Generalized h-index for Revealing Latent Facts in Social Networks of Citations

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ABSTRACT

What is the value of a scientist and its impact upon the scientific thinking? How can we measure the prestige of a journal or of a conference? The evaluation of the scientific work of a scientist and the estimation of the quality of a journal or conference has long attracted significant interest, but the definition of a quality metric is not an easy task. To overcome the disadvantages of the present metrics used for ranking scientists and journals, J. E. Hirsch proposed a pioneering metric, the now famous *h-index*. In this article, we demonstrate several inefficiencies of this index and develop a pair of generalizations and effective variants of it to deal with scientist ranking and with publication forum ranking. The new citation indices are able to disclose trendsetters in scientific research, as well as researchers that constantly shape their field with their influential work, no matter how old they are. We exhibit the effectiveness and the benefits of the new indices to unfold the full potential of the *h-index*, with extensive experiments on the widely known DBLP.

1. INTRODUCTION

The evaluation of the scientific work of a scientist has long attracted significant interest, due to the benefits from obtaining an unbiased and fair criterion. Having defined such a metric we can use it for faculty recruitment, promotion, prize awarding, funding allocation, comparison of personal scientific merit, etc. Similarly, the estimation of a publication forum's (journal or conference) quality is of particular interest, since it impacts the scientists' decisions about where to publish their work, the researchers' preference in seeking for important articles, and so on.

Although, the issue of ranking a scientist or a journal/conference dates back to the seventies with the seminal work of Eugene Garfield [11] and continued with sparse publications e.g., [12, 14], during the last five years we have witnessed a blossom of this field [3, 4, 5, 15, 16, 18, 19, 20, 21, 23, 25, 26] due to the proliferation of digital libraries.

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Until present there are two major popular ways for evaluating scientific work, and a hybrid of them. The first method is by allowing some contacted experts to perform the ranking and the second method is based on what is termed *citation analysis*, a popular technique in the field of *social networks theory*. Citation analysis involves examining an "item"'s (scientist/journal/conference) referring articles. An amalgamation of them is also possible, although it is closer to the latter approach.

The first method adopts an ad hoc approach, collecting the opinion of different domain experts. The study reported in [19] focused in the area of Information Systems and performed an on-line survey for 87 journals with 1000 respondents approximately, whereas the authors of [18] conducted the most extensive survey to date of IS journal rankings. They collected responses from 2559 respondents (32% of the 8741 targeted faculty members in 414 IS departments worldwide). Instead of using a predetermined journal list, they asked the respondents to freely nominate their top-four research journals. This kind of works is very interesting, because they perform a ranking according to readers' (and authors') perception, which is not always adequately expressed through citation analysis, but they suffer from the fact of being basically "manual" and usually biased, and not highly computerized and objective.

On the other hand, the second way of evaluating the scientific work is by defining an objective function that calculates some "score" for the "objects" under evaluation, analyzing the social network formed by the citations among the published articles. Defining a quality and representative metric is not an easy task, since it should account for the productivity of a scientist and the impact of all of his/her work (analogously for journals/conferences). Most of the existing methods up-to-date are based on some form of (arithmetics upon) the total number of authored papers, the average number of authored papers per year, the total number of citations, the average number of citations per paper, the average number of citations per year, etc.

Finally, characteristic works implementing the hybrid approach of combining the experts' judge and citation analysis are described in [16, 28]. Their rankings are realized by taking some averages upon the results obtained from the citation analysis and experts' opinion, thus implementing a post-processing step of the two major approaches.

1.1 Motivation for new citation indices

Although, there is no clear winner among citation analysis and experts' assessment, the former is usually the preferred method, because it can be performed in a fully automated and computerized manner and it is able to exploit the wealth of citation information available in digital libraries. All the metrics used so far in citation analysis, even those which are based on popular spectral techniques, like HITS and PageRank [17, 22], present one or more of the following drawbacks (see also [13]):

- They do not measure the importance or impact of papers, e.g., the metrics based solely on the total number of papers.
- They are affected by a small number of "big hits" articles, which received huge number of citations, whereas the rest of the articles may have negligible total impact, e.g., the metrics based on the total number of citations.
- They can not measure productivity, e.g., the metrics based on the average number of citations per paper.
- They have difficulty to set administrative parameters, e.g., the metrics based on the number x of articles, which have received y citations each, or the metrics based on the number z of the most cited articles.

To collectively overcome all these disadvantages of the present metrics, last year J. E. Hirsch proposed the pioneering *h-index* [1, 13], defined as follows[1]:

DEFINITION 1. *A researcher has h-index h if h of his/her N_p articles have received at least h citations each, and the rest $(N_p - h)$ articles have received no more than h citations.*

This metric calculates how broad the research work of a scientist is. The *h-index* accounts for both productivity and impact. For some researcher, to have large *h-index*, s/he must have a lot of "good" articles.

The *h-index* acts as a lower bound on the real number of citations for a scientist. Think that the quantity h will always be smaller than or equal to the number N_p of the articles of a researcher; it holds that $h^2 \leq N_{c,tot}$, where $N_{c,tot}$ is the total number of citations that the researcher has received. Apparently, the equality holds when all the articles, which contribute to *h-index* have received exactly h citations each, which is quite improbable. Therefore, in the usual case it will hold that $h^2 < N_{c,tot}$. To bridge this gap, J. E. Hirsch defined the index a as follows:

DEFINITION 2. *A scientist has a-index a if the following equation holds [13]:*

$$N_{c,tot} = ah^2. \qquad (1)$$

The *a-index* can be used as a second metric-index for the ranking of scientists. It describes the "magnitude" of each scientist's "hits". A large a implies that some article(s) have received a fairly large number of citations compared to the rest of its articles.

[1]Notice that the economics literature defines the H-index (the Herfindahl-Hirschman index), which is a way of measuring the concentration of market share held by particular suppliers in a market. The H index is the sum of squares of the percentages of the market shares held by the firms in a market. If there is a monopoly, i.e., one firm with all sales, the H index is 10000. If there is perfect competition, with an infinite number of firms with near-zero market share each, the H index is approximately zero. Other industry structures will have H indices between zero and 10000.

The introduction of the *h-index* was a major breakthrough in citation analysis. Though several aspects of the inefficiency of the original *h-index* are apparent; or to state it in its real dimension, significant efforts are needed to unfold the full potential of *h-index*. Firstly, the original *h-index* assigns the same importance to all citations, no matter what their age is, thus refraining from revealing the trendsetters scientists. Secondly, the *h-index* assigns the same importance to all articles, thus making the young researchers to have a relatively small *h-index*, because they did not have enough time either to publish a lot of good articles, or time to accumulate large number of citations. Thus, the *h-index* can not reveal the brilliant though young scientists.

1.2 Our contributions

The purpose of our work is to extend and generalize the original *h-index* in such ways, so as to reveal various latent though strong facts hidden in citation networks. In this context, the article makes the following contributions:

- Introduces two generalizations of the *h-index*, namely the *contemporary h-index* and the *trend h-index*, which are appropriate for scientist ranking and are able to reveal *brilliant young scientists* and *trendsetters*, respectively. These generalizations can also be used for conferences and journals ranking.
- Introduces a normalized version of the *h-index* for scientist ranking, namely the *normalized h-index*.
- Introduces two variants of the *h-index* appropriate for journal/conference ranking, namely the *yearly h-index* and the *normalized yearly h-index*.
- Performs an extensive experimental evaluation of the aforementioned citation indices, using real data from DBLP, an online bibliographic database.

The rest of this article is organized as follows: In Section 2, we present the novel citation indices which are devised for scientist ranking. Section 3 presents the citation indices extending the *h-index* for journal/conference ranking. We present the evaluation of the introduced citation indices in Section 4 and finally, Section 5 summarizes the paper contributions and concludes the article.

2. NOVEL CITATION INDICES FOR SCIENTIST RANKING

After the introduction of the *h-index*, a number of other proposals followed, either presenting case studies using it [2, 7, 24], or describing a new variation of it [9] (aiming to bridge the gap between the lower bound of total number of citations calculated by *h-index* and their real number), or studying its mathematics and its performance [6, 8].

Deviating from their line of research, we develop in this article a pair of generalizations of the *h-index* for ranking scientists, which are novel citation indices, a normalized variant of the *h-index* and a pair of variants of the *h-index* suitable for journal/conference ranking.

The contemporary *h-index*.

The original *h-index* does not take into account the "age" of an article. It may be the case that some scientist contributed a number of significant articles that produced a large *h-index*, but now s/he is rather inactive or retired. Therefore, senior scientists, who keep contributing nowadays, or brilliant young scientists, who are expected to contribute a large number of significant works in the near future but now they have only a small number of important articles due to the time constraint, are not distinguished by the original *h-index*. Thus, arises the need to define a generalization of the *h-index*, in order to account for these facts.

We define a novel score $S^c(i)$ for an article i based on citation counting, as follows:

$$S^c(i) = \gamma * (Y(now) - Y(i) + 1)^{-\delta} * |C(i)| \quad (2)$$

where $Y(i)$ is the publication year of article i and $C(i)$ are the articles citing the article i. If we set δ=1, then $S^c(i)$ is the number of citations that the article i has received, divided by the "age" of the article. Since, we divide the number of Citations with the time interval, the quantities $S^c(i)$ will be too small to create a meaningful *h-index*; thus, we use the coefficient γ. In our experiments, reported in Section 4, we use the value of 4 for the coefficient γ. Thus, for an article published during the current year, its citations account four times. For an article published 4 year ago, its citations account only one time. For an article published 6 year ago, its citations account $\frac{4}{6}$ times, and so on.

This way, an old article gradually loses its "value", even if it still gets citations. In other words, in the calculations we mainly take into account the newer articles[2]. Therefore, we define a novel citation index for scientist rankings, the *contemporary h-index*, expressed as follows:

Definition 3. *A researcher has contemporary h-index h^c, if h^c of its N_p articles get a score of $S^c(i) \geq h^c$ each, and the rest $(N_p - h^c)$ articles get a score of $S^c(i) \leq h^c$.*

The trend *h-index*.

The original *h-index* does not take into account the year when an article acquired a particular citation, i.e., the "age" of each citation. For instance, consider a researcher who contributed to the research community a number of really brilliant articles during the decade of 1960, which, say, got a lot of citations. This researcher will have a large *h-index* due to the works done in the past. If these articles are not cited anymore, it is an indication of an outdated topic or an outdated solution to the problem. On the other hand, if these articles continue to be cited, then we have the case of an *influential mind*, whose contributions continue to shape newer scientists' minds. There is also a second very important aspect in aging the citations. There is the potential of disclosing *trendsetters*, i.e., scientists whose work is considered pioneering and sets out a new line of research that currently is hot ("trendy"), thus this scientists' works are cited very frequently.

To handle this, we take the opposite approach than *contemporary h-index*'s; instead of assigning to each scientist's article a decaying weight depending on its age, we assign to each citation of an article an exponentially decaying weight, which is as a function of the "age" of the citation. This way, we aim at estimating the impact of a researcher's work in a particular time instance. We are not interested in how old the articles of a researcher are, but whether they still get citations. We define an equation similar to Equation 2, which is expressed as follows:

$$S^t(i) = \gamma * \sum_{\forall x \in C(i)} (Y(now) - Y(x) + 1)^{-\delta} \quad (3)$$

where γ, δ, $Y(i)$ and $S(i)$ for an article i are as defined earlier. We define a novel citation index for scientist ranking, the *trend h-index*, expressed as follows:

Definition 4. *A researcher has trend h-index h^t if h^t of its N_p articles get a score of $S^t(i) \geq h^t$ each, and the rest $(N_p - h^t)$ articles get a score of $S^t(i) \leq h^t$ each.*

Apparently, for $\gamma = 1$ and $\delta = 0$, the *trend h-index* coincides with the original *h-index*.

It is straightforward to devise a generalization of both the *contemporary h-index* and *trend h-index*, which takes into account both the age of a scientist's article and the age of each citation to this article, but such index does not provide many additional insights about the real contributions of a scientist. Therefore, we dot not investigate further this generalization in the present article.

The normalized *h-index*.

Since the scientists do not publish the same number of articles, the original *h-index* is not the fairer metric; thus, we define a normalized version of *h-index*, expressed as follows:

Definition 5. *A researcher has normalized h-index $h^n = h/N_p$, if h of its N_p articles have received at least h citations each, and the rest $(N_p - h)$ articles received no more than h citations.*

3. NEW CITATION INDICES FOR JOURNALS AND CONFERENCES RANKING

Based on the original idea of the *h-index* and on the aforementioned generalizations and variants, we define analogous concepts for ranking journals and conferences. For instance, the *h-index* of a journal/magazine or of a conference is h, if h of the N_p articles it contains, have received at least h citations each, and the rest $(N_p - h)$ articles received no more than h. The generalizations of *contemporary h-index* and *trend h-index* can be defined for conferences and journals as well similarly to the Definitions 3 and 4. Direct applications of the *h-index* in journal ranking following this definition appeared in [2, 7, 24]. Though, we observe that the direct application of the index can not guarantee a fair comparison between conferences or between journals, because a) their lifes are different, and b) they publish different numbers of articles.

We deal with the first problem by calculating the *h-index* on a per year basis. In particular, we define that:

Definition 6. *A conference or journal has yearly h-index h_y for the year y if h_y of its articles $N_{p,y}$ published during the year y have received at least h_y citations each, and the rest $(N_{p,y} - h_y)$ articles received no more than h_y citations.*

For instance, the h index for the year 1992, denoted as h_{1992}, of the conference *VLDB* is computed as the number of its articles which have received more than h_{1992} citations. The drawbacks though of the aforementioned metric are:

1. The conferences/journals do not publish exactly the same number of articles. Thus, for a conference which published around 50 articles, the upper bound for its

[2]Apparently, if δ is close to zero, then the impact of the time penalty is reduced, and, for $\delta = 0$, this variant coincides with the original *h-index* for $\gamma = 1$.

h-index is 50. Another conference which published 150 the upper bound for its *h*-index is 150, and it also has larger probability to exceed the limit of 50. The number of articles appearing in a year in a conference or journal reflects the preference of the researchers to this publication forum. If we consider that the forum published 50 articles, because it could not attract more valuable articles, then it correctly has as upper bound the number 50 and it is not a problem that it can not overrule forum B. On the other hand, perhaps we are interested in the average "quality" of the articles published in a forum, no matter what the number of published articles in a forum is.

2. The h_y index constantly changes. Even though we examine a conference which took place in 1970, the h_y index that we can calculate today, is possible to change a few year later. Thus, the drawback of this index is that we can not have a final evaluation for the forums of a year, no matter how old are they.

The only way to overcome the second drawback, is to add a time window after the organization of a conference or the publication of a journal (i.e. ten or five years time window). This would add the notion of the Impact Factor [27] to the metric which is not the scope of this part of our reseach.

To address the first drawback, we define a "parallel" index, is normalized with respect to the number of articles published in a forum. Its formal definition is given below:

DEFINITION 7. *A conference or journal for the year y has* **normalized index** $h^n_y = h_y/N_{p,y}$, *if* h_y *of its* $N_{p,y}$ *articles in the year y have received at least* h_y *citations each, and the rest* $(N_{p,y} - h_y)$ *articles received no more than* h_y *citations.*

Having defined these generalizations and variants of the original *h-index*, we will evaluate in the subsequent sections their success in identifying scientists or forums with extraordinary performance or their ability to reveal latent facts in a citation network, such as brilliant young scientists and trendsetters. For the evaluation, we will exploit the on-line database of DBLP [3].

4. EXPERIMENTS

In the sequel, we will present a small subset of the results obtained for ranking scientists, conferences and journals, using the basic *h-index* definition as well as by using the generalizations and variants developed in the previous sections. Along the lines of [26, 27, 28], our dataset consists of the DBLP collection (DBLP timestamp: Mar/3/2006). The reason for selecting this source of data instead of ISI or Google data is threefold:

1. DBLP contains data about journal and conference publications as well.
2. DBLP data are focused mostly in the area of Databases.
3. The maintainers of DBLP library put a lot of work into resolving the 'names problem' - the same person referenced with (many) different names.

[3]The DBLP digital library with bibliographic data on "Databases and Logic Programming" is maintained by Michael Ley at the University of Trier, accessible from `http://dblp.uni-trier.de/`

It is worthwhile noticing that many top conferences of this area are very competitive (with an acceptance ratio stronger than 1:3 and up to 1:7), and occasionally more competitive that the top journals of the area. In many computer science departments worldwide, publications in these conferences are favored in comparison to journal publications. Therefore, a ranking of conferences on databases is equally important to the ranking of the journals of the area.

The used database snapshot contains 451694 inproceedings, 266307 articles, 456511 authors, 2024 conference series and 504 journals. Also, the number of citations in our dataset is 100205. Although this number is relatively small, it is a satisfactory sample for our purposes. Almost all citations in the database are made from publications prior to the year 2001. Thus, we can assume that the results presented here correspond to the year 2001. From now on, with the term "now" we actually mean sometime near 2001. Although other bibliographic sources, like ISI, are widely available and much more complete, the used collection has the two above desired characteristics and thus it is sufficient for exhibiting the benefits of our proposed citation indices, without biasing our results.

4.1 Experiments with the h-index for scientists

In Tables 1, 2, and 3 we present the resulting ranking using the *h-index*, as well as its defined generalizations. In these tables columns a_c and a_t stand for the factor a of the *contemporary h-index* and *trend h-index* respectively. At a first glance, we see that the values computed for *h-index* (Table 1) are much lower than the values presented in [13] for physics scientists due to the non completeness of the source data. Also, we can notice that the values for h,h_c and h_t are different each other as well as there are differencies in the ordering of the scientists. This confirms our allegation for the convenience of these indices.

A superficial examination of Tables 2 and 3, does not reveal any major difference between their ranking and the ranking obtained by *h-index* (in Table 1). With respect to Table 2, the astute reader though, will catch three important representative cases: the case of Christos Faloutsos, the case of Serge Abiteboul and the case of Jenifer Widom. Christos Faloutsos is at the 16^{th} place of *h-index* table. In

Name	h	a	$N_{c,tot}$	N_p
1.Michael Stonebraker	24	3.78	2180	193
2.Jeffrey D. Ullman	23	3.37	1783	227
3.David J. DeWitt	22	3.91	1896	150
4.Philip A. Bernstein	20	3.39	1359	124
5.Won Kim	19	2.96	1071	143
6.Catriel Beeri	18	3.16	1024	93
7.Rakesh Agrawal	18	3.06	994	154
8.Umeshwar Dayal	18	2.81	913	130
9.Hector Garcia-Molina	17	3.60	1041	314
10.Yehoshua Sagiv	17	3.52	1020	121
11.Ronald Fagin	17	2.83	818	121
12.Jim Gray	16	6.13	1571	118
13.Serge Abiteboul	16	4.33	1111	172
14.Michael J. Carey	16	4.25	1090	151
15.Nathan Goodman	16	3.37	865	68
16.Christos Faloutsos	16	2.89	742	175
17.Raymond A. Lorie	15	6.23	1403	35
18.Jeffrey F. Naughton	15	2.90	653	123
19.Bruce G. Lindsay	15	2.76	623	60
20.David Maier	14	5.56	1090	158

Table 1: Scientist ranking with *h-index*.

Name	h_c	a_c	h	$N_{c,tot}$	N_p
1.David J. DeWitt	14	3.10	22	1896	150
2.Jeffrey D. Ullman	13	3.44	23	1783	227
3.Michael Stonebraker	12	3.98	24	2180	193
4.Rakesh Agrawal	12	3.24	18	994	154
5.Serge Abiteboul	11	4.08	16	1111	172
6.Jennifer Widom	11	3.23	14	709	136
7.Jim Gray	10	3.93	16	1571	118
8.Michael J. Carey	10	3.79	16	1090	151
9.Won Kim	10	3.00	19	1071	143
10.David Maier	10	2.93	14	1090	158
11.Hector Garcia-Molina	9	5.30	17	1041	314
12.Jeffrey F. Naughton	9	3.85	15	653	123
13.Yehoshua Sagiv	9	3.76	17	1020	121
14.Christos Faloutsos	9	3.68	16	742	175
15.Catriel Beeri	9	3.59	18	1024	93
16.Philip A. Bernstein	9	3.49	20	1359	124
17.Umeshwar Dayal	9	3.39	18	913	130
18.Hamid Pirahesh	9	3.34	14	622	67
19.H. V. Jagadish	9	2.88	12	503	151
20.Raghu Ramakrishnan	8	5.05	14	818	147

Table 2: Scientist ranking with *contemporary h-index*.

Name	h_t	a_t	h	$N_{c,tot}$	N_p
1.David J. DeWitt	20	2.73	22	1896	150
2.Michael Stonebraker	17	3.61	24	2180	193
3.Jeffrey D. Ullman	17	3.45	23	1783	227
4.Rakesh Agrawal	17	3.06	18	994	154
5.Jennifer Widom	16	2.81	14	709	136
6.Serge Abiteboul	14	4.07	16	1111	172
7.Hector Garcia-Molina	14	4.03	17	1041	314
8.Christos Faloutsos	14	3.15	16	742	175
9.Jim Gray	13	4.46	16	1571	118
10.Jeffrey F. Naughton	13	3.36	15	653	123
11.Won Kim	13	3.23	19	1071	143
12.Michael J. Carey	12	4.79	16	1090	151
13.Yehoshua Sagiv	12	3.96	17	1020	121
14.Umeshwar Dayal	12	3.41	18	913	130
15.Catriel Beeri	12	3.12	18	1024	93
16.Raghu Ramakrishnan	11	4.41	14	818	147
17.Philip A. Bernstein	11	4.03	20	1359	124
18.David Maier	11	3.94	14	1090	158
19.Hamid Pirahesh	11	3.87	14	622	67
20.H. V. Jagadish	11	3.58	12	503	151

Table 3: Scientist ranking with *trend h-index*.

contemporary h-index table he climbs to the 14^{th} position. Serge Abiteboul climbs up from the 13^{th} position to the 5^{th} position. Similarly, Jenifer Widom appears in the 6^{th} position of the *contemporary h-index* (Table 2), although she does not have an entry in the top 20 *h-index* table (Table 1). This means that the major amount of their good publications is published in the resent years (relatively to the rest of the scientists). In other words, they work on now hot topics. Consequently, we would characterize their works as *contemporary*.

The results appear more impressive in the *trend h-index* (Table 3). Christos Faloutsos climbs to the 8^{th} position, and Jenifer Widom in the 5^{th} position. This shows that their publications get citations during the very recent years. Consequently, we would characterize the work of Faloutsos and Widom as *"trendy"*, in the sense that a general interest exists by the rest of the research community for the work of the specific scientists during the particular time period. Indeed, Faloutsos is recognized as (one of) the main trendsetter in the area of spatial, multidimensional and time series data management. Widom is recognized as (one of) the main trendsetter in the area of semistructured data management.

Name	h	a	$N_{c,tot}$	N_p
1.sigmod	45	6.05	12261	2059
2.vldb	37	7.10	9729	2192
3.pods	26	5.74	3883	776
4.icde	22	6.83	3307	1970
5.er	16	5.80	1486	1338
6.edbt	13	3.89	658	434
7.eds	12	3.65	527	101
8.adbt	12	2.86	412	42
9.icdt	11	4.79	580	313
10.oodbs	11	3.96	480	122

Table 4: Conferences ranking with *h-index*.

Name	h_c	a_c	h	$N_{c,tot}$	N_p
1.sigmod	21	9.49	45	12261	2059
2.vldb	17	11.34	37	9729	2192
3.pods	12	9.73	26	3883	776
4.icde	11	11.88	22	3307	1970
5.icdt	8	5.04	11	580	313
6.edbt	7	6.16	13	658	434
7.oodbs	6	3.63	11	480	122
8.er	5	16.21	16	1486	1338
9.kdd	5	6.89	6	243	1074
10.dood	5	6.57	8	440	171

Table 5: Conferences ranking with *contemporary h-index*.

It is also worthwhile to mention that the *contemporary h-index* and *trend h-index* are fair metrics for the "all-time classic" scientists, e.g., Jeffrey Ullman, Michael Stonebraker, and David DeWitt, whose influential works continue to shape the modern scientists way of thinking.

4.2 Experiments with conferences and journals ranking

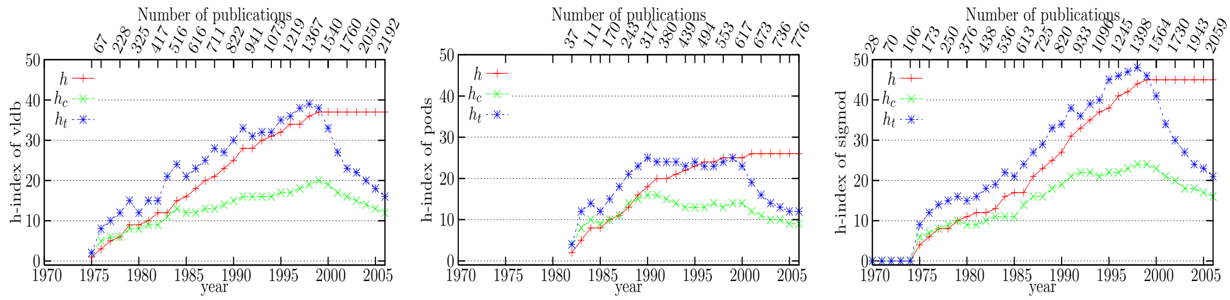
4.2.1 Experiments with conferences ranking

To evaluate our citation indices on conference ranking, we extract only the database conferences (as defined in [10]) from the data we used in the previous section. In the first part of this section we will make experiments using the indicators that we fixed for scientists, namely *h-index*, *normalized h-index*, *contemporary h-index* and *trend h-index*. In Table 4 we present the top-10 conferences using the *h-index* for the ordering[4]. Since the quality of the conferences is relatively constant, we observe that in Tables 5 and 6 there are no significant differences in the ranking. The ordering changes dramatically in Table 7 due to the fact that complete data exist only for some conferences.

In Figure 1 we present in the same way we used for scientists, the progress of selected conferences. Note here that the *h-index* is shown per year in the graphs, which means that this is the computed *h-index* during the specific year. E.g. the *h-index* that is computed for the VLDB for 1995 is the *h-index* that is computed if we exclude everything from our database after 1995. Apparently, this is different from a score for the VLDB'95, which we defined earlier as h_{1995}[5].

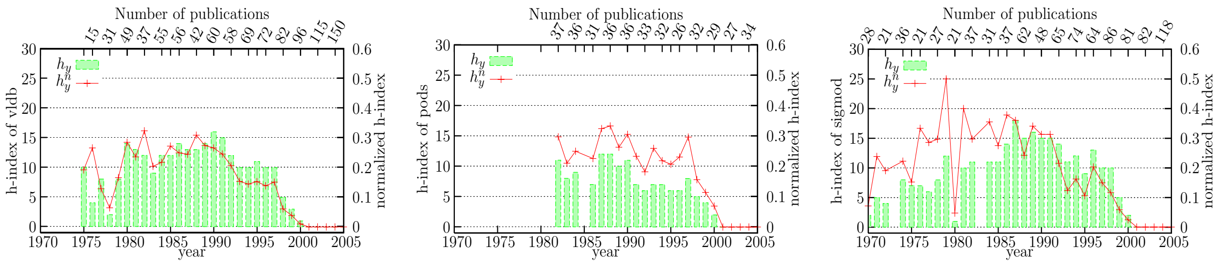
[4] The symbol a_c in Table 4 and the symbol a_t in Table 6 correspond to the *a-index* on Definition 2.

[5] Due to the lack of citations for the years after 1999, in all graphs there is a stabilization of the *h-index* line and a downfall for the indicators *trend h-index* and *contemporary h-index*.



(a) (b) (c)

Figure 1: The *h-index* of major database conferences.



(a) (b) (c)

Figure 2: The *yearly h-index* and *normalized yearly h-index* of major database conferences.

Name	h_t	a_t	h	$N_{c,tot}$	N_p
1.sigmod	34	6.67	45	12261	2059
2.vldb	27	8.00	37	9729	2192
3.pods	19	6.53	26	3883	776
4.icde	16	9.52	22	3307	1970
5.icdt	12	3.67	11	580	313
6.edbt	9	6.02	13	658	434
7.er	8	10.35	16	1486	1338
8.dood	8	4.43	8	440	171
9.kdd	7	6.42	6	243	1074
10.dbpl	7	5.11	8	410	228

Table 6: Conferences ranking with *trend h-index*.

Name	h_n	h	a	$N_{c,tot}$	N_p
1.adbt	0.28	12	2.86	412	42
2.dpds	0.17	7	2.97	146	39
3.eds	0.11	12	3.65	527	101
4.icod	0.11	6	3	108	52
5.jcdkb	0.11	8	3.32	213	70
6.ddb	0.09	4	6.87	110	44
7.oodbs	0.09	11	3.96	480	122
8.tdb	0.08	3	6.44	58	36
9.berkeley	0.07	10	3.52	352	142

Table 7: Conferences ranking with *normalized h-index*.

Figure 1(c) presents the history of the SIGMOD conference. According to the tables, SIGMOD is ranked first. In the figure, we observe its steeply ascending line. Also the *trend h-index* remains higher than the *h-index* (until 1999). On the other hand, the PODS conference (Figure 1(b)) follows a bending line after 1993.

The next step in conference ranking is to evaluate the usefulness and benefit of Definitions 6 and 7. This way, we evaluate, for example, VLDB'95 independently from VLDB'94. Obviously, in this case it is meaningless to add a second time dimension (with indicators *contemporary h-index* and *trend h-index*). The *contemporary h-index* of VLDB'95 will be stable during all the following years, since all papers are published during the same year. On the other hand, it is not important to see whether a conference organized in 1980 still gets citations.

In Figure 2 we present the plots for the values of *yearly h-index* (h_y) and *normalized yearly h-index* (h_y^n) for the top conferences, VLDB, PODS and SIGMOD. The values for h_y are drawn using bars, because each value is independent from the rest ones. The value for h_y of a conference has different upper bound for each year. The upper bound for each year is defined by the number of papers published during this year. This is depicted on the upper x axes. On the other hand, the h_y^n values are normalized. So, it is a comparable value for the two years of a conference and it is drawn with the (red) cross points line. The values for the h_y^n index are presented in axes $y2$. There is no association of axes $y1$ to $y2$, thus we cannot compare (obviously) the values of h_y^n to h_y. The only remark that we can make is that the one curve follows approximately the other.

4.2.2 Experiments with journals ranking

In the case of journals, we can use the basic form of *h-index* as well as the generalizations *contemporary h-index* and *trend h-index* and the variant *normalized h-index* we defined for scientists and for conferences. Here, similarly to the case of conferences, the *normalized h-index* is a valuable indicator contrary to the case of the scientists.

Tables 8, 9, 10 and 11 present the top-10 journals according to the four aforementioned indices. As expected, the ACM TODS (tods), IEEE TKDE (tkde), SIGMOD Record (sigmod) are the top three journals. The striking observation is that the Information Systems (is) drops in the ranking with the *contemporary h-index* and *trend h-index* as compared to its position with *h-index*, implying that it is not considered an exceptionally prestigious journal anymore. On the contrary, SIGMOD Record and VLDB Journal (vldb) show an uprising trend.

In Figure 3 we present the results of computing the defined

Name	h	a	$N_{c,tot}$	N_p
1.tods	49	3.88	9329	598
2.tkde	18	4.69	1520	1388
3.is	16	4.71	1208	934
4.sigmod	15	5.07	1142	1349
5.tois	13	4.37	740	378
6.debu	11	7.13	863	877
7.vldb	9	5.03	408	281
8.ipl	8	6.06	388	4939
9.dke	6	8.77	316	773
10.dpd	6	5.25	189	238

Table 8: Journal ranking with *h-index*.

Name	h_n	h	a	$N_{c,tot}$	N_p
1.tods	0.08	49	3.88	9329	598
2.tois	0.03	13	4.37	740	378
3.vldb	0.03	9	5.03	408	281
4.dpd	0.02	6	5.25	189	238
5.jiis	0.01	6	4.33	156	318
6.datamine	0.01	3	5.11	46	162
7.is	0.01	16	4.71	1208	934
8.ijcis	0.01	4	3.12	50	255
9.tkde	0.01	18	4.69	1520	1388
10.debu	0.01	11	7.13	863	877

Table 9: Journal ranking with *normalized h-index*.

Name	h_c	a_c	h	$N_{c,tot}$	N_p
1.tods	18	6.25	49	9329	598
2.tkde	10	6.40	18	1520	1388
3.sigmod	9	6.17	15	1142	1349
4.debu	6	9.21	11	863	877
5.vldb	6	6.47	9	408	281
6.tois	6	6.09	13	740	378
7.is	5	12.77	16	1208	934
8.dpd	5	4.19	6	189	238
9.jiis	5	3.79	6	156	318
10.dke	4	7.70	6	316	773

Table 10: Journal ranking with *contemporary h-index*.

indices for the major journals of the database domain on a per year basis. Due to the lack of available data after the year 2000, all indices drop steeply. Though, the case of ACM TODS is worthwhile mentioning. Its *trend h-index* drops after 1993, which can be attributed to the relatively large end-to-end publication time of its articles during the years 1990-2000 [29], which acted as an impediment for the authors to submit their works in that venue. Fortunately, this is not the case anymore.

Finally, Figure 4 presents the results of computing the *yearly h-index* and the *normalized yearly h-index* for the major database journals on a per year basis. From these graphs we can easily see that the ACM TODS journal undoubtedly gets the first place. Also, Figure 4(a) shows that the *yearly h-index* follows an descreasing path which comes in aggrement with Figure 3(a). TKDE (Figure 4(b)) seems to follow a descreasing slope and finally, VLDB Journal (Figure 4(c)) follows an uprising trend until 1996.

5. CONCLUSIONS

Estimating the significance of a scientist's work is a very important issue for prize awarding, faculty recruiting; similarly, the estimation of a publication forum's (journal or conference) is significant since it impacts the scientists' decisions about where to publish their work. This issue has received some attention during the last years, but the interest on this topics has been renewed by a path-breaking paper by J. E. Hirsch, who proposed the *h-index* to perform fair ranking of scientists, avoiding many of the drawbacks of the earlier bibliographic ranking methods.

The initial proposal and meaning of the *h-index* has various shortcomings, mainly of its inability to differentiate between active and inactive (or retired) scientists and its weakness to differentiate between significant works in the past (but not any more) and the works which are "trendy" or the works which continue to shape the scientific thinking.

Based on the identification of these shortcomings of *h-index*, we proposed in this article a number of effective *h-index* generalizations and some variants. Some of these novel citation indices aim at the ranking of scientists by taking into account the age of the published articles, or the age of the citations to each article. The other citations indices aim at ranking publication venues, i.e., conferences and journals, taking into account their variable number of articles.

To evaluate the proposed ranking metrics, we conducted extensive experiments on an online bibliographic database containing data from journal and conference publications as well, and moreover focused in the specific area of databases. From the results we obtained, we concluded that *h-index* is not a general purpose indicative metric. Some of the novel indices, namely *contemporary h-index* and *trend h-index*, are able to disclose latent facts in citation networks, like trendsetters and brilliant young scientists. For the case of conference and journal ranking, the indices *normalized h-index*, *contemporary h-index* and *trend h-index* give a more fair view for the ranking. Finally, the *yearly h-index* and the *normalized yearly h-index* can be used in order to evaluate separately each conference/journal's success.

Name	h_t	a_t	h	$N_{c,tot}$	N_p
1.tods	28	4.93	49	9329	598
2.tkde	13	6.64	18	1520	1388
3.sigmod	12	5.85	15	1142	1349
4.vldb	10	3.75	9	408	281
5.is	9	7.11	16	1208	934
6.debu	9	6.98	11	863	877
7.tois	9	4.83	13	740	378
8.dpd	6	4.88	6	189	238
9.jiis	6	4.75	6	156	318
10.dke	5	8.18	6	316	773

Table 11: Journal ranking with *trend h-index*.

6. REFERENCES

[1] P. Ball. Index aims for fair ranking of scientists – h-index sums up publication record. *Nature*, 436(7053):900, 2005.

[2] J. Bar-Ilan. h-index for price medalists revisited. *ISSI Newsletter*, 5, Jan. 2006.

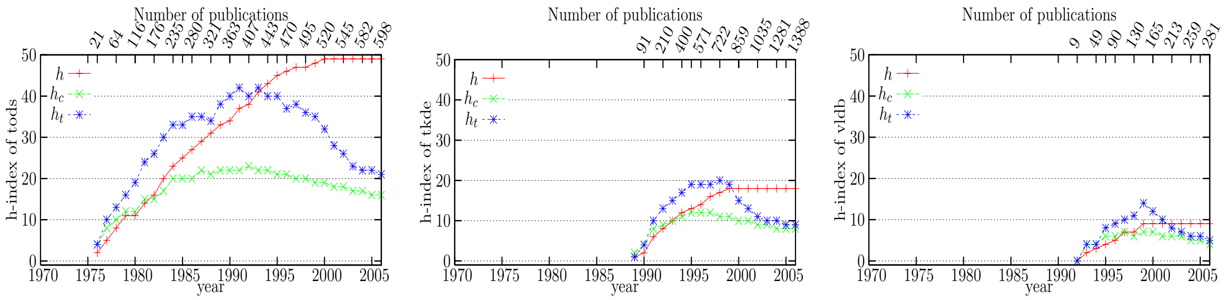
[3] S. J. Barnes. Assessing the value of IS journals. *Communications of the ACM*, 48(1):110–112, 2005.

[4] P. A. Bernstein, E. Bertino, A. Heuer, C. J. Jensen, H. Meyer, M. Tamer Ozsu, R. T. Snodgrass, and K.-Y. Whang. An apples-to-apples comparison of two database journals. *ACM SIGMOD Record*, 34(4):61–64, 2005.

[5] P. Bharati and P. Tarasewich. Global perceptions of journals publishing e-commerce research. *Communications of the ACM*, 45(5):21–26, 2002.

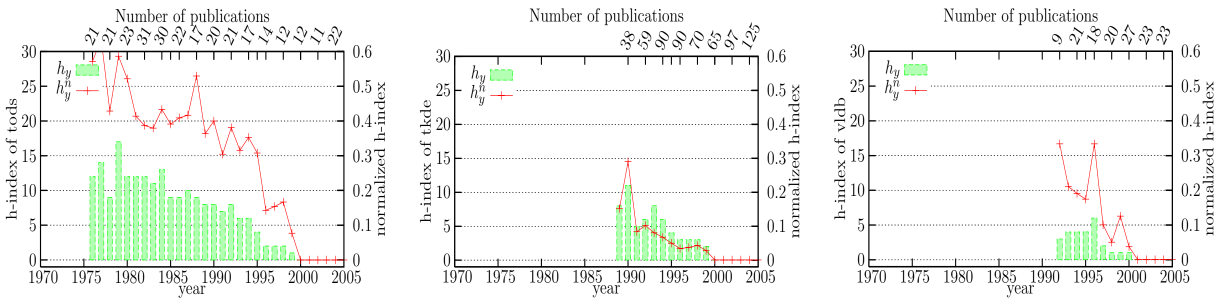
[6] L. Bornmann and H.-D. Daniel. Does the h-index for ranking of scientists really work? *Scientometrics*, 65(3):391–392, 2005.

[7] T. Braun, W. Glanzel, and A. Schubert. A Hirsch-type



(a) (b) (c)

Figure 3: The *h-index*, *contemporary h-index* and *trend h-index* of major database journals.



(a) (b) (c)

Figure 4: The *yearly h-index* and *normalized yearly h-index* of major database journals.

index for journals. *The Scientist*, 19(22):8–10, 2005.

[8] L. Egghe. Dynamic h-index: The Hirsch index in function of time. *Scientometrics*, 2006. to appear.

[9] L. Egghe. Theory and practise of the g-index. *Scientometrics*, 2006. to appear.

[10] E. Elmacioglu and D. Lee. On six degrees of separation in DBLP-DB and more. *ACM SIGMOD Record*, 34(2):33–40, 2005.

[11] E. Garfield. Citation analysis as a tool in journal evaluation. *Science*, 178:471–479, 1972.

[12] B. C. Hardgrave and K. A. Walstrom. Forums for MIS scholars. *Communications of the ACM*, 40(11):119–124, 1997.

[13] J. E. Hirsch. An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences*, 102(46):16569–16572, 2005.

[14] C. W. Holsapple, L. E. Johnson, H. Manakyan, and J. Tanner. Business computing research journals: A normalized citation analysis. *Journal of Management Information Systems*, 11(1):131–140, 1994.

[15] P. Katerattanakul, B. T. Han, and S. Hong. Objective quality ranking of computing journals. *Communications of the ACM*, 46(10):111–114, 2003.

[16] R. Kelly Rainer and M. D. Miller. Examining differences across journal rankings. *Communications of the ACM*, 48(2):91–94, 2005.

[17] J. Kleinberg. Authoritative sources in a hyperlinked environment. *Journal of the ACM*, 46(5):604–632, 1999.

[18] P. Lowry, D. Romans, and A. Curtis. Global journal prestige and supporting disciplines: A scientometric study of information systems journals. *Journal of the Association for Information Systems*, 5(2):29–75, 2004.

[19] N. A. Mylonopoulos and V. Theoharakis. Global perception of IS journals. *Communications of the ACM*, 44(9):29–33, 2001.

[20] M. Nascimento, J. Sander, and J. Pound. Analysis of SIGMOD's co-authorship graph. *ACM SIGMOD Record*, 32(3):8–10, 2003.

[21] S. P. Nerur, R. Sikora, G. Mangalaraj, and V. Balijepally. Assessing the relative influence of journals in a citation network. *Communications of the ACM*, 48(11):71–74, 2005.

[22] L. Page, S. Brin, R. Motwani, and T. Winograd. The PageRank citation ranking: Bringing order to the Web. Technical Report TR-1999-66, Stanford University, 1999.

[23] E. Rahm and A. Thor. Citation analysis of database publications. *ACM SIGMOD Record*, 34(4):48–53, 2005.

[24] R. Rousseau. A case study: Evolution of JASIS' Hirsch index. *Library and Information Science*, Jan. 2006. http://eprints.rclis.org/archive/00005430.

[25] R. B. Schwartz and M. C. Russo. How to quickly find articles in the top IS journals. *Communications of the ACM*, 47(2):98–101, 2004.

[26] A. Sidiropoulos and Y. Manolopoulos. A citation-based system to assist prize awarding. *ACM SIGMOD Record*, 34(4):54–60, 2005.

[27] A. Sidiropoulos and Y. Manolopoulos. A new perspective to automatically rank scientific conferences using digital libraries. *Information Processing & Management*, 41(2):289–312, 2005.

[28] A. Sidiropoulos and Y. Manolopoulos. Generalized comparison of graph-based ranking algorithms for publications and authors. *Journal for Systems and Software*, 2006. to appear.

[29] R. Snodgrass. Journal relevance. *ACM SIGMOD Record*, 32(3):11–15, 2003.