besides, some of the journals in the

first group are distinguished at present by their impact factors (IF) [16, Section 5.1.1] (see also the discussion of the IF in [13, Section 4.4]. The greater the IF, the better is the journal.

- Nevertheless that a lot of conference reports pass peer judgement, they are less valued than, e.g., journal articles or chapters in the books.

A quantitative measure for comparing different kinds of publications that have impact factors is presented in [20]. It is called "weighted sum indicator" and is defined by the formula

$$W(c,t) = cA_t + (1-c)IF \tag{5}$$

where A_t is the number of citations of a work for t years after publication, IF is the impact factor of the journal in which the work was published (evaluated for the year of publication), and c is a constant weight with $0 \leq c \leq 1$.

3.9. Time Dependence

A published paper lives as long as people remember (and use) it and the often they recall about it, the better it is. In the context of this work we can paraphrase this as: a paper lives as people cite it and the more citations it obtains, the more useful it is. Accepting this point of view, we see that the time evolutions of the citations of a work or an author should be taken into account in the citation analysis.

The time distribution of the paper's citations can tell us a lot about the interest for it.

If $h(t)$ is an author's h-index at a time $t > 0$ (usually measured in years of author career), then in [7] is argued that the Hirsch-rate (h-rate) given by the average speed $h(t)/t$ is a good characteristic of the authors and suitable for their comparison.

3.10. Web Resources

With the development of the computer networks, in particular the Internet (World Wide Web), the scientists start to publish documents on them and use such documents on equal footing with the ones printed on paper. The most obvious example of this kind for any physicists nowadays is the arXiv database http://arXiv.org whose documents and the citations to/from them are included in the free web service Google Scholar http://scholar.google.com/.

One of the major problems with the web resources is the stability of their addresses, i.e., where the corresponding files can be found. The uniform resource

locator (URL), known as web address, of a document can change unpredictably. Therefore, when citing web documents, we have to be sure that they have stable and reliable web addresses.

Other problem with citing web documents is that their content may be changed at any moment by anyone having suitable knowledge and access to the corresponding server. Of course, this does not happen on reliable web sites. Now the conclusion is that, when citing web documents we have to be sure that they have constant and reliable content. All possible changes in it should be done only by independent different subsequent documents or in its revised versions in which case it is supposed that all previous versions are available and unchanged after their first publication.

As noted in [14, p 92], the major differences "between print media and the Web is that time plays a different role on the Web" and "the possibility of an almost continuous change of contents on the Web". Besides, the web documents are in general non quality-controlled refereed products as, in principle, information can be published online by anybody. For these and other reasons the bibliometric indications have to be applied with some caution to the Web rescouses (if they are applicable at all in this case) and in general new measures are need for the analysis of web linking of documents.

At any rate, at present more and more scientists use and cite web documents on the same base as they do with other resources. For this reason the web citations should be count on the same footing as citations in paper documents.

4. Citations and Scientific Achievements

Let us have an author's citation list and some of its bibliometric descriptions. What can we say about the author's contribution in the Science and can on this base be compared different scientists?

It is a general opinion that the more citations an author has, the more is his/her impact. But how big? The problems seems open from quantitative position.

The different bibliometric metrics reflect different sides of the problem. Once these metrics are defined, they are a posteriori confirmed or rejected by gathering statistics for them. It seems that no one of the existing single number metrics describes the scientific achievements of the authors in a satisfactory way, which is in conformity with the ideas of [26] that this cannot be done in this way.

A possible measure of an author scientific impact may serve the time distribution of his/her citations, in particular his/her citation life, i.e., the period after which citations stop (which does not mean that they will not appear in future). In general,

the longer the citation life, the bigger is the scientific impact. But how big? The problem seems open from quantitative point of view.

Obviously, there is a connection between citations and their bibliometric measures with the scientific impact of an author. At present this connection is far from being well investigated and the known results in this field of research are mainly based on statistical analysis [5, 6].

5. Taking into Account Papers Content

For pure bibliometric purposes the content of citing and cited works does not matter. But when one begins to interpret and use bibliometrics for scientific evaluation of authors, the content begins playing essential role which may be more important than citation metrics.

If in a citing paper is proved that the cited one contains plagiarism(s), then the bibliometrics simply adds one more citation for the author(s) of the cited work but the common sense tells us that here is something terribly wrong. Our suggestions is to count such citation with negative sign, i.e., by subtracting their number from the other author's citations.

Let a citing paper points to error(s) or wrong result(s) in the cited work. This situation is not so simple as it may look. If it is said that the cited work is so wrong that it cannot be corrected, then such a citations are reasonably to be neglected. If the wrong result(s) are not only pointed but also corrected and then strictly proved in the citing paper, then this means that the cited work has influence on the citing one with inspiration of finding new result(s) in which case the citation may be treated as an ordinary one. There are many other possibilities but we do not want to speculate on them.

Consider now the most difficult problem when a citing work makes particular use (of part(s)) of the cited one. It is clear that to such citations is fair to be given more weight. This weight should surely depend in the particular usage of the cited paper but the problem for its quantitative measure is open. For instance, it may happen that the cited paper follows/develops method(s) from the cited work, applies particular result(s) from it, etc. It is quite obvious, any one of these and many more situations gives arguments for assigning to such kind of citations greater weight than e.g., negative citations (e.g., revealing a plagiarism). But a quantitative measure for such weight is missing.

In Subsection 3.7 we have presented arguments that the different types of publications should not be distinguished for pure bibliometrics reasons but the situation can change if the content of the works is taken into account.

The main output of a research paper are new results, ideas, concepts, methods, etc. and these are the main reasons for citing them.

The general purpose of a (scientific) review paper is a systematic detailed presentation of the material from published research papers, usually on some fixed topic. They contribute to the spread and acceptence/non-acceptance of the information from the papers they review.

The books/monographs are considered as the most "heavy" and reliable sort of publications. Normally they are the most detailed and different-sided presentations of the topic(s) they cover and contain suitable references which in some cases are quite intensive. For these and other reasons a good book can be used by other authors for many years by putting aside review and original works on its topic(s).

The above examples are enough to confirm the opinion that to different publication types may be assigned different weights but a quantitative way for doing this is not known.

The most important thing of any paper is its content. Its citation and all connected with paper's ratings and scientific impact are consequence of its content. But the content of any paper is specific and its evaluation strongly depends on the particular readers of the paper. The final decision on author scientific impact and value is formed by the scientific community on the base of the opinions of persons acquainted with the content of his/her published works. At present it is not known a way to formalize this human-dependent process.

6. Peer Judgements

In the last two sections we have seen that in the evaluation of the impact of scientific works and their authors there are important factors that are completely out of the range of the bibliometrics. These factors are only in the range of the peers which are qualified experts in some field of the Science that give their opinions on some scientific works in this field and their authors. On the base of the peer reports are taken further decisions like acceptens/non-acceptance of the papers for publication and promotions and they are central for many problems of Science like quality control and decision-making. A comprehensive review of the peer review process can be found in [4].

Until now the peer judgements are not formalized in a form of some algorithms and it is unlikely that this will ever be done. The bibliometrics provides quantitative methods for analysis of the scientific and technological literature and in this sense it helps for revealing the impact of the scientific papers and their authors. One of the roles of the peers is to decide upon the applicability of the bibliometric results

to particular situations. On the opposite, the bibliometric results may be used to trace statistically the validity of the peer reports.

7. Conclusion

The peer review judgments, citations analysis or some their combinations are the main methods for evaluation of the scientific impact of authors.

The h-index is analyzed in [8] in different situations and its relations with standard bibliometric characteristics like total number of the papers and their total number of citations, citations per paper, highly cited papers (with no less than 15 citations), etc. The general conclusion is that the Hirsch index is a good thing but it alone cannot be a "complete" measure of a scientists and it should be complimentary to other bibliometric measures. To overcome its disadvantages there were introduced many other indices each of which has its pros and cons [1]. The Hirsch index is not adequate when some or all of the papers in its core have more than one author as it assigns all of the work of the co-authors to one of them and, respectively, the achievements of this work are also assigned to the author whose citation list is considered.

The calculation of bibliometric indices based on Internet databases generally depends on the database [2]. Moreover, the Internet databases do not capture all existing citations [22]. Besides, bibliometrics cannot measure procedures like reviewing, editing and mentoring. In this sense it has serious limitations. Similarly, the peer reviews have limitations too, but each of the both methods partially corrects the disadvantages of the other one. It is observed a correlation between assessment by different bibliometric indicators and quality judgment of peers [4, 24, 32].

Besides documented via citations usage of published works, there can be a lot of other their usages that are not recorded, e.g., full or partial viewing/reading without citing, hearing about them at seminar, conference or a private conversation etc. It is practically impossible to count and/or measure such events and to evaluate their impact, but it is clear that they are due to the authors of the discussed papers and in this sense they contribute to the authors fame and impact on other scientists.

A Web analogue of the standard citations may be considered the Internet (hyper) links to the web pages that contain authors papers or/and relevant information about them. Regardless that such links can be generated automatically by robots, from them can be made conclusions similar to the ones from the citations. It is clear that such an approach to author impact is in favour of authors that (extensively) use the capabilities of Internet but such are the present day realities and possibilities.

Nowadays the methods and tools of bibliometrics are an alternative to the work of peers. Since aspects such as the quality and impact of a paper are not yet formalised in a strict mathematical sense, the peer reviews remain leading. The both approaches seem to be overlapping and complimentary to each other which stimulates the further development of strict methods for assessment of papers and their authors.

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